The Evaluation of Station Workload Through the Application of Work-Study Principles: A Case Study in the Automotive Industry

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Abstract

The study explores the application of lean six sigma in case study of finding recommendation to solve real time production problems to increase efficiency and utilization while looking into manufacturing wastes which have a direct implication on production output. The study considered real production problem and the information was gathered was based on the station workload (time study and process waste) looking an efficiency and utilization of production line. The optimization of production process was based on work-study principles like lean six sigma, kaizen, time study. Data collection used is survey & direct observation in a form of a time study. Based on LSS application, it was discovered that the current production performance standard can be improved & utilization can be increased and more manufacturing wastes were generated. The outcomes show that in this balancing situation, the suggested framework performs better than earlier approaches. The findings would offer insightful recommendations for balancing the line and increasing utilization to enhance assembly lines.

Keywords
Production process, lean six sigma, time study, single model assembly, efficiency & utilization.

Introduction
This project was done in at an automotive manufacturing plant in South Africa. Optimization of workloads involves redistributing processes across the assembly line to increase efficiency and operator utilization. The process sequence in each station is in precedence order, looking into which processes are done before others and what the consequences of doing one before the other are. This study focuses on optimization workstations, which are critical in an assembly system because they balance the line and increase the system's efficiency and productivity. Because of globalization, manufacturers are under enormous pressure to produce products in shorter cycle times while remaining competitive. The assembly line in a flow-oriented production system involves distributing work to different stations by assigning all-important jobs to workstations. Process optimization aims to assign all relevant jobs efficiently and effectively to workstations in a flow-oriented production environment.

Sub-manufactured parts are assembled during assembly to create a finished product. An assembly line is a series of workstations arranged along a table or conveyor that transports items between the workstations. In an assembly system with workstations arranged in a sequential order, work is done on the work parts as they pass from one workstation to the next. The entire burden distributed among the workstations as evenly as possible without disrupting the sequences and relationships in the assembly procedures. To ensure synchronous transfer in the assembly system, the workload is allocated so that each workstation occupies the same time intervals or has the same cycle time. Assembly line balancing or line balancing is the process of assigning equal cycle time to workstations in an assembly system.

The vehicle assembly line is the most complex system, with numerous workstations and many components. The layout of an assembly line is critical due to space constraints and must be optimized. In this plant, manufacturing is still labor-intensive, and automation techniques are underutilized. Lifting and locating, for example, are still done manually in tire assembly. Currently, production targets are met with massive Work-In-Process (WIP) inventories, and equipment maintenance is neglected, resulting in equipment failure. Because the cost of highly skilled labor is high, the trend is to reduce it, which affects productivity. All of today's issues must be addressed. Cycle time is an important consideration when discussing assembly line systems and line balance. The total of all task times must not exceed the cycle time, which is the amount of time available to the workstation. There may be significant differences in cycle time among workstations along an assembly line at times. As a result, multiple workstations of the same type and capacity were used to account for the cycle time differences between the workstations. Multiple workstations of the same type with relatively long cycle times can reduce total production cycle time and ensure smooth production. Cycle time is closely related to the expected production capacity/output of an assembly line, with production rate defined as total production time divided by cycle time.

When planning and managing a mixed-model line assembly, system engineers collaborate to achieve goals such as maximizing line throughput, reducing the number of stations, maintaining a balance of work across stations, satisfying delivery rates, adjusting changes in the product mix, and more. Before proceeding to the more complicated steps, it is critical to understand the number of stations required and the requests assigned to those stations. Products are built sequentially on an assembly line that travels from workstation to workstation until final assembly. Assembly lines have a set number of workstations that are spaced out along the flow production area. Products are passed down the assembly line from one workstation to the next. The total amount of work must be divided into a specific set of elementary tasks to produce any product on an assembly line. A task time, as well as specific equipment and/or skilled workers, are required for a specific operation. The total workload required to assemble a product is calculated by adding all task times. In the automotive industry, however, the car moves from one station to the next as various parts are fitted until the unit is fully assembled and ready for dispatch. Most operations are now bounded by equipment, so man vs machine diagrams are used instead of a single cycle time alone. The problem that the manufacturer facing is unbalanced workstations and underutilized operators who spend approximately 40% of their cycle time idling that is considered a waste. Some of the waiting is caused by environmental obstruction like working with equipment's. Overcoming this obstacle is critical, given the importance of establishing appropriate workload standards. This research aims to utilize theory of constraint and six sigma to recommend ways in which manufacturers can use to increase operator utilization.

Objectives

The study's specific objectives are as follows:

- Investigate current workload.
- Exploring more in depth of the consequences of unbalanced assembly line.
- Recommending optimization of station workload with industrial engineering framework.

The goal is to achieve an efficient balance of processes and workstations to reduce idle time. Line balancing aims at grouping the facilities or workers in an efficient pattern to achieve the best or most efficient balance of capacities. A perfectly balanced line may be impossible in real-world production systems because, in most cases, equal workload allocation to workstations is prevented by precedence and/or technological constraints, or the variability of processing times at individual workstations varies due to differences in the nature of the tasks. The research investigates methods to increase operator utilization on large automotive assembly lines, a linear shape configuration, and the effects of an unbalanced workstation.

1. Literature Review

Adeppa (2015), stated that, a sequential construction system is an assembling method wherein an item is moved by a motorized transport between stations where the different tasks expected for its gathering are performed. It is utilized to rapidly collect huge amounts of a uniform item. Sequential construction systems were initially planned for financially savvy large-scale manufacturing of normalized items, using high work specialization and the related learning impacts. Assembly Line Balancing (ALB), then again, empowers current creation procedures, for example, mass customization by giving proficient streamline frameworks to low volume gathering to-arrange creation. Sequential construction system balancing can be characterized in various ways. Sequential construction system balancing is characterized as the task of numerous work components to various workstations to expand Balancing Efficiency, lessen the quantity of workstations, or accomplish some other objective. Without straying from the priority ordered progression, objective capability for a given result volume. One more method for characterizing ALB is to relegate occupations to few workstations for a particular cycle span as well as to lessen the probability of a creation line end.

Sequential construction system adjusting enjoys the accompanying benefits:

- Decreasing the quantity of workstations expected for a given cycle.
- Diminished process duration for a given number of workstations.
- Diminished balance delay (or) expanded adjusting effectiveness.
- Decline absolute inactive time.
- Shortening the general office or line length (Boysen et al. 2022).

Single model assembly line/ Simple assembly line

A basic mechanical production system, which is utilized to deliver a huge amount of a solitary kind of item, is an illustration of a stream situated assembling framework and can be conceptualized as a progression of straightly coordinated workstations associated by a transport line that transports item units (Kübler et al. 2018). The units are directed through the workstations in the request in which they were gotten during creation. Subsequently, they infused toward the start of the line, moved starting with one workstation then onto the next, and yielded toward the end. The workstations work pair. Each has own arrangement of errands are rehashed on resulting units.

As indicated by Sivasankaran and Shahabudeen (2014) while adjusting a solitary model mechanical production system, just a single model is collected in the mechanical production system; in any case, while adjusting a blended model mechanical production system, different models are gathered in a similar sequential construction system. The utilization of blended model sequential construction system balance is expected for an organization to be receptive to its clients' necessities. At the point when an organization makes different models, the utilization of blended model mechanical production system equilibrium will assist the organization with satisfying the need for various models -9 in assembling and production network the board, yet it's as of late gotten forward movement in other discrete modern associations (Mwacharo 2013). As item request develops, keeping up with quality and constancy has turned into a need for assembling ventures to acquire consumer loyalty (Gupta et al. 2012). To contend on the lookout, organizations should characterize, dissect, improve, and control their current assembling frameworks (Gupta et al. 2012).

Kaizen

Kaizen is a Japanese expression that consolidates the words "Kai" (change) and "zen" (improvement) (great)(Delgado and Castelo 2013). As per a few creators, kaizen is a perspective that urges every worker to consider how we can improve to help both individual execution and business execution. Sutari (Sutari 2015), utilized main driver examination and Kaizen procedures to lay out a training occupied with delivering wind tribune parts.

Time study and Takt time

Taifa and Vhora (2019) defined cycle time as one of the sustainable factors which must be optimized to improve efficiency in the manufacturing industry. Koltai et al. (2021) proposed a dynamic CT setting algorithm. Cycle time measurement the calculation of the cycle time of each operation. Lean helps to reduce production overburdening. Takt time is the customer demand rate, i.e., total available shift time per day / 12-month production program (average daily volume per day) expressed in minutes per car.

Methods

The method adapted in the study is a case study. The method show how is Lean tools are used to evaluate station loading in an automotive manufacturing plant in South Africa. The study also presents the consequences of unbalanced assembly line. The case study method was chosen because it offered flexibility in design and implication by allowing both quantitative and qualitative analyses, which are more sensitive to organization complexities phenomena. A case study method offers a means of investigating complex and critical functions of the value chain. In this study, a real-time problem of customers' dissatisfaction was considered. The gathered data were based on machine functionality (up time, downtime, and cycle time), material and labor flow at every process stage of the production line. The assessment and optimization of the production process of the company were based on lean tools like kaizen, Yamazumi chart, and time study. These tools are valuable for diagnosing and resolving set of organizational problems.

Data Collection

The most notable technique for get-together and evaluating information on unambiguous components including a significantly grounded framework to review results by noting basic solicitations is known as information blend. This study's information came from a diagram outline wrapped up by line chiefs and facilitators. This strategy was picked since it licenses us to make heads or tails of the opening between our doubts and our comprehension. Plus, to the degree that study size, it is a sensible district.

Table 1. Methods of data collection and the time required for each method

Method	**Description**	**Duration** (collection)
Time study (direct observation)	• The operator utilization in an automotive production assembly were determined using time studies. • To determine the current utilization of operators, time studies were conducted.	10 days
Process mapping	• Process mapping was used to visually represent the process assembling an automobile and was broken down into individual processes. • To investigate the current processes, process mapping and analysis were required.	3 days
Survey	• Survey was conducted process designer, Coordinator and the operators working on the line. • Survey was conducted to collect information about process improvement and challenges encountered when planning man vs machine processes.	7 days

Results and Discussion

The overall process for a manufacturing plant has been sketched starting from the bodyshop assembly, paintshop and the final assembly as depicted in Figure2.

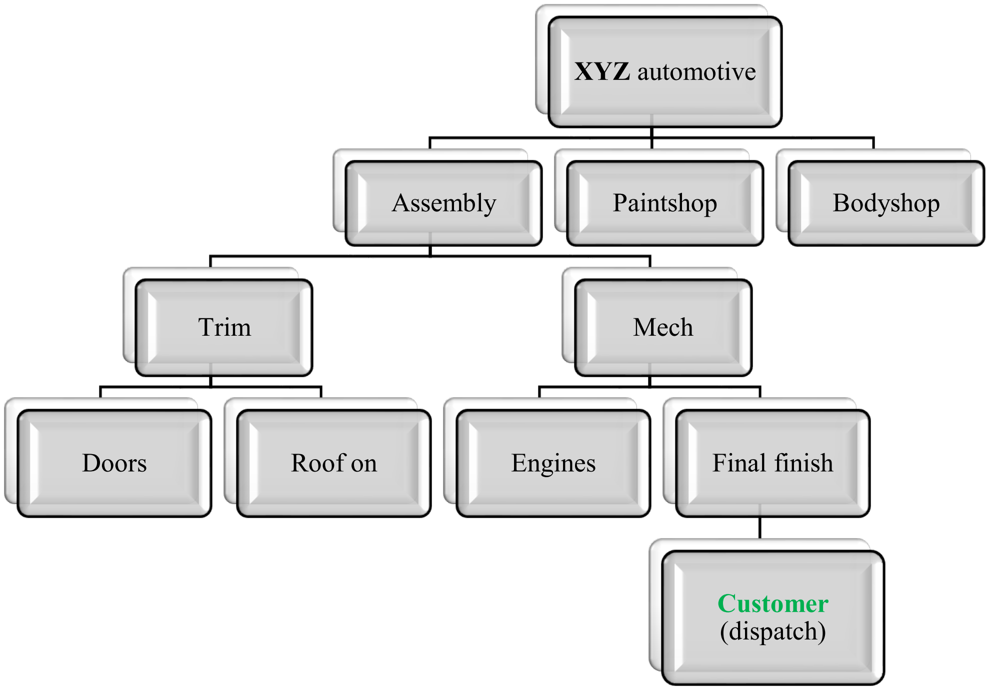

Figure 1.Overview of the entire automotive process from body shop to dispatch

The vehicle assembly line

A vehicle assembly line, in general, consists of a body shop, a paint shop, a trim line, a final assembly line, testing, and a rework line. For body fabrication, the body shop includes a Press shop and Welding stations. Then it is off to the paint shop for pre-treatment and finishing touches. These painted bodies are then sent to the Trim line to be outfitted with seats, covers, electrical, doors, and brakes. The final assembly line starts with unloading the chassis and installing axles, fuel tanks, steering, and other components.

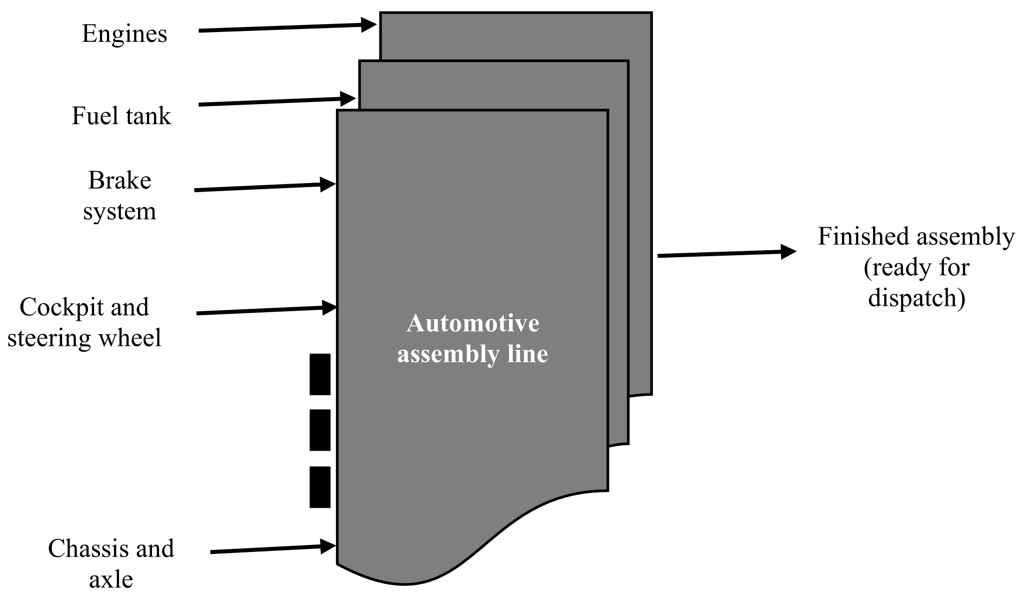

Figure 2 . An image of an automotive assembly line with a list of inputs and outputs

5.2 Current Processes

One of the aims of the study was to analysis the current process. In order to gain a clear understanding of the impact of man vs machine, a time study was conducted in 8 assembly trim stations, four of which are manual and four of which are semi-automated. Each station was subjected to 5 cycles to ensure accuracy. Trim line components are assembled on a moving, paced conveyor. A power conveyor is being used. On the conveyor, there are 12 workstations (but in this research only 8 stations were observed in detail). Cars are routed through ten workstations on either side of the moving conveyor. Stations on the conveyor's left side process the car on the right-hand side of the car, while stations on the conveyor's right side process the car, and there are a few stations where the operator works in the boot, and the engine compartment. Each shift has 12 operators. The car is then conveyed until it reaches the final assembly line.

Table 2. Main processes in an automotive assembly line

No	***Processes***	***No***	***Processes***
1	Chassis Loading and rear axle loading	***11***	Bonnet fitment
2	Fuel Tank fitment	***12***	Cockpit fitment
3	Shock Absorber fitment	***13***	Glass installation
4	Brake system	***14***	Seat fitment
5	Steering gear	***15***	Harness routing
6	Propeller shaft fitment	***16***	Doors on & off
7	Tyre fitment	***17***	Fuel filling
8	Damping's and grommets	***18***	Water test inspection
9	Battery fitment	***19***	Gear box and engine
10	Roof installation	***20***	Harness routing

The assembly line is configured with a fixed number of workstations and a set takt time. The maximum workload is less than a predetermined amount, and the target production is met. The goal is to keep workloads as smooth as possible around the defined takt time. The predefined takt time for each workstation on the assembly line is 156.6 seconds. The time required to complete all the tasks on the workstation. The cycle time, efficiency, and utilization of the stations were calculated using the formulas listed below:

Takt time is the customer demand rate, i.e., total available shift time per day / 12-month production program (average daily volume per day) expressed in minutes per car. Below is an example of our current shift pattern.

$$\text{Takt time} = \frac{Workstation\ cycle\ time}{Customer\ demand}$$
$$= \frac{465x2+420}{518\ units/day}$$
$$= \mathbf{2.61}\text{min or } \mathbf{156.6}\text{secs}$$

- TAKT time is the customer demand rate or how often a customer wants a car
- If the available time is 1350 minutes and the TAKT time is 2.61 minutes, this plant produces = +_518 automobiles per day.

Number of Workstations

The fewer workstations there are for the same task set, the more tasks each workstation includes the more task combinations there are, and the higher the balancing. On the contrary, as the number of workstations grows, so does the number of tasks processed in each workstation, making balancing difficult. In addition, the number of workstations is proportional to the cycle time. As the number of workstations increases, the cycle time for the same task set decreases. As a result, changes in the number of workstations are inversely proportional to changes in cycle time.

Workstation Idle Time

In terms of economics, workstation idle time has a direct impact on manufacturing costs and enterprise profits. In the same cycle time, less idle time means fewer workstations required. To improve assembly line production efficiency, idle time should be kept to a minimum. To compare different solutions, the mean idle time of workstations is chosen as the optimization objective.

Station Time

The total time each station must complete its task is measured against the line takt time. If the operator is unable to complete his/her tasks within the time allotted for the station, there is a risk of overloading or a lack of training. When measuring operator cycle, consider some of the factors that may prevent the operator from completing his or her tasks at a given time.

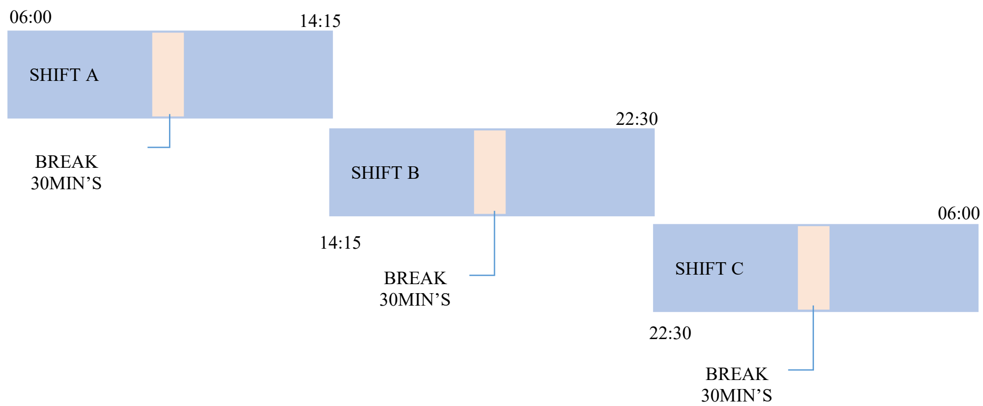

Figure 3. Waterfall for working model time of the company.

The further data below shows the available time and outputs.

Table 3. Calculation of available time in a shift.

	SHIFT A	**SHIFT B**	**SHIFT C**	**Σ**
	06:00 -14:15	14:15 - 22:30	22:30 - 06:00	06:00 - 06:00
Available time	465 min's	465 min's	420 min's	1350 min's
Break	30 min's	30 min's	30 min's	90 min's
Total time	495 min's	495 min's	450 min's	1440 min's
Available time	465 min's	465 min's	420 min's	1350 min's
Takt time	2.61 min's	2.61 min's	2.61 min's	2.61 min's
Output				518 units

The shift start time and end times are : 6.00am – 14.15pm. So, the shift time 8.25 hrs. X 60 min = 495 mins and less 30 min lunch = 465 mins. Therefore, the total shift available time is 7.75 hrs.

1.1. Time studies

A time study was conducted on 12 stations in one line, with 5 cycles taken for each station and the average cycle used as the station's final cycle. Each workstation's cycle time was calculated from the moment the part was picked up until it was delivered to the following workstation. A video camera was used in recording to improve the reliability of the data obtained.

Table 4. Displays the station cycle time, takt time and loading for the workstation.

Station No	**Station time**	**Max cycle time**	**Takt time**	**Operator loading**
#1	122	140.9	156.6	78%
#2	138	140.9	156.6	88%
#3	150	140.9	156.6	96%
#4	130	140.9	156.6	83%
#5 2 Man	130	140.9	156.6	83%
#6	137	140.9	156.6	87%
#7	134	140.9	156.6	86%
#8 2 Man	142	140.9	156.6	91%
#9	142	140.9	156.6	91%

#10	120	140.9	156.6	77%
#11	134	140.9	156.6	86%
#12	146	140.9	156.6	93%

Station 5&6, 8& 9 are two-man process stations where they are also controlled by the takt of the cell.

- 5 & 6 is roof fitment. Station 6 is a bit higher than 5 because the operator at station 6 is the one who is picking the roof from the cell with manipulator and fit to unit.
- 8 & 9 is glass fitment (windshield and rear glass)

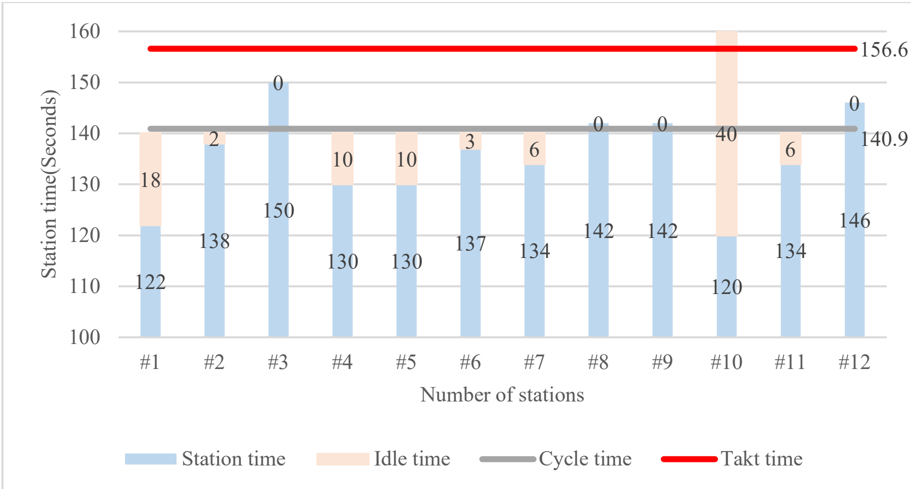

Figure 4. Overview of station times measured against target cycle time and takt time (Trim A stations)

Loading charts of current processes measured against the target loading. When planning processes target loading is set that each operator should not be above or below the loading to allow time to catch up in case there is violation of constraints. Loading charts for one assembly line (Figure 5) measured against the target loading. The average number of tasks completed per hour is another important indicator of a manufacturing line's efficiency. The ratio of current productivity to best practice productivity is defined as efficiency. The highest possible productivity is defined as best practice.

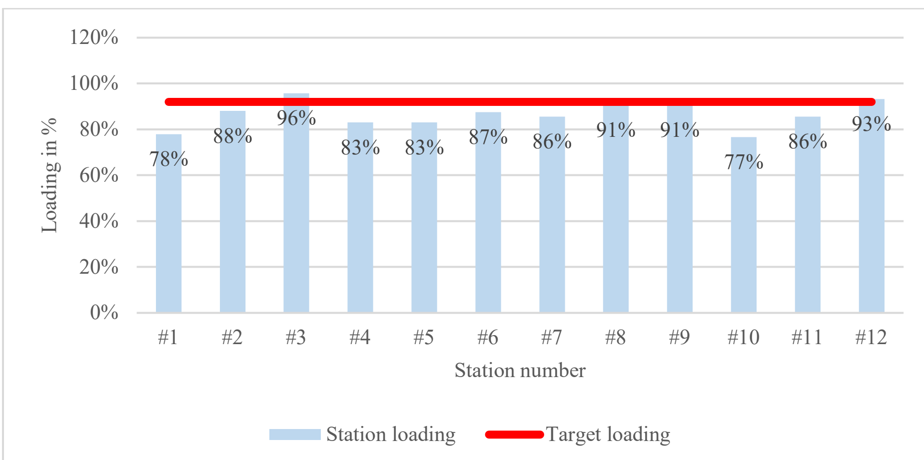

Figure 5. Loading Chart (Trim A stations)

The following formula can be used to calculate the efficiency of a production line:

$$\text{Line efficiency} = \frac{Sum\ of\ all\ tasks\ time\ (Sum\ of\ stations\ cyscle\ time)}{Actual\ number\ of\ workstation\ \ x\ Workstation\ cycle\ time}$$

$$= \frac{1625}{12\ \ x\ 140} = \mathbf{86}\%$$

1.2. Line Efficiency

Figure 6 represents the line efficiency of the stations in the assembly line. The station that was least utilized is Trim A station.

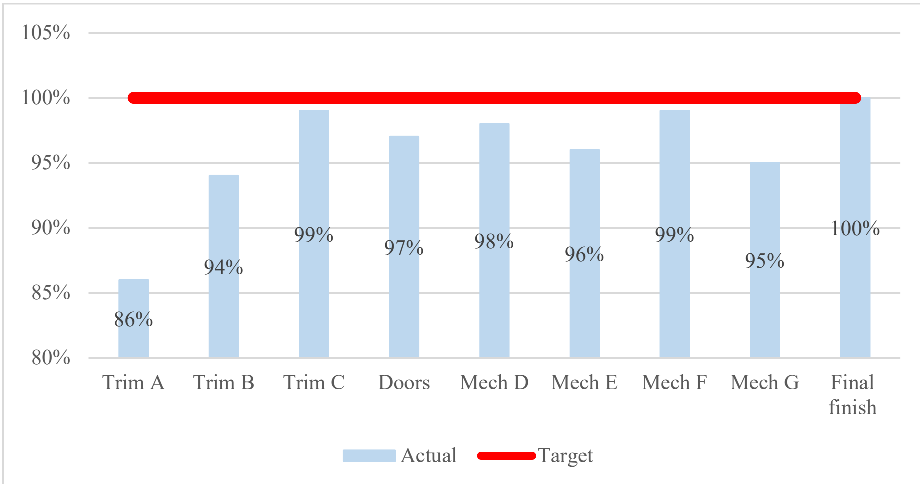

Figure 6. Balanced line efficiency for stations

Trim A utilization is a little low because it is a takt-based line that is constrained by equipment. There are many limitations when it comes to material strip, so the processes that must be present are those that do not require many parts. When looking at stations 5, 6, 8, and 9, there are robots on one side of the station, so supplying parts to the stations with robots is difficult due to space constraints. As a result, the process is primarily reduced to processes that do not require material stripping.

For station 12, where the roof fitting is done, a man vs machine comparison was made (Table 5). The manipulator adds a significant amount of time to the operators' process because it is set slightly lower than the line speed, whereas if it is set to be the same time as the line speed, the operators can use the extra time to perform other processes, according to the findings of the study.

Table 5. Compares process done by man and that done by machine for station 12 (Man Vs Machine)

No	Operation Description	Resources	
		Man	Machine
1	Fetch manipulator for the picking of roof	X	X
2	Scan roof for coincidence check	X	
3	Pick up roof from stillage with manipulator		X
4	Open cell for the application of adhesive	X	
5	Robot applies adhesive to roof		X
6	Open cell for to pick roof	X	
7	Pick roof and fit on unit	X	
8	Walkway to unit	X	

Station 8 and 9 is a two-man process stations and there two operators working at the same time. Since the operation requires two people, all the operators are taking up the glasses at once. Rearlite (rear glass) installation is the first step, after which the windshield is installed (front glass). While station 8 selects the jig for the windshield installation, station 9 opens the boot. They are then placed on the cell for the application of the sealer, selected the windshield for fitting together, and then moved to the rearlite, where the process is repeated for the duration of the shift.

Table 6. Operation conducted in station 8 & 9 two-man process [non-value adding (NV)]

NO	Operator	Task description	Task time (Sec)	Station time (Sec)	Cycle time (Sec)
1	1 and 2	NV# Walkway to next unit	10	142 (each)	140.6
2	1 and 2	NV# Walkway with gauge for rearlite fitment	3.90		
3	1 and 2	NV# walkway to rearlite cell	5.45		
4	1 and 2	Pick up rearlite window with hand suction cup jig and place on body	23.7		
5	1 and 2	Press in rearlite into body with hand	7		
6	1	Pick up joining gauge from trolley (Op1)	6		
7	2	Open boot lid (Op2)	6		
8	1 and 2	NV# Walkway to robot for the fitment of windshield	3.90		
9	1 and 2	Pick up windshield with fitment jig and place on body	20.9		
10	1 and 2	Position and push windshield into body (unit)	15		
11	1 and 2	Insert windshield into body	25		
12	1 and 2	Press in windshield into body with hand	7		
13	1 and 2	Pick up rearlite and windshield gauges and place on storage	6		
14	1 and 2	Stamp to confirm job done	2		

5.4 Five Why Analysis

An iterative, team-based approach to gathering information about potential problem causes. Following the definition of the problem, potential causes should be listed, evaluated, and selected, and the process should be repeated as many times as necessary to identify the root cause. Taiichi Ohno first proposed the 5 whys method in the 1950s (Ohno 1988). It gained popularity in the 1970s and is still used to solve problems by Toyota today. Ohno encouraged his team to investigate each issue until the root cause was found. "Observe the production floor objectively," he suggests. "Ask 'why' five times in every situation; it is regarded as one of the most effective problem-solving tools."
"Five Whys" meetings are held immediately after the company's problems are resolved. Development errors, site outages, marketing program failures, and internal missed deadlines are all examples of issues. When something unexpected happens, we could conduct a root cause analysis." It is important to note that the goal of the 5 whys is to figure out why something unexpected happened, not to assign blame. It also helps a team develop small, incremental steps to ensure that the same problem does not reoccur.

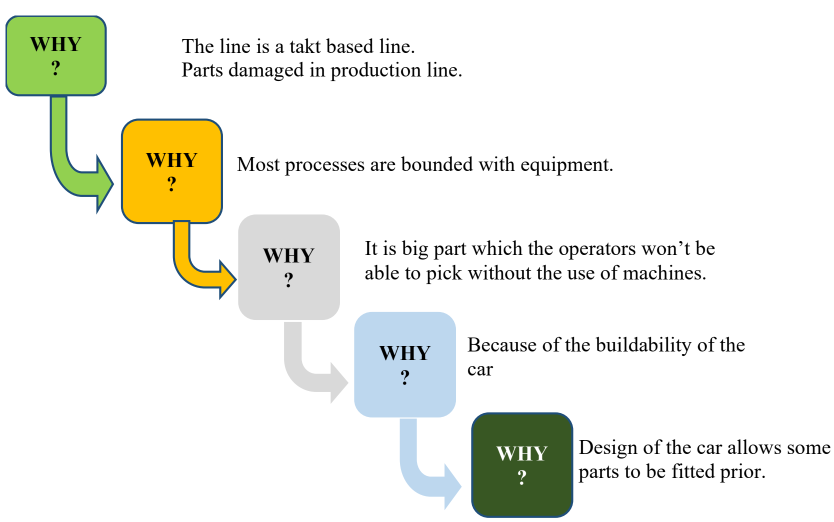

Figure 7. Five-Why Analysis

1.3. Interpretation of Results

1.3.1. Time study

During data collection, it was discovered that there are a few stations that are under loaded and others that have a lot of waiting time, indicating that they still have the capacity to take on more work to reduce idling time. Because it is a semi-automated plant, rebalancing is not simple; several factors must be considered, including:

- Autonomation, such as Toyota's machine strategy, is referred to as "Autonomy." Rather than investing in large homogeneous machines that can do everything but take hours to set up and run large batches, they invest in small machines that perform specialized tasks that humans would find tedious or repetitive and employ autonomation principles to ensure that the operator only needs to stop the cycle if something goes wrong.
- Outsourcing subassemblies to suppliers or establishing stations where subassemblies are completed and delivered to the fitment station.
- Improve the part supply strategy so that parts are delivered directly to the operators rather than being a walking distance away (using concepts such as Just in time or Just in Sequence)
- The cost of rebalancing the process to the other line is determined by the precedence of the processes.

The structure of the simulations is shown in Figure 8 below.

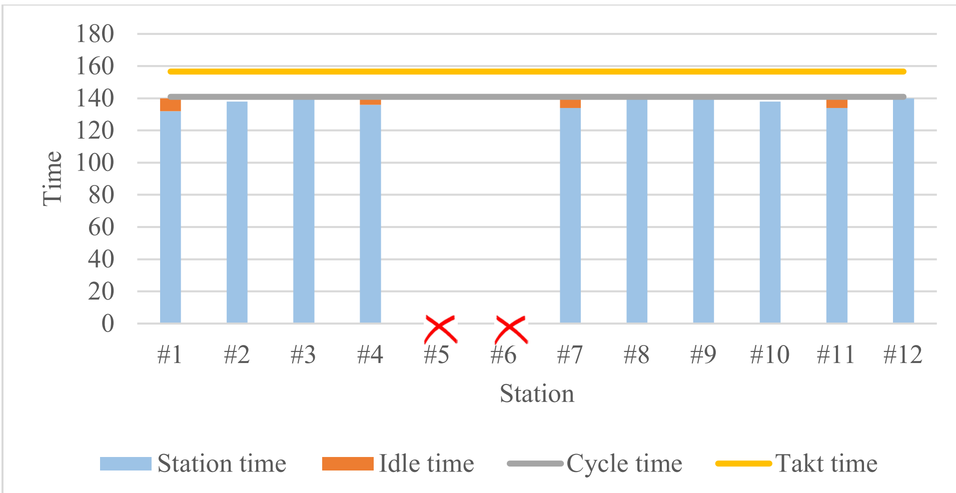

Figure 8. Simulated Station overview after proposed process improvement if rebalancing is done (Trim B Station overview)

If automation is used to automate stations 5 and 6, the organization could save money on labor. With some of the waste mentioned in section 5.4 eliminated, it is possible to remove two stations and move some of the processes around to achieve some balance in the line. Stations that can be eliminated are not only limited to 5 & 6.

Consequences of unbalanced assembly line

An unbalanced line is one that is not perfectly balanced and can occur as a result of different mean cycle times (CT), variability, or workstation breakdown. Unbalanced, unpaced, and asynchronous lines are more common in real-world operations than balanced, paced, or synchronous lines. The problem is that most real-world processes do not resemble the truly ideal balanced line, and the chances of achieving perfect or even near-balance are slim. Imbalance occurs as a result of different mean times between workstations, different variabilities, failure, and so on. Assembly lines are made up of a small number of workstations that are arranged along material handling equipment. As the assembly line moves down the line, workpieces are moved from one workstation to the next. The total amount of work must be divided into a finite set of elementary tasks in order to produce any product on an assembly line. It is extremely rare to put together a truly ideal balanced line without using buffers. Nonetheless, unbalanced lines have received far less attention than balanced lines. These lines are further divided into two subcategories:

- Paced line: The time allowed for a resource to work on the job is limited.
- Unpaced line: There is no limit to the time allowed for a resource to work on the job.

The research focused on a paced line with a time limit to complete the task. The operators have a time and station limit to complete their process, and the idle station is one where the operator can do everything and finish his process in one station. Even when a paced line and deterministic task times are used, unbalancing can occur as an unintended consequence of disassembly lines.

As a result of new, stricter environmental legislation, increased public awareness, and expanded manufacturer responsibility, manufacturers are increasingly recycling and remanufacturing their post-consumer products. In a flow production shape workload configuration, unbalancing a line could result in statistically significant throughput increases. Unbalancing a line in a flow production workload configuration may result in an increase in work in process for the line. Unbalancing a line configuration may increase the cycle time of the line. Unbalanced workload may increase output even in lines with low coefficients of variation. Underutilized operators add additional costs to the company; for example, if the lines have operators sitting at an average loading of 70% - 80%, we will need more operators than if we loaded the operators to target loading, which means fewer headcount and more utilized operators. An unbalanced line adds to headcount and idle time. The different methods can be used to obtain an imbalance in a specific production. As with the balancing line problems, different approaches were used to achieve distinct goals. Line balancing is not required if the material flow is continuous. Bottlenecks occur at some workstations and idle time occurs at others on unbalanced lines. The resulting output is less than if the line could be balanced.

Despite the obvious benefits of unbalanced lines in certain conditions, most assembly line research remains focused on the traditional ALBP. Because human resources are always involved in the operation of assembly lines, more knowledge about how to deal with line imbalance for a variety of performance objectives is required to support production in the twenty-first century, with its speed, flexibility, and performance requirements. Assembly line designers can benefit from simulation, particularly in terms of workstation capacity. As a result, the goal of line balancing is to have all workstations have nearly the same cycle time, resulting in no waiting. If the line is unbalanced, the organization is not meeting its goal of having a balanced line.

2. Recommendations and Conclusion

Robots can take the role of takeout stations 5 and 6, which will help us reduce MV as well as errors related to weariness and carelessness. The robot will pick up the glass from the cell and set it right on the component. Resequencing of processes to allow process that can be done earlier to be moved to the stations that are under loaded. Yamazumi chart line balancing is a technique for increasing labor productivity and line efficiency that is result-oriented and performance-based. The analysis reveals that the existing production system was not oriented toward spontaneous flow. The manufacturing process was designed part by part. Yamazumi chart line balancing can be used to implement flow-oriented production, which allows for complete product output from the first day of production planning.

To improve productivity and meet customer demand, the assembly line balancing problem is critical in all mass production systems. The primary goal of this study was to investigate the applicability of Theory of constraints (TOC) principles and lean six sigma in the automotive industry. In the manufacturing and service industries, lean manufacturing techniques are widely used. Lean is gaining popularity as a method of reducing time constraints. If Lean is not defined, employee quantity and quality will suffer. The six sigma DMAIC model can be used in the identification of problems in the automotive industry. These defects were reduced by appropriate corrective actions in the improve stage, as well as work standardizations and employee trainings to control these continuous improvements. If we are unable to find a solution with high balancing for a given cycle time for a given assembly line, we can change the cycle time to improve the balancing of the assembly line. If a solution with high balancing can be obtained, changing the cycle time is not necessary to improve balancing. The analysis of trade-offs between cycle time and workstation count helps to provide a better overall assembly line. Balancing assembly lines is a constant research topic, and there are numerous avenues for future investigation. When the workstation time exceeds the standard cycle time, for example, the next workstation is assigned based on the maximally-loaded-workstation-rule.

Unbalancing production lines is still an unexplored area of operations research, and a better understanding of their behavior can aid in identifying new approaches and solutions for configuring new lines or improving existing ones. As a result, the scope of this survey is limited to the flow line-balancing problem.

The proposed solutions have the potential to provide numerous benefits not only to the company, but also to other entities involved in its operation. The following are the benefits of this implementation: Customers - increased customer satisfaction because of increased timeliness; employees - improved comfort and organization; lack of overtime. The assumptions made when conducting the study are:

- Production runs with no planned downtime no PMs during production hours.
- Ergonomics for every station was taken into consideration when planning each station.
- The production line only produces one car model.
- Non-Conforming parts are not fitted or used.

Vehicle assembly line optimization has long been a popular area of study. The literature on vehicle assembly line optimization was reviewed in this paper. In this review, we've seen an increase in the use of simulations and optimization. The literature was reviewed to identify theoretical and practical gaps and to suggest future research directions in the field of Vehicle Assembly Line Optimization. Many authors recommend line rebalancing, line optimization, and splitting the bottleneck process into sub-processes as the best solution to the CT problem to maintain standard takt time and improve manufacturing process.

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