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BPJ 420

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FMCSA

Optimization and analyses of workstations which are either over-cycle or under-utilised

27100813

EXECUTIVE SUMMARY

Ford Motor Company of Southern Africa has introduced a new product to the market. The production line of this product is still new and has stations which are not fully optimized. Daily demand is not even made when running the line overtime. Certain stations are not running inside the 2 minute cycle time, causing bottlenecks or line stopping on a regular basis.

This proposal indicates the problem and the planning of how it will be dealt with. The project was covered throughout the whole year and was presented to management at Ford Motor Company of Southern Africa as a suggestion but it isn't intended to be implemented.

By using Queuing Theory to determine buffer capacities and Yamazumi charts for line balancing, the congestion found on the production line was solved. This was verified by a simple simulation (via Excel and Simio). The buffer sizes need to be increase and operators' elements need to be re-allocated.

A resource standing idle is a waste – Eliyahu M. Goldratt

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CHAPTER 1: PROJECT PROPOSAL

1.1) Introduction and Background

Ford Motor Company of Southern Africa (FMCSA) is divided up into an engine plant located in Port Elizabeth and an assembly plant located in Silverton, Pretoria. The assembly plant has recently (2011) launched a new product to the market, publicly known as the all new Ford Ranger. This new production line (known by the Ford employers and employees as the T6 line) will be the only line running in the assembly after the other 3 lines were shut down (Bantam, Focus and the previous Ranger model). The reasons for the removal of these 3 lines were for creating more space for inventory and because FMCSA will be using all of its resources on just this one product.

The T6 line was designed and built by an international manufacturing company named Des-ign. They were contracted by FMCSA to build the line to standards which was provided by FMCSA. Des-ign was responsible for the design manufacturing, installation commissioning and the cycle times. They provided the full turn-key operation.

The T6 line builds a huge percentage of its total production Ford Rangers (Single Cab, Double Cab and Rap Cab), and a smaller percentage of Mazda BT-50's (Single Cab, Double Cab and Rap Cab). Each of these models' processes differs slightly, resulting into variations found in the line e.g. the process times. This however does not change the setup of the stations. Whenever a different model comes up on the line, it is only the part and the process times that differ, and not the measurements of the jigs.

The Silverton plant consists of several subsystems inside the manufacturing department. These areas are:

- Body Shop
- Paint Shop
- Trim Line
- Chassis Line

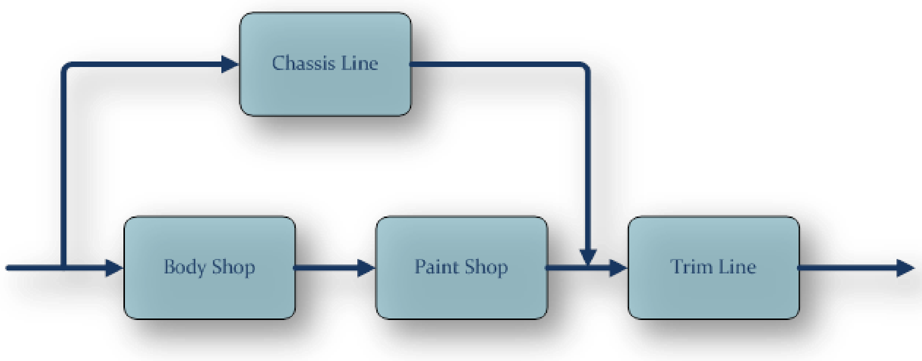


FIGURE 1: OVERALL PROCESS FLOW

The type of assembly line FMCSA is running at Silverton is known as a mixed model assembly line. These lines produce several models of a basic product, in an intermixed sequence. This means that the line would be busy building single cabs, it can just start building double cabs without following a certain pattern. The system will show the operator via a screen which type of model is in his station, and he will then know which process to carry out.

Challenges found on the mixed model assembly balancing problem (MALBP) are the different processes for the different models that are assigned to workstations, thus making the mixed model sequencing problem (MSP) relevant. Here a sequence of all model units has to be found to minimize inefficiencies.

The project will be based in the Body Shop area and will be focusing on the production of the Double Cab units, as they are the majority of the production.

1.2) Problem Statement

The last station at the end of the Body Shop area is the Loading station. This station raises the unit onto the overhead conveyer, which transports the unit to the Paint Shop area. The last few stations here form a line, named the Bolt-on-Line. After the unit received its necessary spot welding, it receives the final framework finishes (the doors, hood, metal finishing etc.). After the unit had gone through the Bolt-on-Line (see Figure 2), it arrives at the Final Buyoff station – before the Loading station. If the inspector at the Final Buyoff station is satisfied with the unit, he "buys" the unit and sends it on to the Loading station. This is the last point of the area, therefor the Loading station also serves as a counter – showing the exact amount of units built in that 8 hour shift.

The stations in the Bolt-on-Line follow the following sequence:

1) Rear Door Fitting (left and right)
2) Front Door Fitting (left and right)
3) Hood and Tailgate Fitment
4) Fender Fitment (left and right)
5) Inspection (QLS) and Metal Finishers
6) Lift to Paint Shop

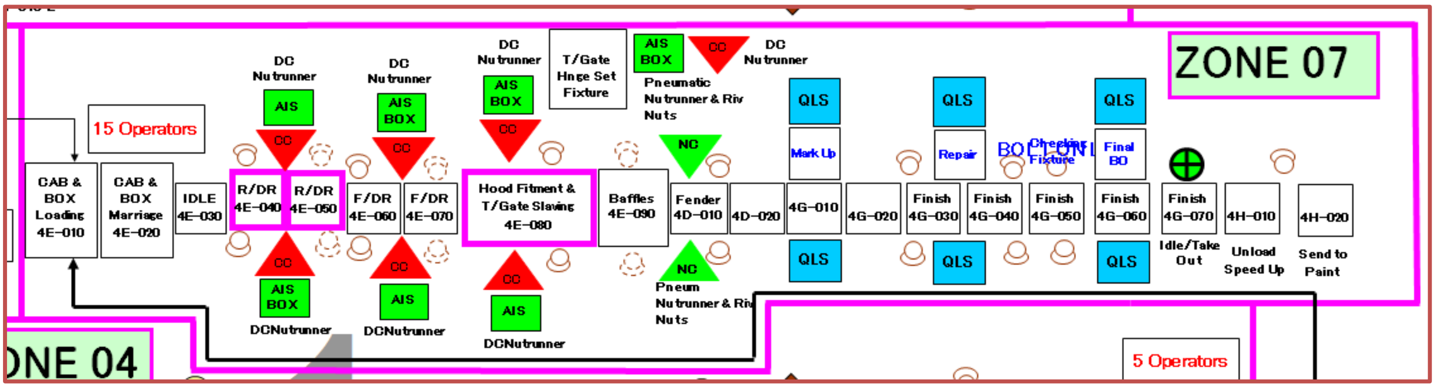


FIGURE 2: BOLT-ON-LINE IN BODY SHOP

At the time of this project, the actual jobs per hour (JPH) achieved, was 85% to target during normal working hours. This means that the actual line is 15% short in performance to what it has been designed to. Factors like the complexity of the models contribute to this. Each brand has 3 different sizes, where those 3 sizes have different coatings. The left hand drive or right hand drive, also makes this more complex. FMCSA is busy in a stage called "volume ramp up", where each day the company increases the production by day by a small amount. For example, that if today the line built 30 units, tomorrow they will strive towards 40. The company addresses its issues in the following three categories:

- Facility
- Cycle time
- Process

When an issue occurs (for example, if the JPH is decreasing), a meeting will be held to let one of the above categories solve it.

The current daily amount of units that the Loading station is loading onto the overhead conveyer to Paint Shop, is not satisfactory for FMCSA yet. In order to try and keep up with the orders, the company is running in overtime with an extra 2 hours after normal shift and then certain weekends. This costs a fairly great amount of money, together with allocating extra employees to stations that can't produce within the cycle time. The stations that are not fully optimized to the two minute cycle time are causing the line to stop frequently.

A full cycle line layout of the Body Shop can be seen by Figure 24 in the Appendix.

1.3) Project Aim

The aim of this project is to improve the workflow by identifying and improving workstations that are either over-cycle (stations completing the process in a time greater than the given cycle time) or under-utilized (stations that are idling) through techniques that will be discussed in the following next chapters.

Initially the aim of this project was to do line balancing through the use of Yamazumi charts and boards. Yamazumi, which was created by the Japanese, was chosen for this project due to its simplicity. Line balancing will not be considered as the only tool for this problem solving. Only after the literature study is done, will it be clearer about the more applicable method/s to use.

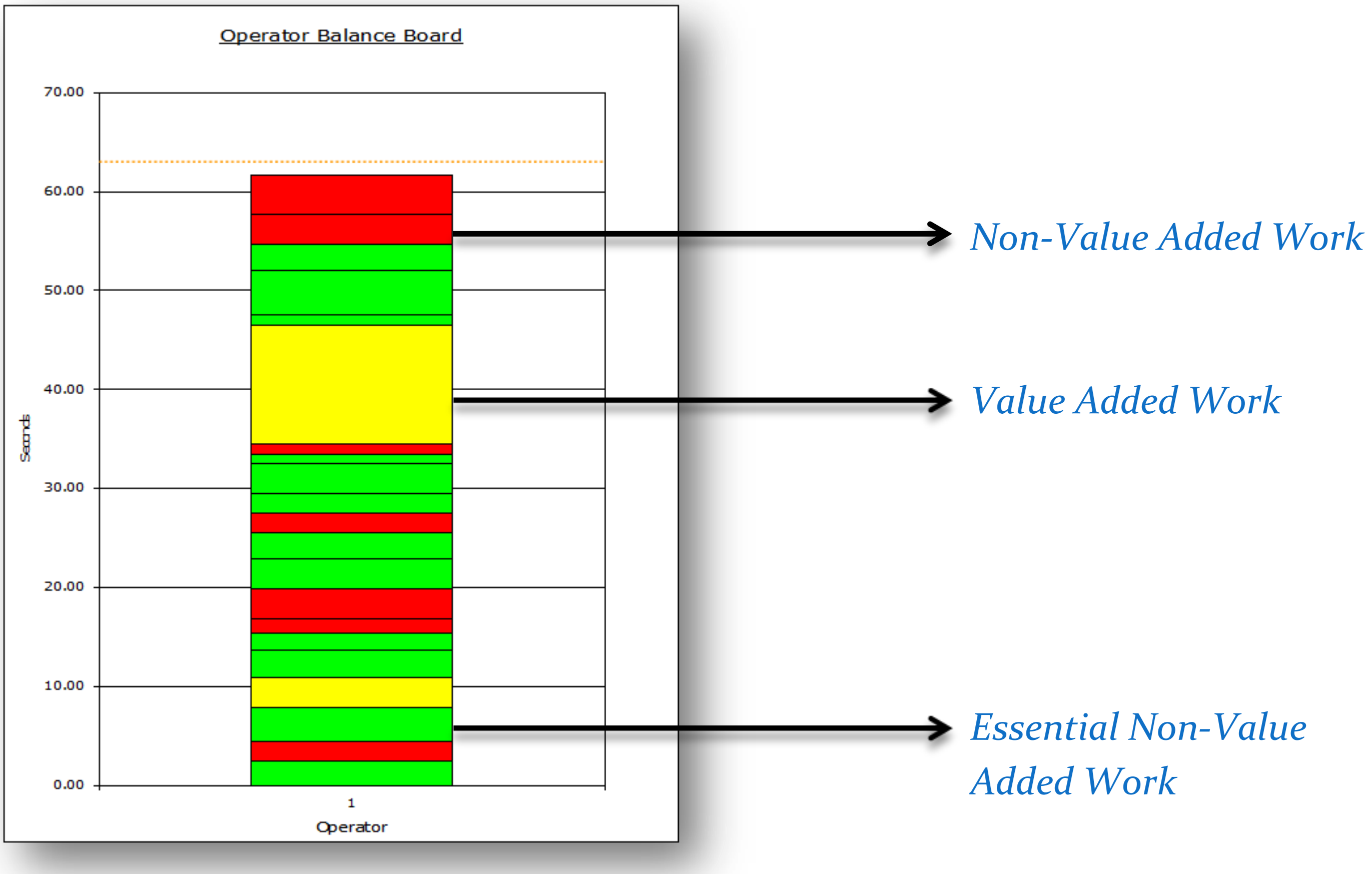


FIGURE 3: YAMAZUMI BOARD

A proper literature study will be done on techniques that are connected to line balancing. With this research, Theory of Constraints (TOC), will be studied to highlight problem areas. Further assessment will show if line balancing will be sufficient for all of the areas, otherwise further research will be done on other techniques.

Time and method studies are necessary at an early stage, because of its importance foundation to the whole project. Stations with robots should be avoided because of their fixed controls which cannot be adjusted to increase the robots' speed. Only their process can be changed, the sequencing of the spot welding. Figure 4 shows the first robot station where spot welding is done on the underbody (the floor panel of the vehicle). There are no variations in the process times when the same type of unit (rap cab, double cab or single cab) is being built. This supports that the scope will mainly focus on the manual stations by examining the workstations with operators.

As previously mentioned, the scope of the project will only be focused on the Body Shop. This is the larger area of the assembly warehouse and has the most room for improvements. The methods that will be researched will be chosen to end up saving money, leaving expensive solutions not to be an option.

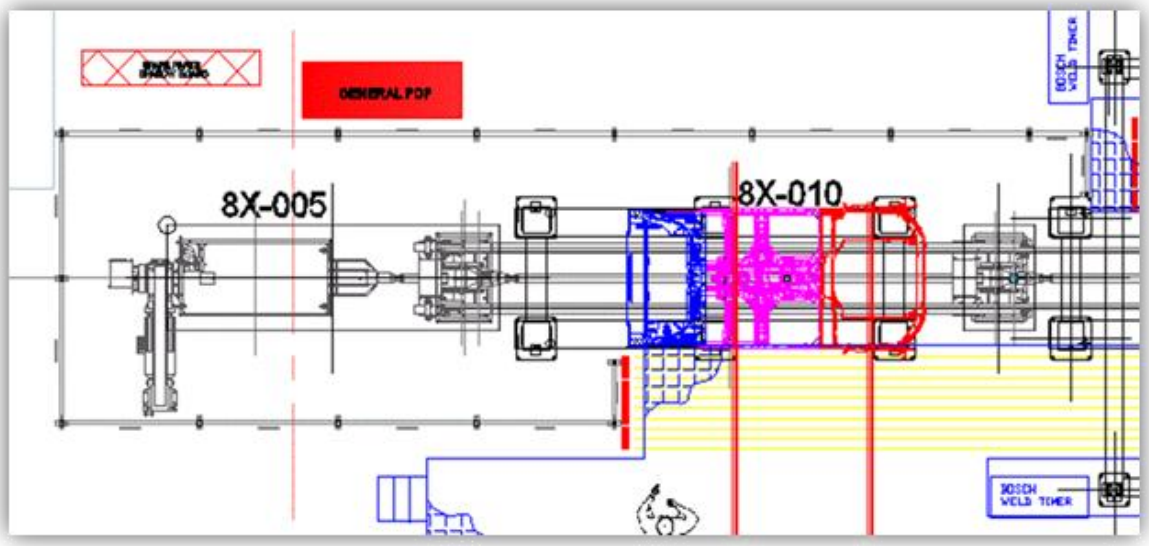


FIGURE 4: UNDERBODY RESPOT STATION

The working environment at FMCSA is familiar with continuous improvement, as this is practised on a daily basis. The duration of this project, with all its phases, stretches over a period of 10 months. The scope will be kept on the conditions the environment was when the project started. At the end of the project, there will be a quite few new changes made along the way. For these reasons, the project can be adapted to these improvements.

Where line balancing is not possible, Queuing Theory will be done to analyse the buffers at specific stations that are far above the cycle time. The time and method studies' data will be used for this technique.

CHAPTER 2: LITERATURE REVIEW

2.1) IDENTIFYING WASTE

KAIZEN

Kaizen is the continuous improvement of a process, for eliminating unnecessary waste. 'The philosophy of continual improvement, that every process can and should be continually evaluated and improved in terms of time required, resources used, resultant quality, and other aspects relevant to the process'. (Miller & Schenk, 1996)

Kaizen consists of four elements:

- ✓ Takt Time
- ✓ Cycle Time
- ✓ Work Sequence
- ✓ Standard WIP

Owen Berkely-Hill (2002) mentions the following 10 Kaizen process steps:

1. Create Value Stream Map tracking parts and subassemblies through the process
2. Calculate the Takt time
3. Measure each operation to every extent an operator has to go for something, for example walking. Establish a baseline using time observation forms for the operations as well as for setup time.
4. Map the physical movements of the operator in his station on a Spaghetti diagram
5. Use a Yamazumi (Work Balance board) to measure work elements for each operator.
6. Review the 5S's
7. Balance the work elements within the team so that everyone is working as close to Takt time as possible.
8. Observe, measure, modify the new flow process by eliminating waste.
9. Document all charts, comparing the "before" and "after" by overlaying them in order to visualize the improvements. Start then with the developing of an action plan.
10. Prepare the results for presentation.

In order to eliminate the wastes from a process, the wastage has to be identified first. There are several tools in highlighting out these non-value added work.

VALUE STREAM MAP

This is a tool used to map and measure what you see. Toyota created this form of process mapping as a common way to communicate about the process flow, anywhere from the shop floor to top management. Thus, anyone will understand it.

YAMAZUMI

'Yamazumi is a Japanese word that means to stack up, and this is because it is made from the stacking on one another of the cycle times of all the operations involved in a process. It is used in lean manufacturing and value engineering to identify value adding, necessary and waste activities'. (Adetunji, O)

Each element is categorized under one of four types of work:

- **Value Added Work (VAW)**
  Work which changes the form, properties or value of the product. Indicated in green.
- **Essential Non-Value Added Work (ENVAW)**
  Non-Value Added work carried out which is required to achieve the change to the form, properties, or value of the product. Indicated in yellow.
- **Non-Value Added Work**
  Work which doesn't change the form, properties or value of the product. Indicated in red.
- **Waiting**
  The operator is idling while waiting for another operator or a machine. Indicated in blue.

2.2) STANDARDIZATION

Standardization is the starting point for continuous improvement.

The key to consistent performance is to constitute standardized processes and procedures. Continuous improvement can only advance when the process is stable.

The origination of standardized processes is based on determining, visualizing, and regularly utilizing the methods that will provide the optimal outcome. Standardization is a continuous activity, for implementing adequate methods and how to go about it, and not a method used for one time only. (Liker and Meier, 2006)

Thus, to achieve consistency in operations and enable the company to achieve their customer requirements by "managing their production effectively", they will need to standardize. Human error in a process is most likely to occur when the variation causes human intervention.

PREREQUISITES OF STANDARDIZED WORK

According to Liker and Meier (2006, p. 147), before starting with standardizing your processes, a certain degree of stability has to be met first with each of the following properties:

1. The processes must be repeated with every cycle. If the work being done is described by referring to "if" something happens, only "then" will a certain process happen, then this will not be possible to standardize.
2. The amount of times the line is being stopped should be at its smallest meaning the equipment of the line should also be reliable. Otherwise it won't be possible to standardize an interrupted line.
3. Quality issues occurring during and after production should be at a minimal. Thus the product must have minimal defects. If the operator is constantly correcting defects or struggling with the effects of the product not having uniformity (like size variation), then it would be difficult seeing what the actual process should be.

> *A frequent mistake when implementing an "improvement" to the work is to leave an operator with a new process and withdraw support too soon, or worse – not be present when the new process is tried for the first time. The operator feels dumped on, it is not confident in what to do with the new procedure, and will view "process improvements" as negative, stressful events.*

WARNING 1: COX AND SCHLEIER, 2010

THE TAKT TIME

Takt time is the fundamental concept to do with the regular, uniform rate of progression of products through all stages from raw material to customer, as defined by Liker and Meier. As such it is important in planning, in cell balancing and in facility design.

For calculating the Takt time, the available time to produce parts (for example per shift) divided by the number of parts demanded in that time shift. The number you get tells you, for instance, that a part needs to be produced every x-amount minutes to satisfy customer demand. (Liker and Meier, 2006)

2.3) Lean Manufacturing

According to Cox and Schleier (2010, p. 1079), 'the origin of lean manufacturing in the United States can be linked to Henry Ford (the assembly line), Fredrick Taylor (industrial engineer), and Dr. Deming (father of quality management).'

These concepts mentioned were refined and honed by Taiichi Ohno, Eliji Toyoda, and Shingeo Shingo to create what is known today as the Toyota Production System (TPS). As shown in Fig. 5, the goal of TPS is to reduce the time-line from order to cash by removing all the non-value added (NVA) waste, known as muda in Japanese. (Ohno 1988, 9)

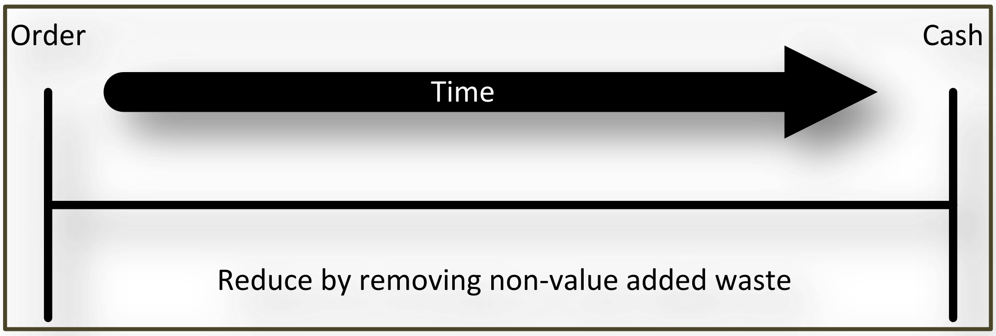


FIGURE 5: CONCEPT BEHIND LEAN MANUFACTURING

Ohno (1988, 9) identified seven types of waste. The most common way to describe the "7 deadly types of waste" that can occur in a system:

1. Over produce – when producing more than the customer has ordered. Can be led by producing to forecast or batching.
2. Waiting – it is the time when no value is being added to the product or service.
3. Transportation – when the movement of part add no value to the product, by moving it unnecessary.
4. Inventory – when having unnecessary raw material, work-in-process (WIP) or finished goods.
5. Motion – unnecessary movements done by resources (operators), which can lead to safety issues.
6. Over process – adding steps or processes that do not add value to the customer, trying to add more quality, when it is not needed.
7. Defects – after work has went through several processes, and needs to be redone or scrapped due to faults.

2.4) Theory of constraints (TOC)

The chain analogy introduces the basic concept of TOC, where the chain is only as strong as its weakest link. When attempting to improve the constraints, but in fact does not actually improve, the system can then be considered a waste. (Cox and Schleier 2010)

TOC is not about finding the bottleneck and speeding it up. The next bottleneck will just appear and the one thereafter, thus leaving you chasing bottlenecks which are not what TOC is about. According to Goldratt (1984), 'TOC is about improving and manage how the system constraint performs in the context of the total system'. This is quite different according to Cox and Schleier (2010, p. 1083), 'it is about managing the total system, which is comprised of interdependencies, variability, and constraints, to ensure maximum bottom-line results for the organization. TOC is about focusing first on the system's leverage points and then on how all parts of the system impact the operation of the leverage points. This is the way to achieve total system improvement, not just localized improvements'.

After understanding the system, the goal of the system and its measurements, then application of the Five Focusing Steps follows:

i. Identify the constraint(s)
ii. Decide how to exploit the constraint(s)
iii. Subordinate, synchronize everything else to the constraint
iv. If needed, elevate the system's constraint
v. If the constraint has been broken, go back to Step one. Do not let inertia become the constraint.

The majority Lean designs calculate the rate at which you need to produce to meet the target demand, and thereafter try to balance the operators (resources) and equipment to that Takt time. Focusing on how to eliminate the waste (capacity in the process which isn't needed), in order to equalize the demand and the capacity. Lean today ensures that the cycle time off all the processes is a percentage below the Takt time, to account for any variation.

A balanced line is possible when the time it takes the process to complete or demand has no variation. But this is unlikely according to Dr. Deming (as quoted by Cox and Schleier), and he reckons that there will always be variation. Variation can have a disadvantage for throughput in a balanced line and an advantage in an unbalanced line. It will require eliminating variation on your whole line, when leaving the variation to continuing on a balanced line, resulting in huge costs at the end reducing the variation. (Cox and Schleier 2010)

"Focus on everything, and you have not actually focused on anything" (Goldratt, 1990, 58).

2.5) Operations Research

Mahmud, Mahbubur and Dr. Nafis stated that the balancing of work cells and production lines is an effective tool for improving the throughput of the assembly lines and work cells while reducing the man assignment (manpower required for production). Line balancing is an optimization problem, found in Operations Research. Thus many algorithms have been proposed for problems where the production lines are not balanced, resulting in cycle times that are greater than the Takt time.

Dewa and Chidzuu (2012) proved that Queuing Theory is applicable to exercise in a manufacturing environment. The objective is to maximise the number of units worked on, with a satisfactory service level (the time the operator takes to complete his tasks). Work-in-Process (WIP) arrives at a particular station, known as the arrival process, where the operator then completes his tasks that is known as the service process. The excess WIP being held by the system from immediate access to the station is the queue. The finite buffers, is seen as the finite capacity of the queue, meaning that a limited amount of WIP can fit in the buffer. There are various queuing disciplines where the most common one is First-Come-First-Serve (FCFS). As soon as the WIP finishes at the previous station, and arrives at the next, it will automatically be first in the sequence of the WIP following on it. Although Body Shop is building towards a certain demanded target, they will still precede building when reaching that target value. Thus the population of WIP from which the arrivals come can assumed to be infinite. (S. Subba Rao et al, 1998)

A flow line (like an automobile assembly line), is designed for producing high volumes of a standardized product. They have been modelled in the past as tandem, series queues or even networks of queues. System configurations like cycle times, buffer sizes (WIP), blocking effects and batching policies have been determined by queuing models at these types of production lines. (S. Subba Rao et al, 1998)

In an assembly operation, different form a processing operations, the WIP has to wait either for the resource (operator) to become available or for the other WIP to arrive at the station so the operator can start with the processing. This means that the WIP can be waiting in a queue even if the operator is available and ready to work on it – even if he is idling. The synchronization constraints at these stations workstations, shows the dependencies between them. A station can have an input and output buffer. If the input buffer runs empty, the station is starved and waiting for WIP to arrive. The opposite goes for when the output buffer fills up; the station is blocked, awaiting the WIP to leave the station. This means that the size and number of buffers are important in an assembly/disassembly (fork/joint) network. (Bacelli and Makowski, 1981)

WAITING TIMES

According to Yadavalli *et al* (2004), a maximum likelihood estimator (MLE), a consistent asymptotically normal (CAN) estimator and asymptotic confidence limits can be calculated for the expected waiting time per customer in the queue.

Model 2 (M|M|1|GD|N|∞), has N finite maximum number of customers in the system (thus a queue length of N-1). Steady state probability equations are given by:

$$-\rho p_0 + p_1 = 0, \quad (n = 0)$$
$$\rho p_{n-1} - (\rho + 1)p_n + p_{n+1} = 0, \quad n = 1,2,3, \dots, N-1$$
$$\rho p_{N-1} - p_N = 0, \quad (n = N).$$

And this results to:

$$p_n = \frac{(1-\rho)}{(1-\rho^{N+1})}\rho^n, \quad n = 0,1,2,\dots,N. \tag{1}$$

The expected number of customers in the system is calculated as follows:

$$L_S = \frac{\rho\{1-(N+1)\rho^N + N\rho^{N+1}\}}{(1-\rho)(1-\rho^{N+1})}, \quad \rho \neq 1. \tag{2}$$

The effective arrival rate λ_{eff}, is calculated because of the limit placed on the capacity of the queue:

$$\lambda_{eff} = \lambda(1 - p_N). \tag{3}$$

Thus:

$$L_Q = L_S - \frac{\lambda_{eff}}{\mu} = \frac{\rho^2\,[1-N\rho^{N-1}+(N-1)\rho^N]}{(1-\rho)(1-\rho^{N+1})}. \tag{4}$$

And by this, we get the expected waiting time per customer in the waiting line:

$$W_Q = \frac{L_Q}{\lambda_{eff}} = \frac{\lambda\,[(\mu^N - \lambda^N) - N\lambda^{N-1}\,(\mu - \lambda)]}{\mu(\mu - \lambda)(\mu^N - \lambda^N)}. \qquad (5)$$

- Maximum Likelihood Estimator

  The average waiting time per customer in the waiting line, computed above in equation 5, can be reduced to:

$$W_Q = \frac{\theta_2^2\,[(\theta_1^N - \theta_2^N) + N\theta_2^{N-1}\,(\theta_2 - \theta_1)]}{(\theta_2 - \theta_1)(\theta_2^N - \theta_1^N)}, \qquad (6)$$

  with $\theta_1 = \frac{1}{\lambda}$ and $\theta_2 = \frac{1}{\mu}$.

  Their MLE's are $\overline{X_i}$ and $\overline{Y_i}$ respectively (with $i = 2$ representing Model 2). Model 1 is not applicable here.

  Thus the MLE of W_Q is shown by:

$$\widehat{W}_Q = \frac{\bar{Y}_2^2[(\bar{X}_2^N - \bar{Y}_2^N) + N\bar{Y}_2^{N-1}(\bar{Y}_2 - \bar{X}_2)]}{(\bar{Y}_2 - \bar{X}_2)(\bar{Y}_2^N - \bar{X}_2^N)}. \qquad (7)$$

- Consistent Asymptotically Normal Estimator

  By the application of the multivariate central limit theorem, shown by Sinha (1986), we have

$$\sqrt{n}[(\bar{X}_2, \bar{Y}_2) - (\theta_1, \theta_2)] \xrightarrow{d} N\,(0, \Sigma)\ as\ n \to \infty, \qquad (8)$$

  and

$$\Sigma = \left((\sigma_{ij})\right) \text{ is given by } \Sigma = diag\ (\theta_1^2, \theta_2^2).$$

  From Rao (1974), we can use $\sqrt{n}(\widehat{W}_Q - W_Q) \xrightarrow{d} N\left(0, \sigma^2(\theta)\right)$, as $\to \infty$.

  Here $\theta = (\theta_1, \theta_2)$ and W_Q and $\widehat{W}_Q$ are found at the above section (MLE).

$$\sigma^2(\theta) = \sum_{i=1}^{2} \left(\frac{\partial_2 W_Q}{\partial \theta_i}\right)^2 \sigma_{ii} = \frac{\theta_2^2[\theta_1^2 + \theta_2^2(2\theta_1 - \theta_2)^2]}{(\theta_1 - \theta_2)^4} \qquad (9)$$

  Thus we can say that $\widehat{W}_Q$ is a CAN estimator of W_Q.

- The confidence limits for expected waiting time for customers in a queue

  By letting $\sigma^2(\hat{\theta})$ be the estimator of $\sigma^2(\theta)$.

$$\hat{\sigma}^2 = \sigma^2(\hat{\theta}) \qquad (10)$$

  Because $\sigma^2(\theta)$ is a continuous function of θ, $\hat{\sigma}^2$ is a consistent estimator of $\sigma^2(\theta)$.

  So $\hat{\sigma}^2 \xrightarrow{P} \sigma^2(\theta)$ as $\to \infty$, and from the Slutsky theorem we can use

$$\frac{\sqrt{n}(\widehat{W}_Q - W_Q)}{\hat{\sigma}} \xrightarrow{d} N\,(0, 1) \qquad (11)$$

for $\Pr\left[-k_{\frac{\alpha}{2}} < \frac{\sqrt{n}(\widehat{W}_Q - W_Q)}{\hat{\sigma}} < k_{\frac{\alpha}{2}}\right] = (1 - \alpha)$. We can find $k_{\frac{\alpha}{2}}$ in the normal tables.

The above equation can be narrowed down, because of the$100(1 - \alpha)\%$ confidence interval for W_Q:

$$\widehat{W}_Q \pm k_{\frac{\alpha}{2}} \frac{\hat{\sigma}}{\sqrt{n}} \tag{12}$$

Chandrasekhar *et al* (2006), did a thorough study on a two station tandem queue that is dependent on service times, assuming the distributions of the service times of the two stations are joint, thus bivariate exponential. They calculated the asymptotic confidence limits for the mean number of customers in the system and each customer's expected service time. It can also be assumed that a joint distribution between interarrival times, service times are trivariate exponential, when working with moment and CAN estimators and asymptotic confidence limits.

Here a customer must pass through all consecutive stations before completing his service. These queues are in series and are also known as tandem queues. For example, a manufacturing process at Ford, WIP must pass through a series of work stations, where each station performs a given job.

It is not only satisfactory to know how many persons are there in the system, but also where they are located at any given moment.

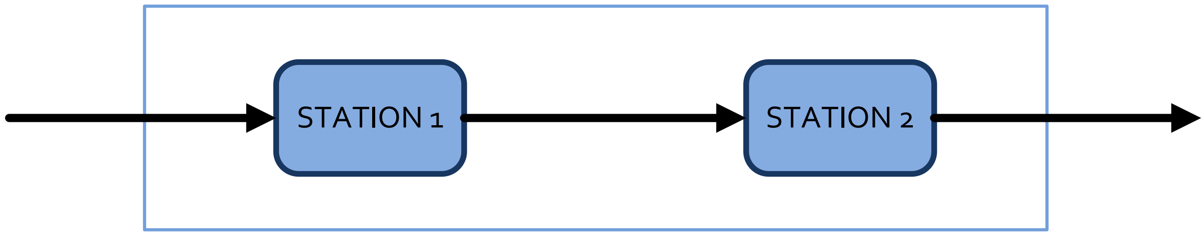


FIGURE 6: SYSTEM CONFIGURBECAUSEATION

Figure 6 illustrates that an arriving customer must go through Station 1 and Station 2 and serviced, before being completely serviced.

2.5) Simulation

According to Jacobs *et al* (2009), waiting lines can be easier simulated on a computer than solving it mathematically. The above two-stage assembly line with its data can be inputted into a simulation program (Arena or Simio) and ran for any given period. The following advantages, helps with the reasoning of why simulation should be used:

- The model developed usually leads to a better understanding of the actual system.
- The time period of the results required, can be compressed in the simulation into seconds or minutes.
- The simulation will not obstruct or cause disruption of the actual system.
- Simulation is more practical and possible than standard mathematical analysis.
- It also creates a more realistic feeling than the mathematical analysis.
- Simulations answers the "what if" questions.

Disadvantages than one should be aware of are:

- The model might not provide good answers, even though much time and effort was put into it.
- The simulation model's enforcement has a probability of not being reliable. The system can crash unexpectedly while running, with all the repetitive sequences.
- Complex systems that need to be simulated can take many years. Dependent on the complexity of the system, the simulation process can take from hours to years.
- A mathematical model will be more appropriate option than a simulation model, because the simulation is randomly based.
- This technique still requires a standardized approach.

Jacobs *et al* continues explaining the different simulation models. Mathematical equations can be found in a continuous model, where the values are on all the points over time. For specific points, the simulation is classified as a discrete model. This is applicable at a station with a waiting line, where the simulations jumps from one point to another. These points are the arrival stage, the initiating and ending of a service, etc. This type of model can run as an event simulation, thus running by units of time.

To validate and test if the simulation is correct, there are 3 ways of making sure:

1. Print out the program's calculations and compare them to actual worked out calculations on another method.
2. Run a simulation that is reflecting current conditions and compare the results.
3. Compare a result found at some stage where a mathematical model also obtained an answer.

Figure 7 is a schematic illustration of the whole simulation process. It demonstrates the major phases that is needed.

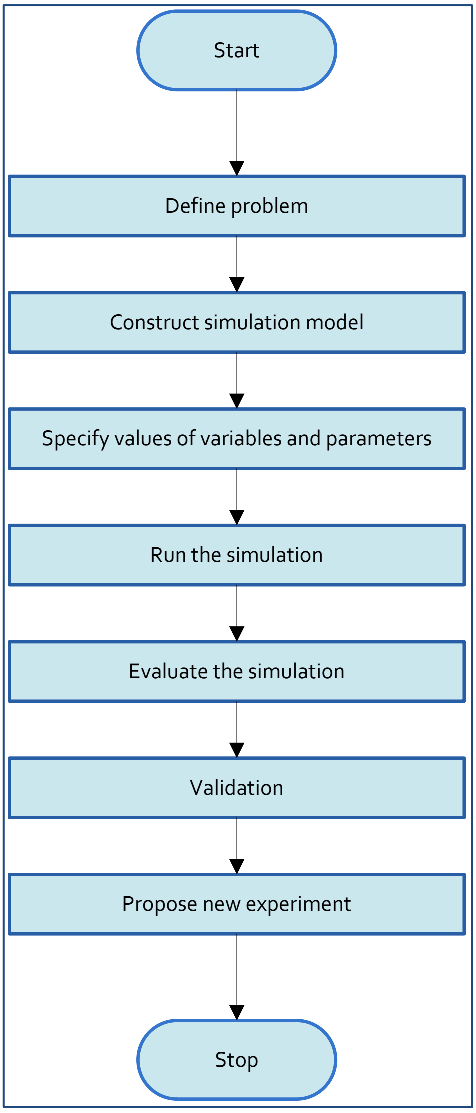


FIGURE 7: DIFFERENT PHASES IN BUILDING THE SIMULATION

CHAPTER 3: SOLUTION APPROACH

3.1) Yamazumi

Yamazumi charts will be used for determining the stations with waste – where the cycle time is greater than the Takt time. The operations will be balanced, if possible, to Takt time. This will be the first stage of the project. This, as seen from the Literature Study, is best use for eliminating waste.

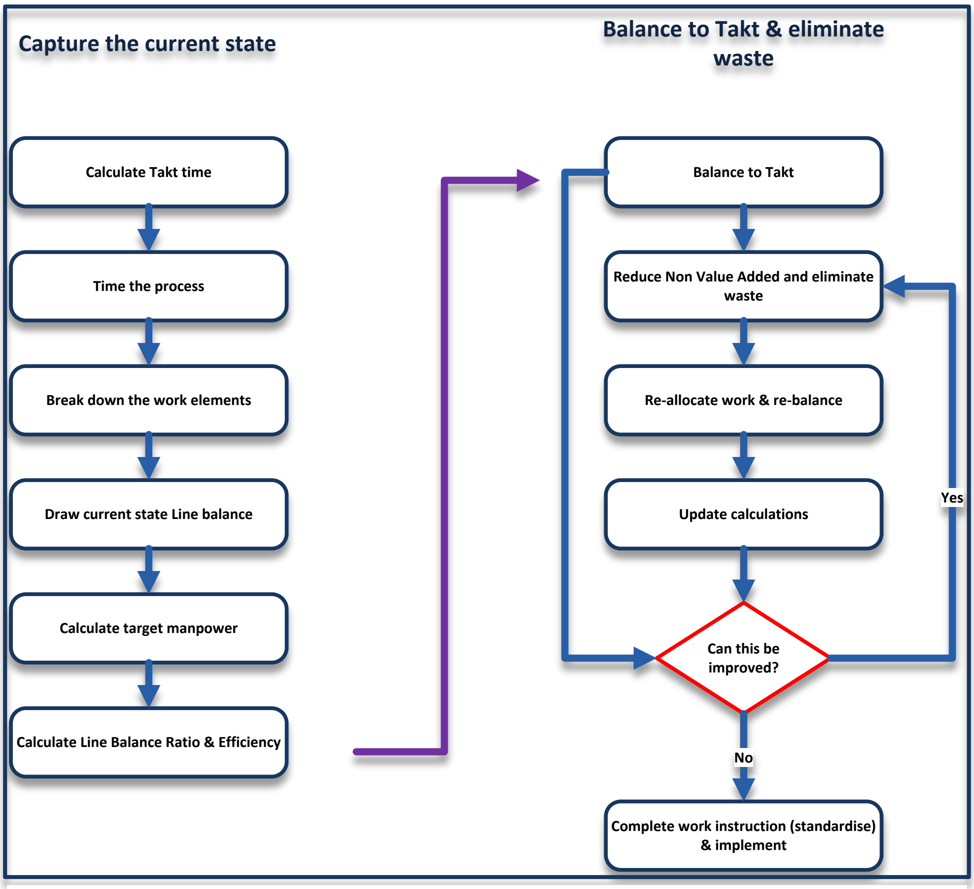


FIGURE 8: PROCEDURE TO FOLLOW

As seen in Figure 8, time studies will need to be done first before balancing can take place.

3.2) Current Environment

Time and method studies have been done by the first three zones of the Body Shop area. The times of every "Leading Operator" (the operator taking the longest to complete his process), were then plotted down onto a graph. Each station is only as good as its weakest link.

Area	Station	Leading Operator's Time	Cycle Time
Underbody	8A-20	167.30	120
	8A-30	172.69	120
	8A-35	141.20	120
	8A-40	167.39	120
	8X-10	153.37	120
	8X-20	143.65	120
	9X-10	113.08	120
	9X-20	185.68	120
	8C-20	147.38	120
	8C-30	147.10	120
Box	3X-10	111.45	120
	3Y-30	102.50	120
	3Y-40	117.93	120
	3B-10	102.25	120
	3B-20	123.32	120
	3B-30	116.22	120
	3B-40	117.09	120
	3B-70	79.21	120
	3B-110	109.17	120
Cab Sides	7K-10	102.97	120
	7K-20	114.80	120
	Cab Outer Sides	102.50	120
	6F-20	117.93	120
	Tabbing	113.44	120

TABLE 1: BLOCK TIMES OF STATIONS IN FIRST THREE ZONES

As can been seen in Table 1, a large portion of the stations are over the cycle time. To illustrate this better, Figure 9 shows that the majority of bottlenecks are found the Underbody area. Figure 9 was done by referring back to the Literature Study about TOC. The production line is only as good as its weaker stations.

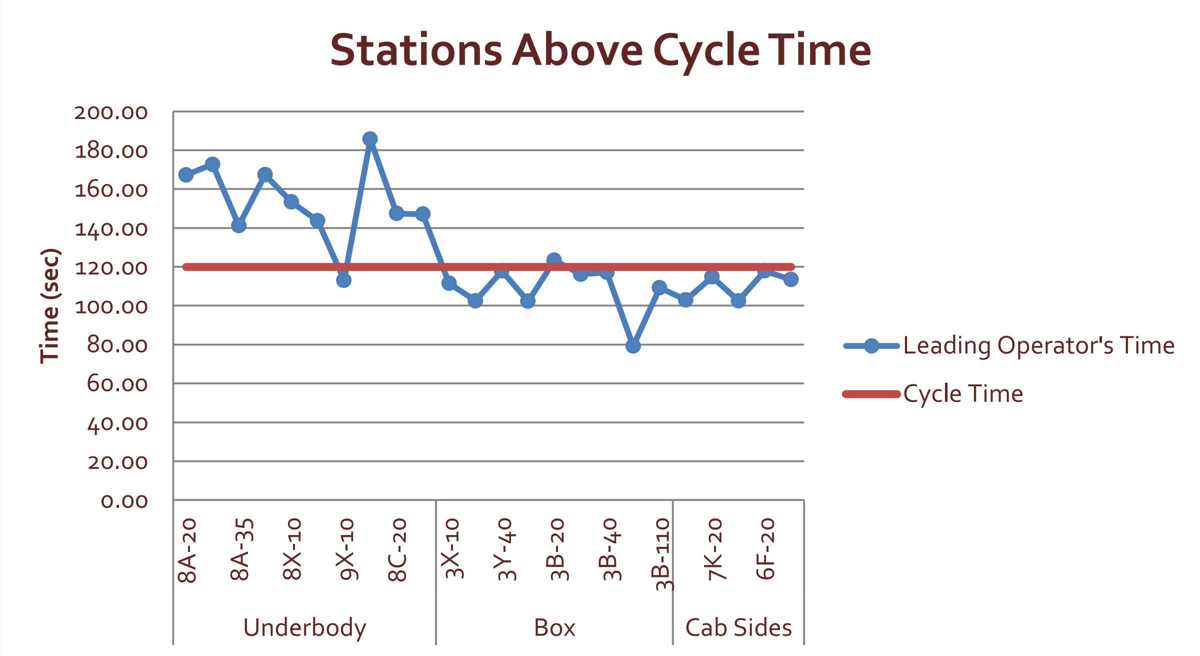


FIGURE 9: GRAPHICAL ILLUSTRATIONS OF PROCESS TIMES OF STATIONS

It will however not be possible to exercise line balancing by the Underbody zone, because of the operators at each station are over the cycle time. There is no operator with enough capacity to take over some work from the others. This will be further discussed in the next Chapter, at Data Analysis.

An ideal area to do line balancing will be on the Bolt-on-Line, because you have variability here. There are stations or operators that a very busy while there are others that has the capacity for additional work content. The operators at the Fender Fitment (Figure 23) station are "drifting". This is a term frequently used by the Industrial Engineers at Ford for when an operator is completing his task over the cycle time, and barely has time to get a break. The Bolt-on-Line consists of a constant moving conveyer, which is not supposed to stop.

The operators at the Fender Fitment station however travel past their station area while processing the unit (they have a fairly large station) into the next station, and sometimes need to stop the line to catch up. The process was designed for two operators to complete it in less than 2 minutes.

There is a robot station up the line, where the spot welds sometimes cause "splats". These "splats" are usually grinded off. But they cannot always get to the difficult hard to reach places, and don't waste time by holding the unit back. When the unit eventually reach the Fender Fitment station, there the operator struggles to fasten the bolts in one certain hole. He then has to spend extra time and effort of the nut.

Time and method studies were done when the operator works on a unit with no "splats". The results are shown in Table 2. From the literature review, we can identify two Value Added Elements.

Figure 10 graphically shows that under normal conditions, the operator just-just finished under cycle time.

LHS Fender Fitment	
Elements	Time
Locate fender to unit	7.75
Fasten jig to unit	4.24
Collect drill to unit	5.60
Fasten bolts (9) of fender	52.39
Resetting of fender after fastened	34.73
Unhook hood stay and lower hood to horizontal position	4.86
Collect fender and return hood stay and drill	9.20
	118.78

TABLE 2: TIME AND METHOD STUDIES OF LHS FENDER FITMENT UNDER NORMAL CONDITIONS

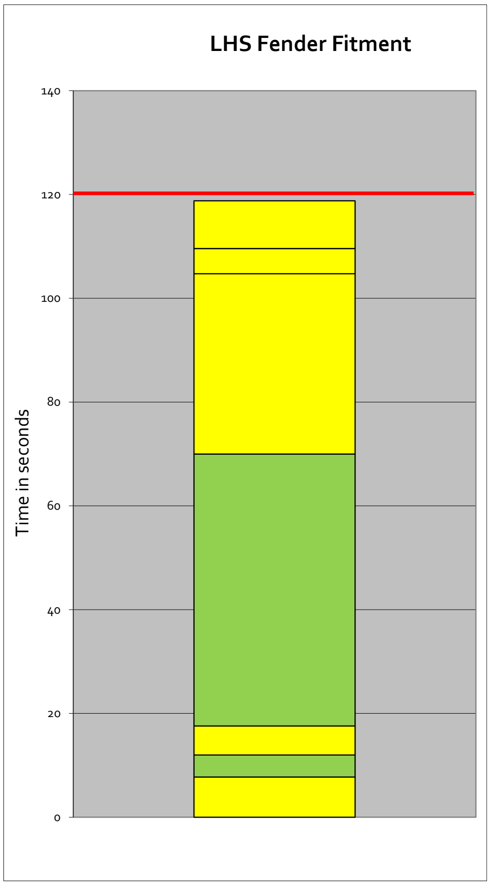


FIGURE 10: YAMAZUMI CHART OF LHS FENDER FITMENT UNDER NORMAL CONDITIONS

Measurements were then taken when a unit with "splats" (abnormal condition), reaches the station. It can be seen in Table 3 and Figure 11 that this problem costs the operator at least 30 seconds. This problem can easily occur 10 times a shift, which results that the line has to stop for 10 times. The exact origin of these splats cannot be pointed out, and it would be easier to solve the problem at the Fender Fitment station.

The times were also taken with the elements of the operator on the right hand side. As can be seen in Figure 22 in the Appendix, the two operators both work at the same pace. Any improvements that will be done to solve this, will need to affect both of them.

LHS Fender Fitment	
Elements	Time
Locate fender to unit	7.75
Fasten jig to unit	4.24
Collect drill to unit	5.60
Fasten bolts (9) of fender	52.39
Fastening of nut	25.63
Positioning drill under bonnet for drilling	5.13
Resetting of fender after fastened	34.73
Unhook hood stay and lower hood to horizontal position	4.86
Collect fender and return hood stay and drill	9.20
	149.54

TABLE 3: TIME AND METHOD STUDIES OF LHS FENDER FITMENT UNDER ABNORMAL CONDITIONS

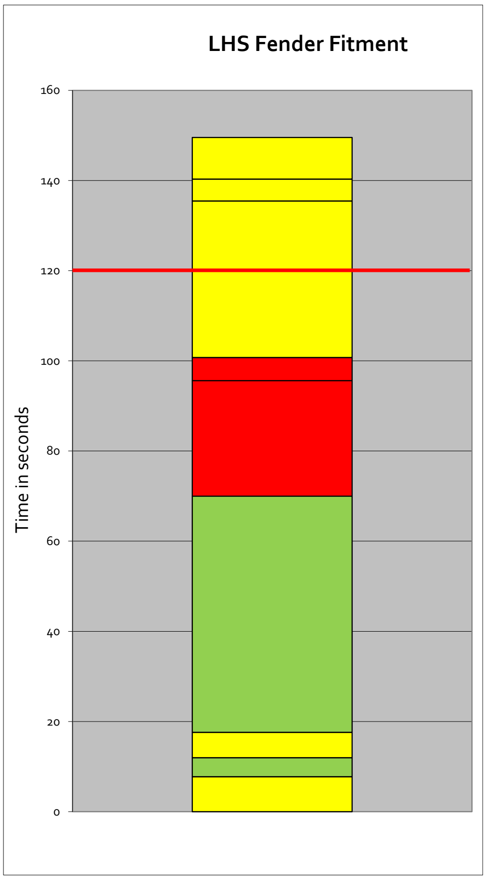


FIGURE 11: YAMAZUMI CHART OF LHS FENDER FITMENT UNDER ABNORMAL CONDITIONS

3.3) Queuing Theory

The first two stations (these stations are the most overloaded) will be analysed. The time and method studies will be used as reference for the processing and transferring times. From the Literature Study, this technique is quite applicable, because the time the unit waits to be processed, is a parameter that also needs to be minimized. The probability of a operator idling is another issue that needs to be minimized and will be studied in the next chapter.

CHAPTER 4: IMPLEMENTATION OF SOLUTION APPROACH

4.1) Data Analysis

Furthermore time and method studies were done on several stations' operators from the first three zones. Each operator was observed five times where the average was then calculated. Each operator's measurement is named accordingly to the following:

8A – 20 – 1 – DBL

The 8A shows the zone and line the station is where the operator is working, and the 20 is sequence number of the station. In this example the 20 is the smallest of the 8A stations, which is the first station in the process flow. The 1 is the number of operators in that station. Station 8A-20 has currently 5 operators, thus the last operator will be named 8A-20-5. The DBL at the end indicates that the line was building Double Cab units when this study was taken.

8A - 20 - 1 - DBL = run 1						
Elements	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Walk to & fro to collect front floor tunnel from error proof fixture	13.43	13.5	13.47	9.97	9.37	**11.95**
Load front floor tunnel onto fixture	6.47	6.91	3.94	7.75	4.59	**5.93**
Position front floor tunnel setting aid onto fixture	5.19	7.91	5.36	5.53	5.12	**5.82**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Walk to & fro to grasp spotgun	8.87	10.09	8.75	9.91	8.97	**9.32**
Spotweld	69.97	62.66	67.78	62.12	63.13	**65.13**
Walk to release spotgun	6.78	7.47	8.37	9.07	8.56	**8.05**
Wait for fixture to open	45.93	45.59	31.75	21.25	26	**34.10**
Release front floor setting aid from fixture	4.72	4.5	7.47	6.15	5.97	**5.76**
Press unclamp button	3.66	4.45	4.5	5.47	3.03	**4.22**
Unload 8A - 20 sub assembly to buffer	11.21	12.03	5.1	6.72	7.65	**8.54**
						167.30

TABLE 4: TIME STUDIES FOR FIRST OPERATOR ON FIRST STATION

8A - 20 - 2 - DBL = run 1						
Elements	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Walk to & fro to collect front floor panel from storage	35.25	35.31	21.34	25.4	34.47	**30.35**
Load front floor to fixture	7.66	7.81	4.63	4.72	6.16	**6.20**
Walk to & fro to collect two cross member from error proof fixture	7.53	7.37	7.5	5.69	5.21	**6.66**
Load two cross members onto fixture	8.4	9.47	7.78	6.66	8.94	**8.25**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Collect spotgun from storage	12.32	11.97	9.94	14.59	7.72	**11.31**
Spotweld 18 spots	81.62	82.25	73.41	65.4	77	**75.94**
Return spotgun to storage	6.91	5.84	6.09	6.85	6.75	**6.49**
Press unclamp button	3.66	4.45	4.5	5.47	3.03	**4.22**
						157.89

TABLE 5: TIME STUDIES OF SECOND OPERATOR ON FIRST STATION

8A - 20 - 3 - DBL = run 1						
Elements	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Assists to position front floor panel to fixture	3.34	4.47	3.34	3.35	3.35	**3.57**
Wait for two operators to load load cross members	10.63	11.16	11.97	9.48	9.12	**10.47**
Assists to position front floor panel setting aid to fixture	3.84	2.96	6.16	7.37	4.95	**5.06**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Collect spotgun from storage	5.16	6.03	6.94	5.33	5.33	**5.76**
Spotweld 18 spots	68.25	68.72	64.66	69.22	73.16	**68.80**
Return spotgun to storage	4.4	5.75	5.97	4.88	4.88	**5.18**
Wait for the two operators to complete spotwelding	23.97	26.12	21	16.32	16.11	**20.70**
Press unclamp button	3.66	4.45	4.5	5.47	3.03	**4.22**
Assists to release front floor setting aid from fixture	1.22	3.06	2.3	2.03	3.12	**2.35**
Assits to lift front floor sub assembly from fixture	2	6.57	6.07	4.34	4.31	**4.66**
Wait to position front floor panel to fixture	10.11	9.89	7.86	9.64	12.72	**10.04**
						149.28

TABLE 6: TIME STUDIES OF THIRD OPERATOR ON FIRST STATION

8A - 20 - 4 - DBL = run 1						
Elements	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Walk to collect two cross members from error proof fixture	8.31	7.22	7.72	7.87	7.28	**7.68**
Load two cross members onto fixture	11.09	8.69	6.69	8.34	7.04	**8.37**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Collect spotgun	12.75	4.97	8.71	8.09	9.54	**8.81**
Spotweld 18 spots	68.56	75.12	76.38	76.5	72.97	**73.91**
Return spotgun to storage	7.57	6.29	6.25	6.31	6.91	**6.67**
Press unclamp button	3.66	4.45	4.5	5.47	3.03	**4.22**
Assist to unload front floor sub assembly to buffer	14.93	19.4	19.97	23.12	24.31	**20.35**
						138.47

TABLE 7: TIME STUDIES OF FOURTH OPERATOR ON FIRST STATION

8A - 20 - 5 - DBL = run 1						
Elements	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Average**
Press clamp button	4.34	4.68	5.12	3.88	3.16	**4.24**
Collect two cross members from storage	7.75	6.78	8.06	7.43	7.68	**7.54**
Load two cross members onto error proof fixture	4.44	5.12	3.96	5.18	5.15	**4.77**
Walk to collect two cross members from storage	12.63	13.24	12.88	11.12	11.46	**12.27**
Load two cross members onto error proof fixture	7.91	5.45	7.16	6.96	5.86	**6.67**
Walk to collect front floor tunnel from storage	8.31	6.89	5.46	7.34	6.32	**6.86**
Load front floor tunnel onto error proof fixture	4.16	3.88	3.19	4.45	4.08	**3.95**
Wait for spotwelding operators to complete	32.72	30.16	26.78	23.02	31.11	**28.76**
Press unclamp button	3.66	4.45	4.5	5.47	3.03	**4.22**
Wait for unloading & loading of parts onto fixture	11.08	10.98	11	9.88	7.43	**10.07**
						89.35

TABLE 8: TIME STUDIES OF FIFTH OPERATOR ON FIRST STATION

Color Codes	
Non Value Added	(red)
Non Value Added - but Necessary step	(yellow)
Value Added	(green)
Waiting	(blue)

TABLE 9: COLOUR CODES OF THE DIFFERENT ELEMENTS OF WORK

More stations were observed, obtaining their cycle times. From the data obtained and show in the Appendix, the first station is the most overloaded. Balancing the workload would be impossible, seeing that all operators are over the required Takt time. This station should be investigated through the use of standardization and queuing theory.

Through investigating the results found after doing the time and method studies and compiling the "Yamazumi" boards, it is clear that the Front Floor station is a bottleneck. Gathering the data that was found from observing the operators, the following "Yamazumi" charts found:

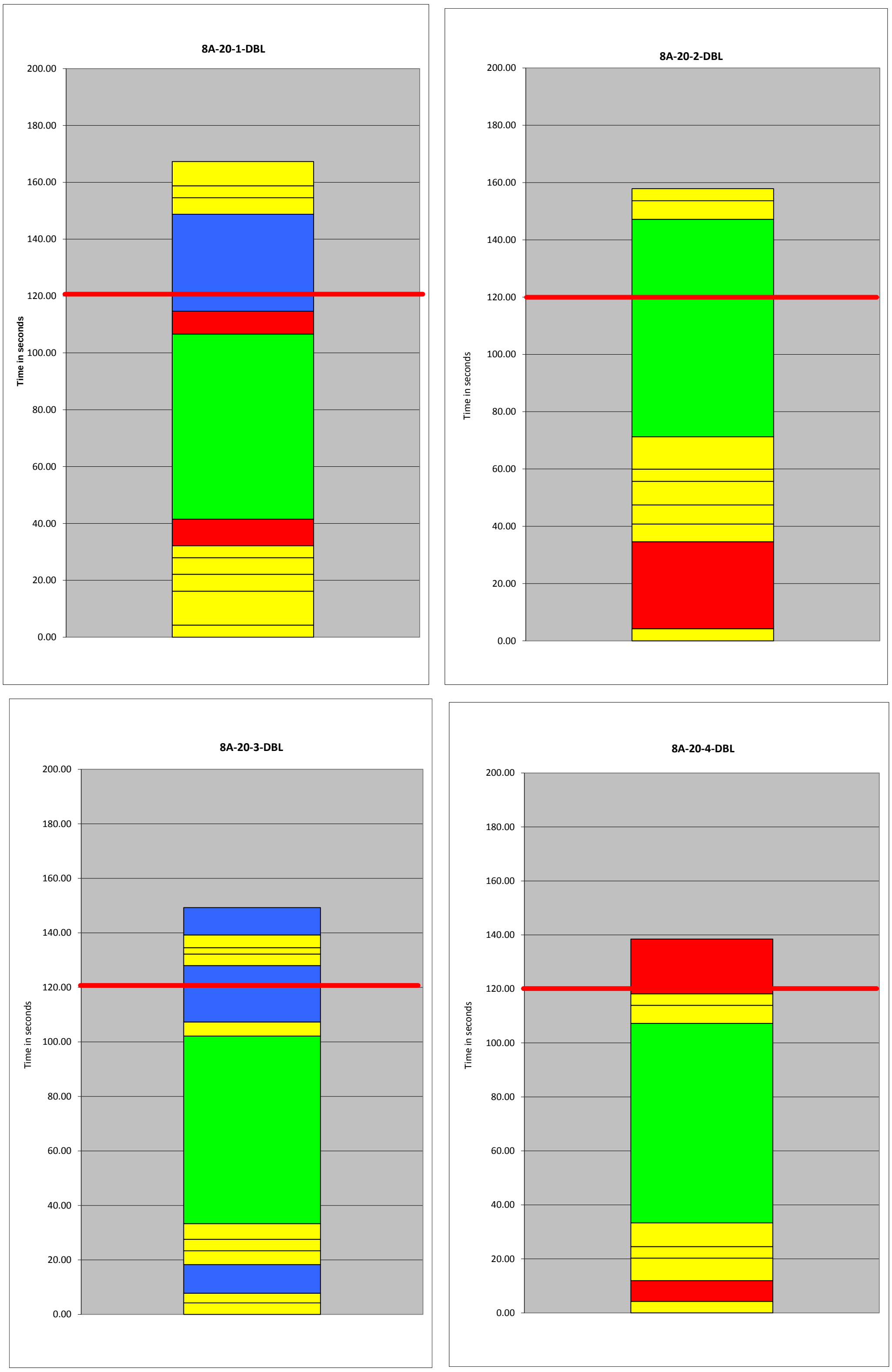


FIGURE 12: YAMAZUMI CHARTS OF THE REQUIRED OPERATORS

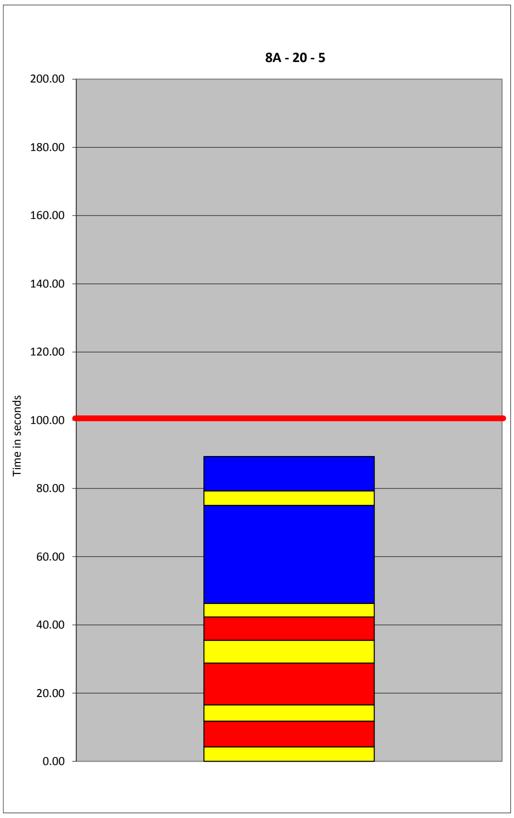


FIGURE 13: YAMAZUMI CHARTS OF THE ADDITIONAL OPERATOR

The actual required amount of operators needed for the first Front Floor station was meant to be four. Although a fifth operator was assigned to handle the error-proofing, the other operators are still overloaded and not within the Takt time. According to the calculations the ideal amount of operators is 6 operators when dividing the total work content by the Takt time:

$$Target\ Manpower = \frac{Total\ Work\ Content}{Takt\ Time}$$

$$= \frac{(167.30 + 157.89 + 149.28 + 138.47 + 89.35)}{120}$$

$$= 6\ operators$$

But using the target manpower of six, the line balance efficiency that can be achieved is 98%. Thus rebalancing is needed.

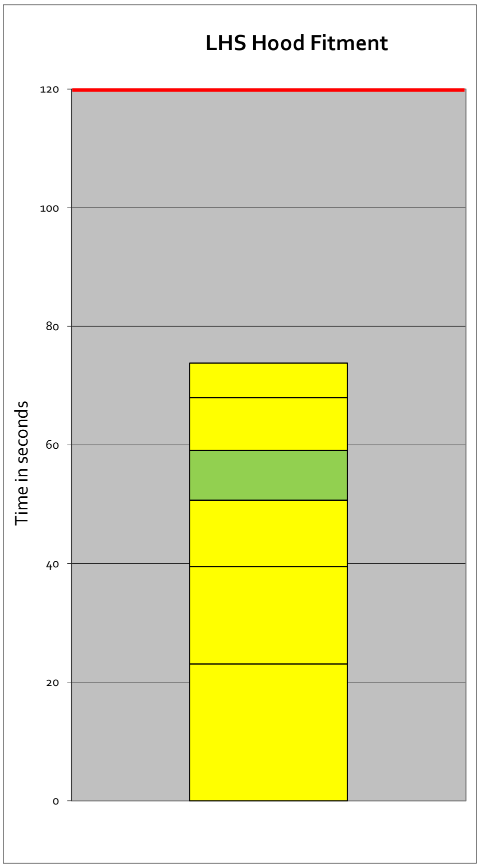
Lean is about cutting the waste away. By reducing the waiting times by the first and third operator, the first operator can finish his task within Takt time and the third operator just over Takt time. This means that the main problem found at these operators is that they either have to wait for the other two operators or for the unclamping.

The second and fourth operators take longer with their spot-welding, than the other operators. The process needs to be investigated and the amount of spot-welds needs to be compared.

4.2) Line Balancing

The Bolt-on-Line has a TOC problem. There is a single station causing regular stoppage of the line, having a negative influence on the flow. What was noticed when observing the Fender Fitment station and the stations before and after:

- ✓ Both the operators on the left- and right-hand side, start working at the previous station and finish at the next station. This causes exhaustion, for walking the distance up and down a stage.
- ✓ While the Fender Fitment operators are working over the 2 minutes, the operator at Tail Gate station and the 2 operators at Hood Fitment station finish their tasks very early in the cycle. These last three mentioned, share the station before Fender Fitment station.
- ✓ Hood Fitment needs the capacity of one operator. But due to safety reasons, it is necessary to have an operator on both sides when placing it onto the unit. That is why the two operators are idling, because they are doing a job equivalent for one operator.
- ✓ The Fender Fitment operators need to bend far down for the bottom fastening of bolts, because of the stage. The stage is meant for ergonomic reasons, to easily fasten the bolts on the top of the fender. This means that timing of how the operator is supposed to do his tasks is out.
- ✓ Enough space for moving fenders more to the earlier station.



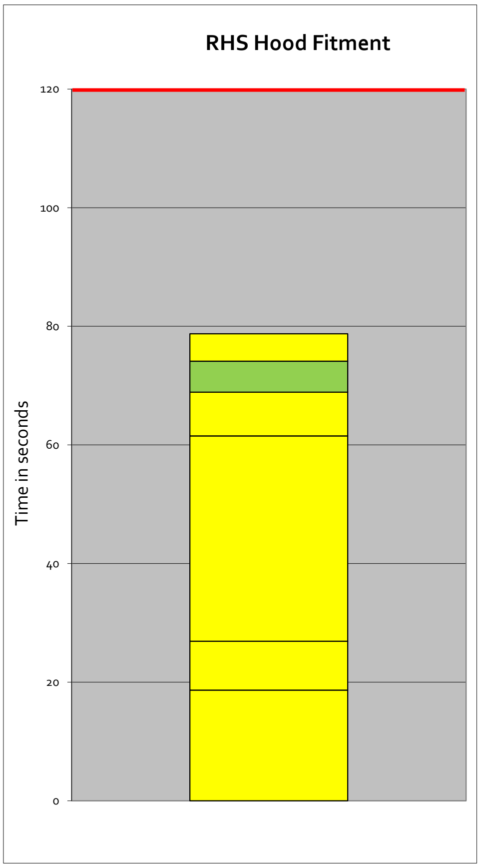


FIGURE 14: YAMAZUMI CHARTS OF THE HOOD FITMENT STATION

It can be seen in Figure 14 that the Value Added work done to the WIP, is quite small. This proves with the fact that stacked bar is low, that the Hood Fitment station is under-utilized. There is a capacity of more than 40 seconds available at both operators.

After comparing Figure 10, Figure 11, and Figure 14; line balancing was a definite solution. By laying down the four charts next to each other, elements could be swapped from one station to another.

The improvements are shown in the Appendix on pages 46-48. The elements in blue are the ones moved from Fender Fitment to Hood Fitment. What it basically comes down to is that by the time Hood Fitment has finished their cycle, they should have hooked the fender onto the unit for the next station. So when the unit arrives at the Fender Fitment, they will just need to fasten it.

All the hoods that arrive from the supply warehouse, should be dropped off between the two stations.

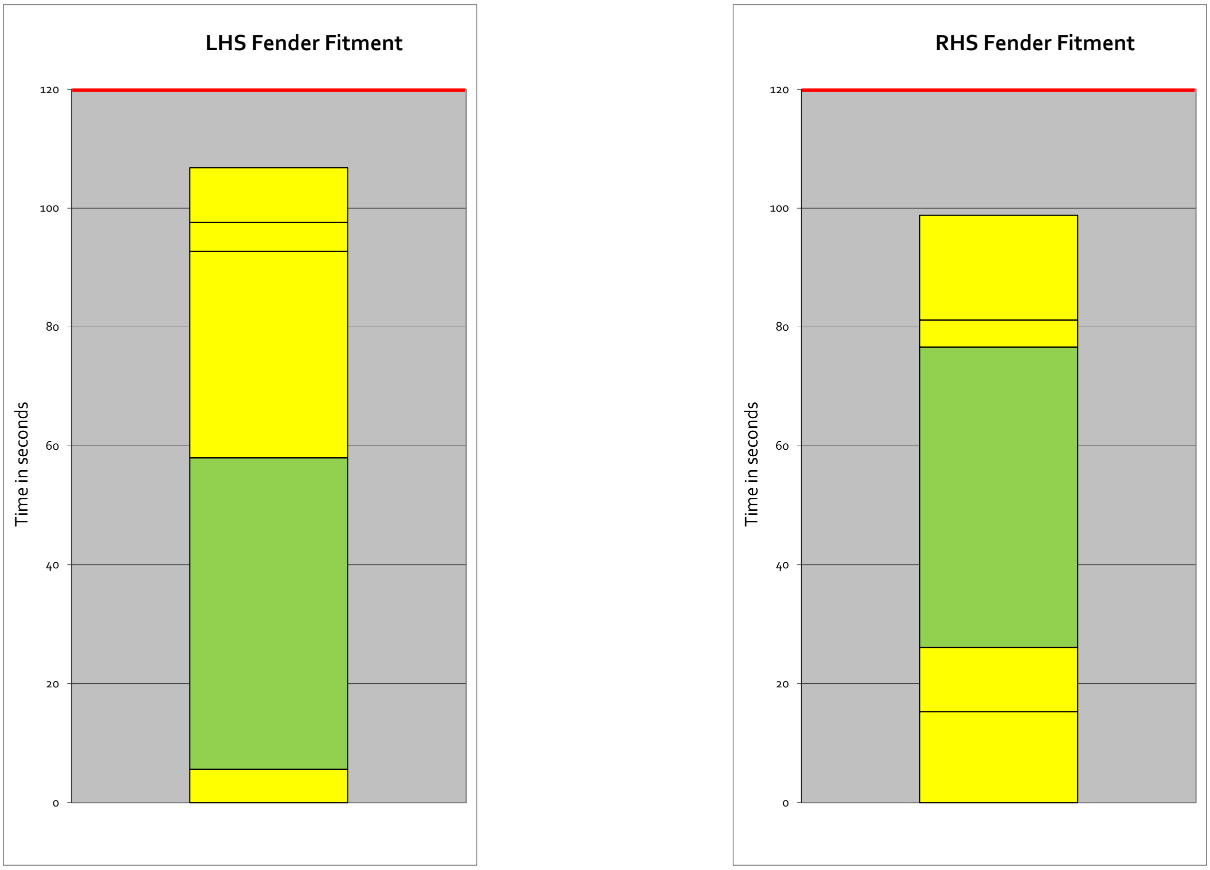


FIGURE 15: YAMAZUMI CHART OF FENDER FITMENT STATION AFTER LINE BALANCING

In above Figure 15, the stacked bar has lowered and in Figure 16 rose. These four charts next to one another, shows that the line is successfully balanced. For future studies, the reducing of the Non-Value Added work can result in even better improvements. This falls under the continuous improvement found regularly in working environments like automobile plants.

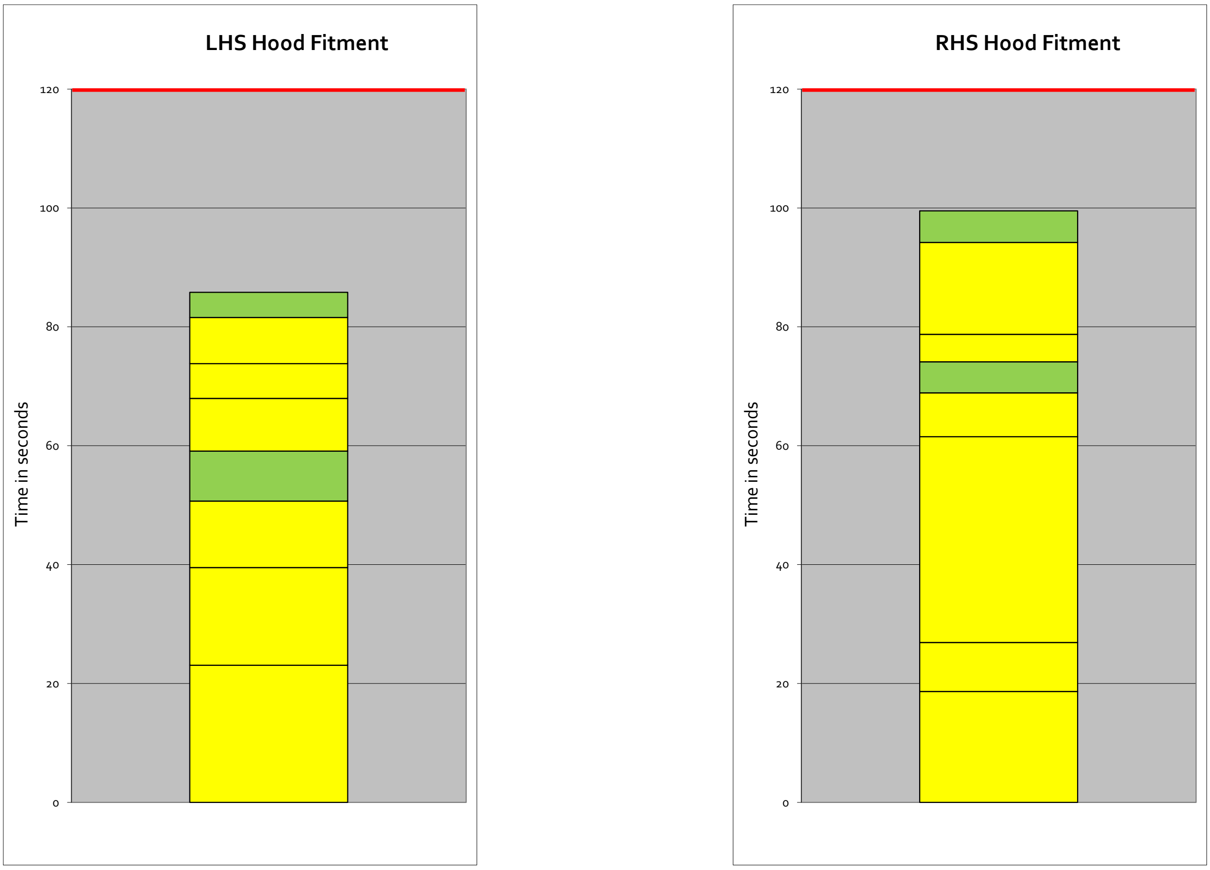


FIGURE 16: YAMAZUMI CHART OF HOOD FITMENT STATION AFTER LINE BALANCING

Before this idea can be implemented, a trial needs to be run to see if as much as it is capable on paper, it is also practically capable. The process engineer needs to give approval, because the sequence of the process might be changed and he has to see if the can affect the product. Thereafter, the safety inspector also has to give approval after he is convinced that no employee's safety is in any risk.

4.3) Queuing Theory

The first two stations (see Table 1) in the line will be considered as a tandem queue in a single channel with finite capacity. The standard parametric techniques of statistical theory are quite suitable when the systems are all out observable when it comes to their basic random components like interarrival times and service times.

From the literature study done on queuing theory, calculations was done for the expected waiting times per unit in buffer. In the next section, it will be clearer that by increasing the buffer size (the queue capacity) it will have a significant impact on the work flow and throughput. Table 10 below, shows the steady state probabilities and how they differ towards an increasing buffer size. The larger the capacity size the less the probability of the station idling. The following equation was used for the calculation of the steady state probabilities:

$$p_n = \frac{(1 - \rho)}{(1 - \rho^{N+1})}\, \rho^n, \quad n = 0,1,2,\dots,N$$

where n is the size of the buffer space.

λ (units/hour)	μ (units/hour)	n	ρ	π_0	π_1	π_2	π_3	π_4	π_5	π_6	π_7	π_8	π_9	π_{10}
30.00	20.85	1.00	1.44	0.41	0.59									
30.00	20.85	2.00	1.44	0.22	0.32	0.46								
30.00	20.85	3.00	1.44	0.13	0.19	0.28	0.40							
30.00	20.85	4.00	1.44	0.08	0.12	0.18	0.25	0.36						
30.00	20.85	5.00	1.44	0.06	0.08	0.12	0.17	0.24	0.34					
30.00	20.85	6.00	1.44	0.04	0.05	0.08	0.11	0.16	0.23	0.33				
30.00	20.85	7.00	1.44	0.03	0.04	0.05	0.08	0.11	0.16	0.22	0.32			
30.00	20.85	8.00	1.44	0.02	0.02	0.04	0.05	0.07	0.11	0.15	0.22	0.32		
30.00	20.85	9.00	1.44	0.01	0.02	0.02	0.04	0.05	0.07	0.11	0.15	0.22	0.31	
30.00	20.85	10.00	1.44	0.01	0.01	0.02	0.02	0.03	0.05	0.07	0.10	0.15	0.22	0.31

TABLE 10: STEADY STATE PROBABILITIES

The average expected number of WIP in the buffer was also calculated using the equations from the literature study. The following equations were used for the above mentioned parameters:

$$L_S = \frac{\rho\{1 - (N+1)\rho^N + N\rho^{N+1}\}}{(1-\rho)(1-\rho^{N+1})}, \quad \rho \neq 1.$$

$$\lambda_{eff} = \lambda(1 - p_N)$$

$$L_Q = L_S - \frac{\lambda_{eff}}{\mu} = \frac{\rho^2\,[1 - N\rho^{N-1} + (N-1)\rho^N]}{(1-\rho)(1-\rho^{N+1})}$$

- L_S represents the number of units being served.
- L_Q represents the number of units in the buffer, waiting to be processed.
- L represents the expected number of units in the system, this includes the buffer and the work station.

λ (units/hour)	μ (units/hour)	n	ρ	L	L_s	L_q
30.00	20.85	1.00	1.44	0.59	0.59	0.00
30.00	20.85	2.00	1.44	1.24	0.78	0.46
30.00	20.85	3.00	1.44	1.94	0.87	1.07
30.00	20.85	4.00	1.44	2.69	0.92	1.77
30.00	20.85	5.00	1.44	3.48	0.94	2.54
30.00	20.85	6.00	1.44	4.32	0.96	3.35
30.00	20.85	7.00	1.44	5.18	0.97	4.21
30.00	20.85	8.00	1.44	6.08	0.98	5.09
30.00	20.85	9.00	1.44	6.99	0.99	6.00
30.00	20.85	10.00	1.44	7.93	0.99	6.94

TABLE 11: EXPECTED NUMBER OF UNITS IN BUFFER

Table 11 supports the statement made with the steady state probabilities. The larger the buffer size, the more the average expected customers in the work station (L_S) increases. With a larger buffer size, there will always be a unit being processed.

From the expected number of units, the average waiting time could also be found:

$$W_Q = \frac{L_Q}{\lambda_{eff}} = \frac{\lambda\,[(\mu^N - \lambda^N) - N\lambda^{N-1}\,(\mu - \lambda)]}{\mu(\mu - \lambda)(\mu^N - \lambda^N)}$$

λ (units/hour)	μ (units/hour)	n	ρ	W (hr)	W (min)	W_q (hr)	W_q (min)	W_s (hr)	W_s (min)
30.00	20.85	1.00	1.44	0.05	2.88	0.00	0.00	0.05	2.88
30.00	20.85	2.00	1.44	0.08	4.58	0.03	1.70	0.05	2.88
30.00	20.85	3.00	1.44	0.11	6.44	0.06	3.56	0.05	2.88
30.00	20.85	4.00	1.44	0.14	8.46	0.09	5.58	0.05	2.88
30.00	20.85	5.00	1.44	0.18	10.62	0.13	7.74	0.05	2.88
30.00	20.85	6.00	1.44	0.22	12.90	0.17	10.03	0.05	2.88
30.00	20.85	7.00	1.44	0.26	15.30	0.21	12.42	0.05	2.88
30.00	20.85	8.00	1.44	0.30	17.79	0.25	14.92	0.05	2.88
30.00	20.85	9.00	1.44	0.34	20.37	0.29	17.49	0.05	2.88
30.00	20.85	10.00	1.44	0.38	23.00	0.34	20.12	0.05	2.88

TABLE 12: EXPECTED WAITING TIME PER UNIT

The expecting waiting time has a linear relationship towards the capacity of the buffer. When the data in Table 12 is plotted, the graph is not perfectly linear, but still shows a satisfactory linear trend.

- W represents the expected time a unit spends in the system (buffer and work station).

- ❖ WQ represents the average expected time a unit spends in the buffer before being processed.
- ❖ WS represents the time a unit spends being serviced. In this case, how long the operator with the longest process time takes.

4.4) Simulation

The data captured in the time studies from the previous chapter, have been used for building simulation runs of the various scenarios. As mentioned by Queuing Theory, by increasing the buffer capacities can lead to a better throughput.

Initially the simulation ran according to the manner the production line was designed. Thus with the same buffer sizes and processing times of 120 seconds for each station, the demanded production would have been met. But that was only theoretical, and the performance of the operator and the measures of his work was not completely brought into calculation.

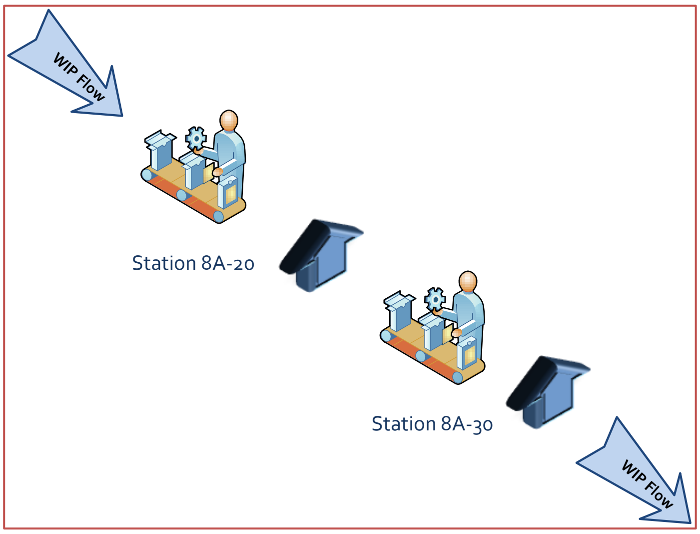


FIGURE 17: CURRENT FLOW CHART

The current flow chart illustrated in Figure 17, shows that there is a small WIP buffer station between the two workstations. A simulation (via Simio Simulation Software) was run and the results support the actual findings.

Parameters	Input Value	Output Value
Interarival Times	30 units/hr	
Station 8A-20 Process Time	167 seconds	
Station 8A-30 Process Time	173 seconds	
Number of Buffers	2	
Buffer Capacities	2 units/buffer	
Number of Arrivals		231
Number of Produced Units		158

TABLE 13: SIMIO RESULTS OF CURRENT STATE

The input time is the average of the times taken, of the operator taking the longest to complete his task of that station. Between Station 1 (8A-20) and Station 2 (8A-30) is a WIP Buffer, where 2 units can be stored. This is merely a metal frame where the panel is transported on, to the operator at the other station. Thus, this is partially a buffer as well as a transport mode.

After running the simulation for a 7.6667 hour shift (20 minute break subtracted from the 8 hours), you can see a bottleneck forming between the 2 stations. This is clearly shown in Figure 18.

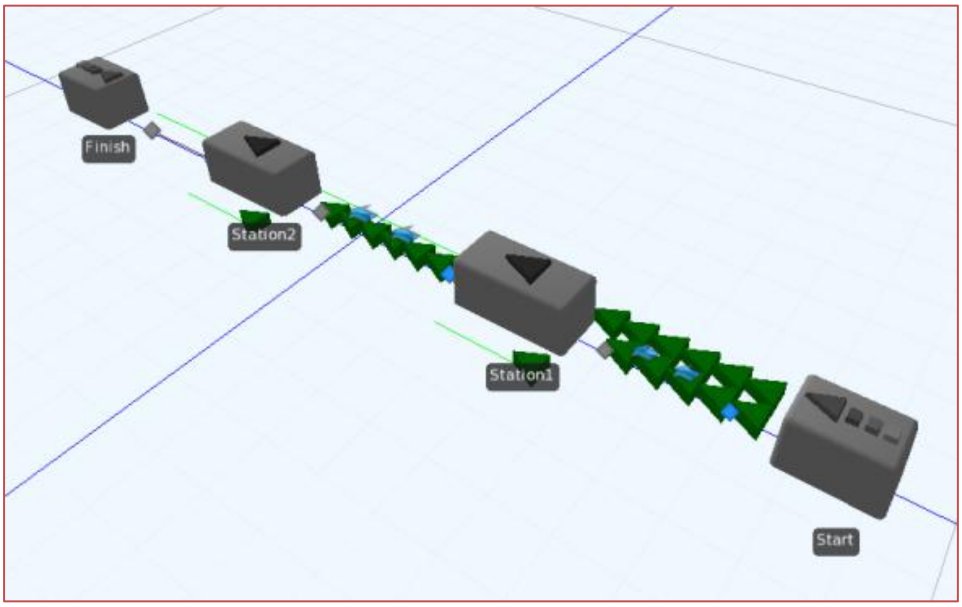


FIGURE 18: SCREENSHOT OF SIMULATION IN SIMIO OF THE CURRENT STATE

The capacities of the buffers were increased to 6 units per buffer and another buffer station was created in the simulation. The two middle buffers (each with the capacity of 3) can be jointed to form one bigger frame, having space for 6 units. See Figure 19.

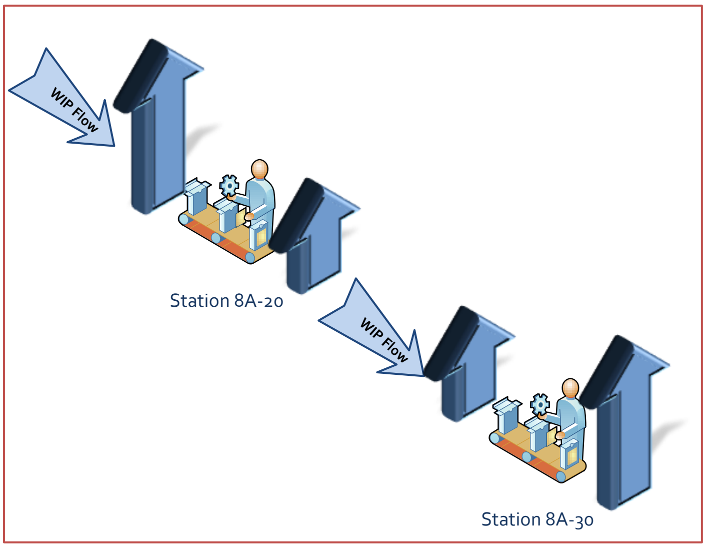


FIGURE 19: SUGGESTED FLOW CHART

After running the simulation with the increased values, the following results were found, shown in Table 14.

Parameters	**Input Value**	**Output Value**
Interarival Times	30 units/hr	
Station 8A-20 Process Time	167 seconds	
Station 8A-30 Process Time	173 seconds	
Number of Buffers	3	
Buffer Capacity's	6 units/buffer	
Number of Arrivals		231
Number of Produced Units		228

TABLE 14: SIMIO RESULTS OF SUGGESTED STATE

The number of daily produced units has increased by 70 units. This is definitely a visible improvement. The bottleneck that was visible in Figure 18, has disappeared in Figure 20.

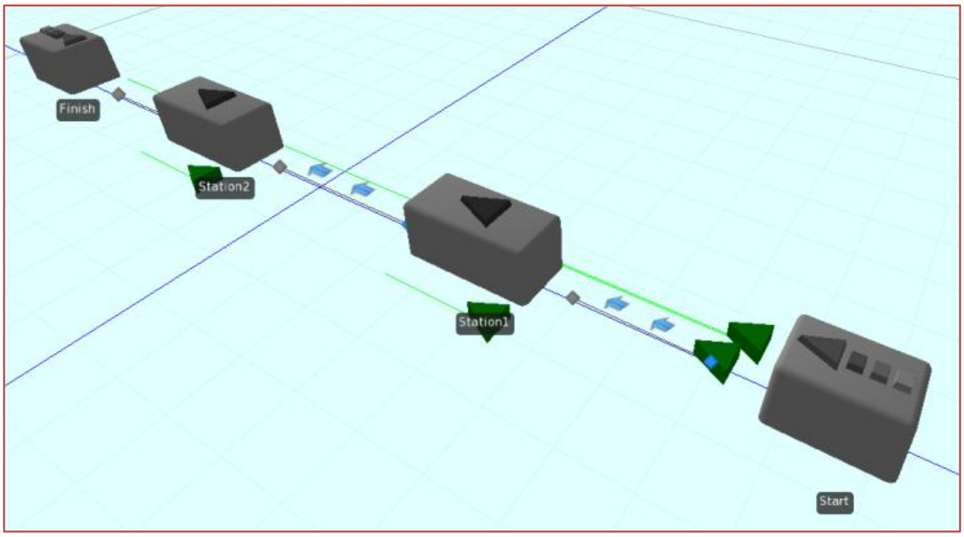


FIGURE 20: SCREENSHOT OF SIMULATION IN SIMIO OF THE SUGGESTED STATE

VALIDATION AND VERIFICATION

According to Mr C. Muller, Manufacturing Engineering Manager of Body Shop, the idea of creating larger buffer station has been brought up in the past. The problem however was the capacity constraints on the production floor and also to what extend the buffers should be increased. Muller continues that this can be a possible solution, when shown to what quantity the buffer sizes should increase.

Mr. J. Kelaotswe, Industrial Engineer at Body Shop, states that after conducting regular time studies at the line, the solution approach is possible and that trial runs can be done at a time when the line is not running at its fullest. Mrs. M.L. Mapheto, Manufacturing Quality Engineer at the Quality Assurance Department, is positive about the idea, and says that is should be a feasible improvement.

To validate the simulation, the second approach from the Literature Study was done. The simulation ran with inputs from the actual current conditions, and gave an output which is close to the actual current results from the production line.

CONCLUSION AND RECOMMENDATION

The Body Shop area is advised to increase the buffer sizes from the first two stations of the production line. There should be a total amount of 3 buffer stations with a capacity of 6 at each of them. Due to facility constraints, buffer racks can be stacked on top of each other (but further ergonomic studies need to be done to see if it consists of any danger towards the operator).

Table 10 shows that by increasing the buffer sizes to 6, the changes of an operator doing nothing, reduce with 37%. This will result in an improved workflow, and balances the stations.

The trolley with the fenders to be processed, needs to be located to the Hood Fitment station. The operators there will then allocate the fender to the unit after completing their original tasks.

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APPENDICES

RHS Fender Fitment	
Elements	Time
Locate jig from finished unit to next unit	15.32
Collect and locate fender to unit	15.46
Fasten jig	5.30
Locate drill and bolts	10.80
Fasten bolts (9)	50.53
Return drill	4.54
Resetting	17.62
	119.56

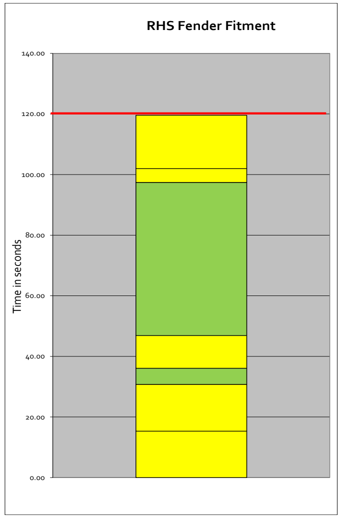

FIGURE 22: YAMAZUMI CHARTS OF RHS FENDER FITMENT STATION UNDER NORMAL CONDITIONS

RHS Fender Fitment	
Elements	Time
Locate jig from finished unit to next unit	15.32
Collect and locate fender to unit	15.46
Fasten jig	5.30
Locate drill and bolts	10.80
Fasten bolts (9)	50.53
Fastening of nut	25.63
Return drill	4.54
Resetting	17.62
	145.19

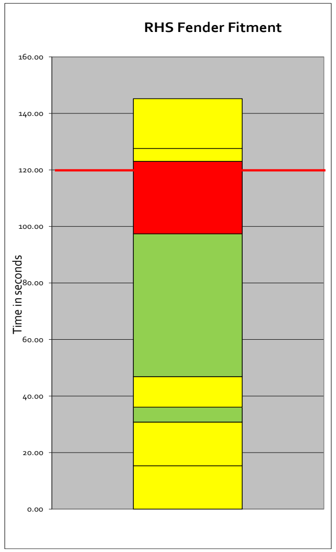

FIGURE 21: YAMAZUMI CHARTS OF RHS FENDER FITMENT STATION UNDER ABNORMALCONDITIONS

Process name:	Front Floor	Date:	2012/05/05	Standardized Work Combination Table	Takt Time
Part Name Part #:	8A - 20	Group:	Station 1		120 sec

Operator	#	Work Elements	NVAW	NVA	VAW	Waiting
Operator 1	1	Press clamp button	4.24			
	2	Walk to & fro to collect front floor tunnel from error proof fixture	11.95			
	3	Load front floor tunnel onto fixture	5.93			
	4	Position front floor tunnel setting aid onto fixture	5.82			
	5	Press clamp button	4.24			
	6	Walk to & fro to grasp spotgun		9.32		
	7	Spotweld			65.13	
	8	Walk to release spotgun		8.05		
	9	Wait for fixture to open				34.1
	10	Release front floor setting aid from fixture	5.76			
	11	Press unclamp button	4.22			
	12	Unload 8A - 20 sub assembly to buffer	8.54			
		Totals	50.7	17.37	65.13	34.1
Operator 2	1	Press clamp button	4.24			
	2	Walk to & from to collect front floor panel from storage		30.35		
	3	Load front floor to fixture	6.2			
	4	Walk to & fro to collect two cross member from error proof fixture	6.66			
	5	Load two cross members onto fixture	8.25			
	6	Press clamp button	4.24			
	7	Collect spotgun from storage	11.31			
	8	Spotweld 18 spots			75.94	
	9	Return spotgun to storage	6.49			
	10	Press unclamp button	4.22			
		Totals	51.61	30.35	75.94	0
Operator 3	1	Press clamp button	4.24			
	2	Assists to position front floor panel to fixture	3.57			
	3	Wait for two operators to load load cross members				10.47
	4	Assists to position front floor panel setting aid to fixture	5.06			
	5	Press clamp button	4.24			
	6	Collect spotgun from storage	5.76			
	7	Spotweld 18 spots			68.8	
	8	Return spotgun to storage	5.18			
	9	Wait for the two operators to complete spotwelding				20.7
	10	Press unclamp button	4.22			
	11	Assists to release front floor setting aid from fixture	2.35			
	12	Assits to lift front floor sub assembly from fixture	4.66			
	13	Wait to position front floor panel to fixture				10.04
		Totals	39.28	0	68.8	41.21
Operator 4	1	Press clamp button	4.24			
	2	Walk to collect two cross members from error proof fixture		7.68		
	3	Load two cross members onto fixture	8.37			
	4	Press clamp button	4.24			
	5	Collect spotgun	8.81			
	6	Spotweld 18 spots			73.91	
	7	Return spotgun to storage	6.67			
	8	Press unclamp button	4.22			
	9	Assist to unload front floor sub assembly to buffer		20.35		
		Totals	36.55	28.03	73.91	0
Operator 5	1	Press clamp button	4.24			
	2	Collect two cross members from storage		7.54		
	3	Load two cross members onto error proof fixture	4.77			
	4	Walk to collect two cross members from storage		12.27		
	5	Load two cross members onto error proof fixture	6.67			
	6	Walk to collect front floor tunnel from storage		6.86		
	7	Load front floor tunnel onto error proof fixture	3.95			
	8	Wait for spotwelding operators to complete				28.76
	9	Press unclamp button	4.22			
	10	Wait for unloading & loading of parts onto fixture				10.07
		Totals	23.85	26.67	0	38.83

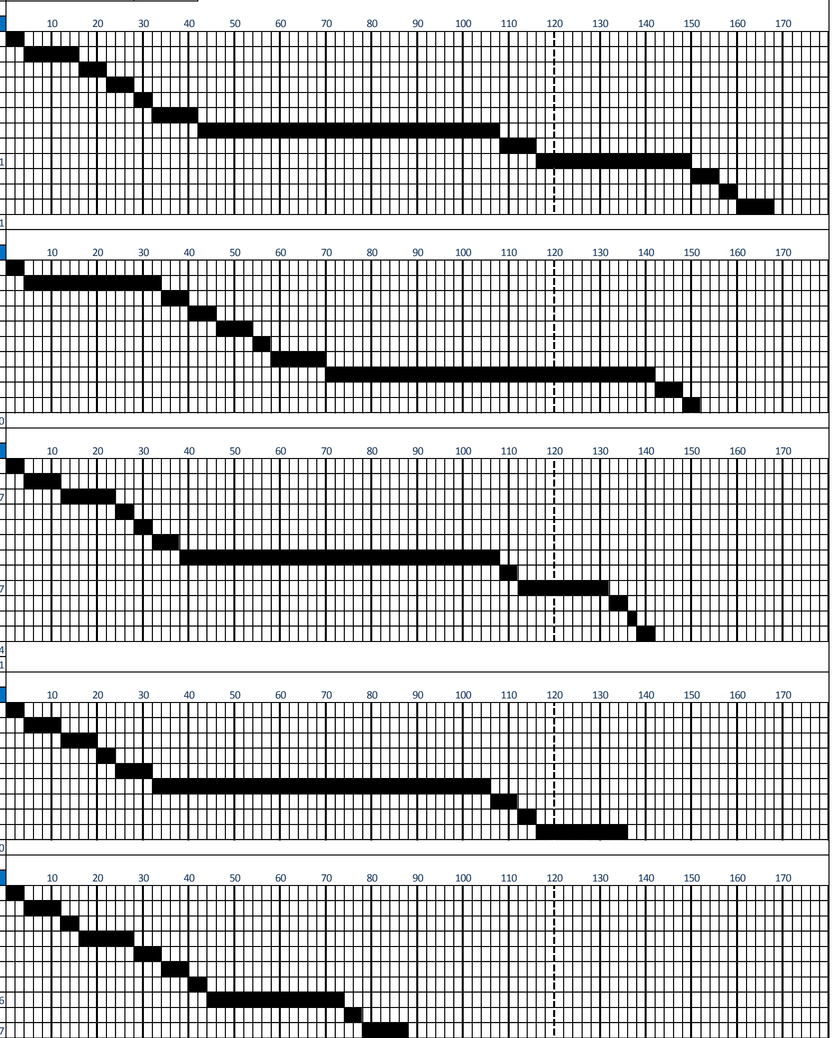

TABLE 15: STANDARIZED WORK COMBINATION TABLE

8A - 30 - 1 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press reset button	1.53	1.87	4.12	6.72	7.41	4.33
Walk to collect small brkt & cross member from error proof fixture	13.37	13.25	16.94	12.78	12.72	13.81
Locate small bracket & cross member onto fixture	5.96	5.82	6	6.84	5.56	6.04
Walk to collect cross member from error proof fixture	6.59	5.84	7.78	7.62	7.29	7.02
Locate cross member onto fixture	5.35	4.00	3.94	4.38	5.53	4.64
Press clamp button	5.54	5.03	6.56	8.62	7.93	6.74
Collect spotgun	5.4	6.12	7.66	7.47	7.72	6.87
Spotweld	25.25	27.63	23.37	26.53	26.59	25.87
Release spotgun	5.82	5.06	6.78	5.53	5.69	5.78
Press unclamp button	8.25	7.87	3.06	10.12	9	7.66
Walk to collect 8A - 20 sub-assembly from buffer	5.68	8.6	7.88	7.81	9.97	7.99
Load 8A - 20 sub-assembly onto fixture	5.04	3.53	4.75	4.07	4.31	4.34
Collect spotgun	4.96	8.65	8.59	7.75	8.81	7.75
Spotweld	44.22	50.28	54.47	53	51	50.59
Release spotgun	6.78	6.85	6.44	10.06	5.63	7.15
Press unclamp button	5.5	4.81	6.22	6.94	7.06	6.11
						172.69

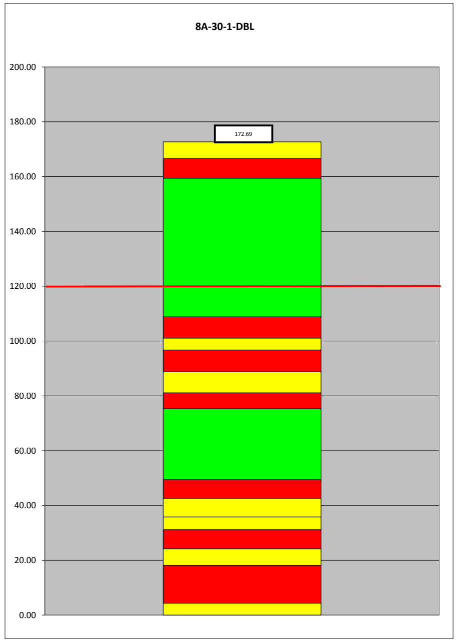

TABLE 16: TIME STUDIES AND YAMAZUMI CHART OF FIRST OPERATOR ON SECOND STATION

8A - 30 - 2 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press reset button	1.53	1.87	4.12	6.72	7.41	4.33
Walk to collect two cross members from error proof fixture	4.87	7.94	6.47	6.59	4.46	6.07
Load two cross members onto fixture	6.86	5.28	5.37	4.57	5.41	5.50
Press clamp button	5.54	5.03	6.56	8.62	7.93	6.74
Collect spotgun	7.46	6.19	6.16	7.34	6.5	6.73
Spotweld	14.1	12.56	10.87	11.5	12.81	12.37
Release spotgun	4.4	4.66	5.13	4.94	4	4.63
Press unclamp button	8.25	7.87	3.06	10.12	9	7.66
Assist to collect 8A - 20 sub-assembly from buffer	10.97	12	8.53	12.13	12.43	11.21
Load 8A - 20 sub-assembly onto fixture	4.41	4.75	4.47	4.91	4.44	4.60
Press clamp button	3.66	3.69	4.06	4.53	6.1	4.41
Collect spotgun	5.96	6.59	5.41	5.62	7.62	6.24
Spotweld	42.1	42.38	35.5	42.81	47.5	42.06
Release spotgun	6.37	5.75	7.03	8.19	6.31	6.73
Press unclamp button	5.5	4.81	6.22	6.94	7.06	6.11
						135.36

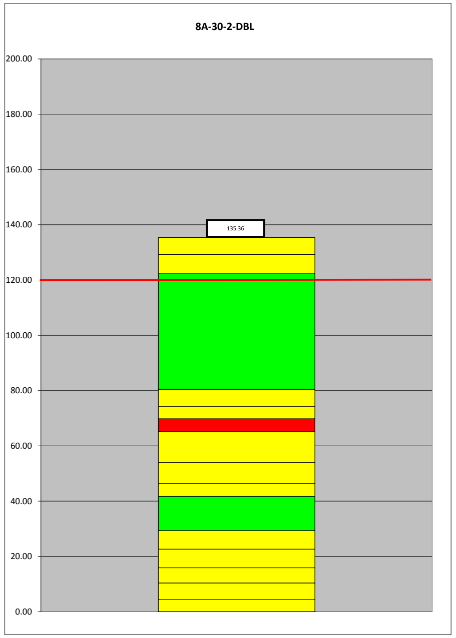

TABLE 17: TIME STUDIES AND YAMAZUMI CHART OF SECOND OPERATOR ON SECOND STATION

8A - 30 - 3 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Collect cross member from error proof fixture	4.00	3.28	4.03	3.89	3.34	3.71
Load cross member onto fixture	2.46	2.28	2,84	3.65	2.16	2.64
Obtain small bracket from storage	2.12	1.89	2.01	1.74	2.16	1.98
Locate small bracket onto error proof fixture	1.69	1.43	1.67	1.33	1.86	1.60
Collect cross member from storage	8.72	5.72	6.17	7.36	7.17	7.03
Load cross member onto error proof fixture	3.81	4.11	3.96	3.98	4.16	4.00
Collect cross member from storage	8.72	5.72	6.17	7.36	7.17	7.03
Load cross member onto error proof fixture	3.81	4.11	3.96	3.98	4.16	4.00
Collect cross member from storage	8.72	5.72	6.17	7.36	7.17	7.03
Load cross member onto error proof fixture	3.81	4.11	3.96	3.98	4.16	4.00
Walk to collect cross member from storage	10.69	12.01	11.34	12.89	11.30	11.65
Load cross member onto error proof fixture	3.81	4.11	3.96	3.98	4.16	4.00
Collect cross member from storage	8.72	5.72	6.17	7.36	7.17	7.03
Load cross member onto error proof fixture	3.81	4.11	3.96	3.98	4.16	4.00
Press clamp & unclamp button	4.34	5.12	4.89	6.78	4.27	5.08
Wait for two operators to complete spotwelding	56.97	40.75	75.87	35.52	51.00	52.02
Collect hoist & unload the 8A - 30 sub-assembly	22.85	27.32	21.06	22.41	19.19	22.57
						149.37

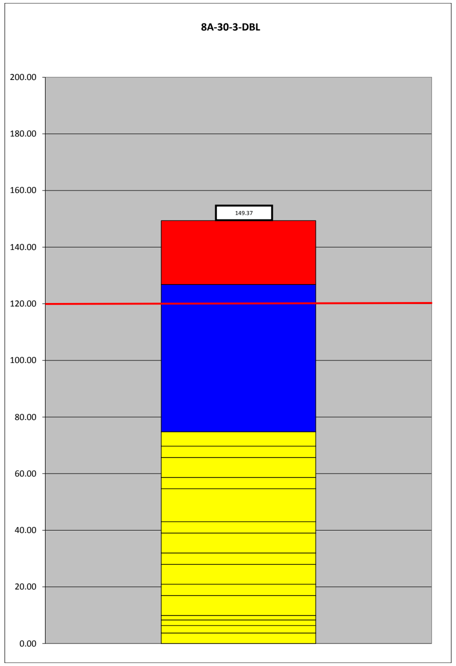

TABLE 18: TIME STUDIES AND YAMAZUMI CHART OF THIRD OPERATOR ON SECOND STATION

8A - 35 - 1 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Collect hoist & hook 8A - 30 sub-assembly from buffer	25.15	27.78	21.43	21.17	20.78	23.26
Load 8A - 30 onto fixture	3.81	3.56	4.06	6.1	6.94	4.89
Return the hoist to position	3.78	4.79	6.19	3.97	4.13	4.57
Press clamp button	3.31	4.93	5.53	7.09	3.9	4.95
Take spotgun	4.53	5.53	5.37	4.07	4.16	4.73
Spotweld	24.97	24.41	22.47	25.65	22.78	24.06
Wait for the fixture to turnaround	8.88	8.41	4.44	8.38	4.62	6.95
Spotweld	45.59	44.15	45.83	44.28	41.97	44.36
Release spotgun	4.91	4.63	4.69	4.78	5.53	4.91
Press unclamp button	3.31	4.93	5.53	7.09	3.9	4.95
						127.64

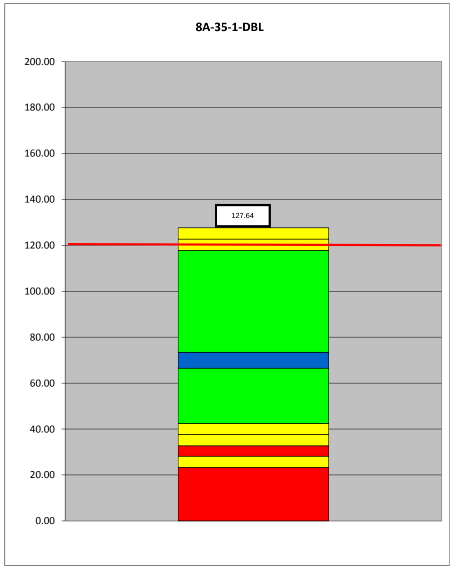

TABLE 19: TIME STUDIES AND YAMAZUMI CHART OF FIRST OPERATOR ON THIRD STATION

8A - 35 - 2 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press clamp button	3.31	4.93	5.53	7.09	3.9	4.95
Take spotgun	4.62	3.4	2.97	5.78	5.63	4.48
Spotweld	29.97	24.75	20.9	16.59	19.75	22.39
Wait for the fixture to turnaround	4.31	5.38	19.28	15.66	16.72	12.27
Spotweld	60.94	53.4	60.31	60.22	61.62	59.30
Press unclamp button	3.31	4.93	5.53	7.09	3.9	4.95
Release spotgun	6.69	5.19	4.53	7.13	6.94	6.10
Wait for the fixture to turnaround	12.03	15	6.31	5.65	8.25	9.45
Assist to hook 8A - 35 sub - assembly	6.84	3.69	5.44	4.81	3.6	4.88
						128.76

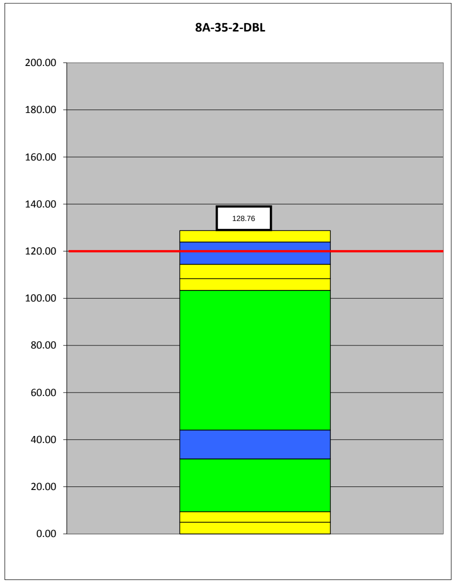

TABLE 20: TIME STUDIES AND YAMAZUMI CHART OF SECOND OPERATOR ON THIRD STATION

8A - 35 - 3 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press clamp button	3.31	4.93	5.53	7.09	3.9	4.95
Collect spotgun	5.06	6.25	4.21	5.47	5.13	5.22
Spotweld	20.25	17.35	20.09	17.68	19.34	18.94
Wait for the floor to turn	12.66	6.81	18.62	24.72	30.94	18.75
spotweld	63.06	59.16	60.19	53.91	60.41	59.35
Release spotgun	5.72	5.84	4.44	5.5	3.94	5.09
Press unclamp button	3.31	4.93	5.53	7.09	3.9	4.95
Collect and position hoist onto 8A-35 sub assembly	17.22	12.57	12.81	14.62	11.87	13.82
Unload 8A-35 sub assembly to buffer	6.06	5.06	5.25	5.47	4.62	5.29
						136.36

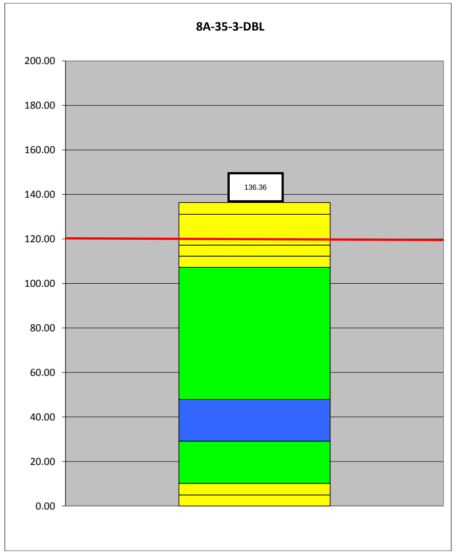

TABLE 21: TIME STUDIES AND YAMAZUMI CHART OF THIRD OPERATOR ON THIRD STATION

8A - 35 - 4 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press clamp button	3.31	4.93	5.53	7.09	3.9	4.95
Assist to hook and load 8A-30 sub assembly from buffer	16.34	11.31	11.00	18.60	22.85	16.02
Collect spotgun	5.41	5.59	4.85	3.68	7.18	5.34
Spotweld	25.40	24.68	24.10	25.09	27.35	25.32
Release spotgun	4.64	4.07	5.03	4.66	4.22	4.52
Turn around the fixture	5.02	18.93	6.93	7.87	8.59	9.47
Collect spotgun	4.65	8.50	6.22	3.94	7.00	6.06
Spotweld	45.66	55	48.41	53.53	47.34	49.99
Press unclamp button	3.31	4.93	5.53	7.09	3.9	4.95
Release spotgun	6.28	3.66	4.09	4.00	4.19	4.44
Turn around the fixture	6.02	10.53	10.53	13.03	10.5	10.12
						141.20

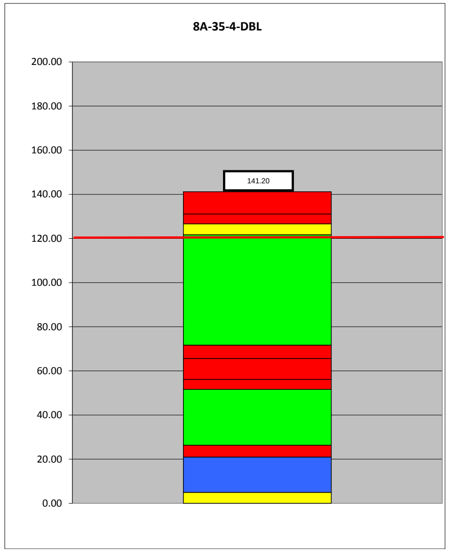

TABLE 22: TIME STUDIES AND YAMAZUMI CHART OF FOURTH OPERATOR ON THIRD STATION

8A - 40 - 1 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press reset button	13.5	14.12	11.41	13.22	11.63	12.78
Collect and load rear floor onto fixture	8.25	8.79	14.34	9.95	11.25	10.52
Obtain and locate setting aid	3.97	4.47	4.06	4.34	4.06	4.18
Assist to load side sill onto fixture	5.12	6.25	5.5	7.19	5.56	5.92
Hand clamp the fixture	6.41	5.19	4.59	3.72	5.16	5.01
Return rear floor transfer tray	4.44	8.34	8.41	8.28	8.03	7.50
Press clamp button	5.79	4.22	3.5	6.18	4.5	4.84
Collect spotweld gun	6.34	6.03	6.88	7.22	5.88	6.47
Spotweld	61.59	64.28	63.31	61.12	59.84	62.03
Release spotgun	4.97	6.65	4.58	7.1	6.97	6.05
Wait for other operator to complete	11.72	8.57	11.12	11.03	11.06	10.70
Unload setting aid	5.84	4.59	7.63	6.06	5.03	5.83
Press unclamp button	4.13	6.75	7.47	4.34	5.13	5.56
						147.39

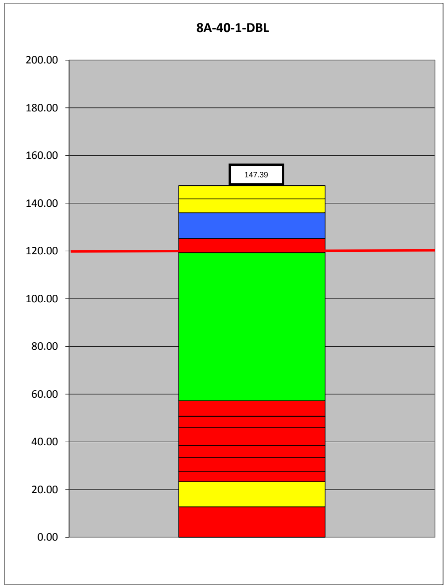

TABLE 23: TIME STUDIES AND YAMAZUMI CHART OF FIRST OPERATOR ON FOURTH STATION

8A - 40 - 2 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press reset button	13.5	14.12	11.41	13.22	11.63	12.78
Load 8A-35 sub assembly onto fixture	8.22	8.53	10.44	16.41	11.34	10.99
Collect side sill from error proof fixture	7.03	7.06	6.03	7.31	7	6.89
Load side sill onto fixture	6.06	5.47	4.6	8.63	5.03	5.96
Collect side sill from storage	7.69	7.56	4.72	7.56	5.44	6.59
Load side sill onto error proof fixture	4.12	3.19	3.88	3.97	4.84	4.00
Press clamp button	5.79	4.22	3.5	6.18	4.5	4.84
Collect spotgun	7.47	6.5	8.12	5.68	6.97	6.95
Spotweld	78	81	86.16	81.47	84.1	82.15
Release spotgun	5.66	6	5.72	5.28	5.19	5.57
Pull 8A-40 assembly onto buffer	12.5	10.66	10.66	10.28	13.03	11.43
Press unclamp button	4.13	6.75	7.47	4.34	5.13	5.56
						163.69

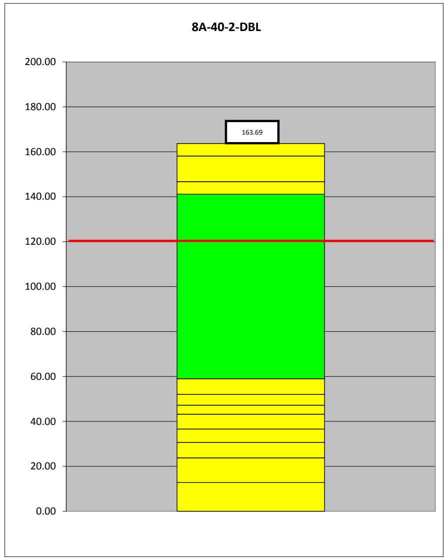

TABLE 24: TIME STUDIES AND YAMAZUMI CHART OF SECOND OPERATOR ON FOURTH STATION

8A - 40 - 3 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press reset button	13.5	14.12	11.41	13.22	11.63	12.78
Load 8A-35 sub assembly	16.46	10.82	11.87	16.44	11.78	13.47
Collect side sill from error proof fixture	6.29	5.21	7.13	7.53	6.19	6.47
Load side sill onto fixture	5.56	4.91	3.97	4.50	3.59	4.51
Collect side sill from storage	9.06	10.56	8.10	8.46	5.31	8.30
Load side sill onto error proof fixture	5.06	3.68	3.78	3.32	4.25	4.02
Press clamp button	5.79	4.22	3.5	6.18	4.5	4.84
Collect spotgun	5.5	6.54	6.82	6.43	6.81	6.42
Spotweld	77.32	79.62	89.81	78.25	80.79	81.16
Release spotgun	5.84	5.16	5.69	6.88	5.5	5.81
Assist to pull 8A-40 assembly onto buffer	17.09	17.75	7.18	20.19	8.06	14.05
Press unclamp button	4.13	6.75	7.47	4.34	5.13	5.56
						167.39

TABLE 25: TIME STUDIES AND YAMAZUMI CHART OF THIRD OPERATOR ON FOURTH STATION

8A - 40 - 4 - DBL = run 1						
Elements	Run 1	Run 2	Run 3	Run 4	Run 5	Average
Press reset button	13.5	14.12	11.41	13.22	11.63	12.78
Collect rear floor from buffer	14.88	11.65	17.15	17.75	14.21	15.13
Load rear floor onto fixture	1.71	2.34	3.00	5.04	4.59	3.34
Return the hoist	8.29	4.37	4.03	5.16	5.25	5.42
Collect and load setting aid	5.03	4.44	3.88	4.87	3.46	4.34
Assist to load side sill	4.87	4.60	6.15	5.94	5.41	5.39
Press clamp button	5.79	4.22	3.5	6.18	4.5	4.84
Collect spotgun	9.19	10.75	10.6	10.16	12.66	10.67
Spotweld	62.09	62.53	58.84	64.00	67.28	62.95
Release spotgun	6.94	5.37	5.25	7.62	5.34	6.10
Wait for other operator	15.41	13.10	12.72	10.16	11.09	12.50
Unload setting aid	3.84	4.78	4.59	4.41	4.56	4.44
Press unclamp button	4.13	6.75	7.47	4.34	5.13	5.56
						153.45

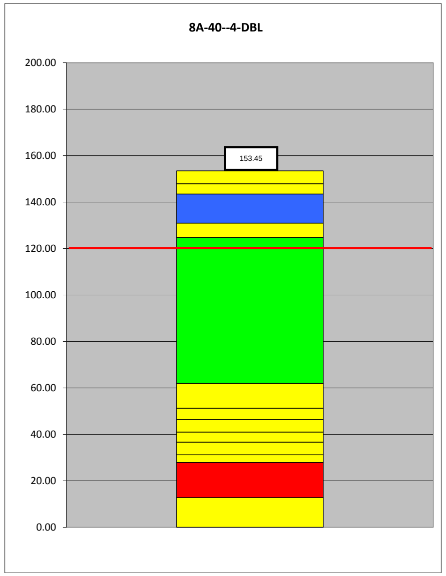

TABLE 26: TIME STUDIES AND YAMAZUMI CHART OF FOURTH OPERATOR ON FOURTH STATION

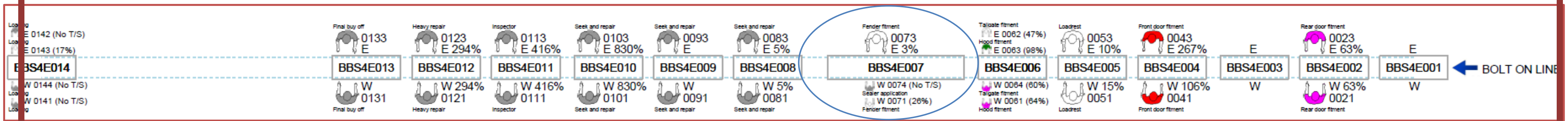

FIGURE 23: LOCATION OF FENDER FITMENT STATION ON BOLT-ON-LINE

Time and Method Study at Fender Fitment Station

Fender Fitment (LHS)

Department: T6	**Daily schedule:**	**230**		**Avail time:**	**3600**
Area: Bolt-on-Line	**Hourly schedule:**	**30.00**		**Required lab:**	**1**
Foreman:	**Cycle time:**	**2.00**	**min**	**Authorised lab:**	**1**
	Cycle time:	**120.00**	**sec**		
Ind Eng: AP. Erasmus	**Unoccupied min:**	**396.24**		**Ass sec:**	**3203.76**
				Load factor:	**89%**
LHS Fender Fitment		**SGL**			
Collect drill to unit		5.60			
Fasten bolts (9) of fender		52.39			
Resetting of fender after fastened		34.73			
Unhook hood stay and lower hood to horizontal position		4.86			
Collect fender and return hood stay and drill		9.20			
Total sec per unit		**106.80**			
Hourly schedule		**30.00**			
Assigned sec		**3203.76**			

Fender Fitment (RHS)

Department: T6	**Daily schedule:**	**230**		**Avail time:**	**3600**
Area: Bolt-on-Line	**Hourly schedule:**	**30.00**		**Required lab:**	**1**
Foreman:	**Cycle time:**	**2.00**	**min**	**Authorised lab:**	**1**
	Cycle time:	**120.00**	**sec**		
Ind Eng: AP. Erasmus	**Unoccupied min:**	**636.03**		**Ass sec:**	**2963.97**
				Load factor:	**82%**
RHS Fender Fitment		**SGL**			
Locate jig from finished unit to next unit		15.32			
Locate drill and bolts		10.80			
Fasten bolts (9)		50.53			

Return drill	4.54
Resetting	17.62
Total sec per unit	**98.80**
Hourly schedule	**30.00**
Assigned sec	**2963.97**

Hood Fitment (LHS)

Department: T6	**Daily schedule:**	**230**		**Avail time:**	**3600**
Area: Bolt-on-Line	**Hourly schedule:**	**30.00**		**Required lab:**	**1**
Foreman:	**Cycle time:**	**2.00**	**min**	**Authorised lab:**	**1**
	Cycle time:	**120.00**	**sec**		
Ind Eng: AP. Erasmus	**Unoccupied min:**	**1026.21**		**Ass sec:**	**2573.79**
				Load factor:	**71%**

LHS Hood Fitment	**SGL**
Collect and locate hood to unit with jig	23.07
Return jig to bonnets	16.42
Locate drill and bolts to unit	11.21
Fasten bonnet to unit	8.41
Return drill	8.86
Clamp jig to drill	5.85
Locate fender to unit	7.75
Fasten jig to unit	4.24
Total sec per unit	**85.80**
Hourly schedule	**30.00**
Assigned sec	**2573.79**

Hood Fitment (RHS)

Department: T6	**Daily schedule:**	**230**		**Avail time:**	**3600**
Area: Bolt-on-Line	**Hourly schedule:**	**30.00**		**Required lab:**	**1**
Foreman:	**Cycle time:**	**2.00**	**min**	**Authorised lab:**	**1**
	Cycle time:	**120.00**	**sec**		
Ind Eng: AP. Erasmus	**Unoccupied min:**	**615.08**		**Ass sec:**	**2984.92**
				Load factor:	**83%**
RHS Hood Fitment		**SGL**			
Locate jig to next unit		18.66			
Help with placing bonnet onto unit		8.24			
Locate drill and bolts to unit		34.63			
Hook hood stay in		7.38			
Fasten bonnet to unit		5.23			
Return drill		4.62			
Collect and locate fender to unit		15.46			
Fasten jig		5.30			
Total sec per unit		**99.50**			
Hourly schedule		**30.00**			
Assigned sec		**2984.92**			

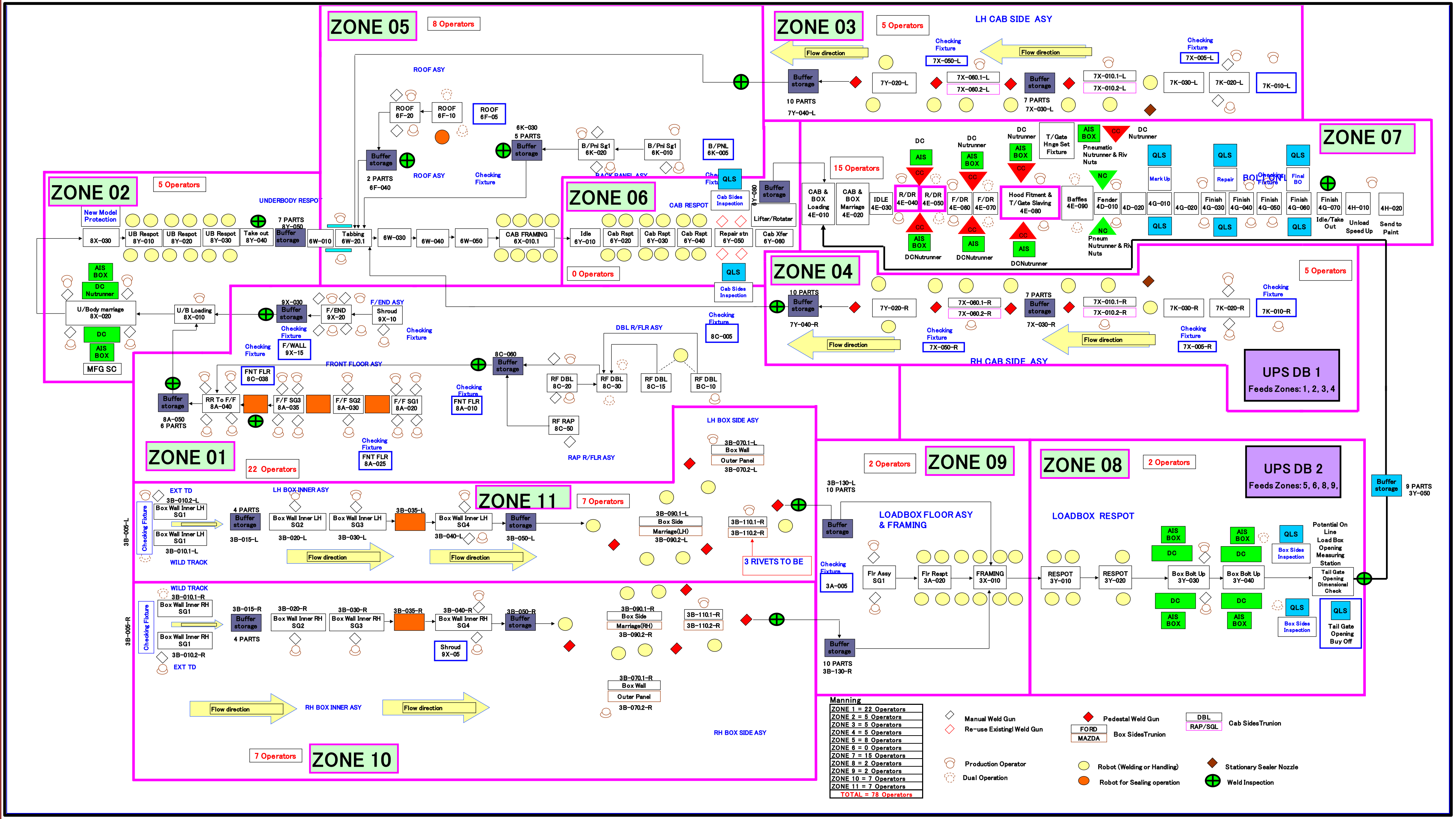

FIGURE 24: T6 BODY SHOP CYCLE LINE LAYOUT