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PRODUCTIVITY STUDY IN VIBRATORY COMPACTOR ASSEMBLY LINE: WORK-STUDY

Ms. Nisha Sahu
Dr. Atma Ram Sahu
Raviraj Garg
Dr. R.C. Gupta

Abstract

In this highly competitive market, the manufacturing industry is developing rapidly in terms of productivity and profiting from high-quality products at the lowest cost. In order to minimize product costs, it is necessary to minimize non-value-added (NVA) activities that have no value to the product. Operators perform these activities on the assembly line during operation and waste their energy. In many manufacturing industries, multiple products are assembled on the final production line and contain NVA. This research paper using principles of elimination, combination, rearrangement and simplification (ECRS) with the help of time study to increase the productivity of vibratory compactors by eliminating non-value-added activities and the number of workstations. To verify productivity improvement operations, case studies in the automotive and heavy machinery industries were examined, in which the assembly process was analyzed in detail and imbalances were observed. To solve these problems, the study of a stopwatch on the assembly line was completed, the workload of the operators was calculated, and the activities were assigned to the operators on the assembly line according to the takt time so that workers are not overloaded with their work on the assembly line and perform their tasks without fatigue. The new balanced production line is designed to reduce the number of jobs from 13 to 8, thus simplifying the process and eliminating unnecessary activities, reducing the number of workers from 27 to 17 and shortening the production time from 504.3 minutes to 405 minutes, and productivity increased from 6 to 8 vehicles per day.

Keywords: Non value-added activity; ECRS; Unbalancing; Time study; Throughput time.

1. INTRODUCTION

Work estimation and method study are the techniques for estimating cycle time for a particular process and operator utilization of vibratory compactor and assigning workload to the operator so that idle time of man and machine can be minimized. A vibratory compactor is a heavy-duty machine that uses either a plate or roller mechanism to compact concrete, soil, or asphalt. The primary objective of this research is to restructure and balance the assembly line of existing vibratory compactors, as line change jobs have been proposed for future implementation. To carry out this objective, video analysis and the study of time at a particular workplace occurs. After analyzing, it was found that the cycle time at different workstations was not similar, and one operator was taking a long time, and another operator was taking less time at one station. In the case of this line, the total time invested by the operator was not balanced and caused the inefficiency of the assembly line. To reduce non-value-added activities, cycle time and the appropriate use of workforce balancing is an effective tool for improving the throughput of the assembly line.

The main objective of balancing the lines is to minimize the workstation and maximize the production rate. The stopwatch time study analyses processes and determine which process involves non-value added activities and consumes time. The main focus of industrial engineering is improving productivity, reducing production cost, ensuring production quality by using strategies. To enhance productivity, time study analysis, motion study analysis, job evaluation analysis, and merit rating can be used to provide specialized services to production departments.

An operation is called the work done along the line at each station, and each operation is a combination of one or more elements. Productive and Efficient balancing on the line means combining the elements to equal the workload of the workforce and equal the processing time of each workstation to the takt time. Based on the literature available and the requirement of case new Holland following objectives are selected for the present research work:

The specific objectives of the project work –

1. To conduct method study and work measurement of vibratory compactor assembly line for minimization of lead time and elimination of wastes.
2. To analyze the line balance and reallocate the activities in the line efficiently.
3. To minimize the number of workstations and maximize output at the desired time.
4. To develop and suggest an improved assembly line with better efficiency.
5. To study how many operators should be present in the assembly line and balance the workload among operators.

There were 13 no. of workstations –

1. Assembling of the front axle, chassis, and hydraulic tank.
2. Assembling of the fuel tank and steering cylinder

3. Assembling of engine and hoses
4. Assembling of ROC and foot pump hose connection
5. Mounting of ROC bracket support
6. Cabin and Tire Mounting
7. Mount the Relay mounting plate
8. Frame and Headlight mounting
9. Roller Mounting
10. Oil filling and powering the machine
11. Mounting Roof
12. Mounting Fix hood and Deflector plate
13. Pasting Decals and finishing

2. LITERATURE REVIEW

The previous research work deals with the utilization of lean tools for lead time reduction in a gear manufacturing industry has influenced the results in the process duration by decreasing 300 minutes to 180 minutes and lead time also reduced from 7 days to 5.5 days proposed by Sivaraman Parthasarathi et al. (2021). Asareilla Findya et al. (2020) using Westinghouse assessment method to calculate standard time performance ratings and determine frequency and abnormalities in skill, effort, conditioning, and consistency. They lead to an efficiency improvement of 76.76% to 89.38% with this approach.

The research work proposed by G. V. Punna Rao and Nallusamy et al. (2020) raises awareness of the importance of implementing phosphorus technology in the medium-sized belt manufacturing industry. This study will help show the selection of the right technology to increase the potential and productivity that exists in the selected industry. They also aim to increase overall productivity by eradicating waste and non-value-added activities at all stages. As a result, after applying the appropriate phosphorus method, we noticed that lead time was reduced by approximately 1256 minutes and total production increased by approximately 9%.

Ismail W.R. Taifa and Tosifbhai N. Vhora (2019) proposed a systematic study to reduce cycle time to improve manufacturing productivity and reducing cycle time in various organizations and industries. Many researchers have applied multiple approaches to reduce the time they are no longer added to final products and services. When assessing the results of manufacturing processes in the manufacturing industry, it is important to keep in mind that the duration of the production cycle is considered one of the most important "economic and technical indicators".

Piyachat Burawat (2019) improve productivity using Lean Six Sigma, ECRS work studies and 5S in the cardboard manufacturing industry. Analyze questions collected from data managers and supervisors through brainstorming Pareto diagrams and cause-effect analysis. The results showed that manufacturing problems were caused by process delays, cluttered warehouse areas, shipping delays, and deceptive reasons in the cutting and die-cutting industries.

The standard assembly line is an important part of a production system that affects overall cost and efficiency. The manpower productivity on an assembly line has a direct impact on actual line efficiency. As a result of heavy physical workloads and monotonous attitudes, workers experience performance and work-related musculoskeletal disorders (WMSD). The WMSD imposes high compensation costs on businesses and completely degrades the quality of life of workers. To improve the efficiency of the assembly line, enterprises must consider not only the constraints of cycle time and priority but also the physical workload of the station. This article discusses the PFBA (Assembly Line) Type 2 balance problem, where the number of workstation lines is known. The main purpose is to balance the physical workload with the cycle time of the station at the same time. A rapid systemic assessment (REBA) methodology in the literature is proposed to determine workload. Goal programming models have been developed to solve problems and are used to explain the methodology of well-known examples of instances of small benchmark problems. (Olcay Polat et. al, 2018).

Jagdeep Singh (2017) investigating the importance of phosphorus manufacturing technology in the manufacturing environment. This study seeks to assess the performance of various phosphorus manufacturing tools in the manufacturing industry in northern India. The importance of the various phosphorus tools, the significant benefits gained after successfully implementing the phosphorus manufacturing approach, and the benefits gained after implementing the various phosphorus tools was identified. We surveyed one company and implemented the most important aspects of Lynn Productions. Research results clearly show that Just-in-time manufacturing is the most crucial element of value-added production. The results show a net reduction of 2,42,208 rupees per year after implementing the case company's lean manufacturing technology. This white paper shows the actual application of phosphorus technology and shows how manufacturing can lead to a real breakthrough in cost savings.

To increased productivity and profits of the leather goods industry by minimizing excess labour and developed the new methodology for specific tasks. Human resources research is the most important tool that helps increase productivity in the leather goods industry. Therefore, this investigation will help identify bottlenecks and suggest appropriate systems for improving productivity. Finally, applying the concept of a questioning technique, in which all relevant information is registered, and critical analysis was carried out on a specific production line. As a result, new and improved methods can significantly reduce the amount of work. We then did a time study on the stopwatch to determine the default time for all task sequences and calculated the daily capacity of each workstation. Applying industry method research and work measurements on the Surma production line for women's bags increased productivity by 12.71%. Md. Abdul Moktadir et al., (2017).

Ramadina, Chyntia., and Sosodoro, Widaningsih, Ineu (2016), planning the manpower with the help of the yamazumi chart and precedence diagram based on the takt time to arrange of workstations. The Chompoonoot Kasemset et al. (2016), have improve the efficiency with the ECRS and simulation techniques used to reducing the processing time from 4.99 hours to 3.49 hours (28.06 %) in the paper package factory in Thailand. Arivoli, Ashwinkumar., and Ravichandran, Vignesh (2015), deals with the cycle time reduction in the manufacturing line by mapping the current state and find out problem areas in the line and focus on only the bottleneck station. Morshed, Md. Niaz., and Palash, Saifujjaman, Kazi (2014), focuses on efficiency improvement of the single model assembly line with the help of reducing the non-value-added activities, cycle time and distribution of workload by using line balancing.

Amardeep, Rangaswamy, and Gautham (2013) using traditional assembly line balancing with the cycle time calculation and workload distribution among operators in an optimal sense of the vibratory compactor shop. The proposed research was carried out in the heavy machinery manufacturing industry, specializing in loader backhoe and vibratory compactors to improve the production process and checked the machine's quality until final inspection.

3. METHODOLOGY

This assembly line was proposed to be shifted to another workplace; therefore, this research work objective was to perform a time study and find out the area of improvement between workstations so that these problems can be overcome in the proposed line. Initially, one shift was working, but the operator's workload was very hectic. They did overtime to complete their task on a daily basis to fulfil the demand of a particular day. This overtime duration was 4-5 hours after shift over. Sometimes, this assembly line needed workers from another assembly line also indicates that there was a need to plan this assembly line in an efficient manner from the industrial engineering perspective. For achieving the target of an efficient and productive Vibratory compactor assembly line following research framework follows:

1) Video analysis of operations at a different workstation.
2) Stopwatch time study takes place
3) Determine value-added, and non-value added activities
4) Determine workforce utilization
5) Proposed the modified assembly line by using ECRS
6) Comparison of calculation results before and after improvements.

The first stage of this research is video monitoring of the process based on this stopwatch time study performed to identify the exact value of timings. Classify the activities as value-added and non-value added, direct observation of workforce at workstation monitored to identify operator's utilization. Based on the data collection and classification of activities ECRS approach is used for eliminating non-value-added activities.

Line Balancing Efficiency Calculation

Processing time was measured with a stopwatch. The processing time for each work item is randomly measured five times. Takt time is the estimated time to produce one unit of product.

$$Talk\ time = \frac{Total\ avibaletime}{Customer\ demand}$$

This study focused on the vibratory compactor assembly line where before line balancing calculation as follows when the shift time is 430 minutes, customer demand = 6unit/day, takt time = 430/6 = 71.67 minutes.

Total Work Content = Sum of cycle time on all the workstations.

= M1 + M2 + M3 + M4 + M5 + M6 + M7 + M8 + M9 + M10 + M11 + M12 + M13

= 46.5 + 40.96 + 43.8 + 47.4 + 21.4 + 53.6 + 36.2 + 40.3 + 38.5

+ 36 + 49.6 + 25.36 + 32.8 = 504.3 minutes

After calculation of total work content, theoretically, the minimum number of workstations (N_{min}) can be calculated as:

$$N_{min} = \frac{Output\ required * Total\ Work\ Content}{Production\ time\ available}$$
$$= \frac{6 \times 504.3}{430}$$
$$= 7.036 = 8\ Workstation$$

From the above calculation, it is clear that N_{min} should be 8 but in the existing assembly line, 13 workstations are present. Therefore, it is estimated that there is a possibility to decrease the number of a workstation with some improvements.

$$\text{Line balancing efficiency} = \frac{\text{Sum of task time}}{\text{No. of workstations} \times \text{Largest cycle time}}$$
$$= \frac{504.3}{13 \times 53.7}$$
$$= 72\%$$

It is clear that 72% of achievable efficiency would improve this efficiency by eliminating unproductive activities. The table below represents the manpower at the assembly line, and their idle time, utilization ratio are also calculated. As observed from the table, operation timings cause unbalancing between workers; this causes fatigue to some workers, and overloading occurs. As a result, the balancing of the lines with the ECRS methodology was applied on this line, and the number of workstations and operators was reduced. The translation of the ECRS concept is eliminated (excluded from unnecessary movements), combined (more efficient because it is a combined movement that can be executed at the same time), and redeployed (the work elements of different workstations are exchanged more efficiently) and simplified (Simplify repetitive exercise) [Asarailla].

1. Eliminate – The elimination method is a method of deleting work elements that have been determined to be inefficient so that processing time can be reduced. Remove the OP3 load on the workstation and repair the work element. Deletion of unwanted work elements occurs on workstation 1, and human resources on 1, 5, 8 workstations. You can save time by reducing unnecessary motion elements in the assembly process through the removal process. Factors related to removal included packaging/unpacking, walking, searching, body movements, waiting due to mechanical cycle time, handling, hoisting, and extra quality inspection. Find research time limits in stopwatch time study and eliminate unnecessary processing time for specific productive work tasks.

2. Combine – In this process, activities performed by more workers at a single workstation shifted to other workers of the different workstation so that operator's idle time is minimized and the number of operators also minimized. The combined method is a method that reduces processing time by combining several work elements into single. To the improvement of the work element by combining work station 3 with work elements 1 and 2. The combination of work elements combined at 2,3,4,5,6,7,8 work stations.

3. Re-arrange – Arrange activities in sequential order as Rear axle and front axle, chassis mounting takes place at workstation 1. The mounting of steering cylinder and hose mounting at workstation 2. The ROC mounting activity is completed at workstation 3. The cabin mounting takes place at workstation 4. The front frame assembly mounting is completed at workstation 5. The roller mounting is situated at workstation 6. The mounting roof and hood at workstation 7, and other remaining finishing activities like decal pasting situated at workstation 8. By the arrangement of these activities, the cycle time of all the workstations will be balanced and maintain the takt time of the assembly line.

4. Simplify – At this stage, simplify the work element as possible to reduce unwanted movement of the worker from one place to another for pick up any machine component at each and every workstation so that unwanted time can be reduced.

4. RESULT AND DISCUSSION

From the collection data, the production target of the assembly line was identified the six vehicles per day. The production of vibratory compactor has 13 workstations on the assembly line, and the line has one shift with 27/430 workers per shift with proper network time or daily operating time. Therefore, the target takt time for the assembly line is 53.75 minutes/unit. The following are the calculation results obtained through the collection and processing of data. Based on the results of the calculations performed, we obtained a 72% line efficiency value. This value does not reach the company's productivity target of 99.50%. Therefore, the assembly line needs to be improved to increase the value of the productive product. Improvements were proposed by improving the work method of the assembly line. In order to balance the assembly line of the vibratory compactor time study was carried. There were 13 workstations where some operators performed different activities, and classification of activity with timings in minutes presented in Table 1.

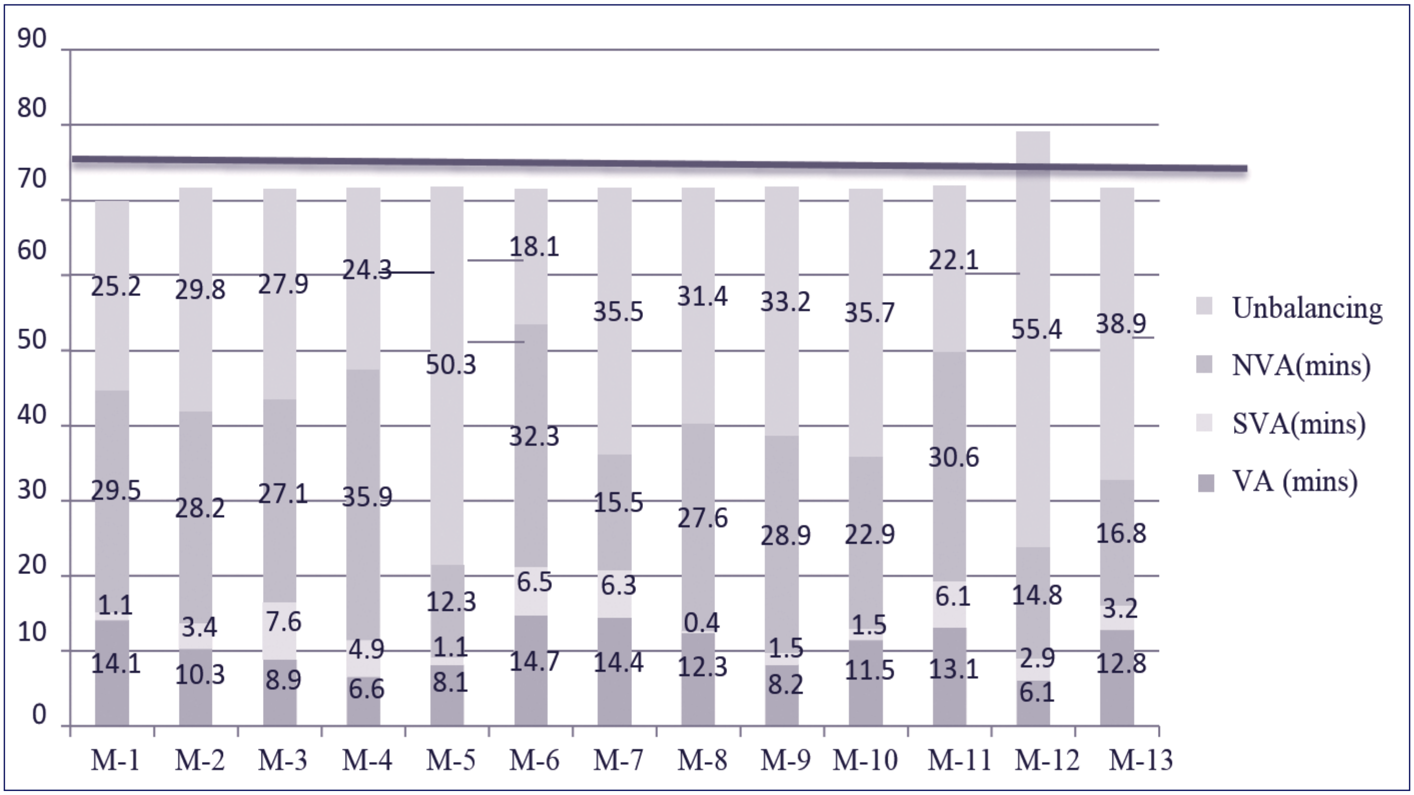
Table 1: Unbalancing and Cycle time for all the workstations before line balancing

Station	M1	M2	M3	M4	M5	M6	M7	M8	M9	M 10	M 11	M 12	M 13
VA (mins)	14.1	10.3	8.9	6.6	8.1	14.7	14.4	12.3	8.2	11.5	13.1	6.1	12.8
SVA (mins)	1.1	3.4	7.6	4.9	1.1	6.5	6.3	0.4	1.5	1.5	6.1	2.9	3.2
NVA (mins)	29.5	28.2	27.1	35.9	12.3	32.3	15.5	27.6	28.9	22.9	30.6	14.8	16.8
Cycle Time (mins)	46.5	41.9	43.8	47.4	21.4	53.6	36.2	40.3	38.5	36	49.6	16.3	32.8
Takt time (mins)	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7	71.7
Unbalancing	25.2	29.8	27.9	24.3	50.3	18.1	35.5	31.4	33.2	35.7	22.1	55.4	38.9

These workstation timings, which are given in the above table, can be better understand with the help of this graph.

Based on direct observation and brainstorming with a segmented head on the assembly line, it is possible to generate a yamazumi graph, as shown in Figure 1. The factors affecting the efficiency of the target line have not been satisfied, especially human factors, machines, environment, materials and methods. Regarding the human factor, there are two factors. Specifically, the moderator handles the defective product because he is less meticulous and talkative while working. As for the mechanical factor, there is a factor called the reliability and quality of the vehicle, which requires inspection during assembling without affecting the work of the line.

Figure 1: Yamazumi chart before line balancing



The methodological factor is that there are contributing factors. The work takes a long time due to wasted moving elements. There are two factors; the shortage of materials due to the lag in the supply and the lack of materials caused by the poor quality of materials put into the process. Then two elements are environmentally responsible: noisy workspace and small work area. The figure shows the unbalancing of the assembly line due to unproductive factors. The concept of ECRS (eliminate, combine, rearrange, simplify) is one of the methods used to improve the way we work and maintain the balance of our production lines. The proposed upgrade will enhance the efficiency of the line and the productivity of the assembly line. The improvement of working methods based on the ECRS concept is illustrated in Figure 2.

After visualizing the unbalanced yamazumi chart in the assembly line, analyses of the activities carried out depending on the cycle time were conducted to eliminate these tasks. To eliminate workstations in the production line, combine tasks from separate workstations. The following is the calculating part after eliminating and merging activities:

After line Balancing-

After balancing the line number of workstations can be reduced to 8. From the formula, we can calculate what should be the output if the line was balanced.

Total Work Content = Sum of cycle time on all the workstations.

= M1 + M2 + M3 + M4 + M5 + M6 + M7 + M8

= 53.1 + 53.4 + 53.1 + 53.6 + 53 + 53.3 + 52.7 + 32.8

= 405 minutes

The lead time is reduced, then from the formula of the minimum number of workstation output, can be calculated.

$$N_{min} = \frac{Output\ required * Total\ work\ content}{Production\ time\ available}$$

$$8 = \frac{Output \times 405}{430}$$

Output = 8.47 = 8 Vehicle per day

The output of the assembly line should be 8 if some activities are eliminated. Then takt time was also reduced to 53.75 minutes in the modified assembly line. The improved line balancing efficiency is given as:

$$\text{Line balancing efficiency} = \frac{505}{8 \times 53.75} \times 100$$

$$= 94.2\%$$

The observation indicates that the efficiency of line balancing is more significant in the altered assembly line. With the elimination of unnecessary movement, activities are merged into workstation 8 and space-saving has also occurred.

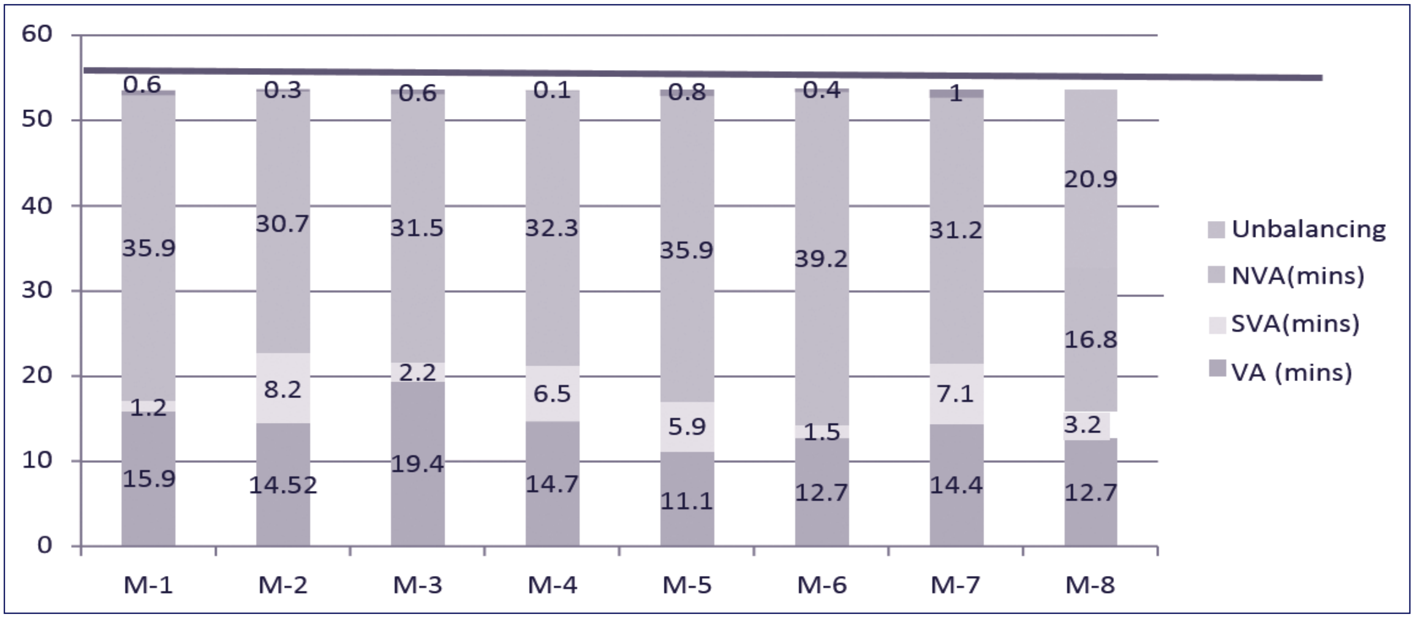
After Line Balancing-

From the investigation, the cycle time should be equal to the takt time of the assembly line. It is clear that the timing of the various activities is in Table 2 and in the graph since the number of workstations is reduced by 8 after the removal and combination of tasks in one workstation, which is illustrated in Figure 3.

Table 2 Unbalancing and cycle time for all workstations after line balancing

Station	M1	M2	M3	M4	M5	M6	M7	M8
(VA (mins	15.9	14.52	19.4	14.7	11.1	12.7	14.4	12.7
(SVA (mins	1.2	8.2	2.2	6.5	5.9	1.5	7.1	3.2
(NVA (mins	35.9	30.7	31.5	32.3	35.9	39.2	31.2	16.8
(Cycle Time (mins	53.1	53.4	53.1	53.6	52.9	53.3	52.7	32.8
(Takt time (mins	53.7	53.7	53.7	53.7	53.7	53.7	53.7	53.7
Unbalancing	0.6	0.3	0.6	0.1	0.8	0.4	1	20.9

Figure 3: Yamazumi chart after line balancing



5. CONCLUSION

The main goal of this project was to design an assembly line as efficient as possible while using as few workstations and operators as possible. There are no idle operators because the operator's usage is optimized. This enhancement has made the production of assembly processes more effective as new assembly lines are created with a minimum labour force and assembly costs.

Table 3: Comparison of Result

Parameters	Before	After	Remark
Production Qty. per hour	6	8	Improvement % 33.33
No. Of workers	27	17	Reduction % 37
No. Of Workstation	13	8	Reduction % 38
Line Balancing Efficiency	72.37	94.2	Improvement % 30
(%) Balance delay	45.87	5.67	Reduction % 87.6
Throughput time	504.3	405	Reduction % 20
Takt time	71.67	53.75	Reduction % 25

From the table, we can conclude the data after modification in the assembly line. The outcomes of the improvements can enhance working procedures with trajectory efficiency values of 72% to 94.2%. This means that the ECRS concept can improve the efficiency of the line within the assembly lines. Efforts to raise the production target can be made using the idea of ECRS (Eliminate, Combine, reorganize and Simplify), and line balancing. The concept of ECRS makes it possible to eliminate, combine, reorganize and simplify inefficient and ineffective work elements. After improvements to the ECRS concept were made, several work stations provided reduced mating, relocation and a streamlined set of assembly processes for work elements. In this study, this increase can reduce total working time, improve balancing efficiency, reduce balancing delay, and achieve production goals by reducing overall cycle time or maximum station time and increasing production. It needs to be accompanied by more efficient methods to develop ECRS concepts in other industrial fields through additional research and to adapt to the industrial age 4.0. This study impacts industry managers to recognize the merger of activities and assign activities to operators in an efficient way that no worker will do overtime and should not be overburdened with the work. This assembly line shifting work was proposed in the future, so this work helps them set up their assembly line in a productive way.

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AUTHORS

Ms. Nisha Sahu, Academic Associate, Operations Management and Quantitative Techniques, Indian Institute of Management Indore, Prabandh Shikhar, Rau-Pithampur Road
Indore - 453 556 (Madhya Pradesh) India
Email: nsahu91@gmail.com, Mobile No. 9074484205

Dr. Atma Ram Sahu, Assistant Professor, Depaertment of Mining Engineering Godavari Institute of Engineering & Technology (A) Rajamahendravaram, Andhra Pradesh - 533296
Email: atmars.rs.min15@itbhu.ac.in,
Mobile No. 9424917835

Raviraj Garg, Chairperson, DL Healthcare Pvt. Ltd,
Email: dlmedical21@gmail.com,
Mobile No. 7566529174

Dr. R.C. Gupta, Professor, Department of Mechanical Engineering, SGSITS Indore, 23, Sir M. Visvesvaraya Marg, Vallabh Nagar, Indore – 452 003, (Madhya Pradesh) India
Email: rcgupta.indore@gmail.com,
Mobile No. 9425072465