ROOF RAIL ASSEMBLY CELL PRODUCTIVITY ENHANCEMENT VIA TIME STUDY ANALYSIS

Rishya Shringhan Ravichandran

Abstract - *The principal objective in manufacturing operations is maximizing output with minimal workforce exertion, ensuring to achieve the desired product and target quality. In manufacturing, the optimization of operation efficiency and productivity of a product is a prevailing issue. To enhance the productivity among several manufacturing units, the motion and time study strategy is employed. This technique is used to determine the most efficient approach for executing repetitive tasks and to accurately measure the time required by an average operator to complete a task within a standardized work environment. In every manufacturing industry, optimizing assembly line configurations is important for productivity augmentation. The objective of this paper is to analyze the implementation of motion critically and time study methodologies on 2-station and 3-station assembly lines and their effects on productivity enhancement. The pre-and post-application of motion and time study techniques have been assessed, presenting a detailed comparison of process outcomes. The findings reveal a remarkable 30.86 % increase in average productivity. Thus, it can be inferred that time study serves as an effective tool for enhancing productivity in manufacturing processes.*

Key Words: **Productivity Enhancement, Motion and Time Study, Operation Efficiency, Manufacturing Operations**

1. INTRODUCTION

Assembly lines are well-planned production systems designed to accommodate the increase in demands of society. The growing demand for product diversity and shorter product life cycles has led to the replacement of traditional manufacturing methods with well-designed assembly lines. The goal of the system is to achieve high-volume production at accelerated rates, optimize efficiency, and ensure a guarantee of stringent quality guidelines.

An assembly line is an array of workstations that are sequenced strategically along a conveyor mechanism. Each workstation is assigned specific operations within predefined constraints. The bottleneck is the cycle time, defining the time span between the two finished units or the maximum allowed time for fabricating any workpiece at a designated workstation. The effectiveness of product or service efficacy is typically determined through detailed time studies, adherence to time standards, utilization of work sampling methods, and analysis of operator's feedback. These methodologies highlight the importance of time as a fundamental metric in organizational performance and operational efficiency.

F.W. Taylor [1], the progenitor of modern time and motion study methodologies, commenced his time study research in 1881. Despite facing significant criticism initially, the technique has progressively gained widespread acceptance as a fundamental method for work measurement in technical contexts. Womack et al. (1990) [2] extrapolated from the highly efficacious Toyota Production System, emphasizing the systematic eradication of all forms of waste to optimize operational efficiency.

Krafcik (1998) [3] elucidates the Japanese manufacturing paradigm championed by Toyota, characterized by a spectrum of methodologies such as Just-In-Time (JIT) inventory systems, Kaizen-driven continuous improvement, and the implementation of quality circles. Niebel (1988) [4] posits that the exclusive method for a business or enterprise to attain growth and amplify profitability is through the enhancement of productivity across all operational dimensions, including sales, finance, production, engineering, cost management, maintenance, and organizational administration.

Imad Alsyouf (2007) [5] demonstrated the impact of a robust maintenance policy on the productivity and profitability of manufacturing processes. Additionally, the study highlighted the influence of productivity changes on profitability, distinct from the effects of uncontrolled factors such as price recovery. As per Atkinson et al. (1995) [6], productivity is quantified as the ratio of the monetary value of outputs (produced goods or services) to the monetary value of input resources (including wages, equipment costs,) and similar expenditures utilized in the production process.

S. Vijaya Kumar et al. [7] undertook a study to optimize production planning and process efficiency at an impeller manufacturing facility. The goal was to minimize CNC machining time for impellers, and vital components in centrifugal pumps, employing Overall Equipment Effectiveness (OEE) strategies. Additionally, the author implemented quick changeover techniques to streamline setup times for standardized products using the OEE methodology. The outcome demonstrated a 4.4% performance boost and a significant 47% reduction in setup times for certain impeller types.

Odior and Oyawale [8] conducted a case study focusing on the development and implementation of a time study model in a rice milling firm. The findings reveal that a direct correlation between the milling time for a 50-kilogram rice bag, the number of production stages, and the time allocated to each stage. The study underscores the importance of employing time study models for effective employee monitoring and control. It also highlights the influence of uncontrollable factors like erratic electricity supply, raw material shortages, and frequent machine breakdowns due to aging equipment on productivity. Prajapati D.R [9] applied time and motion study techniques to enhance crane hook forging productivity in a northern Indian industry. Their findings suggest a potential 107% productivity increase with proper implementation of these methods.

Various researchers have proposed an ideal OEE range, typically falling between 60% and 70% [10] and [11]. Hemant Singh Rajuput et al. [12] utilized time study methodologies in a manufacturing setting, demonstrating that the implementation of Total Productive Maintenance (TPM) can elevate the Overall Equipment Effectiveness (OEE) of shot Peening Machines from 66.4% to 85%. Parshetty Siddheshwar [13] utilized Time and Motion study techniques to boost production in small scale industries. By analyzing and adjusting machining times based on standard time calculations, productivity surged by 19.16%.

Abdul Talib Bon [14] applied time and motion study techniques in a rice processing company in Sabah. The study successfully established the standard time for manpower involved in rice processing, reducing it from 3.39 hours to 3.21 hours, a 5.31% improvement. Data analysis was conducted using Stat Fit and Pro Model software, with recommendations made for alternative space utilization in storage, cleaning, and packaging areas. Ann Hendrich et al. [15] conducted a study focused on augmenting the efficiency and effectiveness of nursing care, vital for hospital operations and ensuring patient safety. They utilized time and motion study methodologies to meticulously document nurses time utilization, aiming to pinpoint inefficiencies in nursing workflows and unit design. The study highlighted three primary areas for enhancing nursing care efficiency: optimizing documentation practices, streamlining medication administration procedures, and refining care coordination protocols.

In the ongoing investigation, time study methodologies were implemented to optimize the productivity of a manufacturing assembly line. This facility manufactures roof rails and assembles in two workstations for one of the leading automotive companies in the USA.

2. TIME AND METHOD STUDY PROCEDURES

Time study is a standard work measurement approach extensively used in repetitive manufacturing industries [16].

Procedure :

(i). Select: Identify the specific job or operation to be timed

(ii). Define: Break down the task into individual elements suitable for precise timing

(iii). Obtain and Record: Gather comprehensive details about the operator, job specifications, methodologies, and working conditions. Document all relevant information

(iv). Observe: Monitor the task and record the time taken for each element using a stopwatch or time study software

(v). Extend: Convert the observed time into normal time (basic time) by applying performance ratings

(vi). Measure: Evaluate and assess the performance rating and time duration for each element to ensure accuracy

(vii). Compute: Calculate the standard time for the entire operation by summing the normalized times for all elements and considering allowances

(viii). Determine: Establish relaxation and personal allowances to adjust the standard time, ensuring it reflects realistic working conditions

(ix). Review and Validate: Verify the accuracy and consistency of the recorded times and calculated standard time through repeated observations and analysis

(x). Document and Implement: Prepare a detailed report of the time study findings and implement the optimized standard times in the production process

Method study entails the systematic documentation and critical evaluation of current and prospective work methods to foster the adoption of more efficient practices and cost-saving measures [17].

Procedure:

(i). Selecting the work: Identify the specific work or process to be studied

(ii). Recording Current Methods: Record and document the existing methods used in performing the work

(iii). Examining the Methods: Analyze and review the recorded methods to identify inefficiencies, bottlenecks, and areas for improvement

(iv). Developing Improved Methods: Brainstorm and develop alternative methods or procedures that can improve efficiency, reduce waste, and enhance productivity

(v). Implementing Changes: Test and apply the new methods or procedures in a controlled environment to assess their effectiveness

(vi). Maintaining and Monitoring: Monitor and maintain the improved methods, gather feedback from workers, and make necessary adjustments to ensure sustained improvement over time.

3. DESIGN LAYOUT

The design layout shown below is an assembly cell of the roof rail. It's a 3 station layout that comprises operator 1, operator 2, and a robot station. Figure 1 shows the 3-station assembly cell with 2 operators and a robot station.

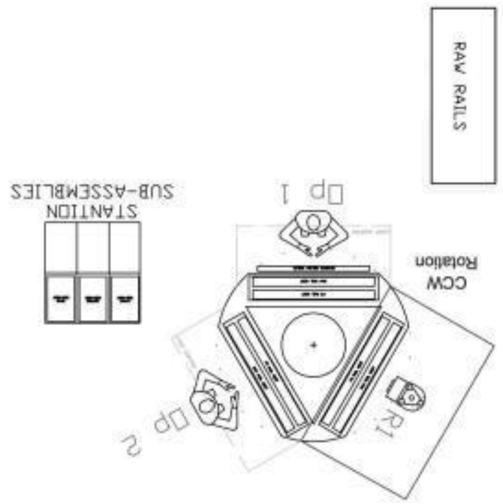

Fig -1: 3 station assembly cell

Fig -2: Roof rail on jig fixture without stanchions

Fig -3: Roof rail on jig fixture with stanchion at station 2

The operator 1 takes the raw roof rail from the stand and fixes on the jig fixture to install a screw to support the stanchions which is shown in figure 2. Then, the roof rail is transferred to the operator 2. The roof rails transfer to the next station by rotating the whole table in the counterclockwise direction. The operator 2 fixes the stanchion on all the sides which is shown in figure 3. Again, the table rotates to the robot station to install the riv nuts to tighten the stanchions on the roof rail. The 3 station assembly cell faced some issues at the robot station as the robot failed to maintain the accuracy to drill the riv nuts at the hole position on the roof rail. Due to this, the target number of roof rails assembled is missed and the operation done by the robot is considered as a bottleneck.

To overcome the bottleneck in the 3 station assembly cell, an alternative 2 station assembly cell eliminating the robot operation is implemented.

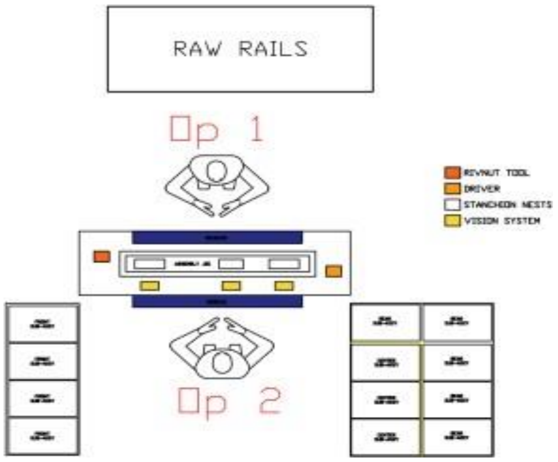

Fig -4: CAD Layout of 2 station assembly cell

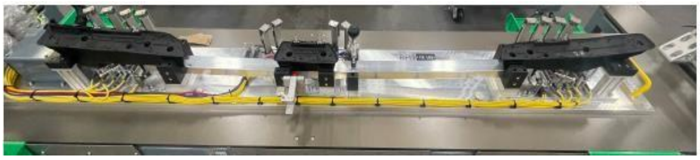

Fig -5: 2 station assembly cell

Figure 4 shows the 2 station assembly cell and figure 5 shows the 2 station assembly cell. This 2 station assembly cell has only one table with 2 jig fixtures employing 2 operators only. This also eliminates the time consumed by the turn table. Operator 1 takes the raw roof rail from the stand and fixes on the jig fixture to install a screw to support the stanchions which is the same task involved in the 3 station assembly cell. Then, operator 2 fixes the stanchions and installed the rivnuts with a rivnut gun.

The time study is carried out on these two different assembly cells and compared them effectively, the structured procedure that is mentioned above is followed. This methodical process will ensure that the comparison yields valuable insights into the efficiency and productivity of each design layout, ultimately guiding decisions to optimize operations and enhance overall performance.

4. TIME AND METHOD STUDY OBSERVATIONS

The time study is performed using a stopwatch for both layouts. The efficiency of the production rate is determined by comparing the time taken to complete each task at each station.

Table -1: Time and motion study on 3 station assembly (before implementation of method & time study)

S.No	Description of activity	Operator	Average timing calculated in seconds
1	Obtain the raw rail from the rack and	1	6.43

	do a quick inspect		
2	Place the rail on the jig fixture and clamp	1	5.21
3	Install the screws	1	9.81
4	Table rotates to the next station	2	3.53
5	Obtain the stanchions and fix on the roof rail	2	6.77
6	Table rotates to the next station	Robot Station	3.65
7	Robot move to position 1	Robot Station	3.34
8	Drive the riv nut 1	Robot Station	2.12
9	Robot move to position 2	Robot Station	1.12
10	Drive the riv nut 2	Robot Station	2.01
11	Robot move to position 3	Robot Station	2.99
12	Drive the riv nut 3	Robot Station	1.33
13	Robot move to position 4	Robot Station	1.56
14	Drive the riv nut 4	Robot Station	1.76
15	Robot move to position 5	Robot Station	3.23
16	Drive the riv nut 5	Robot Station	1.54
17	Robot move to position 6	Robot Station	2.2
18	Drive the riv nut 6	Robot Station	1.67
	TOTAL		60.27

Table -2: Time and motion study on 2 station assembly (after implementation of method & time study)

S. No	Description of activity	Operator	Average timing calculated in seconds
1	Obtain the raw rail from the rack and do a quick inspect	1	6.89
2	Place the rail on the jig fixture and clamp	1	4.88
3	Install the screws	1	8.79
4	Obtain the stations and fix on the roof rail	2	6.68
5	Drive the (6x) rivnuts on the stanchions using the rivnut gun	2	14.43
	TOTAL		41.67

The time recorded in table 1 and 2 is an average of 10 recordings of each task with the same operators performing the same tasks.

5. RESULT

From the comparison between 3 station and 2 station assembly cells, the average time taken to rotate the table and the operation performed by robot was eliminated. Now, the productivity of each assembly cell is calculated.

Productivity is a measure to determine the efficiency of work employed on a task, product, goods, service etc.

The average time taken on 3 station assembly cell (before implementation of method and time study) = 60.27 seconds

The total time taken on 2 station assembly cell (after implementation of method and time study) =41.67 seconds

The total time taken on 3 station assembly cell (before implementation of method and time study) - total time taken on 2 station assembly cell (after implementation of method and time study) = 60.27 - 41.67 = 18.6 seconds

Increase in productivity = 18.6/60.27 = 0.3086

% Increase in productivity = 30.86%

6. CONCLUSION

In general, time and method study on any manufacturing process increases productivity and reduces the time consumed to complete an action. Through this study, it is evident that the comparison of the previous process and the current process has made a huge difference in productivity. The average time consumed was reduced by 18.6 seconds and productivity increased by 30.86 %.

On the other hand, cooperation among the operators, training, comfort, manual & power tool facility, and communication are a few essential factors that indirectly drive to achieve the desired target.

REFERENCES

[1] W. Charles, Theory and Practice of Time Study. Century, 1966.

[2] Womack, James P., Daniel T. Jones and Daniel Roos. The Machine That Changed the World: The Story of Lean Production - Toyota's Secret Weapon in the Global Car Wars that Is Now Revolutionizing World Industry. New York: Free Press, 2007.

[3] Krafcik, John F. (1998). "The Japanese Style Manufacturing Process: Pioneered by Toyota."

[4] Niebel, Benjamin W. (1988). Motion and Time Study. Homewood, IL: Richard D. Irwin, Inc.

[5] Alsyouf, Imad. (2007). The role of maintenance in improving companies productivity and profitability. International Journal of Production Economics. 105. 70-78. 10.1016/j.jipe.2004.06.057.

[6] [Atkinson, A.A., R.D. Banker, R.S. Kalpan, & S.M. Young. (1995). Management Accounting. Prentice Hall, England. (p.514)

[7] Vijay's Kumar, S., et al. (2014). "Production Planning and Process Improvement in an Impeller Manufacturing Using Scheduling and OEE Techniques." Procedia Materials Science, Vol. 5, pp. 1710-1715.

[8] Odior, Oyawale. (2011). "Application of Time Study Model in Rice Milling Firm: A Case Study." Journal of Applied Science and Environmental Management, Vol. 15 (3), pp. 501-505.

[9] Prajapati, D.R. (2014). "Productivity Improvement of a Forging Industry Using Time Study Technique - A Case Study." International Journal of Management, IT and Engineering, Volume 4, Issue 12, pp. 72-84.

[10] Braglia, M., Frosolini, M., & Zammori, F. (2009). "Overall Equipment Effectiveness of a Manufacturing Line (OEEML): An Integrated Approach to Assess Systems Performance." Journal of Manufacturing Technology Management, Vol. 20, No. 1, pp. 8-29.

[11] Rahmani, K., Bonab, M.P., & Naghadeh, M.K. (2011). "Evaluating the Overall Effectiveness of Production Equipment and Machinery." American Journal of Scientific Research, Vol. 31, pp. 59-68.

[12] Rajput, H. S., & Jayaswal, P. (2012). "A Total Productive Maintenance (TPM) Approach to Improve Overall Equipment Efficiency." International Journal of Modern Engineering Research, Vol. 2(6), pp. 4383-4386.

[13] Siddheshwar, Parshetty. (2020). "Paper on Time and Method Study Productivity Improvement in Machining Industry by using Time Study and Method Study Techniques." International Research Journal of Engineering and Technology, Vol. 7, Issue 7.

[14] Bon, A. T. & Daim, D.(2010). "Time Motion Study in Determination of Time Standard in Manpower Process." Proceedings of Engineering Conference on Advancement in Mechanical and Manufacturing for Sustainable Environment, Kuching, Sarawak, Malaysia, pp. 1-6.

[15] Hendrich, A., et al. (2008). "A 36-Hospital Time and Motion Study: How Do Medical - Surgical Nurses Spend Their Time?" The Permanent Journal, Vol. 12 (3), pp. 25- 34.

[16] Rehman, A., Ramzan, M., Shafiq, M., Rasheed, A., Naeem, S., & Savino, M. (2019). "Productivity Improvement Through Time Study Approach: A Case Study from an Apparel Manufacturing Industry of Pakistan." Procedia Manufacturing, 39, 1447-1454. doi:10.1016/ j. promfg.2020.01.306.

[17] International Labor Office. (1979). Introduction to WorkStudy. International Labour Office.