IMPROVEMENT IN LABOR PRODUCTIVITY BY ESTABLISHING TIME STANDARDS USING M.O.S.T

Vikram Kedambadi
Vasu Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bengaluru, India, vikramkv123@gmail.com

Pallavi G
Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology Bengaluru, India, pallavigowda697@gmail.com

Rahul A R
Department of Mechanical Engineering Nitte Meenakshi Institute of Technology, Bengaluru, India, rahulargowda@gmail.com

N R Prashuth
Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bengaluru, India, nrprashuth@gmail.com

Mayur U
Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bengaluru, India, mayuru14@gmail.com

Pramodh R
Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bengaluru, India, pramodh106@gmail.com

Abstract—Establishing Time Standards for Fixing Body Side Panel onto the Chassis Using Maynard Operation Sequence Technique (MOST) is the focus of the current research work. For the installation of the "Body Side Panel" onto the chassis of the Reva NXR vehicle, the REVA Company has introduced a novel idea of bonding methodology; a specific Bonding Fixture is employed for this. The "Maynard Operation Sequence Technique (MOST)" is used to determine the new benchmark time for assembly tasks. For each assembly process, the tools description, the process description, and the already-existing MOST sheets were evaluated, providing comprehensive information about all the movements of assembly activities. It was discovered that several assembly-related operations were taking longer than necessary. Most of these movements were adjusted, and only a small number were deleted, which reduced the amount of time that these movements took.
Keywords—MOST, Bonding, Sealant Application, Non-Value Added Activities, Total Work Content.

Submitted: 16/11/2022 **Accepted**: 05/12/2022

Introduction

The fundamental premise behind Productivity improvement as per Japanese philosophy is "Without measurement there cannot be any improvement". Each corporation focuses on high efficiency as the market competition becomes more and more fierce [1]. And it is seriously interested in ways to boost production effectiveness. Productivity is used to quantify efficiency, which is a method for gauging the performance of any industry organization. Numerous methods have been developed to address issues from diverse fields in order to increase productivity, including work measurement, method improvement, quality improvement tools, line balancing techniques, and simulation approaches. This essay addresses the issue by going over the assembly-line process of gluing the panel to the chassis. This is done in an effort to make the situation better by doing better work. In order to calculate realistic production standards, eliminate waste, increase productivity, assess departmental efficiency, and enhance employee relations, MOST is a predefined time approach. In this study, MOST is used to calculate the cycle time for the bonding stage of the body side panel. Mahindra Reva Electric Car Manufacturing Company has established a new assembly line to assemble Electric cars. In this assembly line, they have adopted a new Methodology to fix the body side panel using the Bonding Fixture. It is necessary to establish the feasibility of this fixture for effective assembly of the Body Side Panel onto the Car.

The Bonding fixture is basically made of a tubular structure comprising a base frame and two swing arms thatswing sideways at the LH and RH side of the top frame for holding side panel LH and RH onto the chassis respectively. The entire fixture assembly is hungonto a superstructure and the fixture is mounted below an electric monorail which facilitates the movement of the fixture from one station to another.

Eight sets of pneumatic actuators per side and one top locator, which covers the side portion of the roof, are fixed on the fixture. Through the use of human-machine interfaces, these actuators are integrated and controlled by PLC software to enable automatic cycling and error-proofing of manual errors. Using a controller, the bonding fixture is moved from the buffer station to the bonding spot, and the "cycle start" switch is depressed to close the bonding fixture's wings and engage the front and rear clamps. After pressing the "cycle start" button to close the pads once more, they automatically reopen after the curing process is complete.

Related Work

Although there is a large quantity of literature on the Maynard Operation Sequence Technique, which is a work-measuring method, Kjell B. Zandin [1] produced the first thorough work. Work measurement is a set of methods used to assess how long it takes the average human worker to complete a task. Work measurement generally concentrates on the output of human labor while taking into consideration the individual demands, fatigue, and delays that are unavoidable throughout the course of assembly.

The initial stage in work measurement and the foundation for using time standards is the development of manufacturing data [2]. The distinction between Engineered Standards and Non-Engineered Standards was made clear. An illustration of a Non-Engineered Standard is a "Guesstimate". The outcomes of all the research will be more reliable if engineering standards, realistic and consistent engineered time standards, are used. The MOST work measuring technique is built on the specified time study [3]. They emphasized that precise times cannot be calculated using observation estimate techniques. The direct observation method is very time-consuming and cannot be utilized for stations that do not exist. Assembly cycle times might be accurately calculated by PMTSs. Therefore, MOST is a common way to identify potential errors that reduces the amount of time needed to complete an operation or assignment. The most important thing in manufacturing is Productivity. The author pointed out the utilization of Process Mapping and MOST for Labor productivity improvement. As a result, he employs Maynard Operation Sequence Technique (MOST) as the time study method and process mapping as the method study in his research. By conducting a work-study on the manual operators' activities, calculating the present operator's utilization, and establishing a standard time for the manual process, it was hoped to find areas where the current production system might be improved [4]. Using manufacturing technology for continuous improvement of the system to optimize technology utilization, increase throughput, identify bottlenecks and work-in-process inventory, and identify machine and labor utilization [5]

Based on the examination of standard routings, a generic activity hierarchy was created, and the cost drivers for each activity were identified and compiled. Then the MOST was employed to analyze each operation of standard routings to determine the associated standard time. Standard routings provided a basis for estimating time requirements based on historical data [6]. The design of an assembly line and its workstations is characterized by line balancing and is strictly related to the number of workstations, process and set-up times, and type of operations (hand-operated or automated) [5-6]. They noticed that one of the foremost necessary approaches for finding outline leveling (with workstations characterized by manual operations) is the figure mensuration technique i.e.; Maynard Operation Sequence Technique. They recommended that for planning a line, each the road leveling yet because the work mensuration technique must be thought of, that plays a crucial role in the measurement of the time standards within the assembly method.

To cut down on unproductive activity in an assembly line, Ashish R. Thakre et.al., [7] devised the MOST work measuring technique. The case study was conducted in a plant that made tractors and had an assembly line just for tractor engines. According to the MOST study, the operators' excessive motions significantly enhanced the content of the fundamental work. Critical changes in workplace design were recommended in order to lessen stress-related actions that are unproductive.

They divided their investigation into three stages: (i) Utilizing Basic MOST, current TWC (Total Work Content) calculations (ii) Identifying NVA (Non-Value Added) Activities, Performing a Basic MOST Analysis, and, (iii) Elimination of NVA Activities through the application of necessary modifications to the workspace/workflow [8].

Finally, an experiment to stop or diminish the NVA activity associated with each parameter identified throughout the approach was carefully investigated. Every time, it had been discovered that some minor modifications to the workspace's design resulted in a large reduction in the quantity of labor that needed to be done. Enhancing the assembly line by bringing the storage bins closer to the conveyors and elevating the ground clearance of the storage racks. Apply MOST once more to get a new standard time. Additionally, it was discovered from the literature evaluations mentioned above that Basic MOST is the method used to establish time standard times. The time of assembly plays the main role in the assembly operation because it is related to the cost of the assembly [9].Literature summarizes the work carried out from 1990 to 2021. Since there was no majority of work carried out in the field of M.O.S.T, the literature is summarized considering the timelines as mentioned.

Proposed Method

Work measurement is a methodical approach for analyzing work and figuring out how long it takes to complete important activities in processes. For manual jobs, time standards are often used to measure work. The majority of manual labor incentive schemes use these norms as a point of reference. The 1940s Methods-Time Measurement (MTM) approach improved predictive work measurement. As defined by this method, “any manual operation or method can be broken down into the basic motions required to perform it and the time required to accomplish it” [10].

An individual standard is assigned to each motion based on the nature of the motion and the conditions under which it is performed”. As the term implies, "work measure" refers to a method of analyzing labor and determining how long it takes to complete relevant tasks within a process. In manual jobs, time criteria are frequently used to evaluate labor. Incentives programs primarily use these standards as a reference. Methods-Time Measure (MTM) was introduced in the 1940s, which was a significant development in prophetic work measurement. Based on the way each motion is performed and the circumstances under which it is performed, define this technique as breaking down manual operation or technique into its basic motions [11].

As a result of carefully observing and recording each movement, MTM is extremely labor-intensive when applied to industrial operations. Additionally, using such a strategy generates a lot of data that needs to be managed. Many of these issues were solved when the Maynard Operation Sequence Technique (MOST) was created and published in the 1960s since it is much easier to use and more effective. Several predetermined characteristics are assigned values to each of three fundamental categories of human motion [12].

It is the latest work activity method that may be easily implemented and maintained to not only estimate the standard time but also to develop strategies and make the most effective use of resources. It had been created by H. Maynard & Company INC. in three versions: Basic MOST (for tasks under twenty seconds) and Maxi MOST (for tasks over two minutes) [13].

Basic MOST is built around the concepts of balancing time and balancing effect. The least quantity of work that must be analyzed using the system in order to reach a certain degree of accuracy in the analyzed time is known as the balancing time. The statistical phenomenon known as the "Balancing Effect" will result in the achievement of the desired degree of accuracy within the time period under study. The aggregate effects of individual component variations within an operation are what it refers to.

The movement of items is the focus of the Maynard Operation Sequence Approach (MOST), a work-measuring technique. It is employed to evaluate labor and establish the typical duration of a given procedure or operation. The movement of items is the focus of the Maynard Operation Sequence Approach (MOST), a work-measuring technique. It is employed to evaluate labor and establish the typical duration of a given procedure or operation.

MOST is used to [14-15]:

1. Observe and record the operational procedures
2. Divide the sub-operation into logical actions.
3. Decide which sequence model is best for each activity.
4. Choose the proper "indices values" for the model
5. Calculate the operation's Standard Operation Time.

Three categories of object movements that are focused on by MOST:

[1] General Move: this type of movement occurs when objects are manually moved while flying through the air. The activity sequence comprises of four smaller tasks that look into the many possibilities for a General Move. The action distance is A. B: Body movement, G - Take charge, and P – Position.

The sequence model describes the activities or actions that always take place when an object is transferred from one location to another. The sub-activities are then given time-related index numbers depending on the motion content of the sub-activities or the sequence model parameters. This method offers total analysis flexibility while maintaining the sequence model's overall control. Any combination of motions could happen for each object that is moved, and by using MOST.

[2] Control move: "Controlled Move Sequence" describes operations such as turning a crank or lever, pressing a button or switch, or even sliding an object across a surface. The A, B, and G parameters from the general move sequence are also included in the sequence model for a controlled move, along with the following sub-activities:M (Move controlled), X (Process time), and, I (Alignment). Controlled movements may be a part of as much as one-third of machine shop processes. The sequence model for a controlled move contains the following sub-activities:

[3] Tool Use: The Tool Usage Sequence Model covers the use of hand tools for tasks such as fastening or loosening, cutting, cleaning, measuring, and recording. Additionally, certain mental tasks involving the use of the brain, such as reading and thinking, might be categorized as Tool Use. The Tool Use Sequence Model combines General Move and Controlled Move activities, as shown in table I.

TABLE I. Sequence models comprising the Basic MOST technique

Activity	Sequence Model	Sub – Activities
GENERAL MOVE	**A B G A B P A**	A - ACTION DISTANCE
		B - BODY MOTION
		G - GAIN CONTROL
		P - PLACEMENT
CONTROLLED MOVE	**A B G M X I A**	M – MOVE CONTROL
		X – PROCESS TIME

		I – ALIGNMENT
TOOL USE	**A B G A B P _ A B P A**	F – FASTEN
		L – LOOSEN
		C – CUT
		S – SURFACE TREAT
		M – MEASURE
		R – RECORD
		T – THINK

Time Study Of Body Side Panel Bonding Process

Assembly line of Body Side Panel Bonding Fixture

The Bonding fixture is basically made of a tubular structure comprising a base frame and two swing arms thatswing sideways at the LH and RH side of the top frame for holding side panel LH and RH onto the chassis respectively. The entire fixture assembly is hungonto a superstructure and the fixture is mounted below an electric monorail which facilitates the movement of the fixture from one station to another.

On the fixture, pneumatic actuators are mounted 8 sets on each side and one top locator which covers the side portion of the roof. These actuators are integrated and operated through a PLC program to enable auto cycling and fool proofing of manual errors through human, and machine interfaces. The Bonding Fixture from the buffer station is moved to the bonding location using a controller and the “cycle start” switch is pressed to close the wings of the bonding fixture and engage the front and rear clamps. Once again "cycle start" button is pressed to close the pads and after curing time the pads open back automatically. Hence, this Bonding Methodology is called as Butterfly Operation as shown in Figures 1 and 2.

Fig 1. Bonding Fixture Area in REVA Assembly line

Fig 2. Bonding Fixture in REVA Assembly line

Bonding of Body Side Panel

After this, the Bonding fixture is moved from the buffer station using a controller, and then the "cycle start" button is pressed to close the wings of the bonding fixture. The pads open back automatically after the curing time of the Body side panel onto the chassis. The total time taken to complete the entire operation is 9 Minutes and 39 Seconds.

To establish a uniform bonding process and the operating of Graco Extruder machine (to apply Sealant) is applicable for regular production practice for bonding body side panel onto chassis. The Procedure for operating the Graco Extruder Machine is as follows (i) Switch on air inlet main valve by turning the lever in vertical position. Set the ram down pressure at 345 KN/m^2 (50 psi) by rotating the lever in anti-clock wise direction and then lock its position by hand tightening the lock nut. (ii) Set the air regulator of the president air motor to 276 KN/m^2 (40 psi) by rotating the lever in a clockwise direction. Open pump control air valve by turning the lever into a vertical position. Now fit the gun with a nozzle/static mixture tightly. (iii) Open the trigger lock and start triggering for the sealant application and ensure uniformity in the mixture by dispensing the sealant equal to the length of the static mixture (iv) Apply the sealant indicated on the roof, rear hatch surround, and chassis as per the pattern. Once the dispensing of sealant is over for a shift, keep the used static mixture until the next shift starts. Install a new static mixture just before the operation begins in the shift. (v) The sealant used for the Bonding of the Bodyside panel onto the chassis is the Lord Sealant 7545 AC. This consists of two adhesives A [Brown] and C [White]. These two adhesives mix in the nozzle and form a single adhesive whose curing properties are as shown in figure 3.

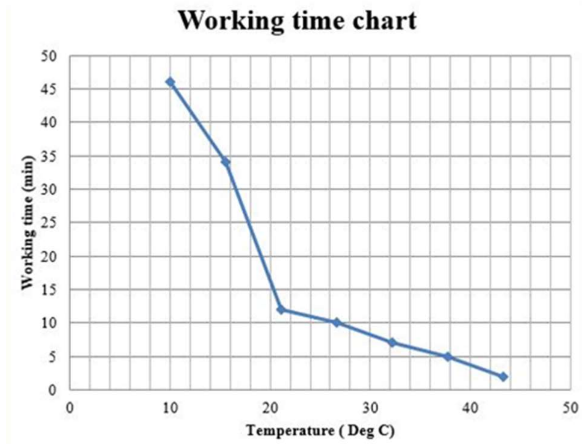

Fig 3. Sealant Working Chart of LORD 7545 AC

Application of MOST Methodology in the Assembly Line

In this study, Basic MOST is used to estimate TWC (Total Work Content) for an offline stage of bonding. To find NVA activities and enhance the layout, the most recent bonded assembly process approach was used.The study was done in three stages: (i) Analyzing MOST in the Basics to Find NVA Activities, (ii) Basic MOST Calculations for Existing TWC, and(iii)Elimination of NVA Activities Through Required Work Method Changes.

(i) Existing TWC Calculations

Each workstation's operations are segmented into easily distinguishable and quantifiable sub-activities. After further breaking down each sub-components activity into smaller units, the parameters and index values from the MOST Data Card were used to simulate the sequence of these smaller units. Unit sub-activities share a similar set of elements that are ordered in the same order throughout numerous different activities. The elements are sequentially modeled utilizing the parameters and index values using the MOST estimation sheets. An operation's division into sub-operations and activities is described in the MOST estimating sheet. The index values for an element are added, and the total is multiplied by (0.36 * FRQ/DIV), to determine the cycle time (in seconds). The frequency of the repeated items is represented by FRQ. DIV (division) is the term used to describe when an operator does two or more tasks concurrently, such as moving two carts at once. The cycle times of the elements are added to determine the sub-operations cycle time.

To obtain the cycle time of the sub-activity, the cycle times of the sub-operations are additionally added. The work content is then calculated by adding the sub-activities cycle times. It is important to keep in mind that the bulk of studies only focuses on online components, or the times when a machine is not running automatically and humans conduct tasks like loading, unloading, configuring, etc. The time required for manual elements cannot be calculated based on OFFLINE elements, or those carried out by machines (in automatic cycles).

By personally watching the workers' motions, the Body Side Panel Assembly activity was divided into 42 sequences of operations. The parameters and index values in terms of TMU were determined for each operation using the MOST Data Card. Based on the parameters and index values, the operation time is determined for each operation. Adding the index numbers for each individual sub-operation and multiplying the result by 10 yields the time value for a sequence model in basic MOST. TMU is then converted to seconds by multiplying by 0.036.

(ii) Basic MOST Analysis

Using the MOST evaluation of operation time pertaining to 42 sequences of operations involved in Body Side Panel Bonding Process is carried out; details of the evaluation are given below.

(1) Move Chassis Trolley

The chassis is moved from the buffer station to the body side panel bonding bay by getting hold of the heavy object (G3) within reach (A1) and applying pressure on the chassis and moving 5 to 7 steps (A16) with heavy resistance (M6) and positioning the chassis with Precision (P6) in the body side panel bonding bay.The standard duration in SECONDS for the parameter sequence A1 G3 A16 P6 M16 is,(A1 + G3 + A16 + P6 + M16) * (0.036 * FRQ/DIV) i.e., (1 + 3 + 16 + 6 + 16) * (0.36* 1/1) = 42 * 0.36 = 15.12 s.

Index numbers for walking towards the Bonding bay, Positioning the chassis, and pushing the chassis towards the bonding bay with resistance are 16, 6, and 16 respectively (A16 P6 M16). By directly observing the worker's motions, these relatively high index numbers were carefully investigated to lower the NVA activity related to that parameter. No alternative movements were possible for this activity; hence these index numbers are considered without any modifications.

(2) Locate the chassis

Once the chassis is moved to the bonding bay, it is located using a foot-operated pedal present within reach (A1) with little resistance (M3) and slight adjustments (P3).The standard duration in SECONDS for the parameter sequence A1 P3 M3 is, (A + P + M) * (0.36 * FRQ / DIV) i.e., (1 + 3 +3) * (0.36* 1/1) = 7 * 0.36 = 2.52 s.

Index numbers for slight adjustments of the chassis and little resistance from the foot-operated pedal are 3, 3 respectively (P3 M3). By directly observing the worker's motions, these relatively high index numbers were carefully investigated to lower the NVA activity related to that parameter. No alternative movements were possible for this activity hence these index numbers are considered without any modifications.

(3) Take the front locator

Move 5 to 7 Steps (A10) and gain control (G3) of the front locator in the storage rack by bending (B6) and attach it to the chassis crushing zone by walking 5 to 7 towards the chassis (A10) and insert the dowel pin & toggle clamp with precision (P6).The standard duration in SECONDS for the parameter sequence A10 B6 G3 A10 P6 is, (A + B + G + A + P) * (0.36 * FRQ/DIV) i.e., (10 + 6 + 3 + 10 + 6) * (0.36* 1/1) = 35 * 0.36 = 12.6 s.

The index numbers for walking toward the storage rack and bending to get the front locators and then moving towards the chassis are 10, 6, and 10 respectively (A10 M6 A10). Higher index numbers indicate higher work content. Hence by personally observing the worker’s movement the higher index parameter is reduced from 5 to 7 Steps (A10) to 3 to 4 steps (A6) and Bending (B6) to no Bending (B0) in the process by fixing the Front Locators onto the superstructure at a certain height in the assembly line.

The updated sequence of parameters A6 B0 G3 A6 P6 has a standard time in seconds of (A + B + G + A + P) * (0.36 * FRQ / DIV) i.e., (6 + 0 + 3 + 6 + 6) * (0.36* 1/1) = 21 * 0.36 = 7.56 s.For this specific task, the time decrease is (12.6 - 7.56) = 5.04 seconds.

(4) Take the rear locator

Move 5 to 7 Steps (A10) and gain control (G3) of the rear locator by bending (B6) and attach it to the rear end of the chassis by walking 5 to 7 towards the chassis (A10) and inserting the dowel pin and toggle clamp with precision (P6).

The standard duration in SECONDS for the parameter sequence A10 B6 G3 A10 P6 is, (A + B + G + A + P) * (0.36 * FRQ /DIV) i.e., (10 + 6 + 3 + 10 + 6) * (0.36* 1/1) = 35 * 0.36 = 12.6 s.

The index numbers for walking toward the storage rack and bending to get the Rear locators and then moving towards the chassis are 10, 6, and 10 respectively (A10 M6 A10). Higher index numbers indicate higher work content. Hence by personally observing the worker's movement the higher index parameter is reduced from 5 to 7 Steps (A10) to 3 to 4 steps (A6) and Bending (B6) to no Bending (B0) in the process by fixing the Rear Locators onto the superstructure at a certain height in the assembly line.

The parameter sequence's standard duration in SECONDS A6 B0 G3 A6 P6 is,(A + B + G + A + P) * (0.36 * FRQ / DIV) i.e., (6 + 0 + 3 + 6 + 6) * (0.36* 1/1) = 21 * 0.36 = 7.56 s.The time reduction for this particular activity is (12.6 – 7.56) = 5.04 seconds.

(5) Insert the rear bottom locator into the top locator

The formula is (A + B + G + A + P) * (0.36 * FRQ / DIV) i.e., (3 + 6 + 3 + 1 + 6) * (0.36* 1/1) = 19 * 0.36 = 6.84 s.

The parameter sequence's standard duration in SECONDS A3 B6 G3 A1 P6 is 6.84 s.For bending to obtain the rear bottom locator, the index number is 6. (B6). Higher work content is indicated by higher index numbers. Because of this, by fixing the Rear Bottom Locator to the superstructure at a specific height in the assembly line, the higher index parameter is decreased from (B6) to no Bending (B0) in the process.

The standard time in Seconds for the revised sequence of parameter A3 B0 G3 A1 P6 is,(A + B + G + A + P) * (0.36 * FRQ / DIV) i.e., (3 + 0 + 3 + 1 + 6) * (0.36* 1/1) = 13 * 0.36 = 4.68 s.The time reduction for this particular activity is (6.84 – 4.68) = 2.16 seconds.

(6) Attach both the locators

By grasping the Light object (G1) within reach (A1) and with slight adjustments (P3) the locating pin is inserted at their mating point.The standard duration in SECONDS for the parameter sequence A1 G1 P3 is, (A + G + P) * (0.36 * FRQ/DIV) i.e., (1 + 1 +3) * (0.36* 1/1) = 5 * 0.36 = 1.8 s.

The index number for finding pins that need a small modification is 3. (P3). By directly observing the worker's motions, this relatively high index value was carefully investigated to lower the NVA activity related to that parameter. No alternative movements were possible for this activity, hence this index number is considered without modification.

(7) Attach the rear bottom locator

Move 3-4 Steps (A6) and grasp the rear bottom locator (G1) from the storage rack provided and then move 3-4 steps (A6) towards the chassis and with precision (P6) position the rear bottom locator using two toggle clamps with 2-3 revolutions (M6) at the bottom side of the chassis after butting the surface against the chassis.The parameter sequence's standard duration in SECONDS A6 G1 A6 P6 M6 is,(A + G + A + P + M) * (0.36 * FRQ/DIV) i.e., (6 + 1 + 6 + 6 + 6) * (0.36* 1/1) = 25 * 0.36 = 9 s.

Index numbers for walking towards the storage rack and then moving towards the chassis and placing the rear bottom locator onto the chassis with precision and 2 to 3 revolutions for the toggle clamps are 6, 6, 6, 6 respectively (A6 A6 P6 M6). By directly observing the worker's motions, these relatively high index numbers were carefully investigated to lower the NVA activity related to that parameter. No alternative movements were possible for this activity; hence these index numbers are considered without any modifications.

(8) Clean the bonding surface

Gain control of the Cloth (G1) within reach (A1) and with light pressure (P3) place the cloth within reach (A1) to the chassis for surface treatment (S42) using a cloth with a slight bend and rise occurrence (B3).

The parameter sequence's standard duration in SECONDS A1 B3 G1 A1 P6 M6 is,(A + B + G + A + P + S) * (0.36 * FRQ/DIV) i.e., (1 + 3 + 1 + 1 + 3 + 42) * (0.36* 2/1) = 5 * 0.72 = 36.72 s.

Index numbers for Bending and Rising 50% occurrence to clean the surface, with light pressure, and then surface treatment are respectively 3, 3, 42 (B3 P3 S42). By directly observing the worker's motions, these relatively high index numbers were carefully investigated to lower the NVA activity related to that parameter. No alternative movements were possible for this activity; hence these index numbers are considered without any modifications.

(9) Keep the cloth aside

Place the cotton cloth after cleaning the bonding surface aside (P1) within reach (A1).

The parameter sequence's standard duration in SECONDS A1 P1 is,(A + P) * (0.36 * FRQ/DIV) i.e., (1 +1) * (0.36* 1/1) = 2 * 0.36 = 0.72 s.In this activity, there are no higher index numbers hence it is considered without modification.

(10) Collect the body side panel

Move 3 to 4 Steps (A6) and collect the body side panels (G3) and then move 3 to 4 steps towards the chassis (A6) and place the body side panel LH and RH on the chassis with adjustments (P3).The standard time in Seconds for sequence of parameter A6 G3 A6 P3 is,(A + G + A + P) * (0.36 * FRQ/DIV) i.e., (6 + 3 + 6 + 3) * (0.36 * 2/1) = 18 * 0.72 = 12.96 s.

(11) Place the locators on the LH and RH panel

Place the locators within reach (A1) with a few adjustments (P3) onto the panels with two point's alignment (I6).The typical time in seconds for the parameter A1 P3 I6 sequence is, (A + P + I) * (0.36 * FRQ/DIV) i.e., (1 + 3 + 6) * (0.36 * 6/1) = 10 * 2.16 = 21.6 s.

(12) Inspect the flushness and gap

Inspect with eyes/fingers the flushness & gap between the windshield, roof, rear hatch surround, rocker beam, and rear bumper area (T3).The standard time in Seconds for sequence of parameter T3 is,(T) * (0.36 * FRQ/DIV) i.e., (3) * (0.36 * 6/1) = 3 * 2.16 = 6.48 s.

(13) Adjust the fitness of the panel

Adjust the panel within reach (A1) by holding the panels (G1) and within reach (A1) adjust the panels (P3) with respect to the roof panel.The parameter sequence's standard duration in SECONDS A1 G1 A1 is,(A + G + A + P) * (0.36 * FRQ/DIV) i.e., (1 + 1 + 1 + 3) * (0.36 * 2/1) = 6 * 0.72 = 4.32 s.

(14) Disengage the Panel

Grasp the panels (G3) within reach (A1) and move 1 to 2 steps to disengage the rear end of the panel (A3) with precision (P6).The standard time in SECONDS for sequence of parameter A1 G3 A3 P6 is,(A + G + A + P) * (0.36 * FRQ/DIV) i.e., (1 + 3 + 3 + 6) * (0.36 * 2/1) = 13 * 0.72 = 9.36 s.

(15) Place back the panels onto the storage Rack

Move 3 to 4 steps towards the chassis (A6) and get hold of the panels (G3) with light pressure (P3) remove the panels and then move 3 to 4 steps (A6) towards the storage rack in the controlled move (X6).The standard time in SECONDS for sequence of parameter A6 G3 A6 P3 X6 is,(A + G + A + P + X) * (0.36 * FRQ/DIV) i.e., (6 + 3 + 3 + 6 + 6) * (0.36 * 2/1) = 24 * 0.72 = 17.28 s.

The activities from (10 to 15) are considered as non-value added activities because once the production starts the chassis and panels are checked for flushness and gaps before they are brought into Assembly line Stage 15. The time saved by elimination of these activities are (12.96 + 21.6 + 6.48 + 4.32 + 9.36 + 17.28) = 72 seconds.

(16) Use a cotton cloth

Grasp the cotton cloth (G1) within reach (A1) for cleaning the surface of the body side panels. The standard time in Seconds for sequence of parameter A1 G1 is,(A + G) * (0.36 * FRQ/DIV) i.e., (1 + 1) * (0.36 * 1/1) = 2 * 0.36 = 0.72 s.

(17) Using the Scuffing Tool

Move 3 to 4 steps towards the scuffing tool (A6) and grasp the scuffing tool (G1) and then move 3 to 4 steps towards the panels (A6) and switch on the scuffing tool (M1) and scuff the surface of body side panel using the nozzle (S42).The parameter sequence's standard duration in SECONDS A6 G1 A6 M1 S42 is,(A + G + A + P + X) * (0.36 * FRQ/DIV) i.e., (6 + 1 + 6 + 1 + 42) * (0.36 * 2/1) = 56 * 0.72 = 40.32 s.

(18) Clean the scuffed area

Move 3 to 4 steps (A6) and place the cotton cloth on the Scuffed area and clean the surface of the panels with a cotton cloth (S3) and lay the cotton cloth aside (P1).The standard time in Seconds for sequence of parameter A6 P1 S3 is,(A + P + S) * (0.36 * FRQ/DIV) i.e., (6 + 1 + 3) * (0.36 * 16/1) = 10 * 5.76 = 57.6 s.

The activities from (16 to 18) are considered as non-value added activities because once the production starts the panels are scuffed by the vendors (Panel Providers) and then brought into

Assembly line Stage 15. The time saved by elimination of these activities are (0.72 + 40.32 + 57.6) = 98.64 seconds.

(19) Get LORD A/C Cartridge

Move 3 to 4 steps to get the LORD A/C Cartridge (A6) attached to Extruder Machine and gain control (G3) of the sealant gun within reach (A1) and with light pressure (P3) turn the knob (M1) and insert the sealant gun.The parameter sequence's standard duration in SECONDS A6 G3 A1 P3 M1 is,(A + G + A + P + M) * (0.36 * FRQ/DIV) i.e., (6 + 3 + 1 + 3 + 1) * (0.36* 1/1) = 16 * 0.36 = 5.76 s.

Index numbers for walking towards the Extruder Machine and getting hold of the sealant gun and turning the knob with light pressure are 6, 3, 3 respectively (A6 G3 P3). By directly observing the worker's motions, these relatively high index numbers were carefully investigated to lower the NVA activity related to that parameter. No alternative movements were possible for this activity; hence these index numbers are considered without any modifications.

(20) Remove the Caps

Grasp the light object cap (G1) within reach (A1) and turn the knob (M1) to remove the caps from the sealant gun.The parameter sequence's standard duration in SECONDS A1 G1 M1 is,(A + G + M) * (0.36 * FRQ/DIV) i.e., (1 + 1 + 1) * (0.36* 1/1) = 3 * 0.36 = 1.08 s.

In this activity, there are no higher index numbers hence it is considered without modification. To estimate the task contents of each of the remaining 22 activities, similar computations were made. The total work content, or TWC, was calculated to be 5 minutes and 53 seconds.

(iii) Elimination of NVA Activities by required adjustments to Work Methods

To stop or minimize the NVA activity related to each of the 42 indicated activities, a thorough analysis was done on each one. Each time, it was found that a few little adjustments to the workspace's architecture caused a significant decrease in the amount of work to be done. For instance, by moving the front and rear locators closer to the bonding bay and mounting them to the assembly line's superstructure, a small adjustment in activity can shorten the operation time. All 42 of the Existing Method's actions underwent a similar exercise. Five tasks were found to be taking longer than necessary, and 11 were determined to be non-value-added, according to an evaluation of the actual process. The number of activities was decreased from 42 to 31 by modifying 5 activities and eliminating 11 others, for a reduction in total operating time of 3 minutes 58 seconds. As a result, from 9 minutes and 56 seconds, the overall operating time for the Body Side Panel Bonding Process is decreased to 5 minutes and 53 seconds. There is a 41% decrease in operation time as a result of the adjustments made to 5 activities and the deletion of 11 activities.

RESULTS AND ANALYSIS

An exhaustive and detailed examination and assessment of each action were done prior to the new criteria being developed. The current procedure took 9 minutes and 39 seconds to complete and consisted of 42 tasks. Five actions were discovered to be taking longer than necessary when the actual process was examined; revised time standards were set for these activities which are shown in Table II and shown in figure 4. Additionally, 11 activities were determined to be non-value-added, as indicated in Table III. As a result, the number of activities decreased from 42 to 31. According to Tables 1 and 2, the operation time for the body side panel bonding process has been cut by 54.72 seconds and 3 minutes, and 4 seconds, respectively. As a result, the overall operation time is now 5 minutes, and 53 seconds. There is a 41% decrease in operation time as a result of the adjustments made to 5 activities and the deletion of 11 activities. The time reduction is justified by the decrease in travel time caused by the division of Stage 15 of the Assembly Line into operations and the subsequent sequential execution of each operation as shown in Figure 5.

TABLE II. Details Of Operation Time Reduction

Operation Name	Existing Time in Seconds	Modified Time in Seconds	Reduction of Time in Seconds
Take the front locator	12.6	7.56	5.04
Take the rear locator	12.6	7.56	5.04
Insert rear bottom locator into the top locator	6.84	4.68	2.16
Dispense adhesive	5.76	3.6	2.16
Sealant Application Process time	126.72	86.4	40.32
Total	164.52	109.8	54.72

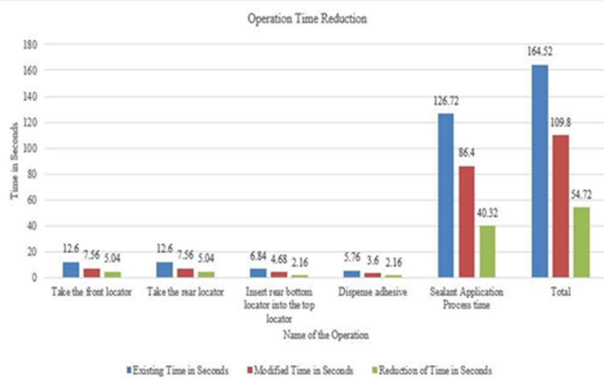

Fig 5. Operation Time Reduction

TABLE III. Details Of The Time Elimination Operation

Eliminated Operation Name	Operation Time in Secs.
Collect the body side panel	12.96
Place the locators on the LH and RH panel	21.6
Inspect the flushness and gap	6.48
Adjust the fitness of the panel	4.32
Disengage the Panel	9.36
Place back the panels onto the storage Rack	17.28
Use cotton cloth	0.72
Using the Scuffing Tool	40.32
Clean the scuffed area	57.6
Get the Masking Tape	4.68

Fix the masking tape onto the chassis	9.72
Total	184.32

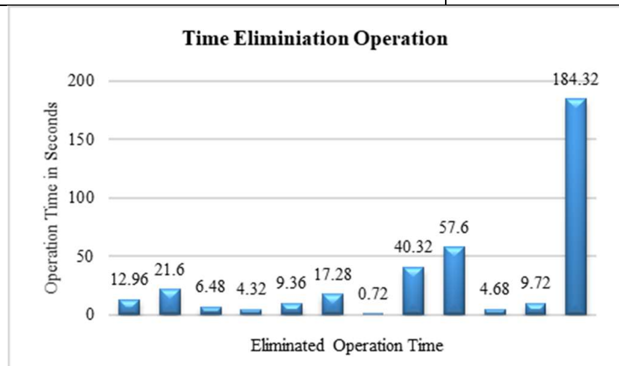

Fig 5. Time Elimination Operation Using MOST

Conclusion

A study of the current setup for body-side panel assembly has shown that 11 non-value-added tasks have been eliminated. The total assembly time for these tasks was 3 minutes and 4 seconds. And 5 tasks were discovered to be taking 54 seconds longer than needed, leading to the establishment of revised time criteria for these tasks. Assembly time was decreased by 41% to 5 minutes and 57 seconds from an earlier 9 minutes and 56 seconds after the modification of 5 activities and the elimination of 11 activities. The current research has shown that the three sequence models employed in MOST, such as "General Move," "Control Move," and "Tool Use," are particularly successful at spotting pointless motions during assembly. And in the current work, these sequence models were successfully employed to create new benchmark times for certain tasks and get rid of pointless motions.

References

[1] Kjell B. Zandin MOST - Work Measurement Systems, Maynard's Industrial Engineering Handbook (New York: Marcel Dekker, INC, 17.65 – 17.82, 1990
[2] Parmar, K., Parth, D. and Shingala, N, An optimization of process parameter in crankshaft using with time study method, International Journal of Engineering Development and Research, Vol. 4, No. 2, pp.2321–9939, 2016
[3] Patil, K., Tonape, S. and Umrani, A, Assembly line optimization using lean principles, International Research Journal of Engineering and Technology, Vol. 3, No. 7, pp.1055–1060, 2016
[4] Vekariya, A. and Kumar, A, A review on improvement of workflow and productivity through application of time and motion study technique, International Journal for Scientific Research & Development, Vol. 2, No. 10, pp.338–341, 2016
[5] Mossa, G., Boenzi, F., Digiesi, S., Mummolo, G. and Romano, V.A, Productivity and ergonomic risk in human based production systems: A job-rotation scheduling model, International Journal of Production Economics, Vol. 171, No. 4, pp.471–477, 2016

[6] Kumar, K.K., Muthukumaran, V. and Kumar, S.N, Productivity improvement in compressor assembly line by adopting lean concepts and MOST technique, International Journal of Engineering and Future Technology, Vol. 13, No. 13, pp.1–9, 2016
[7] Ashish R. Thakre, Dhananjay A. Jolhe & Anil C. Gawande, Minimization of Engine Assembly Time by Elimination of Unproductive Activities through 'MOST', Second International Conference on Emerging Trends in Engineering and Technology, ICETET-09, 2009.
[8] Vivek A. Deshpande, "M.O.S.T. – The Most Advanced Work Measurement Technique", Journal of Engineering & Technology, S. P. University, December 2007, Vol.20, 109-113, March 2016.
[9] Barros, R.S. and Ferreira, A.M.D.S.D.C, Time-driven activity-based costing: designing a model in a Portuguese production environment, Qualitative Research in Accounting & Management, Vol. 14 No. 1, pp. 2-20, 2017.
[10] Ganorkar, A.B., Lakhe, R.R. and Agrawal, K.N, Implementation of TDABC in SME: a case study, Journal of Corporate Accounting and Finance, Vol. 29 No. 2, pp. 87-113, 2018.
[11] Ashwin Bhimrao Ganorkar, Ramesh Ramchandra Lakhe, Kamalkishor N. Agrawal, Time Driven Activity Based Costing (TDABC) Model for Cost Estimation of Assembly for a SSI, International Journal of Productivity Management and Assessment Technologies, 2018
[12] Ashwin Bhimrao Ganorkar, Ramesh R. Lakhe, Kamalkishor N. Agrawal. "Methodology for application of Maynard Operation Sequence Technique (MOST) for time-driven activity-based costing (TDABC)", International Journal of Productivity and Performance Management, 2019
[13] Islam, Md.S., Sarker, S. and Parvez, M., Production Efficiency Improvement by Using Tecnomatix Simulation Software and RPWM Line Balancing Technique: A Case Study. American Journal of Industrial and Business Management, 9, 809-820., 2019.
[13] Puvanasvaran A. P., Yap Y. Y. and Yoong S. S., Implementation of Maynard Operation SequenceTechnique in dry pack operation - A Case Study, ARPN Journal of Engineering and Applied Sciences, Vol. 14, No. 21, November 2019.
[14] Medha and Sharath Kumar Reddy, Labour productivity improvement using hybridMaynard operation sequence technique and ergonomic assessment, International Journal of Enterprise Network Management, Vol. 11, No. 2, 2020
[15] Mr. Rugved Rajendra Joshi, Case-Study on Process Activity Improvement by M.O.S.T. – An Advanced Work Measurement Technique, International Research Journal of Engineering and Technology (IRJET), Volume: 08 Issue: 08, Aug 2021.
[16] Ranjithkumar, S. "Performance Divergence And Financial Distress Of Selected Steel Companies In India." International Journal Of Mechanical And Production Engineering Research And Development 7 (2017): 375-386.
[17] Mahajan, Surabhi, Harminder Saini, And Amanpreet Kaur. "Working Efficiency And Impediments Faced By Production Labour In Medium Sized Knitwear Units Of Ludhiana." Age (Years) 15.24: 15.

[18] Kommadath, Basanth, And Binayak Rath. "Mining Boom, Structural Changes And The Dynamics Of Labour Market Transitions In Bellary Region Of Karnataka." Int J Econ Commer Res 5.2 (2015): 1e24.
[19] Dey, Abhirup, Rajasekaran Rajkumar, And Jolly Masih. "An Analytical Study And Visualisation Of Human Activity And Content-Based Recommendation System By Applying Ml Automation." International Journal Of Mechanical And Production Engineering Research And Development 9.3 (2019): 75-88.
[20] Kumar, Raja Ram, Et Al. "Design, Control And Experimental Investigation Of Fault-Tolerant Five Phase Pmsg For Wind Power Application." (2018).
[21] Mahroogi, Faisal O., And S. Narayan. "Design And Analysis Of Double Wishbone Suspension Systems For Automotive Applications." International Journal Of Mechanical And Production Engineering Research And Development (Ijmperd) 9 (2019): 1433-1442.