Addis Ababa University
Addis Ababa Institute of Technology
School of Mechanical & Industrial Engineering

Production Flow Analysis and Improvement in Bishoftu Automotive Engineering Bus Body Manufacturing

A Thesis Submitted to the School of Graduate Studies of Addis Ababa Institute of Technology, Addis Ababa University in partial fulfillment for the Degree of Master of Science in Industrial Engineering

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Authors' Declaration

I, Taddese Yohanesse, declare that this thesis entitled "Production Flow Analysis and Improvement in Bishoftu Automotive Engineering Bus Body Manufacturing" is my original research work and no material has been submitted previously for the award of any other academic degree.

The research work was done under the guidance of Dr. Ameha Mulugeta at Addis Ababa university, Addis Ababa Institute of Technology School of Mechanical and Industrial Engineer.

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This is to certify that the above declaration made by the author is correct to the best of my knowledge.

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ABSTRACT

Today's automotive manufacturing companies face increasing customer demand and highly competitive for quality products at competitive prices in a timely manner. For this reason, manufacturing companies, especially in the automotive industry, need to increase their productivity. The main problems of the case company are non-value-added activities, bottleneck and the unbalanced task of the stations in the assembling line. These issues affect the company's production rate. The study aimed to improving the production capacity of bus body assembling line in BAEI by reducing the NVA activities, eliminate bottleneck stations and recommend suggestions to produce more products.

The first approach that showed the existing production system by identifying non value added activities and the bottleneck area was value stream mapping. Other approach applied for this research was flow control analysis that gave greater insight by comparing takt time with cycle time of the processes. The final approach was involved creating and simulating existing model by using theoretical distributions of the existing processing times to assess the current system performance and create alternative simulation models. According to the simulation result the first scenario increased the product of the company. The report of simulation showed eight (8) buses built per month and a decrease in average cycle time from one hundred forty-two hours to one hundred twenty-three hours and non-value added activity decreased from forty-two hours to twenty-eight hours while adding a station serially for the front and rear compartment assembly and correction station. Second scenario increased the product to thirteen (13) buses per month after taking into account the elimination of the bottleneck processes by adding one parallel station for a bottleneck station, that results additional seven (7) buses produced in a month compared to the existing. The average cycle times and NVA times also reduced from one hundred forty-two (142) hours to one hundred three (103) hours and from forty-two (42) hours to eighteen (18) hours respectively. The findings demonstrated that utilizing VSM and simulation technique, which focuses reduction of wastes to bus assembling line, increase the number of buses built in the assembly line from six buses per month to thirteen buses per month that is 16% increment.

Key words – value stream mapping, simulation, cycle time, takt time, value added and non-value added activities.

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Abbreviation

AU-Africa union

BAEI- Bishoftu Automotive Engineering Industry

CAGR- Compound Annual Growth Rate

CBU- Completely Built Up

CKD- Complete Knock Down

GDP- Growth Domestic Product

ILO- International labor organization

LCR – Largest candidate rule

MTEIRDC- Manufacturing Technology & Engineering Industry Research & Development Center

NNVA- Necessary but non-value added

NVA- non-value added

SKD- Semi Knock Down

SUVs- Sport Utility Vehicle

VA- value added

VSM- Value Stream Mapping

CHAPTER ONE

1. INTRODUCTION

The fundamental duty for the survival of manufacturing firms is to improve their productivity. It plays a vital role in increasing the number of customers, changing technology, and more competitors emerging in the market. Enhancing the productivity of the company is the most important factor for today's manufacturing sector. Productivity is the measurement that can indicate the whole efficiency of employees, machineries, raw material's nature, management performance, and the overall manufacturing efficiency (Chhabra, 2019). It is vital for small, medium, and huge industries. The country 's production capacity can indicate the societies living standard, the quality of life, level of employees, the country's economy growth and progress. By enabling companies to be better competitive by participating in the global market, productivity plays a leading role in creating a great impact on the country's development. (B.Davis, 2000). The manufacturing sector significantly shows the production success of a country. In addition, the manufacturing industry must consider lead time, international competition and meeting the needs of customers in terms of quality and quantity. (Swarna & Sayid Mia, 2018).

The general concept of improving the production of manufacturing process is reducing wastes that occurred in the system. Womack, Jones and Roos, (1990) stated Reducing these deadly wastes of production is the commonly used perception for the improvement of productivity in manufacturing firms. These wastes are waiting, excessive motion, un necessary transportation, defect, over production, over processing and inventory. Even though companies recognized these wastages, they couldn't avoid or reduce them, and the bus body manufacturing firms also face challenges like other automotive industries to be productive, Thus, it will be necessary to use the appropriate productivity improvement tools to enable the companies involved in the sector to be competitive and continue their work in a sustainable manner (Chepkania, 2018). Moreover, companies need to deliver products based on customer demand.

Occurrence of NVA activities and bottleneck stations make industries low productive because, they don't have any impact on the output. Due to this reason reducing non-value-added activities and eliminating bottlenecks are important factors to improve the flow of production. And also, poor manufacturing processes, unnecessary motion, and material handling problems are wastes. These listed wastes are theoretical reasons for reducing the number of products (Jayaganthan, 2014).

1.1 Background of the Study

Currently, the automotive industry is playing a vital role in several economies to sustain. China takes a leading role mainly by producing electric vehicles, with regard to quantity, features, alternatives, trades, and the contribution of the industry to GDP grown progressively from the countries that automotive industry originated like Germany, France, North America, Japan, and Korea republic respectively. The current situation is the same as in the twentieth century when mass production and mass consumption twisted together; it has been called the "industry of industries" (ILO, 2021).

The automotive manufacturing center is the largest industry in the world. According to (Moore, 2022) 60 million vehicles are manufactured and more than 4 million people are employed in the industry. Its value is $2.9 trillion in 2022 and growing an approximate CAGR of 3.1%, although the market dropped by 0.6% between 2017 and 2022. The decline is faster than the decline of other economies, which were hit by the Covid-19 pandemic. The future of the industry is predicted to carry on increasing by 3.71 CAGR between 2020 to 2030 and can produce 122.83 vehicles by the end of twenty twenties. In terms of market size, it is the first of all manufacturing industries. The steel mills, component factories, and glass factories that feed into the production of automobiles are frequently located close to automotive manufacturing plants all over the world. These other industries are attracted to the automotive industry, and clusters that result in new municipalities and a need for infrastructure are formed.

Although there are 50 companies producing different vehicles in Ethiopia, imported vehicles dominate the market mainly the second hand vehicles. Africa Business, (2020) described Ethiopia's second most valued import overall in 2019 was Commercial vehicles, cost US$955 million. Now it is moving to a certain level from importing a car to assembling. Its automotive development levels are compared in Figure 1:1. On the other hand, BAEI takes a lion's share which enables the country highest-earning automotive export by commercial vehicles. BAEI is a governmental company that assembles various vehicles and operates major tasks in automotive industry such as overhaul, assemble, upgrade, and localize different vehicles like bus, pick-up, SUVs], truck and military equipment's. Mainly Ethiopian military and AU peacekeeping use military vehicles, civil vehicles are also provided to government and private transportation providers (Africa Business, 2020).

This study proposes an integration of VSM with simulation in minimizing the non-value added activity (NVA) and eliminating bottlenecks to improve the flow of production and evaluate the result. Thus based on the problems seen in BAEI, the study is focused on finding impediments and bottlenecks for improving production line of case company.

1.2 Statement of the Problem

Automotive manufacturing plays a crucial role in import substitution in Ethiopia and currently, there are over 50 companies engaged in the production of minibus, bus, pickup, truck, two-wheel and three-wheel vehicles with a capacity of 148,849units/year (MTEIRDC, 2022). The country has good opportunities in different ways like low manpower and energy costs compared to other countries, but efficiency level of the manufacturing industries is lower. According to MTEIRDC, (2023), the efficiency level of automotive industries is reported 15% in 2022-2023.

In Ethiopia BAEI is a well-known bus body assembling manufacturing company. The company provides different types of buses for governmental and non-governmental organizations according to the order and struggles to minimize the country's foreign currency for purchasing abroad. When the factory was established, the designed production rate was 45 buses per month in a single shift. However, the current rate is 6 buses per month. Another bus assembling factory the so-called Ada bus assembling factory can also produce 12 buses in one month, even though the designed production rate was 40 buses per month. This indicates the productivity of BAEI is lower compared to its designed capacity. The current percentage productivity for bus assembling line of BAEI is around 13% of its designed capacity. The reason behind the decline of the production rate is the existence of non-value-adding activities and the occurrence of bottleneck in the assembling line. Those issues bring a lack of competitiveness and consistency of survival. In addition, it exposes the country to unnecessary foreign currency, the company can’t be able to produce at full capacity, and if this continues, it will lead to the closure of the company.

The paper focused on avoiding bottlenecks by identifying the root causes and reducing NVA activities for the improvement of production process in BAEI.

1.3 Research Questions

Based on the problems mentioned above, this study tries to answer the following research questions

1. Which activities of the case company are value adding and non-value adding?
2. Which potential improvement areas can be found in the assembly line?
3. How to possibly integrate VSM and simulation to minimize production wastes and eliminate bottlenecks for better performance of workstations and other partners in the bus body manufacturing process?
4. How to develop the improvement model to address the issue?

1.4 Objective of the Study

1.4.1 General Objective

The general objective of the study is to analyze the production flow and improve of BAEI bus assembling lines.

1.4.2 Specific Objectives

The specific objectives of the study are: -

- ➢ To assess the case company of value adding and non-value adding activities
- ➢ To assess potential improvement areas in the assembly line.
- ➢ To integrate VSM and Simulation, to reduce NVA and avoid the bottleneck station of the assembling line.
- ➢ To develop a better simulation model by using different alternative scenarios and
- ➢ To develop a future map.

1.5 Scope of the Study

The study focused on identifying non value added activities and bottleneck areas of bus assembling line. The bus assembling production factory is one of the eight factories established under BAEI. In this factory different types of buses are assembled. From those products, the public bus is among the products produced by the company, which takes a longer lead time to produce.

Even though there are a lot of challenges to make the company productive, from supply up to final delivery of the product to the customers, the study has focused on the technical problems of the assembling line without considering the cost. So the study was limited to finding NVA activities, identifying bottlenecks and reducing the impediments to assembling the only luxury bus (public bus) out of other products.

1.6 Significance of the Study

By using production improvement techniques to be improved in the factory, increasing the production flow and implementing the production process the study's findings support BAEI manufacturing and other automotive manufacturing firms. On top of that, the reform plan will bring visible changes to the automotive manufacturers as well as to the entire production process of other manufacturers. The findings of this study are used for:

- A resource for other academic works,
- It can satisfy its customer,
- It can produce more products with optimized time, and
- It can be competitive in the market.

1.7 Limitation of the Study

As the company was not in operation at the time of this study, it was not possible to capture the cycle time of each station. Instead the researcher took the data from the documents and daily time sheet of the company. In addition, the distances between all stations, logistic unit, employee criteria, supplier of raw materials are not included in the simulation. Thus, the study only limited on bus assembling line performance improvement, due to the lack of time and data.

1.8 Organization of the Research

The study is organized and divided into five main sections, and chapter one discussed about introduction and background on automotive manufacturing production process and its challenges including problem statement, research questions, objectives, scope, and significance and limitation of the study. Chapter two discussed about VSM, Flow control analysis, and simulation techniques from different literatures with arguments mainly in production process of vehicle manufacturing. Chapter three presented data collection and analysis tools and research design approaches. Chapter Four discussed the Data presentation, analysis, interpretations and discussion part of simulation output result**.** Chapter five summarizes and makes recommendations based on the results of the study.

CHAPTER TWO

2. LITERATURE REVIEW

In this chapter, various literatures are explored, especially those related to productivity improvement. This chapter is focused on understanding productivity; identifying bottlenecks, NVA activities and their root causes, improvements in the automotive industry, and NVA definitions, concepts, and equations relating to productivity.

The procedure of analyzing relevant literature started by investigating different sources using frequently employed terms and acquiring books and articles with the most appropriate summaries. The reviewed papers were collected and evaluated from, articles, conferences, unpublished papers and books. The distribution of appraised literature by years of publication is depicted in the figure below.

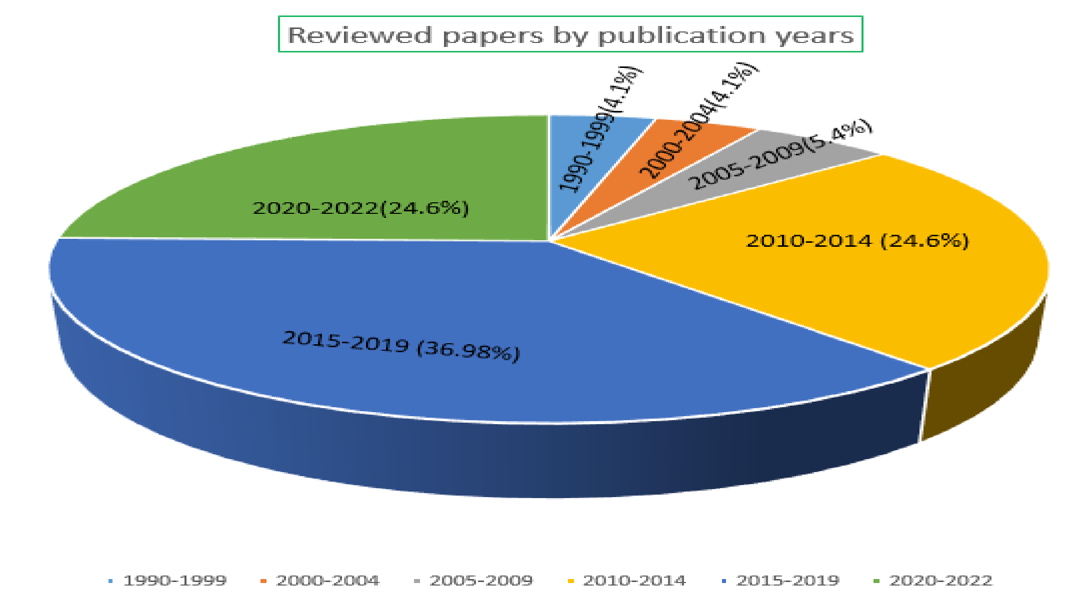


Figure 2-1 Reviewed papers

2.1 Introduction

Production Flow Analysis is a method to analyze the flow of a production process, thereby improving the production process by linking stations and related work units. Before proceeding with production flow analysis, a representative sample should be taken to determine the number of stations to be included in the study, otherwise all stations should be included.

2.2 Definition of Concepts

The goal of Lean is to improve production by eliminating waste, thereby identifying process value and value streams and focusing on process flow. It is a better and more efficient technique by improving the production process and flow. VSM improves the process flow by segmenting the process flow from start to finish, identifying the current state of information and material flows, and then identifying the future state map wastes.

The concept of productivity is applicable to any economy, small and medium, large businesses, government and individuals. The main goal of productivity is to increase the product and service in quantity and quality by using resources properly, demanded by consumers at the lowest possible cost. Although there are many ways to express productivity, it is typically measured as either labor, machine, or value productivity.

(Berhe et al., 2015) also defined productivity is the output-input ratio of the plant or industry. It is used as the performance measurement of the country's economy at macro level (Khatun, 2016). Comparing the production and service provision of the countries with their potential resources is one way to understand whether the productivity of the countries high or low. From a nation's viewpoint productivity is the availability of goods and services compared with the potential resources of the country.

Nowadays due to a complex and complicated production system, manufacturing systems need large investment for all of their life cycle from start to finish. The past literature confirmed that the increase in production performance can reduce costs related to setup of machines, maintenance, shortage cost, holding inventory, the cost earned because of poor quality product (Iwao & Marinov, 2018). The involvement of decisions relating to enhanced efficiency of the manufacturing system is dynamic. The primary task of the manufacturing system is design and optimization of production system (Rane, 2015).

In general, the definition of productivity is the ratio of outputs and inputs by measuring the relation of outputs such as goods and services produced, and inputs including labor, and capital (Lana et. al, 2013). More outputs from equal amount of inputs can be produced, outputs can be produced equally with less input, or a combination of the two can increase it. The general concept of improving productivity in manufacturing is the reduction of the seven wastes in the production system (Womack et al., 1990).

Dennis (2008) states waste with the Japanese word ―Muda, the opposite of value. It is also common to see the definition of seven wastes that the lean philosophy seeks to eliminate. Andersson and Middle, (2010)stated organizations find that 90-95% per cent of activities in a lead time are non-value-added activities for which customers don't want to pay. Those are overproduction, wait, defect, transport, inventory, motion and over-processing.

1. **Overproduction**

Overproduction is one of the main sources of waste. This means more products are delivered than what is demanded by the succeeding process. According to (Abraham, 2016) Overproduction generates different kind of waste like excess inventories that causes lots of investment for the company. Rather than maximize the utilization of resources, production managers and supervisors were critiqued by the number of products. According to lean philosophy, the utilization of machine and humans for production need to be according to customer's demand (Andersson & Middle, 2010) Thus it should be better to start manufacturing according to customer orders instead of predicting. Manufacturing beyond the market demand and more than the capacity of the sales division is a wastage of money. The loss caused by overproduction is the loss of materials and other costs to produce the product. As a result, it difficult to return on investment of raw materials and various expenses required to produce the product, which leads to loss, even though the product is going to be sold later (Soliman, 2017).

2. **Defects**

Alaya, (2016) noted that problems occurred in a single station such as quality defects, inventory shortages, etc., have a significant impact on the efficiency of the assembling line. The product which is below the level of the customer requested is a defect. Mchugh, (2018) in his journal article identified defect is the main cause that makes waste in the production process, which is 21.57% results inventory wastage 20.59%. It directly impacts your bottom line and affects inventory, scheduling etc…Most of the time these defects appear in the paperwork and produce a damaged product that negatively impacts delivery performance (Ahmed, 2011).

3. **Waiting**

The occurrence of bottlenecks and inefficient production flow in the manufacturing process generate idle times for stations, machines or employees. It includes small delays between the processing of units (El-namrouty & Abushaaban, 2013). The waiting waste is occurred by spending time ineffectively. Waiting is a waste when the time taken by one station to produce the product is longer than the following stations and other stations are idle. According to (Chahal & Narwal, 2017) job plans, orders, machine parts, e-mail, and unnecessary processing procedures are different types of waiting for that lead to waste of time. Chiristina Gay, (2019) states that lack of process control, idle machines and poor communication between stations are among the issues that cause waiting. And also waiting for parts in the product flow, information feedback, machine setup or changeover time all consume time. This denotes waiting for parts which are delaying due to huge inventory and long periods of idle employees, information or goods, resulting in poor flow and long lead times (Of & An, 2015).

4. **Inventory**

Mostly wastes like defect, unplanned transportation, motion and unbalanced process flow are the cause of inventory (William, 2011). It is often due to planning problems and a mismatch between purchasing and the real demand of particular resource. Out dated equipment’s and sluggish movement of materials are also other causes of inventory

(Domingo, 2015). Stadnicka and Litwin, (2019) stated the higher the level of inventory costed more capital that freezes in materials. Further (Binyam, 2021) stated the more inventory in the manufacturing process leads to high inventory and financing costs, and high defect rate also occurred. According to the lean philosophy, inventory can be reduced by reducing batch size, product inventory and supply of materials at the right place, time, and quantity (Mohopadkar & Patil, 2018).

5. **Motion**

Unnecessary motion is the movement of workers without adding value to the product**.** Thus, during production Workers need to avoid unnecessary walking, lifting heavy object that requires great physical exertion lead to exhausted and get bored to perform the tasks (Desta et al., 2014). (Soliman, 2017) stated unnecessary body movements generates motion waste when performing a task. Numera, (2021) describes that layout problems, unorganized workplaces and location of stores, non-standard work instruction and unclear processes are the causes of unnecessary motion.

6. **Unnecessary Transportation**

It is the way of delivering the product from one position to another or handing off from one employee to the other that couldn't make any value addition to the product. Transportation waste is the material movement from preceding to succeeding station that does not add value to the product. Andersson and Middle, (2010) stated that, most of the time layouts of the plant and production style are the cause of unnecessary transport in production system. This includes the distance and location of each succeeding process, the distance between workstations and warehouses, and the distance between the work stations and other sections like maintenance and satellite stores. (Soliman, 2017).

7. **Over-processing**

It is one type of waste that occurred by using resources, materials, and equipment's more than needed or When the method or process used to produce the product is inappropriate. (Desta et al., 2014) described a product that is not completed on time leads to waste because many workers are involved in the process and the product is not delivered on time to the market. (Thessaloniki, 2006) also stated One of the causes of quality problems is the mistakes made by unnecessary workers. If there are many workers at one station, the lead time increases and the cost of the work increases

2.3 Factors influencing production system of manufacturing firms

The factors that influence productivity can be categorized generally into two groups:

(A) Controllable Factors.

(B) Uncontrollable Factor

(A) Controllable Factors:

These factors are controlled internally by participating all employees and managements of the company, in general the factors are in control of the industrial organization. These factors play an important role to enhance productivity such as Material and Power, Technological Factors, Machinery and Plant Layout, Human Factors, Organization and Managerial Factors.

- **Human Factors:**

The most significant factors to improve productivity are the nature and behavior of humans including both their ability as well as their willingness. Some of the factors like employment rates, wage rates, job stability, job satisfaction, or employability in occupations or industries are the reflection of employee productivity (Fisseha, 2021).

- **Ability to Work:**

It is the main factor run by the employees' education, aptitude, work experience, and train. In order to increase the productivity of companies, the efficiency of the employees working in the company has a high role.

- **Willingness to Work:**

The important factors that can improve productivity are motivation and the morale of people. Some of the things that can stimulate the employee's desire to work include division of labor, salary increases, good relations, relationships outside of work, leadership skills, working hours, sanitations, allowances, and transportation etc.

- **Organization and Managerial Factors:**

The role of corporate affairs in sustaining improved industrial relations is high, and by summarizing the measures of delegation and distribution of power, they can bring high productivity in groups their goals contribute to the objectives of the organization, and increase motivation. The skill and outlooks of managers have an important role in productivity. Managers need to be Competitive and dedicated to achieving unexpected outcomes from ordinary people. A manager's ability and willingness can improve the job performance of employees to work.

(B) Uncontrollable Factors:

These factors are external factors which companies couldn’t manage.

Natural Resources, Government Factors, Economic Political and Social Changes are included.

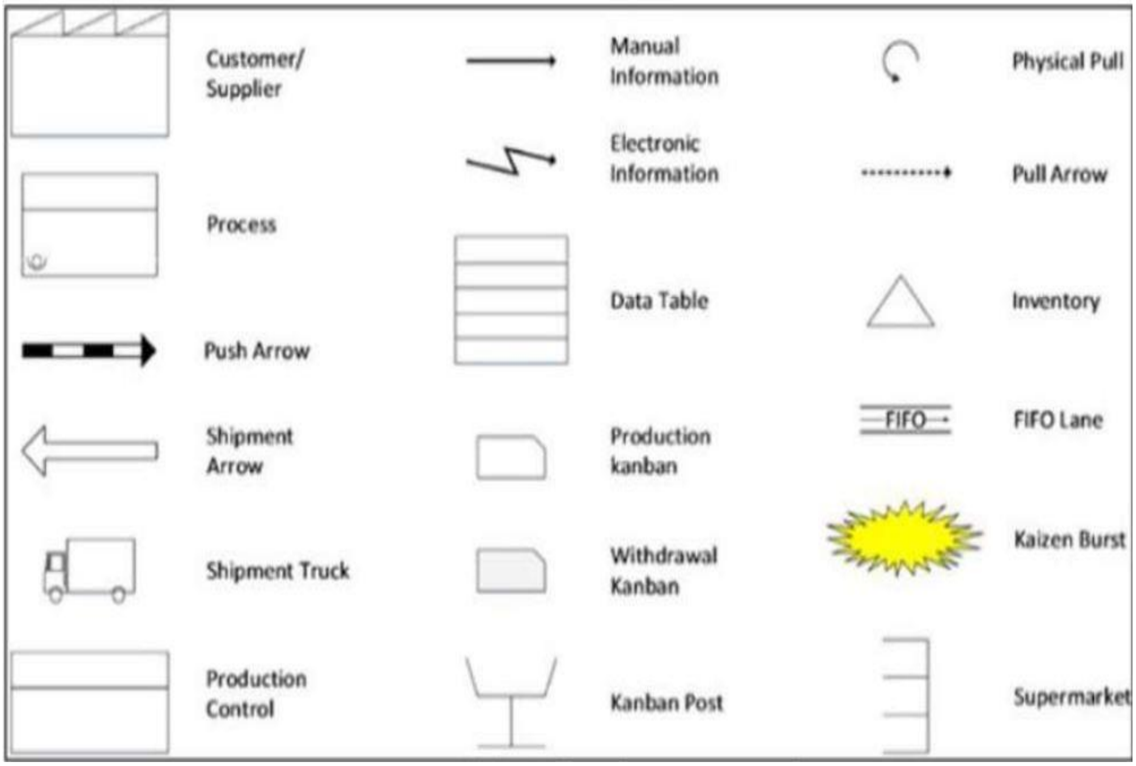
2.4 VSM for Production Flow Improvement

Value stream mapping is originated from the Toyota production system is known as “product and data stream mapping.” The technique utilizes the methods of lean manufacturing for analyzing and calculating some manufacturing processes in the system. Value stream mapping (VSM) is an effective tool for the practice of lean manufacturing. VSM approached the entire process flow in three-step methods in which first producing a diagram showing the actual material and information flows or Current State on how the actual process operates. Tyagi *et al.*, (2014) stated the tool enables to detect, exhibit wastes and also can generate smooth flow in manufacturing process. Sharma, (2014) applied VSM in automotive manufacturing and stated that it is used to map the current practice by using VSM symbols. It enables to identify the improvement areas by considering cycle time, lead time and work in process from current state mapping. The paper has brought out important result with respect to tact time, process inventory level, lead time, manpower reduction, process time, line speed and process ratio. With VSM, the company was able to satisfy their customers based on cost, delivery and quality.

Jasti et al., (2020) examined VSM process can radically decrease and simplify the process to the necessary little activities. Martins & Cleto,(2016) also stated Value stream mapping can optimize individual processes by considering the big picture as a whole. In order to see the processes clearly, it requires walk along throughout the whole production process and information to think about the value stream of the product. In another study (Gracanin et al., 2014) described that to increase the process speed, improve percentage of VA times and reducing wastefulness (NVA activities) is the major factor. In internal manufacturing perspective, three types of activities are undertaken (Hines and Rich,et.al 1997).

These can be characterized into:

1. Non-value adding (NVA); They are unnecessary activities for both the production of the product and the customer. The non-value added are wastes and unnecessary activities that doesn't contribute value for the product and need to be eliminated. Non-value added activities are un-necessary manufacturing processes some of them are material handling problem, waiting, backtracking, etc.
2. Necessary but non-value adding (NNVA); These activities are activities that help the organization complete its work, regardless of whether the customer sees them as wasteful. Therefore, these activities are difficult to eliminate easily and can be reduced by making various changes in the production process. A long journey to bring products made at each station, Loading and unloading of goods, are some of examples.
3. Value-adding (VA). These activities transform the product's input into the desired output, and the customer is willing to pay for these activities. Welding, machining, forging, casting, and heat treating are some of the examples.



Source: (Mansor, 2022)

Figure 2-2 VSM symbols

These tasks are the necessary steps to do VSM in Massachusetts Institute of Technology (2012),

- Define customer value and the process
- Create existing VSM
- Analyze the existing state map to determine opportunities for improvement
- Create a future state map to visualize the desired and realistic next state
- Create action plans to move toward future state.

2.4.1 Takt Time

Takt-time is the time necessary for a supply rate to keep up with the demand rate (Frandson et al., 2014). The production speed must be adjusted in real time to account for customer demand. If the production speed is determined by customer demand, some of the wastages reduced because overproduction would be avoided, and production delays would also be avoided. It shows how quickly products must be produced to meet the demand. Lean suggests calculating takt time and balancing the process of the production line to deliver to the customer at the required time and enough amount of product.

Tact time means adapting production speed to the customer demand and the production speed is determined based on the customer demand, it will reduce the waste by avoiding over-production and also help to prevent the production from being delayed. It indicates how fast would be a process to manufacture a product according to the customer demand. To ensure that the production line delivers the product on time and without generating shortages to the customer Lean offers calculation of the takt time and balance the process based on the value.

2.4.2 Cycle Time

Cycle time demonstrates the assembly line's capacity for production and the amount of output that can be achieved using available manpower and other resources. It serves as a reliable gauge of how the assembly line is currently operating. Cycle time is the production time it takes to complete work on the assembly line at each station, or in a multi-station workroom, to the time needed to produce a product. There is a difference between cycle times and takt time. Takt time provides a service based on the customer's needs by indicating the maximum time, whereas cycle time refers to the actual amount of time required for a station to carry out an action or complete one cycle of a process. Takt and cycle times are both implemented to show the bottleneck and perform an activity or complete one cycle of the process.

Moreover, Lean Manufacturing suggests calculating the Takt Time and balancing the process based on that value to ensure that the production line delivers the product to the customer on time and without creating shortages. Takt time and cycle time should ideally be as close as possible because if the cycle time is too short, orders won't be filled on time, and if it's too long, there will be excess capacity. Takt Time is the main element of manufacturing systems based on customer demand. It is an indicator of consumer demands that have leveled and become more normalized as production times have gotten longer. Takt time facilitates the ability to calculate in a challenging flow. Furthermore, the required speeds of machines and other equipment's are determined

To calculate the takt time the following formula is used:

Tact time = $\frac{\textit{available time}}{\textit{average demand}}$ …………………………… Equation [2-1]

By defining takt time one can:

- Create a smooth flow of work.
- Enhance the capacity of meeting customer demand.
- Reduce inventory by removing overproduction.

2.5 Time Study

It is based on measuring the work content of the selected assembly, including any personal allowances and unavoidable delays. It is the primary step required to determine the opportunities that improve assembly operations and set production standards (Yerasi, 2011). The key objectives of a time study are:

- To increase productivity.
- To deliver effective planning and control in production system
- To determine the production capacities.
- To balance the work force with available resources.
- To determine standard costs of a product.
- Efficient plant layout.

2.6 Simulation

A simulation is a tool that imitates and shows the real manufacturing system including its performance. It is widely known in flight simulators and business games. To design a new product line, it is common to first implement a computer simulation of product requirements (Antonelli & Stadnicka, 2018). To support the decision making process in today's business world, companies progressively use simulation software to indicate possible future states.

As Fisseha, (2021) states "Computer simulation is a program that designs and conduct experiments of the existing system to understand the nature of the work, evaluate different strategies and identify the best one.

- Risk avoidance – It will ensure that the research is carried out without any financial, material or physical damages that may be caused by chemical manufacturing systems and others, even war and others will be studied with minimum cost and risk-free.

- Physical scaling – It has the potential to perform the study large and small tasks in the system clearly and cost-effectively.
- Control – It is able to minimize the uncertainty in order to control the objects and to allow the control to be accurate.
- Repeatability – Simulation allows the study of different systems in the same environment and the same systems in different environments.
- Component integration – It can integrate automotive industries with several economy sections and playing a vital role in sustaining the system.
- Time compression –. It can Show the real system in a short amount of time, even though the real system takes longer time.

The simulation enables most business firm’s increase efficiency; decrease costs, and enhance profitability by reducing various problems. The purpose of simulation is to identify bottlenecks and problems in the manufacturing process. In this way, there is no time loss when various problems are detected in the production process (El-Hawary et al., 2020). Today Managers have a better understanding of the stream of their operations and how it executes by using dynamic animation (W. D. Kelton, R. P. Sadowski, 2015). The ability that compresses and expands time is the benefits of simulation. It can simulate many years of firms’ performance in a short time (minutes or seconds) and it can also show phenomenal activities that cannot detect in a real situation by extending time-taking perception at exceptionally little interims of time (Latif, 2014). This permits a clear understanding of how the company works energetically. Spieckermann et al., (2000) also formed a strategy that improves the automotive body shop performance which needs to be prepared and adjusted each year was the center of the study.

2.6.1 Determine problem via animation

Conforto & Laffaille, (2007) discussed that Simulation is essential to discover where the system is working accurately and to show the real system before decision. The allocation of pictures to parts that will offer ease in succeeding the parts during the production run can improve in animation. The important features to be focused on animation are:

- State of resource
- Statistic – Cycle time, production output, resource utilization, WIP.
- Entity movement and size of queue.

In general, utilization of simulation is implemented to evaluate the performance of manufacturing firms, various model of manufacturing processes, mainly activities of the assembling line established for different purposes and the next planning production system, offering the way of identifying bottlenecks and improve station utilization, by implementing different alternative scenarios.

2.7 The integration of VSM with Simulation

VSM is a tool particularly used for continuous improvement and in lean manufacturing. VSM provided the data, by differentiating the improvement areas and could increase precision and applicability of simulation, whereas simulation increases perception of dynamism. In simulation, applying the iterative process will make the correct model to reach the verified model. Thus, the iterative process allows us to determine bottlenecks, implement changes, different scenarios and experiments for the improvement of production system (Stadnicka & Litwin, 2019). VSM clearly showed where the bottlenecks exist within the process and the areas that need major improvement. Then the simulation model implemented only on the stations that need improvement. After the simulation, VSM changes from a snapshot to a motion picture that brings perceptions which is impossible to show by using only VSM. The integration of tools allows the study to find the recommended improvement areas in which VSM depicted without affecting the process; in addition, different ideas can be tested in a short period and less money. The combining of the tools enhance the performance of both techniques to identify bottlenecks (Goh & Goh, 2019).

Therefore, the priority of reducing the cycle time of the bottleneck station was determined by breaking the constraint that is needed for downstream processes and the whole system. Finally, the improved process simulated and different alternative scenarios delivered to select the best alternative.

2.8 Improving the Manufacturing system in Automotive Sector

Automotive industries face great competition that needs to be adapted continuously. Eliminating waste, lowering costs and increasing quality, are the regular concern of these companies (Costa et al., 2018). To get the capability for maintaining their competitiveness, the implementation of the lean tools integrating with others need to be applied in the bus manufacturing industry.

Bus body manufacturing companies face limited automation due to diversity in manufacturing and customer requirements. In addition to that large numbers of labor in the industries have become an obstacle in the effort to improve the productivity.(Chepkania, 2018). Selecting and controlling of appropriate manufacturing system is vital to overcome the challenge. In this way, the company can produce more products with less materials, energy and reduced manpower (Efthymiou et al., 2016). Chandra, (2013) States that cost reduction correspondingly improves productivity as the value addition and content to the input in improvement. Another study (Santos et al., 2018) addressed the analysis focusing on automotive manufacturing costs, specially the losses incurred by bus assembly companies. By providing different methods to evaluate the cost of failure during the production of a product, it will lead to improvement in indicating the cost of quality. The studies focus only on the reduction of costs in the assembling process. There will be other features to improve the productivity.

Nallusamy and Adil Ahamed, (2017) state identification and elimination of wastages (NVA) in the manufacturing industry by analyzing the existing layout and performed using the lean tools like VSM, line balancing and 5S. As a result, it showed a 13% improvement in time spent on NVA activities reduced and a 10% improvement in process cycle efficiency. Parab and Shirodkar, (2019) also in their journal paper address implementation of the VSM in the automotive industry. In this study, substantial reductions in non-value added time and WIP are observed which verified the effectiveness of value stream mapping. However, it enables the static analysis only in the production system that all the current problems cannot be easily identified with VSM (Stadnicka & Litwin, 2019). The study also focuses on two processes to reduce WIP. It also has to consider about the whole system to improve productivity continuously. Pegels and Watrous, (2005) described that it will always have at least one link (bottleneck) that is not quite as strong as the others in the system.

A journal paper that improved the productivity of automobile assembling line through line balancing published by (Firake & Inamdar, 2014) identified the workstations that hinders to produce more in the existing layout and eliminated the activities which took too much time in the production system. Ultimately, the engine assembly line was thus found to be improved. In another study (Abebe, 2020) presented with the help of LCR, one can find out the way to synchronize the work stations for the workflow and sequencing. After applying the LCR method, the rate of production is increased. Despite the productivity was enhanced and it is likely to result in good solutions but heuristic approaches don't guarantee optimum solutions. Further (Getachew, 2019) presented by focusing line balance application to reduce idle time of stations and to improve the efficiency of the company implemented the three methods such as Ranked position, Largest candidate rule and Kilbridge and Wester's Column. It is better to discover whether the system is working correctly and to show the real system before decision by using simulation.

Emmanuel Lorou *et al.*, (2021) also revealed arena is a highly useful simulation tool for improving productivity and working with different models. There were 16 trucks produced before optimization. The primary concern of this study indicates increasing number of output by adding trucks and operators in each workstation. After optimization by using different scenarios produced 36 trucks, the productivity has increased significantly, thus it improved about 110%. Another study (Samanta & Philip, 2015) state that the simulation model can identify bottlenecks and change the flow process by examining the effects of changes in processing time without using additional resources or new machines, But instead of further investigation, he pays more attention to the current situation. Avoiding bottlenecks in the system will not be completed in a single step.

Emad Alzubi, (2019) applied different bottleneck detection methods by using the simulation output; they are waiting time, utilization, and scenario based methods without considering customer demand and evaluating whether the intended design of the production system is being met. As (Urban & Rogowska, 2020) stated to improve productivity of the manufacturing system, identification of bottlenecks allow to implement things that need to be implemented first. Some of the alternatives for the elimination of the bottleneck operation in the system are merging stations, and adding stations serially or parallel. Hadi Go¨kc-ena, and Recep Benzera, (2006) stated that if the production capacity of the assembly line is not enough and if it is necessary to increase the capacity, building an additional parallel line is one option with additional equipment for the production line. In another study Neumann et al., (2006) suggests even though both systems had room for improvement, from previous data in automotive assembly operations, the parallel production has greater essential potential.

It is important to increase the company's production capacity by improving productivity in order to fulfill the customer's needs. Following this, some academics can be heard saying that the production capacity of companies can be increased up to 50 percent (Mahmood & Shevtshenko, 2015). However, it is difficult to achieve this result in a single-step product improvement study. So this study targets by combining VSM with simulation to eliminate wastes and bottlenecks that make the assembling line an ongoing and constant improvement process.

2.9 Literature Review Summary

The review of literature showed that it is possible to balance the flow of the production process, satisfy the customer's needs and ensure economic benefits by substituting and adjusting the best of various tools and methods (Tuan et al., 2014).

As it can be seen from the literature which implemented in various automotive and manufacturing companies that enable them to produce more products. Most studies have applied a specific technique and indicated the results of implementing a method to increase production capacity. Among the frequently used methods, line balance and simulation were used to improve the use of resources in the production process. Some of them have been also proposed as an option to improve the production process by using methods like waste reduction and time study.

From the literature review the researcher could detect that there is a lack of research on combining VSM and simulation for the improvement of productivity in Ethiopia automotive assembling factories. After identifying the improvement areas of the assembling line, simulation is the best way to evaluate the proposed proposal numerically. However, the studies done by BAEI would be difficult to implement because they brought results that have not been evaluated. This clearly shows that this work on VSM with integrated simulation for productivity enhancement needs further study. This is also the motivation for this study. So, to achieve higher productivity and address the growing industrial market, it is critical to eliminate waste and bottlenecks using these powerful tools and techniques. Therefore, this topic presents a great opportunity for application in Ethiopia automotive industry.

CHAPTER THREE

3. METHODOLOGY

3.1 Research Design

The research design is the implementation of research including Plans and procedures (Araya, 2018). It covers everything from gathering and analyzing primary data, secondary data, and others for implementing different techniques. So the selection of the research design need to be based on different factors such as the challenges of the company, the researchers experience and attitude, issue being addressed, and also for the audience. The research design is experimental type. The primary and secondary data are also both qualitative and quantitative. This study was started from collecting primary data about the assembling process of the company and the secondary data also collected from various researches, documents of the company. Then the actual manufacturing system sequence of the assembling line is analyzed by process mapping, Value stream mapping, and flow control analysis to show the existing system of proceeding and succeeding stations, differentiate the bottleneck station, and to identify wastes. Simulation also showed the existing situation and how the future state improved the productivity of the company. These tools clearly showed where the bottlenecks exist within the process and the areas that need major improvement. Visio and arena simulator software's are also used for analysis and improvement. In addition, problems related to prioritization of different bottlenecks are clearly defined under the flow control analysis. After these solutions are given for the bottleneck, the proceeding steps such as addition of a station length wise and parallel implemented and the newly improved process or the future map is simulated to measure the performance of the new system. Purposive sampling is used as a sampling method and the data's were collected from each department that included in bus assembling operation. Lastly, graphs, Tables, and Equations used for presentation of results on various variables in the study are revealed as required.

3.2 Data Collection Method

3.2.1 Literature Review

Literature survey is mainly to analyze, understand the idea of different researches from the published journals and articles about VSM and simulation techniques. To achieve the final goal of the study journals, articles, case studies, reviews and company reports are reviewed. The implementation brought knowledge on the research area for finding best tools and methods. The reviewed literature mainly focused on lean manufacturing and simulation for productivity improvement

3.2.2 Primary Data Collection

It was collected from BAEI employees, discussion groups, including from in-depth interview made with department heads and other staffs. Other data's like current production process, customer demand, lead-time, and productivity of the company were collected through observing and interview by developing questionnaire.

The simulation model need to be represented the real system of the assembling line using the collected data of manufacturing processes, like operational sequence, cycle times, number of working days, Number of stations and man power of each station.

3.2.3 Secondary Data Collection

The data's like manufacturing process and assembling cycle-time for this research were assessed from different reports, including from other relevant documents.

Document review- It is reviewed the production daily activity and production shop scheduling to indicate the existing capacity and challenges of bus assembling line in BAEI.

- Theoretical capacity and rate of production
- Cycle times in each station
- Rework or reject rate

3.3 Summarized data collection

- Direct observations: Through visiting of the company, important information for the study was being collected by observing of working condition like, product flow, scheduling, working environment, and number of operators.

- Collecting data from different section: gathering data's from the daily activity of different department's like plan of production, production capacity, number of shifts from production planning department to identify the schedules and procedures of the process and their implementation.
- Interview: It was one of the important inputs for the study, and thus interviews were conducted with supervisors, product planners, technical managers, and marketing staffs. From the interview the researcher has got the information about productivity of the company, and its challenges, the performance of each station in the assembling line, number of idle and active workers in assembling time. It was focused on the area of problem and the objective of the paper including the specific objectives for advancing precise evaluation of the features observed and to describe in detail like VA and NVA activities and the bottleneck station.
- Time recording: - The time taken of each process were gathered from company document to detect the processing time of each station that results bottlenecks in the assembly line and the difference of time between VA and NVA activities of each operation.
- Focus group discussion: - The group discussion was held particularly about bottleneck station, the possibility of using additional floor area, transfer of tasks and employees with production heads, design head, PPC head, and front and rear compartment welding station supervisor.

3.4 The study area

In the study, population is entire group of individuals or persons that are believed to provide important information for the research. The population is decided based on purposive sampling. Purposive sampling is used because it is necessary to focus in depth on the whole bus assembling line.

3.5 Sampling

It is implemented by selecting a representative sample of a population that determines the sampling from the case company employees. The Purposive sampling technique implemented in this study for interview. The sampling comprises assembling work shop supervisors, Testing and adjustment supervisors, Design and engineering head, PPC engineers, Bus body painting supervisors, marketing officers, and team leaders. The respondents have sufficient information about the whole or partial assembling line. Generally, from these departments twelve employees participated for the interview.

3.6 Conceptual model development

3.6.1 Product selection

Automobiles, buses, and dump trucks are assembled in three different assembling shops. The first activity that needs to determine the improvement of the productivity of the company is the selection of similarity of product and task performed in the manufacturing shop. The struggling of delivering the solution for all production reduce the final output of the study, proper utilization of assets, the company's productivity. Based on similarities of processes assembling stations and products categorized in BAEI. To get a huge change of the existing manufacturing system, the researcher has to focus in a single product that needs improvement. From those products of BAEI model Zk6116D was chosen for investigation and enhancement because it has the highest number of cycle time to produce.

3.6.2. Process mapping

Total flow of the production system helps the researcher to prepare and understand easily the sequence and the flow of products. Then alternatives would be proposed for the next analysis. As process mapping primarily showed the flow of the product and data to make a solution for that particular assembling line. For assembling lines process maps were created based on the arrangement and sequence of operations of each station.

Table 3-1 Data collection

No	Type of data collection	Objective	Sources of data
1	Observation	To understand how the assemble line organized and To recognize number of stations and sequences	Bus assembling line stations

2	Interview	To have an overview of what the bus assembly line is lacking and what measures should have been taken, to solve the existing productivity of BAEI and how operations are being carried out within the bus assembling operation	Assembling shop supervisors, Testing and adjustment supervisors, Design and engineering head, PPC engineers, and marketing officers.
3	Focus group discussion	To ensure and discuss whether the assembling area has enough room for parallel station and the possibility of transferring employee's station to station.	Production manager, deputy production manager, design head, PPC head, bottleneck station supervisor.

3.7 Data Analysis

After collecting the data in direct observation, interviewing, and referring company documents are presented using tables, pie charts and bar graphs as required. The VSM analyzed the collected data to differentiate the VA and NVA activities clearly, in addition VSM can identify bottlenecks that reduce productivity of the company according to the deigned capacity decline. Finally, simulation (Arena software) was implemented to evaluate the outcome of any variation to the existing line and selection of better scenario of the process.

3.7.1 Value stream mapping

VSM showed the current production system of the bus assembling line and flow of information in the value stream. Then, the information about customer demand is collected in the interview. To analyze the collected data, the first technique that shows the bottleneck station and the entire assembling line an existing state map was created. It includes the duration required to run the process of the bus assembling line on each workstation. Each workstation has its own task to perform and represented as a process to simplify the map. Frame alignment and body welding, for example, involves loading, aligning, drilling holes, welding, and much more, but it required a process.

All the process steps and the tasks performed that the product family goes through are shown in VSM. Some examples of process steps include chassis preparation, engine and gear box assembly, partition welding, front and rear compartment assembly and painting. Various process characteristics are measured at all stages. In general, cycle time, VA and NVA times, available work capacity hours, and the number of workers are among those different characteristics.

3.7.2 Flow control analysis

As described above VSM identified bottleneck station, VA and NVA activities, and showed the improvement areas by using existing state map. Excel also used to compare and show the difference between cycle time of the stations and takt time for the results of flow control analysis. Then arena simulation was done including validation and verification that the model is the representation of the existing process.

3.7.3 Simulation

The final step of analyses is simulating the actual or existing assembling line. To apply this specific purpose, fitting input analyzer was created with the observed data distributions, estimating the parameters, and assessing the best fit of each station. The use of input analyzer enabled the existing model run through probability distribution. The cycle times of each station of the assembly processes were considered. Input Analyzer needs text files with fundamental data in order to fit the probability distributions of the data. The model then uses these input distributions as input variables. It is appropriate to take into account important information such as input parameters and entity arrivals obtained from observation. Then to validate and verify the input and output data of existing situation, the VSM and output of the simulation report compared. The implementation of simulation is limited to body assembling station up to the final station that is adjusting and testing station. The simulation model need the following activities.

- Model validating and verifying.
- Design the Experiment.
- Result and Analysis

❖ Validating and Verifying the model

The researcher proposes integrating VSM with simulation to address current problem of the company, by defining objectives, limitations, run time and visualizing the assembly sequence. The model has been prepared according to the program and information has been collected. Verification and validation processes are performed to ensure that it accurately represents the existing state map of the bus assembly line. Verification ensures whether the model replicates or not to the existing correctly by focusing and determining the operating logic of the model is in the right way. The existing system and simulation output similarity and accurate work in the same manner is ensured by model validation. The Validity of the model determines the representation of the production system and ensured the accuracy of the input data. The way of validation before running the model is vital to precede and improve the existing manufacturing system. Model validation in the manufacturing system is generally performed with evaluation and comparison of actual data in current production line and simulation output. Thus, to complete the study successfully the researcher collected detailed information through documents, daily report sheets, focus group discussions, and interview.

❖ Design the Experiment

An experimental study was carried out through a simulation which aimed to enhance the assembling line's performance starting from existing and testing other scenarios. The experiment involved extracting statistics related to cycle time of the stations, utilization of resources, outputs, and waiting time. These simulation results were obtained from an automated software report.

❖ Replication Number

The replication analysis starts by choosing the initial number of replicates. A close number of simulation runs are required to statistically analyze the real and the simulation mode differences. First initial simulation run was started from one up to ten replications, then the final replication has been done in computing half width, standard deviations and mean within these trial different measurement parameters were examined to make the assembly line productive by enhancing the measurement parameters of productivity in this study

- **Result and Analysis**

The number of outputs in the assembling line was figured for each simulation outcome. Finally, after running the simulation ten times and analyzing the measurement parameters and the whole system comparing the existing manufacturing system and enhanced performance or productivity improvement was made to draw conclusions and provide recommendations. Generally, the tools which are used in this research are summarized on the table below.

Table 3-2 Detail data analysis

No	Method	Input for analysis	Objective/Purpose	Task/Activities	Expected Result
1	Process mapping	Observation	Show the existing product flow	Draw using visio	Understand the sequence of products
2	Value stream mapping	Observation, interviews and document	To assess the existing productivity of BAEI, to identify problem areas and wastes, as well as create flow in the bus assembling line	All information's compiled on a map and analysis is performed	Identify VA and NVA activities of each station
3	Flow control analysis	Interview and VSM	To decide the constraint is located in the assembling line.	Calculate and compare the takt time	By identifying the

			To assess existing productivity of BAEI	and cycle time.	constraint(s) and balance cycle time of stations with the takt time and finally, the customer’s demand is being satisfied

Table 3-3 Software’s for research

Tool	Purpose
Visio	To generate Bus body assembling process, existing and the future VSM
Arena	Used to implement the assessment of the existing productivity of BAEI, simulate the performance of existing and the future state map, to identify value-adding and non-value-adding activities in the assembly line. To develop a better simulation model by using different alternative scenarios

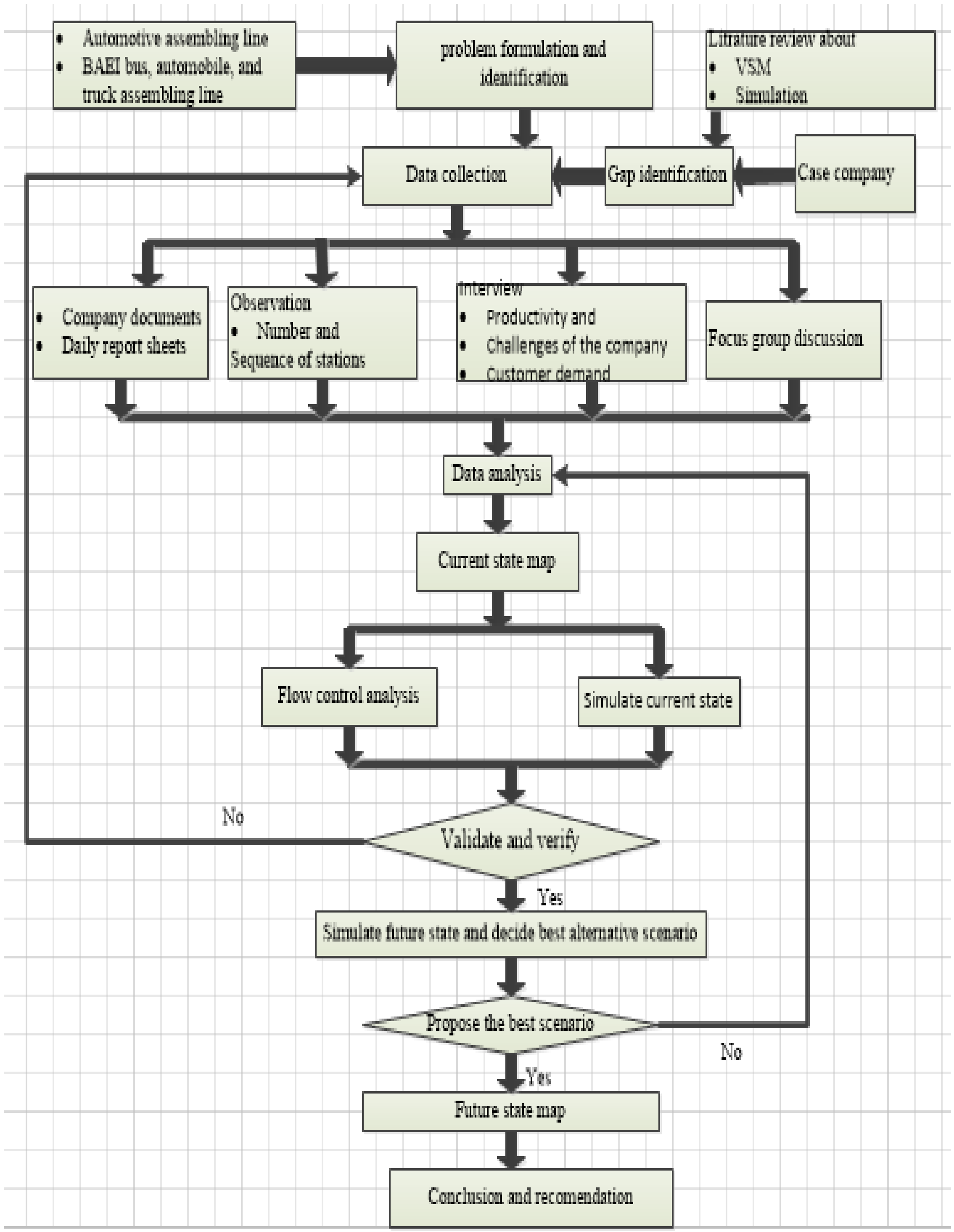


Figure 3-1 Research design framework

CHAPTER FOUR

4 DATA PRESENTATION, ANALYSIS, AND INTERPRETATIONS

4.1. Background of the case company

4.1.1 Brief Description of the Company

There are different military organizations in Ethiopia. Bishoftu automotive engineering industry (BAEI) is one of the companies of the Ethiopian Defense Industries established in 1981 to support the Defense Force, by repairing and overhauling different military vehicles, heavy armament, and tanks. The industry is located in Bishoftu city in Oromia region and the initial capital was around two million. In its establishment, it started its work under the name of Project 40720 and provided maintenance and intermediate maintenance services for military vehicles, armored vehicles, tanks, optical equipment, artillery, communication devices and small equipment's.

Since the factory was reorganized in the middle of 2012. It is an institution capable of accomplishing an admirable task in the field of automotive industry. The factory's main focus is public transportation vehicles for city and cross country. It started the business in Anbasa city bus production by importing from abroad. Efforts to increase accessibility and to improve the operation by increasing the type and quantity of the product.

In February 1984, the project started but interrupted in May 1991 following the fall of Derg regime. A substantial magnitude of construction works of the project was executed and some machineries and equipment erection has been carried out prior to the interruption of activities.

The project was started again in 1991 and completed in 2008. It began to repair tanks and military vehicles. After completion it reorganized by the name of Bishoftu Moterization Engineering Complex under defence industry sector. Then the industry continued to build the capacity of defence force by maintaining and overhauling of tanks, armored personnel carriers, artillery materials, optical devices, communication equipment, military trucks and generators until 2008.

In 2010, those sectors that included in military industry separated from defense, and they worked under a new civil organization. In 2012 the industry reorganized to Bishoftu automotive industry and locomotive sub industry. Locomotive sub industry is separated from Bishoftu automotive industry and found in Addis Ababa. The industry carried out overhauling, up grading, assembling and production of vehicles until 2012. Bishoftu automotive industry has eight factories and one VIP Referral garage under it. Those are Light vehicles, Heavy duties, Buses, Power trains, Vehicle systems, chassis and body frames, Tanks and armored vehicles production factories and painting work shop.

4.1.2 Products of company

Since the factory was reorganized in the middle of 2012 in our country, it is an institution capable of accomplishing an admirable task in the field of automotive industry.

Currently, the industry consists of six factories and one large office building

- ✓ Heavy and light vehicle manufacturing plant,
- ✓ Bus Manufacturing Factory,
- ✓ Vehicle System and Power Train Manufacturing Factory,
- ✓ Chassis and body frame Manufacturing Factories,
- ✓ Armored vehicles and tank manufacturing plant and
- ✓ Vehicle repair or after sales service.

As can be seen from the figure, BAEI mainly produces some of the products that have been sampled

Figure 4-1 Major products of the company

The factory's main focus is public transportation vehicles for city and cross country. It started the business in Ambasa city bus production by importing from abroad CKD & SKD Bus Parts. It's a factory that makes efforts to increase accessibility and to improve the operation by increasing the type and quantity of the product. It manufactured and distributed 1934 Huanghai model buses and 1057 Yutong model buses. However, the company faces some problems in terms of productivity currently**.**

The products of the company are as follows.

Table 4-1 Company products

No	Name of the product	Model
1	Double cabin pickup	JE493ZLQ4CB
2	Mini truck	KMC1100P3
3	Intercity mid bus	WP 5-180E30
4	Intercity bus	Zk6116D
5	Bishoftu dump truck	E32340HP
6	Luxury city bus	HSB6125B02
7	Single cab pickup	JB1TL
8	Bishoftu station wagon	VMR425
9	Double décor city bus	ISLe32531
10	School bus	ISDC23030

4.1.3 Process Description of Bus Assembling line

Sequential activity of bus manufacturing process performed in the factories started in chassis preparation till delivery of products. In bus assembling line there are fourteen stations and around 368 workers with different professions and level. The bus assembling line sequences is shown below.

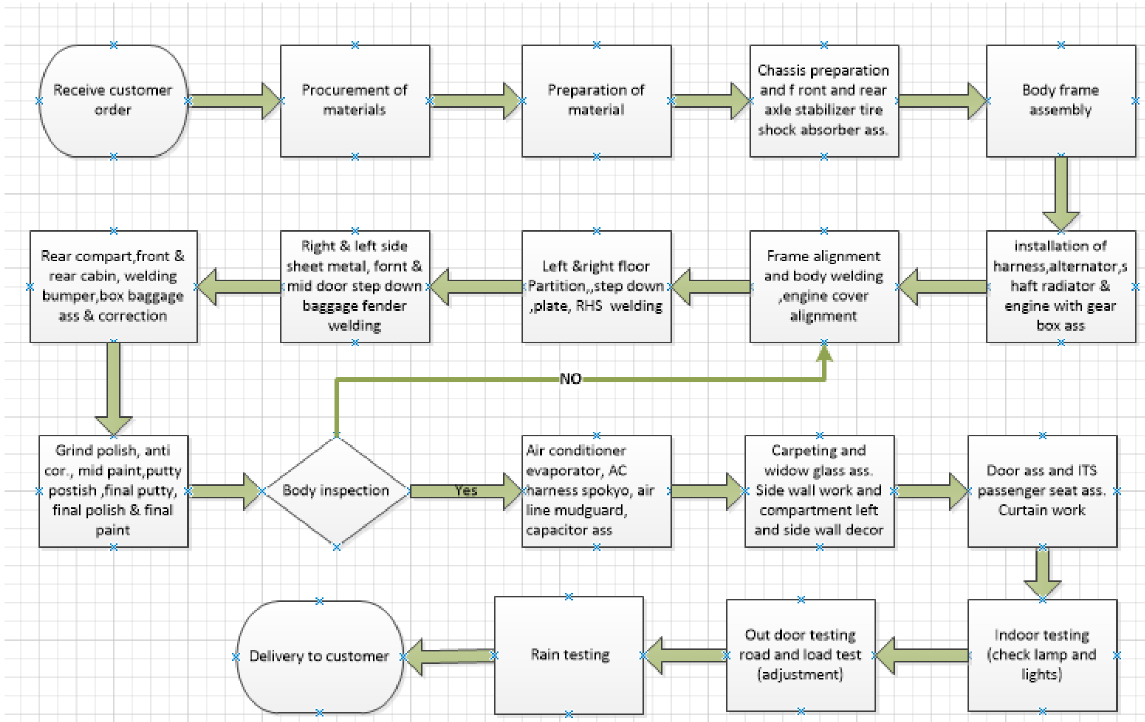


Figure 4-2 The process flow of bus body assembling

4.2 Collection of data and Analysis

It was necessary collecting of data and examining it in different ways for the improvement of the existing VSM and simulation model. The data was collected in different operations performed at each station, the assembly processes and the number out of the product. The results of these activities will depend on the accuracy of the information. Once the routines of all stations are known, the scope of individual's activities and workstations can be determined. A station is a region where it does limited work and has a specific purpose. Based on this, determining of number of stations, functions, and manpower will be applied. In each task time is measured in hours recorded in the data document.

For the determination of enhancing the company productivity focus group has been conducted to gather a qualitative data. The researcher discussed with the department heads of the company and deputy heads such as production head and deputy production head, PPC head, design department head, rear and front compartment assembling and correction station supervisor. The discussion was mainly about the area of assembling line and transferring of employees other stations which is possible if the task of the stations is similar and need identical tasks performed in each station. Data were combined and analyzed leading to the determination of model development for sustainable productivity improvement of the company.

4.2.1 Wastes

Interviews were conducted with factory supervisors, team leaders, and production unit managers, and although it was stated that there are various challenges to improve productivity, the study focused on waste, so if they were eliminated or reduced the company would improve its productivity. Wastes in the production system that influenced the overall productivity of the organization are mainly waiting, unnecessary motion, and inventory.

4.3 Current state map

The study began by gathering various data, such as chassis preparation and identifying overall assembly line activities, including cycle time, number of workers, and value-added time to create existing VSM. The collected data of cycle time, unnecessary motion, and waiting of stations collected using daily time sheet, interview and document of the company. The assembling line data of each station cycle time is collected and received from the company documents starting from July 2013 - September 2014 EC; the average collected data of each station summarized in the table, but the collected data of each station is shown in Appendix two.

Table 4-2 The processing time of bus body assembling line

Processes	**No of operators**	**Cycle time (Days)**	**Cycle times (hours)**	**NVA times in hrs.**
Chassis preparation and assembling	20	$\frac{1}{2}$	4.5	1
Body frame assembly	19	$\frac{2}{3}$	5	1.5
Installation of alternator, shaft engine and gearbox	25	1	9	4
Frame alignment and body welding	27	$1\frac{1}{4}$	10	3

Floor frame and partition welding	24	$1\frac{1}{4}$	9.5	3
Fender, up and down steps welding	27	$1\frac{3}{4}$	15	3
Front and rear comp &correction	35	3	24	6
Painting	34	$1\frac{1}{4}$	11	3
AC and wood works ass.	45	1	9	4
Carpeting and glass ass.	40	$1\frac{1}{4}$	10	4
Door, ITS, and passenger seat ass.	40	1	8.5	3
Indoor testing elect and mech. Works	20	1	7	4
Outdoor testing &adjustment	8	1	7	4
Rain testing	4	$\frac{1}{2}$	4	1

The VSM showed the whole manufacturing line, which is gathered from the company documents to understand the system of production behavior.

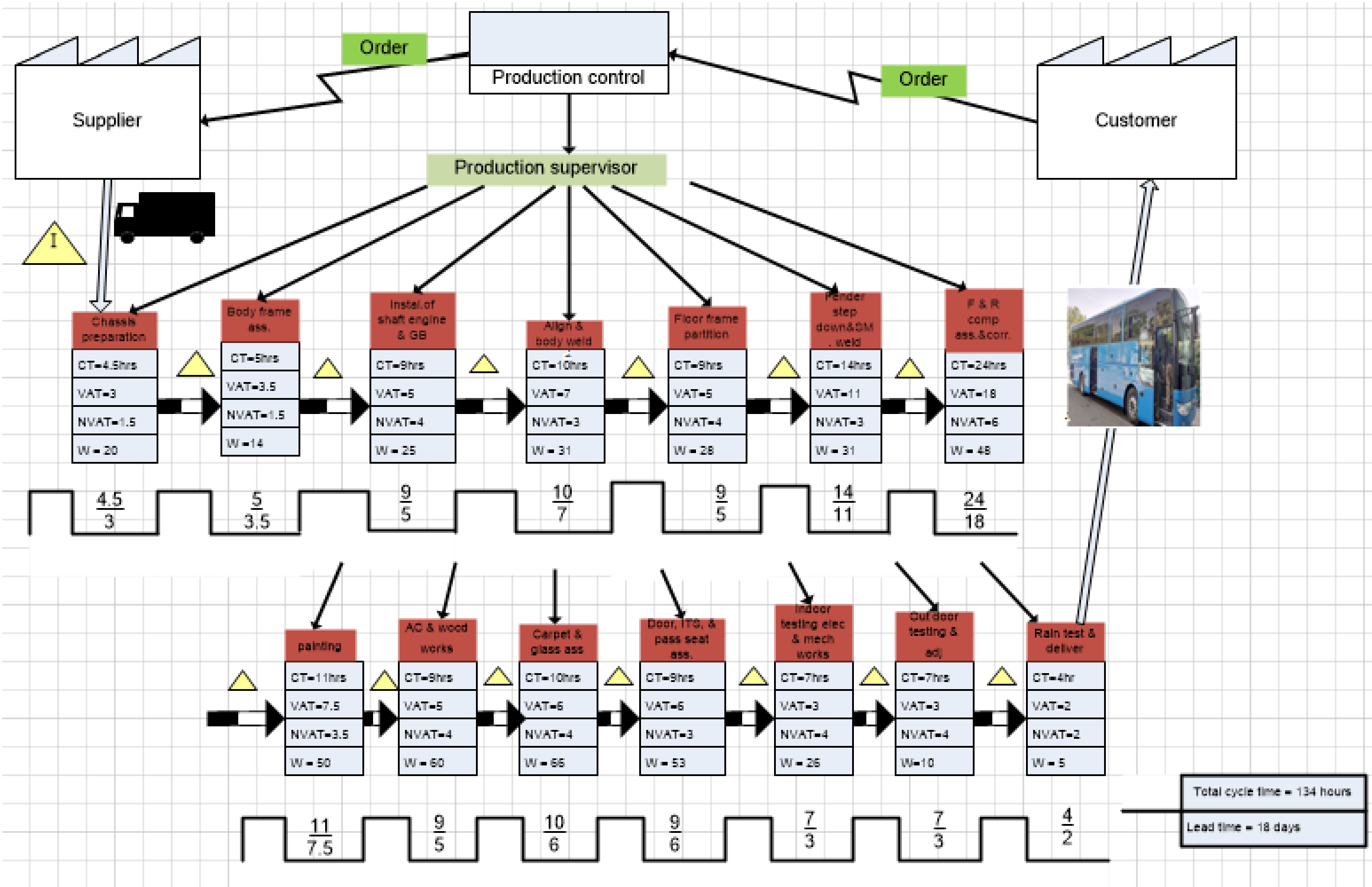


Figure 4-3 Current state map

4.4 Flow control analysis

It is a method that implemented to fulfill customer demand by improving the productivity. The flow control analysis enables to identify the bottleneck station of the assembling line using the difference of the takt time and cycle time of bottleneck station. In the production system, the station is said to be a bottleneck when the time it takes to complete its work is longer than the time required completing the order.

Table 4.2 showed the cycle times of each station and the bottleneck station, which took 24 hours to perform for that particular job.

The calculated takt time has shown below

Manufacturing time availability per month = 26 days * 8hrs / day = 208hours.

Demand of customers = 15 buses per month

Takt time = availablity of time to produce in a month/demand in one month

$=\frac{208}{15}$ = 13.86 = 14hrs per bus

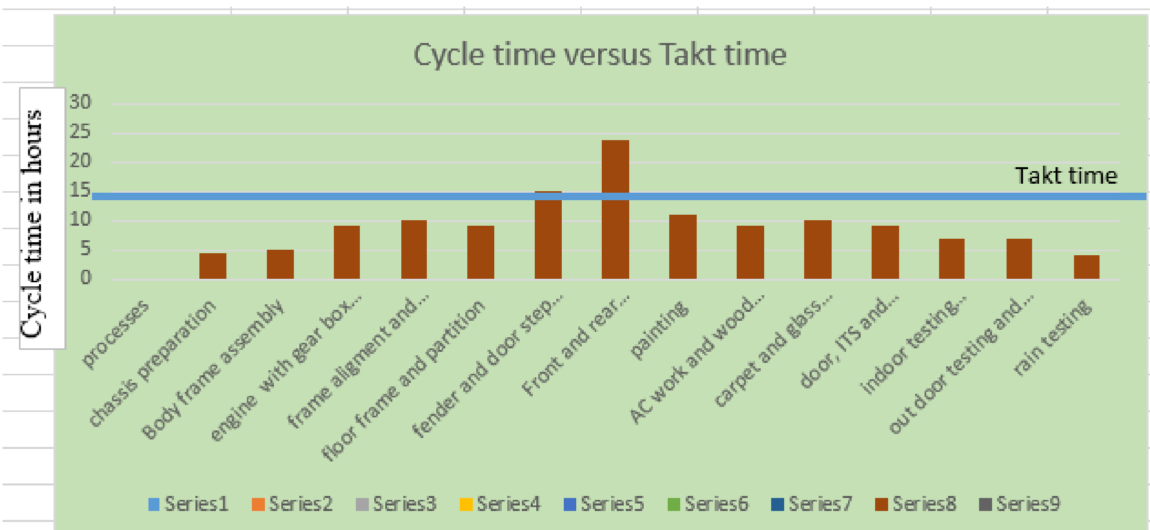


Figure 4-4 :Cycle time of stations and takt time

4.5 Simulation Model

The collected data represent for all operations from engine and gearbox assembly up to final assembling and adjustment. The processing time of each station is the major input for simulation. Number of observations taken from documents for each operation during data collection was ten.

4.5.1 Performance Criteria:

The evaluation standards are the benchmarks used to assess the functioning of the system under the chosen operational strategies. The outcomes derived from tests conducted on the prototype must offer comprehension of the system's conduct and the bottlenecks it faces. The study prerequisites necessitate selecting multiple criteria, which are described as follows:

- Total cycle time
- production output
- waiting time

4.5.2 Model Assumptions

In BAEI, the work shift is one and the working hours are eight hours a day unless there is an urgent work situation. To make a model that represents the existing system, it must be able to maintain the balance and clearly show the existing system. The representative of the real model must be simplified so that it is not as complex as it really is. To simplify the model, it is necessary to make the following assumptions, and it is necessary to verify that the assumptions do not lead to a wrong model.

- No labor absence
- Machine failure is not considered
- Logistics and raw material supply aren’t considered
- The work does not stop due to fatigue and various reasons
- The speed of product one station to the other is constant
- Assembling workers are always in their working station.
- Transportation, communication, and others such as power supply aren’t considered
- Eight hours working time does not include lunch breaks

The above assumptions were discussed and evaluated by the focus group and were approved. By reducing the various simulation requirements, the computer can use only those necessary to run the program and save time.

4.5.3 Data Distribution Analysis

The theoretical distributions included in the simulation are the bus assembly operations implemented at each station, and the process of creating a model has been done by collecting data.

Probability distributions are entered into the simulation using input analyzer. For the purpose of determining the associated parameters and the exact statistical distribution functions input analyzer is used. The intervals used for the data's histogram have a significant impact on the fitting process within the input analyzer. These raw data were gathered from the document and daily report of bus assembling line.

The data distribution fits of different station are shown in table 4-3 starting from engine and gear box assembly up to final assembly and adjustment. The different integrated distribution functions of the input analyzer have fitted automatically the histogram of the actual data. For this study to select the best fit distribution, the researcher has compared square error of each distribution. If the square error is small, it is close to the actual data, and on the contrary, if it is large, it is far from the actual data. The best fitting distribution, expression and square error are given in the table below.

Table 4-3: Processes’ Probability Distributions

Operation description	Best Distribution	Expression	Square error
Engine and gearbox ass	Beta	2.5 + 3 * BETA(1.19, 1.19)	0.001711
Frame loading and alignment side wall welding	Gamma	4.5 + GAMM(0.768, 2.21)	0.012554
floor frame and partition welding	Beta	2.5 + 4 * BETA(0.901, 0.995)	0.007483
mid front door and fender step down welding	Normal	NORM(10.4, 1.43)	0.012461
Front and rear bumper and compartment welding	Triangular	TRIA(15.5, 19.1, 21.5)	0.006421
Painting	Beta	4.5 + 4 * BETA(1.86, 2.25)	0.000813

AC electrical part and ply wood works	Gamma	2.5 + GAMM(0.5, 4.2)	0.006349
Carpeting, postish and window glass assembling	Triangular	3.5 + ERLA(0.633, 3)	0.017895
Door, luggage box, ITS, passenger seat and curtain assembling	Logonormal	3.5 + LOGN(2.06, 1.62)	0.005665
Indoor testing electrical and mechanical adjustment	Normal	1.5 + WEIB(1.58, 2.13)	0.000939
Outdoor testing and adjustment	Normal	NORM(3, 0.632)	0.000918

Figures 4-5a, and b show the distribution time of engine and gearbox assembly and frame alignment with side wall welding. The engine and gear box assembly process shows that the distribution function and expressed 2.5 + 3 * BETA (1.19, 1.19) has a least squares error 0.001711. Similarly, frame alignment and side wall welding process states that the distribution function of the data expressed 4.5 + GAMM (0.768, 2.21) has a least squares error of 0.012554. Whereas; other data distribution functions for all assembling line processes are shown in Table 4-3.

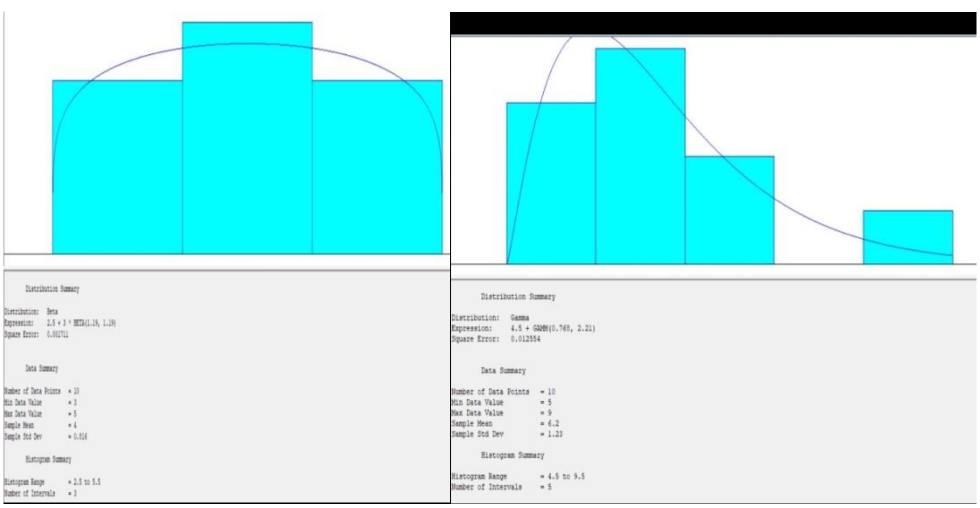


Figure 4-5: (a) Engine and gearbox assembly station (b) Frame loading and alignment side wall welding

4.5.4 Simulation Model Formulation

When a suitable model is prepared, make sure that it is able to solve the problem. In order to develop the right model there is a need to understand how the real system behave and determine basic requirement of the model.

The Arena14.0 student version of simulation software selected to construct the model for simulation. The construction period of the model was basically performed the current process flow production diagram of the bus assembly line. The assembly stations were sequentially organizing accordingly the flow of the product, and then VSM determined, and highlighted areas for improvement. The Development of the model targeted and focused to determine how the model replicates the existing production line. Developing the model began with declaration of entities, workstation locations, path networks, and resource generation, as well as arrival declarations and process programming. The logic flow describes how an entity behaves as it passes through the simulation model. The following model illustrates the current bus assembly line system.

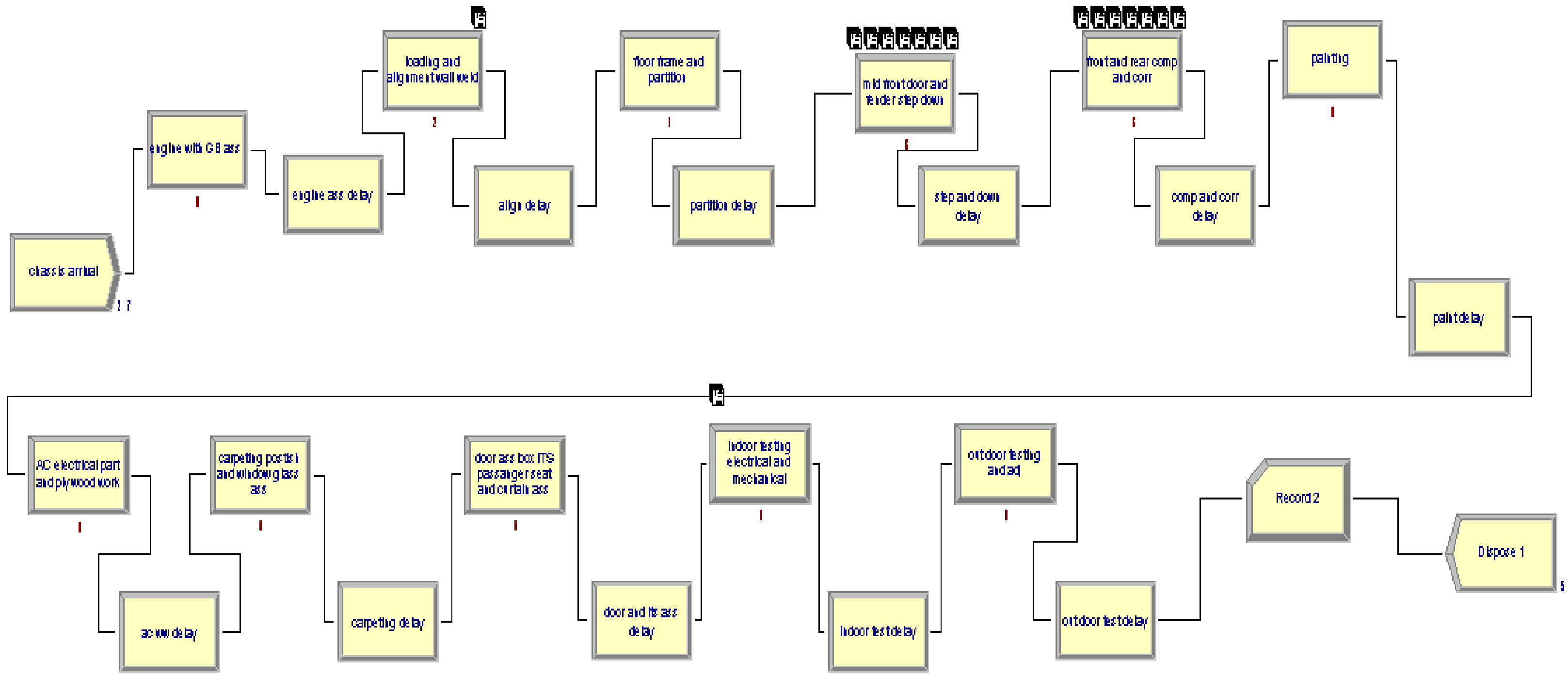


Figure 4-6 : Existing simulation model of bus assembling Line

4.5.5 Model Verification and Validation

Verification and validation are the major steps in making a model and help in further work by confirming the accuracy of the model. The model represents the current system by displaying the interaction of the whole system. It reflected the activities of the whole system. A model needs to deliver the outcome close to the current system and show how the whole system interact each other, even though it is difficult to deliver exact duplication of the real system. The way of assuming the model development implementation, causes the variation occurred between the created model and the current system. If the model exactly couldn't describe the actual system, it would be difficult to make a decision and affect the reliability of the system. So in order to implement the improved model, it must be first verified and validated.

- **Model Verification**

Verification is an activity implemented for the purpose of evaluating the model accuracy and ensuring the model created in the appropriate manner. It is the most important process to determine the accuracy of the operational logic. The assessment of the model logic whether it is identical or not requires concentrating on arrival times, waiting times, non-value added times and other parameters need to be investigated with the current system. A model that Performs without any errors by including the factors and parameters in the simulation is supposed to be validated. Another way of verifying the existing model is verification code which implemented using the run, SIMAN, and view showed there is no dead end trapped the flow of entities from start up to final assembling line. The model also needs to be operated without interruption and error even the arrival time of the system vary.

Finally, the verification of the bus body assembling line implemented by simulation test run, as a result the model of the bus body assembling line is accurate, including consistency and similarity. Further, the model of bus body assembling line was achieved with an exact set of inputs, and the resultant output was compared to the actual output. Consequently, this model is confirmed and represents a genuine system.

- **Model Validation**

Validity is one of the processes that enable the model to represent a system. Even though model validation techniques are wide ranging and need holistic approach, the implementation needs to be specific to the particular model. It is the way of supporting the researchers to decide and apply simulations. Validity of the system is determined by comparing the actual values of the simulation outputs with the inputs. The comparison of number out in the simulation result with the actual output showed the model would be validated. From these concepts the existing assembly line output and the simulated model output are identical. From the interview with different station supervisors and department heads the existing assembling line output is 6 buses per month, the simulation output also showed 6 buses per month (8 hours per day for 26 days). The buses produce in one month of the actual system and simulation output are similar to each other. The model is also compared the VSM cycle time and the simulation result. The maximum cycle times of the simulation result varies from the VSM cycle time by 4.5 % (134– 128)/ 128. The difference is not more than 10%, so it is identical to the real system.

The maximum cycle time and product out reports from the simulation are displayed in Tables 4-4. Other simulation reports are displayed in the Appendix.

According to the data in Table 4-4, the maximum value of 86 hours and 42 hours of value added and nonvalue added times respectively, for a total of 128 hours. It shows the approximate result of the simulation compared to the Value stream map.

So as we have seen from the simulation and VSM results in all aspects there is a similarity to determine the model is valid. If the input and output have difference to each other the collected data need to be analyzed.

For the validation and reliability of the model a test run with sixty-three replications was implemented in comparison of the existing with the simulation output.

Table 4-4 Existing simulation report of products in one month, VA and NVA

Existing bus assembling simulation

Replications: 63 Time Units: Hours

Key Performance Indicators

System

	Average
Number Out	6

Replications: 63 Time Units: Hours

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	71.5120	0.35	68.5865	74.6238	62.6294	86.4578

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	42.0000	0.00	42.0000	42.0000	42.0000	42.0000

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	28.9295	1.60	16.8263	42.7851	0.00	79.8246

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	142.44	1.68	128.21	156.76	105.97	191.35

4.5.6 Number of replication

The replication number is the analysis of result variation used to approach the exact result of the simulation that begins by choosing an initial replication number. The first ten replication results lead to calculate and decide whether additional replications needed or not. Mainly the outputs of the ten replications differ, then more replications would be needed and the calculation of standard deviation, average replication, and initial half width would be implemented.

The more number of iteration leads in reducing the variance of the simulation and in determining the width of the confidence intervals. That is, iterating more than N iterations results in unnecessary use of computer time, while lower iterations lead to incorrect results and therefore lead to incorrect decisions being made. Therefore, the simulation expert should understand that it is inappropriate to present the simulation results in a single simulation run due to differences in output parameters.

Then to provide the required number of replication standard error calculation should be done.

Standard error = $\boldsymbol{t_1 - {}^{\alpha}/_{2}},\ \boldsymbol{n-1} * \frac{\boldsymbol{S}}{\sqrt{\boldsymbol{n}}}$ .... Equation [4-1]

t: The probabilities distribution for 1- $\frac{\alpha}{2}$ from t table

n - 1: Represents degree of freedom

S: The standard deviations of replications

n: initial number of replications (The number of observations in the sample)

If we need the result of our analysis 95% confident, the alpha level should be one minus the level of the confidence that is 0.05. The sample standard deviation would be computed by the formula computed below.

$\sqrt{\frac{\sum_1^n (\bar{x}_i - \bar{\mathrm{x}})}{n-1}}$..Equation [4-2]

S: Standard deviations of samples

$\bar{x}_i$: Replications average

x̄: An average of the replications average

n: The replication number

Half width also calculated using the above standard error formula

h = $\boldsymbol{t_1 - {}^{\alpha}/_{2}},\boldsymbol{n-1} * \frac{\boldsymbol{S}}{\sqrt{\boldsymbol{n}}}$... Equation [4-3]

From t table t (at 95%, 9) = 2.262

The half width for 95% confidence interval would be

$\boldsymbol{h_0}$ = 2.262 * $\frac{\boldsymbol{S}}{\sqrt{\boldsymbol{n}}}$... Equation [4-4]

h_0 = 2.262 * $\frac{0.14}{\sqrt{10}}$ = 0.1

Table 4-5 Initial number of replication

No of replications	No of products
1	6
2	5.5
3	5.6667
4	5.75
5	5.8
6	5.8333
7	5.7143
8	5.75
9	5.6667
10	5.6
Mean	5.73
Standard deviation	0.14
Half width	0.1

For the purpose of getting a specific half width that is smaller than the half width calculated from the initial set of replication. We can try the half width formula

n = $\boldsymbol{t^2_{n-1,1-\alpha/2}\frac{s^2}{h^2}}$.. Equation [4-5]

Using this formula to solve is difficult because there is n that depends on the right hand side. Therefore, the t-probability distribution is used instead to obtain a rough estimate of the required sample size. This led to the following as an estimated necessary test estimate to realize a certainty interim with half width rise to a desired value.

$\boldsymbol{n = z^2_{1-\alpha/2}\frac{s^2}{h^2}}$... Equation [4-6]

Where n: is number of replications

s: is standard deviation

z: is 1.96 for 95% confidence level

h: is the half width reduced from the initial 0.1 to 0.04 given by assumption

another equation for more approximation is also implemented

n = $\boldsymbol{n_0\frac{{h_0}^2}{h^2}}$ .... Equation [4-7] where n_0 is initial number of replications

h_0: half width of initial replications

$n = 1.96^2 \frac{0.14^2}{0.04^2}$= 47 replications

n = $10 \frac{0.1^2}{0.04^2}$ =

62.5 ≅ 63 replications

From the two results 63 replications would be selected for low acceptance error

4.6 The improvement of Bus Body Assembling Line Production Process

Based on the existing model, VSM and Bottleneck Analysis, the front and rear compartment and correction station was the bottleneck. The existing model needs improvement, so implementing different alternative scenarios were essential for the productivity improvement of bus assembling line. For this reason, alternative scenarios need to be created for the purpose of reaching the final goal then investigating the simulation result and evaluating of variables would be performed according to the desired result.

Therefore, after running the simulation model the performance measures such as number out, non-value added time, total average time, waiting time are analyzed for alternative proposed scenarios and existing scenario to improve manufacturing system of the company.

In the first scenario, the front and rear compartment and correction station was changed into two consecutive stations, one for the front compartment of bus assembly station and the other for the rear compartment of bus assembly and correction station. During the discussion with focus groups the more time taking reason in the station is the correction task which performs and corrects the whole bus body before the product goes to painting station. In order to complete the correction of the bus body workers need to move from front up to back that brings unnecessary movement of workers. So to reduce the movement of workers the task need to be different for the two consecutive stations, one station works front compartment assembling and correction only the other one also the rear compartment assembling and correction of the bus body. Then the simulation result showed the number of buses in one month increased by 5 % from the existing assembly line, which allowed producing 8 buses per month from 6 buses per month and could reduce the unnecessary movement of workers (back and forth). The simulation results of the assembling line that performed the bottleneck station splitting serially is showed in appendix five.

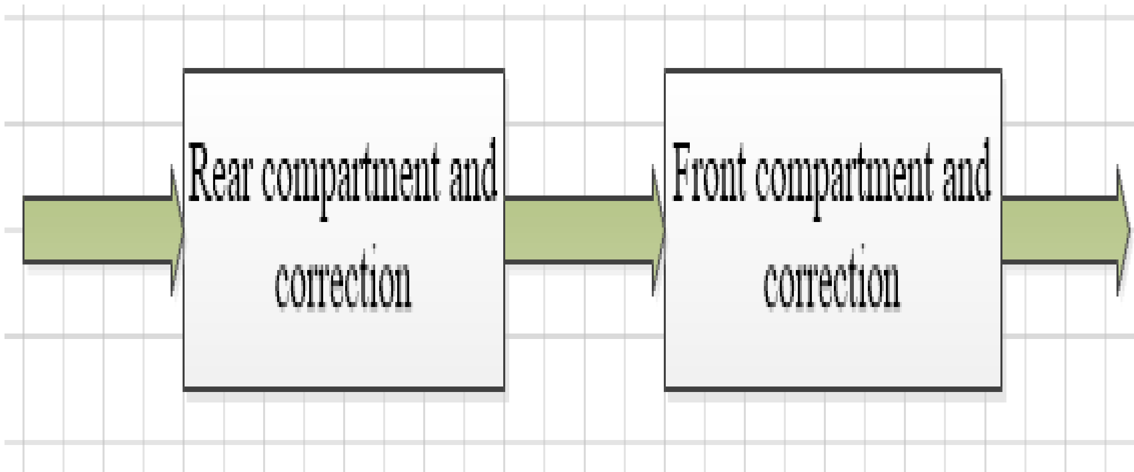


Figure 4-7: Splitting the station serially

In the second scenario, as we have seen from the existing state, the processing time of front and rear compartment welding and correction is longer and affect the output. Hence for the reduction of NVA activity of the other stations and WIP of the bottleneck station, splitting the workstation and perform the assembling process in parallel was applied. The existing of two parallel stations enable the workers perform two buses at a time. The two workstations replaced the existing station, to increase the number of products of the station and to provide a smooth flow of a product from one process to another which is effective and saves time to reduce the total cycle time of the product. The three sides of the two buses such as front, back, left side of one bus and right side of the other bus are operated at the same time without waiting the ladder and some equipment's. By dividing the station into two and allowing them to work in parallel, the assembly line increased the production rate and enables to work both parallel buses cooperatively and to reduce unnecessary movement of workers. Moreover, the two parallel stations can receive two buses at a time and provide two buses for down streams.

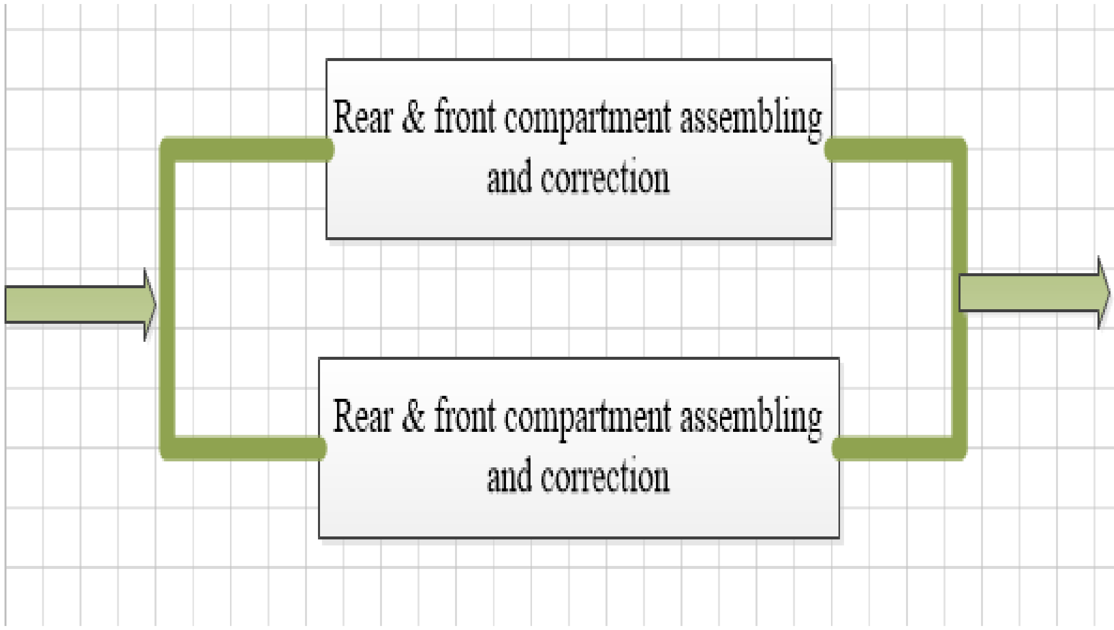


Figure 4-8: Splitting the station in parallel

The researcher discussed with focal groups about applying room for additional station, equipment's and transfer of employees from each stations to the additional parallel station, those are idle by different cases. The determination of transferring of employees makes the company more productive and performs at full resource capacity.

Finally, Changes in the existing model permit the assembling line more productive and while implementing a technique that was avoiding the effect of the bottleneck station in the bus assembling line by splitting the workstation in parallel. After implementing there is an improvement output of the product from the existing 6 buses per month to 13 buses per month and there is a reduction of average total time from 142 hours to 103 hours. The NVA activities also reduced from forty-two (42) hours to eighteen (18) hours. Based on the simulation reports, average total time report, and waiting, non-value added and other improved simulation run results are showed in Table 4-6. Other simulation outputs are showed in appendix four.

Table 4-6 Improved simulation report of output, VA and NVA

8:32:48AM **Category Overview** August 16, 2023

Values Across All Replications

bus assembling improved in parallel

Replications: 63 Time Units : Hours

Key Performance Indicators

System

	Average
Number Out	13

Replications: 63 Time Units : Hours

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	50.3899	0.25	47.2386	52.3749	31.5456	75.4214

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	18.1410	0.03	18.0000	18.2692	14.5000	21.5000

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	34.7858	1.33	21.4175	43.4476	0.00	99.26

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	103.32	1.36	89.9335	111.98	56.5655	187.52

The improved model run by splitting front and rear compartment station into two parallel stations that needs additional workers to operate both stations at the same time. In the figure 4-9 simulated model is shown.

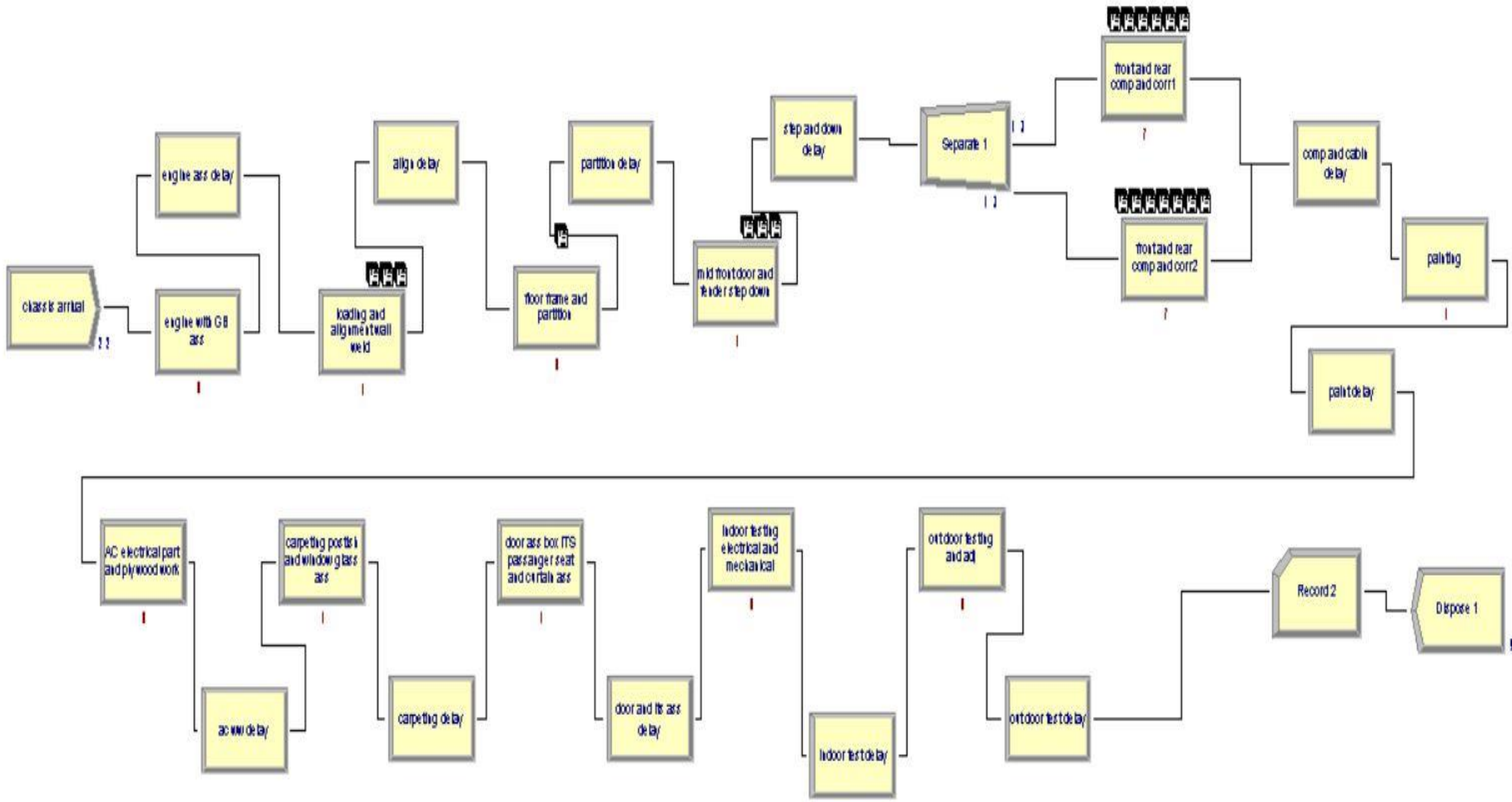


Figure 4-9: Simulation Model for improved bus Assembly Line

4.7 Comparison of existing system and different scenarios developed

Starting from the existing two alternative scenarios tested and compared to each other. Table 4-7 and table 4-8 showed the number of resources in each scenario and measuring parameters.

Table 4-7 The number of stations and workers in the existing system and in different alternative scenarios.

Different scenarios	Number of operators	Number of stations
Existing scenario	305	10
First scenario	305	11
Second scenario	305	11

Table 4-8 A statistical comparison of the existing system with different alternative scenarios

Different scenarios	Product per month(buses)	Non-value added	Average total time in hours
Existing scenario	6	42	142
First scenario	8	28	123
Second scenario	13	18	103
Company plan	45		

4.8 Future state map

Finally, the future VSM was created to illustrate and suggest improvements to the product entirely based on the best scenario result. The implementation of future state map that can appear in a short time could identify the source of wastes in each station and aims eliminate them for the enhancement of the assembling line. The purpose of creating future VSM is to avoid bottlenecks, reduce non value added time, to make the assembly line more productive and where each station performance needs to be dynamic according to customer demand by connecting to its customers either by continuous flow. The modified VSM is depicted in figure 4-10, after employed the changes in the map reducing non-value added time, total time, and other change was done. Future state map reveals the changes and the improvement of different measuring parameters based on the data's identified in the snapshot of the existing state and improved simulation reports.

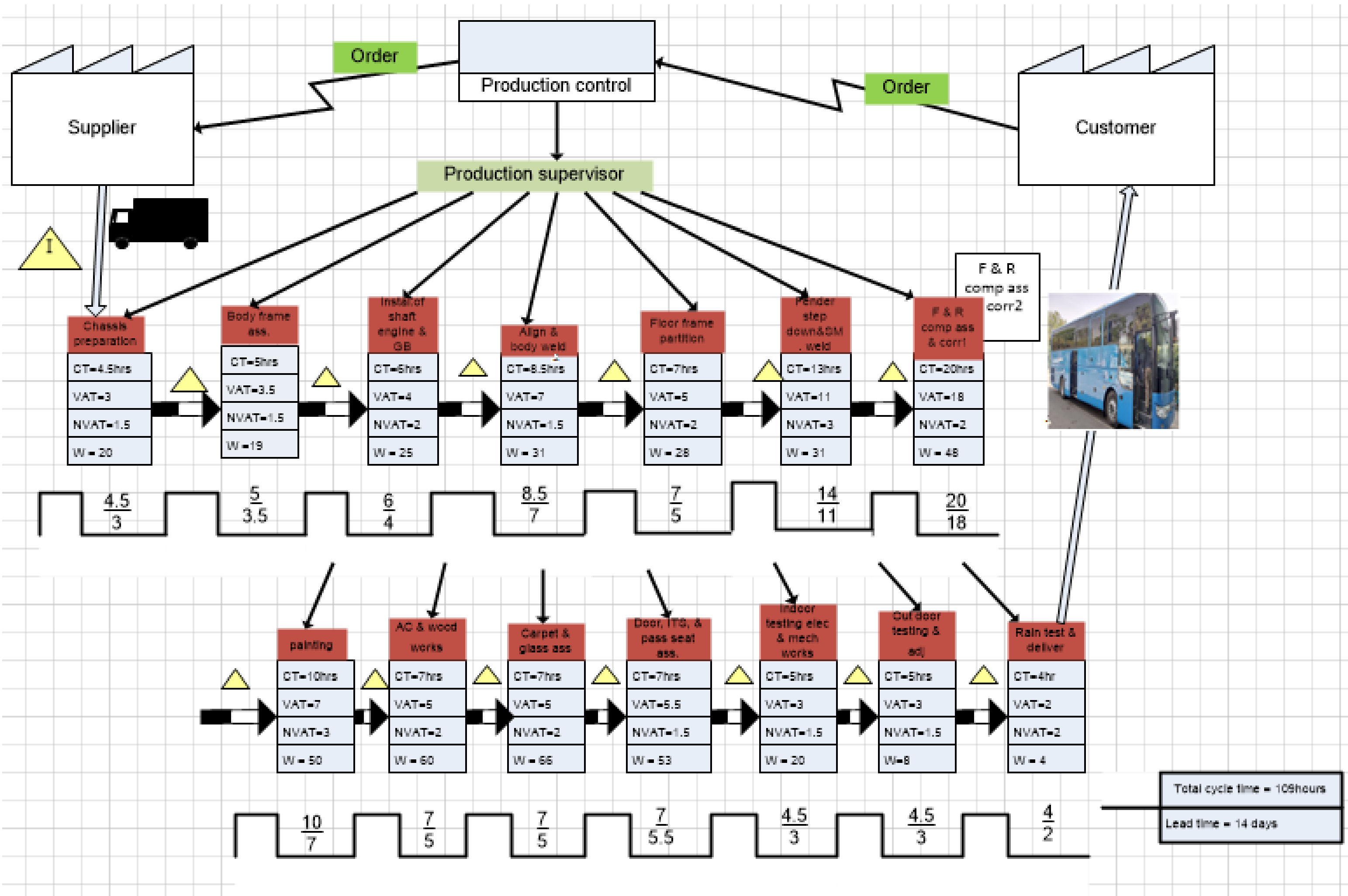


Figure 4-10: Improved VSM

4.9 Result and Discussion

Data's were collected from different documents and assembling stations in the company. Bus body manufacturing systems, which feature numerous workstations with related processes, frequently face productivity issues that make it difficult to produce more with the same amount of personnel, materials, and energy. When all of these aspects are focused on simultaneously, it does not produce the desired outcomes. By concentrating only on bottleneck areas and non-value added activities, production flow can be improved with little more effort. VSM and simulation both assisted in identifying bottleneck areas and non-value added activities. More over by using flow control analysis the bottleneck area analyzed with respect to takt time and finally the way of elimination the bottleneck could lead to the improved VSM. Besides that, front and rear compartment assembling and correction station need an average of around 24 hours in assembling of buses to complete, which brought a high waiting time and idle time for the remaining stations.

The comparison of cycle time of stations with takt time showed that the front and rear compartment assembling and correction process has cycle times that are longer than takt times. As a result, process capability needs to be improved in order to fulfill the demand of customers within the assigned time and to improve the flow of production. Due to the addition of a station, the product would be produced close to the desired demand of customers. The existing production was 6 buses per month but from the interview the demand of customers is 15 buses per month. So the existing production rate was 40% of the customer demand. After improving the production system of the assembling line 87% of customer demand fulfilled. It's around 47% enhancement. VSM also showed the entire bus assembling line including cycle time, VA, NVA time, and number of operators in each station. The existing state map showed the whole assembly line starting from chassis and structure preparation up to rain testing and the areas that need improvement using cycle time and NVA time of each station. Then simulation took the stations by considering the improvement areas from engine and gear box assembly station up to outdoor testing and adjustment stations to build the existing model. Finally, the improvement in the bus assembly line is applied by using different alternatives but the second scenario is the best alternative that can reduce the idle time or waiting time of other stations by adding a work station which is parallel to the bottleneck station. The additional station needs other workers to perform the task. In this way, instead of hiring a new worker, the idle workers in each station will be qualified for the job by giving them a strategy to get them into the job, and it will allow the proper use of the human resources. We discussed this issue with the focus group and they confirmed that the idea is acceptable from the point of view of resource utilization and product improvement. This results the front and rear compartment assembling and correction station can produce two buses at a time and make other stations more productive by reducing the idle time. Moreover, some of the workers of that particular station need to do for the upper part of the bus and others also for the lower part of the bus. In this way, the front, rear and parallel sides of the upper part of the two buses work in one operation, while the lower parts of the buses also assemble in the same way. These can reduce the unnecessary (up and down) movement of the workers. Those activities enable the assembling line to produce 13 buses per month from 6 buses per month.

Finally, after running different alternative scenarios including the existing to improve the company's productivity, addition of a parallel station to the bottleneck is selected and proposed to the case company. The results showed the second scenario enhance the bus assembly line production rate of the case company.

- The total average cycle time has decreased from one hundred forty-two (142) hours to one hundred three (103) hours, it is 27 % reduction.
- The NVA has shown a reduction of time from 42 hours to 18 hours 57% reduction
- It also showed that the possibility of producing 13 buses per month from the existing 6 buses per month. The design capacity of the company was 45 buses per month but the existing production rate is six buses per month that is 13 % of the design capacity. The improved bus assembling line can produce 13 buses per month that is 16 % increment from the existing.

Generally, the unbalanced task of the stations in the whole assembly line depicts the inefficient usage of resources. Workers in some stations perform their tasks while others waste the operating time with NVA activities like waiting of products. Thus, most of the stations workers are spending most of their time on NVA activities like unnecessary movements or waiting for work. The bottleneck station was the cause of waiting for other stations. When one assembling station performs the task in a short period of time and the other doesn't, waiting occurred. The researcher also proposed to shift employees from other stations to the bottleneck station to balance the tasks of each station by considering idle workers in the assembly line. Finally, the researcher concluded that integrating VSM and simulation can really improve productivity in automotive manufacturing companies.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The automotive industry is struggling to improve productivity and shorter cycle times to remain competitive in the market. The competitiveness of automotive products and market share are highly dependent on improving productivity through reducing non value adding activities and elimination of bottleneck. Automotive assembling line greatly depend on labor, machines and equipment's like welding, drilling, compressor, grinder, rivet gun, and other accessories that perform complicated and progressive operations.

The most challenging factors that influenced the production rate of BAEI was non value added activities and bottleneck area of the assembling line. The major wastes which are identified in this study were waiting time, and unnecessary motion. Reducing these wastes and avoiding bottleneck area make the production flow better. By making the flow of production in the manufacturing process smooth and better, the company's production capacity would be improved. For this result selecting appropriate techniques and tools is vital.

This study offered an integration of VSM with simulation by minimizing NVA activities and eliminating the bottleneck of the assembling line for the improvement of production flow in BAEI bus manufacturing shop. Bus body assembling line contains multiple stations interconnected to each other. There are challenges to make more productive and produce more with minimum number of labor, machine, and less energy. It would be difficult to focus on all those factors and try to solve at the same time. Instead of that focusing the main challenges and avoiding the bottleneck in the assembling line brings huge improvement in the production system.

The study identified the non-value added activities and bottleneck station that disturbs the free flow of the product due to long cycle times of that station compared to other stations. The implementation of VSM was to identify NVA activities and to show the improvement areas. The current VSM is plotted to assess current status. Then simulation model for bus assembling line was built. It was constructed based on observations and company documents. Validation and verification also done by comparing the results of simulation with VSM cycle time, personnel's interview and using simulation test run. Waste reduction and bottleneck elimination are performed by adding additional station. And the improved model and future VSM is also presented for improvement. The results of the study showed 57 % waste reduction in non-value added activities from the existing assembling line, hence average total time is reduced by 27 % and the assembled buses in one month increased from 6 buses per month to 13 buses per month 16 % improvement.

Improving the production flow of bus body assembling line by reducing wastes and eliminating bottlenecks to increase the number of products is the major objective of this research. The research mainly focused on reduction of wastes and avoiding bottlenecks by means of VSM and simulation.

5.2 Recommendations

Finally, the result of the research recommends and proposes the following activities:

- ❖ Wastage reduction is the main factor of winning the competition for the overall markets. So the company needs to improve constantly its productivity by reducing waste.
- ❖ Addition of parallel station is the better way of improving the production flow of the assembling line, and some workers also need to be transferred and trained for that particular task to the additional workstation is recommended.
- ❖ BAEI and other bus assembling companies should consider the performance of the production system in current and future operations over many years.
- ❖ The external influences aren't taken into account in this study, but taking into account the contribution of external causes in the analysis of production efficiency can bring substantial improvement for the company.

5.3 Future research area

This research study invites other interested researchers implement cost analysis.

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APPENDIX 1 Literature gap

Table: - 1 Literature gap analysis

NO	Name of authors	Problem	Finding	Gaps
1	Emmanuel Lorou *et al.*, (2021)	Bottleneck happened in the manufacturing of truck assembling line	Improvement of productivity of trucks and the queue had also reduced for two stations.	The study only focused on operator assigning and adding machineries.
2	Emad Alzubi, (2019)	The production line was unbalanced and long lead time to manufacture	By using different bottleneck methods the utilization rate increased and the manufacturing cost also decreased	Didn't consider about customer demand.
3	Getachew, (2019)	Bus assembling performed below its capacity	presented a comparative study about line balancing of a manufacturing industry and could get improved efficiency	Did not consider the stochastic nature of variables. And heuristic approaches don't guarantee optimum solutions.
4	Pereira et al., (2013)	The challenges of the manufacturing process causes slow to produce, poor flexibility and more raw materials in the stock, consequently there was delay of delivery.	The study tried to show in combining losses in the process and the prioritization steps to eliminate the losses by identifying the existing challenge.	The gap of this study is it looks into theoretical aspect, it doesn't show the impact of the study.

Source: - Own

APPENDIX 2 The cycle time of bus assembling line 2013-2014

No	Station	2013								2014	
		July			August				Pagume	September	
		W2	W3	W4	W1	W2	W3	W4	W1	W1	W2
1	Chassis and structure preparation	5	5.5	6	5	3.5	4	3	5	4	4
2	Body frame assembly	4.5	5	4	3.5	6	3	4	3	4	3
3	Instal. of alternator, shaft engine & gearbox	8	9	9	10	7	8	6	9	7	8
4	Frame alignment and body welding	12	10	11	7	9	8	13	9	10	11
5	Floor frame and partition welding	10	11	9	12	8	10	11	11	9	10
6	Fender, up & down steps weld	16	15	13	17	12	14	12	15	17	17
7	Front and rear comp &correction	27	25	26.5	23	22	24	23	21	23.5	24
8	Painting	11	13	12	9	8	9	10	12	14	11
9	AC and wood works ass.	9	8	10.5	7	8	10	8	12	10	8.5
10	Carpeting and glass ass.	11	9	13	10	8	11	7	12	10	8
11	Door, ITS, and passenger seat ass.	9	7	8	10	7	11	10	8	6	9
12	Indoor testing elect and mech. Works	7	8	8	9	6	5	9	5	6	7
13	Outdoor testing & adj.	8	6	7	5	6	9	8	5	7	8
14	Rain testing	4	5	4	5	3.5	3	2.5	4	4	3

APPENDIX 3 Statistical Output Report for Existing System

Table 3-a Waiting time report

Existing bus assembling simulation

Replications: 63 Time Units: Hours

Queue

Time

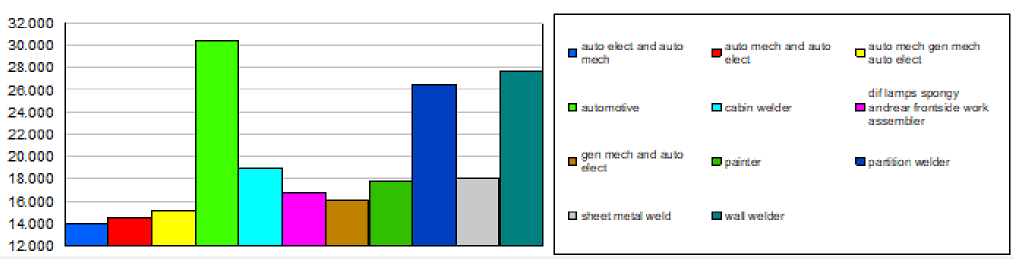
Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AC electrical part and ply wood work.Queue	0.00	0.00	0.00	0.00	0.00	0.00
carpeting postish and window glass ass.Queue	0.00	0.00	0.00	0.00	0.00	0.00
door ass box ITS passanger seat and curtain ass.Queue	0.00830119	0.02	0.00	0.5230	0.00	3.1378
engine with GB ass.Queue	2.4596	0.34	0.2756	5.9112	0.00	24.3847
floor frame and partition.Queue	0.0901	0.02	0.00	0.4073	0.00	2.8597
front and rear comp and corr.Queue	32.9250	0.96	24.6093	41.2467	0.00	83.0527
indoor testing electrical and mechanical.Queue	0.00	0.00	0.00	0.00	0.00	0.00
loading and alignment wall weld.Queue	7.9659	1.75	0.6911	30.2089	0.00	54.0596
mid front door and fender step down.Queue	24.6397	2.23	3.1835	39.9060	0.00	75.0078
out door testing and adj.Queue	0.00	0.00	0.00	0.00	0.00	0.00
painting.Queue	0.00	0.00	0.00	0.00	0.00	0.00

Table 3 b Total number siezed

Resource

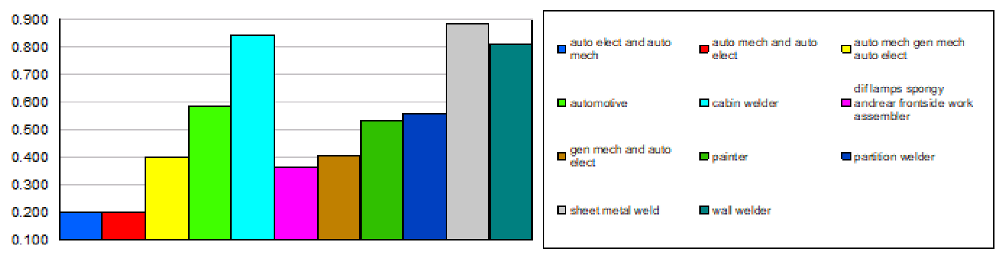
Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
auto elect and auto mech	13.9365	0.10	13.0000	15.0000
auto mech and auto elect	14.5238	0.14	13.0000	15.0000
auto mech gen mech auto elect	15.1905	0.11	14.0000	16.0000
automotive	30.3492	1.31	21.0000	43.0000
cabin welder	18.9524	0.05	18.0000	19.0000
dif lamps spongy andrear frontside work assembler	16.7619	0.11	16.0000	17.0000
gen mech and auto elect	16.0317	0.08	15.0000	17.0000
painter	17.8254	0.10	17.0000	18.0000
partition welder	26.4444	0.92	17.0000	33.0000
sheet metal weld	17.9683	0.23	15.0000	19.0000
wall welder	27.6349	0.93	18.0000	35.0000



Appendix 3-c Schedule utilization report

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
auto elect and auto mech	0.1976	0.00	0.1726	0.2251
auto mech and auto elect	0.1975	0.00	0.1683	0.2406
auto mech gen mech auto elect	0.4002	0.01	0.3555	0.4716
automotive	0.5827	0.02	0.3771	0.8026
cabin welder	0.8423	0.00	0.8009	0.8670
dif lamps spongy andrear frontside work assembler	0.3617	0.00	0.3214	0.4236
gen mech and auto elect	0.4063	0.01	0.3590	0.4702
painter	0.5326	0.01	0.4798	0.5756
partition welder	0.5559	0.02	0.3406	0.7189
sheet metal weld	0.8807	0.01	0.7049	0.9198
wall welder	0.8089	0.03	0.5050	0.9767



Appendix 3-d Instantaneous utilization report

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
auto elect and auto mech	0.1976	0.00	0.1726	0.2251	0.00	1.0000
auto mech and auto elect	0.1975	0.00	0.1683	0.2406	0.00	1.0000
auto mech gen mech auto elect	0.4002	0.01	0.3555	0.4716	0.00	1.0000
automotive	0.5827	0.02	0.3771	0.8026	0.00	1.0000
cabin welder	0.8423	0.00	0.8009	0.8670	0.00	1.0000
dif lamps spongy andrear frontside work assembler	0.3617	0.00	0.3214	0.4236	0.00	1.0000
gen mech and auto elect	0.4063	0.01	0.3590	0.4702	0.00	1.0000
painter	0.5326	0.01	0.4798	0.5756	0.00	1.0000
partition welder	0.5559	0.02	0.3406	0.7189	0.00	1.0000
sheet metal weld	0.8807	0.01	0.7049	0.9198	0.00	1.0000
wall welder	0.8089	0.03	0.5050	0.9767	0.00	1.0000

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
auto elect and auto mech	0.1976	0.00	0.1726	0.2251	0.00	1.0000
auto mech and auto elect	0.1975	0.00	0.1683	0.2406	0.00	1.0000
auto mech gen mech auto elect	0.4002	0.01	0.3555	0.4716	0.00	1.0000
automotive	0.5827	0.02	0.3771	0.8026	0.00	1.0000
cabin welder	0.8423	0.00	0.8009	0.8670	0.00	1.0000
dif lamps spongy andrear frontside work assembler	0.3617	0.00	0.3214	0.4236	0.00	1.0000
gen mech and auto elect	0.4063	0.01	0.3590	0.4702	0.00	1.0000
painter	0.5326	0.01	0.4798	0.5756	0.00	1.0000
partition welder	0.5559	0.02	0.3406	0.7189	0.00	1.0000
sheet metal weld	0.8807	0.01	0.7049	0.9198	0.00	1.0000
wall welder	0.8089	0.03	0.5050	0.9767	0.00	1.0000

Table 3-e Number waiting

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AC electrical part and ply wood work.Queue	0.00	0.00	0.00	0.00	0.00	0.00
carpeting postish and window glass ass.Queue	0.00	0.00	0.00	0.00	0.00	0.00
door ass box ITS passanger seat and curtain ass.Queue	0.00023946	0.00	0.00	0.01508581	0.00	1.0000
engine with GB ass.Queue	0.4054	0.07	0.02119755	1.1969	0.00	7.0000
floor frame and partition.Queue	0.01165768	0.00	0.00	0.05874601	0.00	1.0000
front and rear comp and corr.Queue	2.7087	0.11	1.5213	3.9224	0.00	10.0000
indoor testing electrical and mechanical.Queue	0.00	0.00	0.00	0.00	0.00	0.00
loading and alignment wall weld.Queue	1.2410	0.31	0.04651676	5.3572	0.00	10.0000
mid front door and fender step down.Queue	3.0782	0.33	0.1990	5.3958	0.00	13.0000
out door testing and adj.Queue	0.00	0.00	0.00	0.00	0.00	0.00
painting.Queue	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX 4 Statistical Output Report for final improved System

Table 4-a Waiting time report

bus assembling improved in parallel

Replications: 63   Time Units : Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AC electrical part and ply wood work.Queue	0.00185245	0.00	0.00	0.03853665	0.00	0.6551
carpeting postish and window glass ass.Queue	0.04229297	0.02	0.00	0.3669	0.00	3.6933
door ass box ITS passanger seat and curtain ass.Queue	0.1398	0.04	0.00	0.7777	0.00	6.8989
engine with GB ass.Queue	2.2939	0.27	0.4611	4.6763	0.00	21.8285
floor frame and partition.Queue	0.08392079	0.02	0.00	0.3872	0.00	2.7175
front and rear comp and corr1.Queue	35.9272	1.20	22.1766	43.5539	0.00	83.9285
front and rear comp and corr2.Queue	42.0182	1.08	29.5297	49.1382	10.0000	86.4209
indoor testing electrical and mechanical.Queue	0.00038090	0.00	0.00	0.02399700	0.00	0.3600
loading and alignment wall weld.Queue	7.1460	1.31	1.2646	27.5660	0.00	54.1704
mid front door and fender step down.Queue	25.1899	2.28	3.6881	42.5364	0.00	82.1589
out door testing and adj.Queue	0.00416823	0.00	0.00	0.06501499	0.00	0.9102
painting.Queue	0.00	0.00	0.00	0.00	0.00	0.00

Table 4-b Total number seized

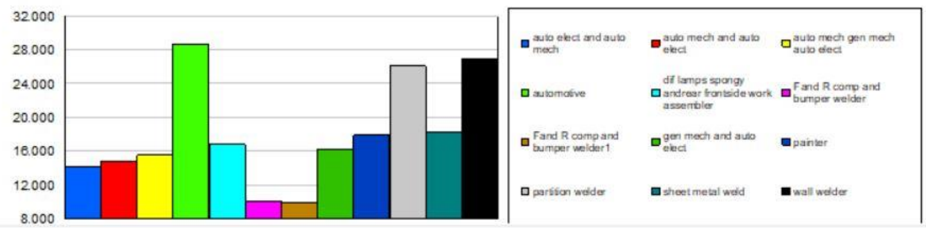
improved bus assembling line with parallel

Replications: 10 Time Units: Hours

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
auto elect and auto mech	14.2000	0.45	13.0000	15.0000
auto mech and auto elect	14.8000	0.45	14.0000	16.0000
auto mech gen mech auto elect	15.5000	0.38	15.0000	16.0000
automotive	28.7000	3.16	23.0000	38.0000
dif lamps spongy andrear frontside work assembler	16.8000	0.30	16.0000	17.0000
Fand R comp and bumper welder	10.0000	0.00	10.0000	10.0000
Fand R comp and bumper welder1	9.9000	0.23	9.0000	10.0000
gen mech and auto elect	16.2000	0.30	16.0000	17.0000
painter	17.9000	0.23	17.0000	18.0000
partition welder	26.1000	2.04	22.0000	31.0000
sheet metal weld	18.3000	0.59	17.0000	19.0000
wall welder	26.9000	2.04	23.0000	32.0000



Appendix 4-c Schedule utilization report

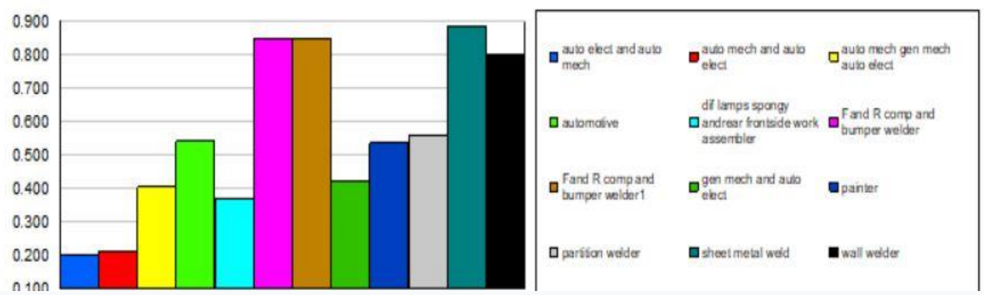
improved bus assembling line with parallel

Replications: 10 Time Units: Hours

Resource

Usage

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
auto elect and auto mech	0.2000	0.01	0.1838	0.2269
auto mech and auto elect	0.2110	0.01	0.1863	0.2241
auto mech gen mech auto elect	0.4030	0.02	0.3634	0.4416
automotive	0.5407	0.06	0.4442	0.7227
dif lamps spongy andrear frontside work assembler	0.3673	0.02	0.3157	0.3991
Fand R comp and bumper welder	0.8465	0.01	0.8348	0.8684
Fand R comp and bumper welder1	0.8465	0.01	0.8348	0.8684
gen mech and auto elect	0.4201	0.01	0.3970	0.4481
painter	0.5353	0.02	0.4948	0.5693
partition welder	0.5554	0.05	0.4444	0.6441
sheet metal weld	0.8814	0.03	0.7710	0.9148
wall welder	0.8000	0.07	0.6354	0.9490



Appendix 4-d Instantaneous utilization report

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
auto elect and auto mech	0.2000	0.01	0.1838	0.2269	0.00	1.0000
auto mech and auto elect	0.2110	0.01	0.1863	0.2241	0.00	1.0000
auto mech gen mech auto elect	0.4030	0.02	0.3634	0.4416	0.00	1.0000
automotive	0.5407	0.06	0.4442	0.7227	0.00	1.0000
dif lamps spongy andrear frontside work assembler	0.3673	0.02	0.3157	0.3991	0.00	1.0000
Fand R comp and bumper welder	0.8465	0.01	0.8348	0.8684	0.00	1.0000
Fand R comp and bumper welder1	0.8465	0.01	0.8348	0.8684	0.00	1.0000
gen mech and auto elect	0.4201	0.01	0.3970	0.4481	0.00	1.0000
painter	0.5353	0.02	0.4948	0.5693	0.00	1.0000
partition welder	0.5554	0.05	0.4444	0.6441	0.00	1.0000
sheet metal weld	0.8814	0.03	0.7710	0.9148	0.00	1.0000
wall welder	0.8000	0.07	0.6354	0.9490	0.00	1.0000

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
auto elect and auto mech	0.2000	0.01	0.1838	0.2269	0.00	1.0000
auto mech and auto elect	0.2110	0.01	0.1863	0.2241	0.00	1.0000
auto mech gen mech auto elect	0.4030	0.02	0.3634	0.4416	0.00	1.0000
automotive	0.5407	0.06	0.4442	0.7227	0.00	1.0000
dif lamps spongy andrear frontside work assembler	0.3673	0.02	0.3157	0.3991	0.00	1.0000
Fand R comp and bumper welder	0.8465	0.01	0.8348	0.8684	0.00	1.0000
Fand R comp and bumper welder1	0.8465	0.01	0.8348	0.8684	0.00	1.0000
gen mech and auto elect	0.4201	0.01	0.3970	0.4481	0.00	1.0000
painter	0.5353	0.02	0.4948	0.5693	0.00	1.0000
partition welder	0.5554	0.05	0.4444	0.6441	0.00	1.0000
sheet metal weld	0.8814	0.03	0.7710	0.9148	0.00	1.0000
wall welder	0.8000	0.07	0.6354	0.9490	0.00	1.0000

Table 4-e Number waiting

bus assembling improved in parallel

Replications: 63 Time Units : Hours

Queue

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AC electrical part and ply wood work.Queue	0.00015140	0.00	0.00	0.00314963	0.00	1.0000
carpeting postish and window glass ass.Queue	0.00325668	0.00	0.00	0.02822406	0.00	1.0000
door ass box ITS passanger seat and curtain ass.Queue	0.01028364	0.00	0.00	0.05608490	0.00	1.0000
engine with GB ass.Queue	0.3592	0.05	0.05133109	1.0348	0.00	6.0000
floor frame and partition.Queue	0.01077707	0.00	0.00	0.04300390	0.00	1.0000
front and rear comp and corr1.Queue	2.9338	0.11	1.4422	3.7384	0.00	9.0000
front and rear comp and corr2.Queue	3.3870	0.11	1.8953	4.1885	0.00	9.0000
indoor testing electrical and mechanical.Queue	0.00002747	0.00	0.00	0.00173055	0.00	1.0000
loading and alignment wall weld.Queue	1.1262	0.25	0.1160	5.2936	0.00	11.0000
mid front door and fender step down.Queue	3.2848	0.37	0.2747	6.1574	0.00	14.0000
out door testing and adj.Queue	0.00028055	0.00	0.00	0.00437601	0.00	1.0000
painting.Queue	0.00	0.00	0.00	0.00	0.00	0.00

APPENDIX 5 Statistical Output Report for improved bus assembly line serially.

Table 5-a product out put

12:04:13PM **Category Overview** August 16, 2023

Values Across All Replications

serial simulation

Replications: 63 Time Units: Hours

Key Performance Indicators

System	Average
Number Out	8

Table 5-b simulation report about cycle time and others

Replications: 63 Time Units: Hours

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	64.2516	0.29	61.9321	66.7292	56.3270	78.7379

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	28.0000	0.00	28.0000	28.0000	28.0000	28.0000

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	31.1376	2.23	8.7131	45.4721	0.00	90.3707

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	0.00	0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entity 1	123.39	2.25	101.17	137.26	86.0551	183.62

Table 5-c waiting time report

serial simulation

Replications: 63 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
AC electrical part and ply wood work.Queue	0.00511262	0.01	0.00	0.1993	0.00	2.1918
carpeting postish and window glass ass.Queue	0.00801992	0.01	0.00	0.2298	0.00	2.0679
door ass box ITS passanger seat and curtain ass.Queue	0.03533937	0.04	0.00	0.8843	0.00	7.9583
engine with GB ass.Queue	2.3892	0.47	0.6251	8.4737	0.00	25.0907
floor frame and partition.Queue	0.07971999	0.02	0.00	0.2644	0.00	2.1977
front comp and corr.Queue	13.5547	0.87	4.4545	19.7273	0.00	35.0000
indoor testing electrical and mechanical.Queue	0.00266462	0.00	0.00	0.08911211	0.00	0.8020
loading and alignment wall weld.Queue	7.4251	1.49	1.0854	27.8236	0.00	51.7973
mid front door and fender step down.Queue	24.1137	2.34	4.6173	40.6660	0.00	74.9435
out door testing and adj.Queue	0.00809549	0.01	0.00	0.1223	0.00	0.9786
painting.Queue	0.01074532	0.01	0.00	0.0997	0.00	0.9973
rear comp and corr.Queue	13.4016	0.74	5.3861	18.3161	0.00	35.5226

Table 5-d instantaneous utilization

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
auto elect and auto mech	0.1161	0.00	0.0983	0.1540	0.00	1.0000
auto mech and auto elect	0.1161	0.00	0.0927	0.1573	0.00	1.0000
auto mech gen mech auto elect	0.1709	0.01	0.1350	0.2218	0.00	1.0000
automotive	0.5676	0.03	0.3699	0.7826	0.00	1.0000
cabin welder	0.8255	0.00	0.7622	0.8518	0.00	1.0000
dif lamps spongy andrear frontside work assembler	0.2173	0.00	0.1756	0.2546	0.00	1.0000
gen mech and auto elect	0.1951	0.00	0.1540	0.2328	0.00	1.0000
painter	0.3095	0.00	0.2680	0.3529	0.00	1.0000
partition welder	0.5452	0.02	0.4134	0.6729	0.00	1.0000
sheet metal weld	0.8680	0.01	0.7585	0.9084	0.00	1.0000
wall welder	0.7923	0.03	0.5626	0.9671	0.00	1.0000

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
auto elect and auto mech	0.1161	0.00	0.0983	0.1540	0.00	1.0000
auto mech and auto elect	0.1161	0.00	0.0927	0.1573	0.00	1.0000
auto mech gen mech auto elect	0.1709	0.01	0.1350	0.2218	0.00	1.0000
automotive	0.5676	0.03	0.3699	0.7826	0.00	1.0000
cabin welder	0.8255	0.00	0.7622	0.8518	0.00	1.0000
dif lamps spongy andrear frontside work assembler	0.2173	0.00	0.1756	0.2546	0.00	1.0000
gen mech and auto elect	0.1951	0.00	0.1540	0.2328	0.00	1.0000
painter	0.3095	0.00	0.2680	0.3529	0.00	1.0000
partition welder	0.5452	0.02	0.4134	0.6729	0.00	1.0000
sheet metal weld	0.8680	0.01	0.7585	0.9084	0.00	1.0000
wall welder	0.7923	0.03	0.5626	0.9671	0.00	1.0000

Table 5-d Schedule utilization

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
auto elect and auto mech	0.1161	0.00	0.0983	0.1540
auto mech and auto elect	0.1161	0.00	0.0927	0.1573
auto mech gen mech auto elect	0.1709	0.01	0.1350	0.2218
automotive	0.5676	0.03	0.3699	0.7826
cabin welder	0.8255	0.00	0.7622	0.8518
dif lamps spongy andrear frontside work assembler	0.2173	0.00	0.1756	0.2546
gen mech and auto elect	0.1951	0.00	0.1540	0.2328
painter	0.3095	0.00	0.2680	0.3529
partition welder	0.5452	0.02	0.4134	0.6729
sheet metal weld	0.8680	0.01	0.7585	0.9084
wall welder	0.7923	0.03	0.5626	0.9671

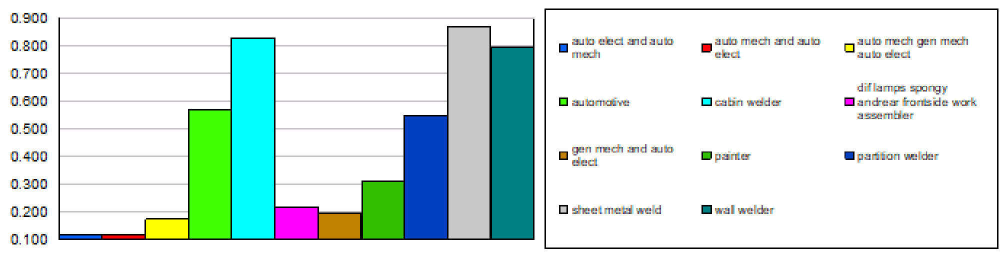
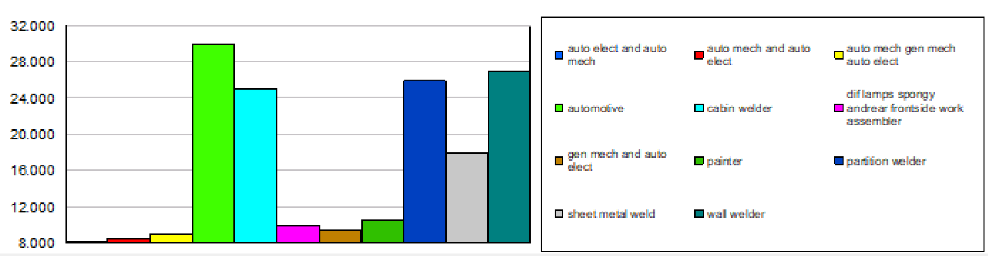


Table 5-e Total number siezed

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
auto elect and auto mech	8.1270	0.08	8.0000	9.0000
auto mech and auto elect	8.5238	0.13	8.0000	9.0000
auto mech gen mech auto elect	8.9524	0.11	8.0000	10.0000
automotive	29.8095	1.34	21.0000	41.0000
cabin welder	25.0476	0.12	23.0000	26.0000
dif lamps spongy andrear frontside work assembler	9.9048	0.12	9.0000	11.0000
gen mech and auto elect	9.3651	0.12	9.0000	10.0000
painter	10.5397	0.13	10.0000	11.0000
partition welder	25.9206	0.90	19.0000	33.0000
sheet metal weld	17.9206	0.22	15.0000	19.0000
wall welder	26.9841	0.94	20.0000	34.0000



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I am conducting research in Bishoftu automotive engineering industry, entitle “Production Flow Analysis and improvement in Bishoftu Automotive Engineering Bus Body Manufacturing” for the fulfilment of a master’s degree in Industrial engineering from Addis Ababa University Institute of technology, school of Mechanical and Industrial Engineering.

The objective of this interview is to identify areas for improvement that challenges the production flow of bus assembling line in BAEI. I would like to thank and express my gratitude for helping me to response the attached interview questions. Your feedback is important to the success of the survey. All information will be handled in the most confidential manner and the respondent's name will not be disclosed.

For more information, you may contact us at the above address. Thank you for your cooperation, feedback and for your precious time!!!

Information about respondents

Working experience ______________________

Current position in the case company ______________________

Level of qualification ______________________

Gender ______________________

The questionnaires below are for factory managers, production supervisors, and team leaders to evaluate the company's bus production process.

1. What is your current average production rate per month?
2. What is the existing productivity of the bus assembling line (percentile), and its theoretical goal?
3. What are the major challenging factors in this company that leads to reduce the production flow of the company? List out.
4. What factors could you mention to help your organization increasing the production process?
5. In what way do you measure the performance and effectiveness of each stations production line?
6. Of all the stations, which station took more number of labors and cycle times?
7. How many working hours per day and active employees are there?

8. Does the assembling line have adequate room for the movement of materials and workers?
9. In which area you prefer to improve the assembly line?

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I am conducting research in the Bishoftu automotive engineering industry, entitle "Production Flow analysis and improvement in Bishoftu Automotive Engineering Bus Body Manufacturing" for the fulfilment of a master's degree in Industrial engineering from Addis Ababa University Institute of technology, school of Mechanical and Industrial Engineering.

The purpose of this interview is to identify areas of improvement that can be improved based on the needs of the company's product beneficiaries. Your response is very important for the successful completion of the study. In this interview, the respondent's name will not be mentioned, and the information will be kept confidential.

Thanking you for your cooperation, you can contact us at the above address.

Information about respondents

Working experience ______________________

Current position in the case company ______________________

Level of qualification ______________________

Gender ______________________

The following open type structured interviews are presented for Sales & Marketing team leaders.

1. Does the company recognize their regular customers? Please describe
2. How does the company conduct customer satisfaction surveys? Please describe briefly
3. Is there a value addition beyond what your customers expected? Please describe briefly
4. Is the company's offering based on the customer's needs?
5. Does your company deliver the product according to customer demand?
6. Does the company use customer complaint handling procedures? Please explain
7. Does the company keep a record of customer complaints? Please explain
8. Does your company discuss customer complaints with relevant departments? Please describe briefly
9. Does your company respond efficiently to complaints from customers according to the procedure? Please describe briefly
10. Does the company take after up on the customers' fulfillment after corrective activity are taken? please clarify