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Title: - Productivity Oriented Assembly Line Balancing for Manufacturing of School bus; A Case of Bishoftu Automotive Industry

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Adama, Ethiopa

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL CHEMICAL AND MATERIALS ENGINEERING

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A Case of Bishoftu Automotive Industry"

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CANDIDATE DECLARATION

I, Kibrom Hailemariam Berihu declare that the work which is being presented in this thesis entitled "Productivity Oriented Assembly Line Balancing for Manufacturing of School Bus: A Case of Bishoftu Automotive Industry" in partial fulfilment of the requirements for the award of the degree of Masters of Science in Manufacturing Engineering is an authentic record of my own work carried out from November 2017 to September 2018 under the supervision of Dr. Kassu Jilcha (Asst. professor) Mechanical Design and Manufacturing Engineering program, Adama science and Technology University, Ethiopia. The matter embodied in this thesis has not been submitted by me for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

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Candidate	Signature	Date

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with our approval:

Dr. Kassu Jilcha (Asst. professor)	…………………	..……..………..………
Advisor	Signature	Date

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ABSTRACT

This paper addresses about snags of productivity oriented ALB of Bishotu Automotive Industry (BAI) with respect to their corresponding solutions; which the case of related domain school bus manufacturing industries is also. Though several researches concerning ALB has been presented, there were so many constraints regarding how to innovate concrete ALB system of manufacturing yet. For that motive, this research, which was the occasion of Bishoftu automotive Industry had come in to the front. The principal target of this research was to improve productivity rate oriented Assembly line balancing for manufacturing industries which was a Case of Bishoftu Automotive Industry in depth with bus production factory of the case company. Hence, the importance of the thesis was to advance both continuous improvement on customers' satisfaction, as well as comprehensive reduction of production time and cost of the company; besides, other related manufacturing industries. From all stations of the case company primary and secondary data, the research analysis was done using simple mathematical model with the help of heuristic methods and grouping comparable parallel work processes technology transfer system. Primarily, the company was providing only two busses per day; now, detail analysis of the paper resulted on 4.52 buses that is highly (77.55%) efficient than the former investigations. Global discussion and results of the profound method displays, it is bright to avail a drastic modification (birr 487,628 profit per day) of availability on productivity rate of the case company. This value was grown by minimizing the working cycle time into 3.5226 hours to produce one bus per day. Productivity oriented ALB can be promoted by the pre stated techniques. Subsequently, it is better to introduce the upshot of this exploration even for companies other than Bishoftu Automotive Industry throughout the world.

***Keywords**: Productivity, Assembly Line Balancing, Manufacturing BAI.*

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ACRONYMS

AL---------------------- Assembly Line

ALB -------------------- Assembly Line Balancing

ALBP------------------- Assembly line balancing problem

ALWABP ------------- Assembly line worker assignment and balancing problem

BAEI ------------------- Bishoftu Automotive Engineering industry

BAI ---------------------- Bishoftu Automotive Industry

BALI -------------------- Bishoftu Automotive and Locomotive industry

BPF ---------------------- Bus production factory

LB ------------------------ Line Balancing

MP ----------------------- Man power

Pred. ---------------------- Predecessor, order of alternatively parallel work done.

St.: ------------------------- Station Number.

SULB--------------------- Simple U-type assembly line balancing

SYMBOLS

A, B, C... Z___ letters to denote alternatively parallel precedence work elements

Mp ___________man power

t 1 : -------------- the time taken to accomplish one bus in a functional steps of production.

t 2 : -------------- the time taken to accomplish the second bus in a functional steps

t 3 : -------------- the time taken to accomplish third bus in a functional steps

t 4 : --------------- the time taken to accomplish forth bus in a functional steps

t ave : ------------ average time taken to complete four buses in a functional steps

T tot: __________ total time of all lines of production per one bus

T: ----------------- total time taken to confirm all stations of a given line.

Ta _____________ total time of adjustment line

Tb _____________ total time of body production line

Tbf: ___________ total time of body and frame production line

Tc _____________ total time of chassis production line

Tf _____________ total time of final line.

Tp _____________ total time of painting and polishing production line

CHAPTER ONE

1. INTRODUCTION AND BACK GROUND OF THE STUDY

1.1. Introduction

Assembly Line Balancing (ALB), Naveen K. and, Dalgobind M., (2013), is commonly used to refer to the decision process of assigning tasks to workstations in a serial production system at a certain cycle time so that predetermined goal is achieved. Assembly line balancing problem (ALBP) was originated with the invention of the assembly line. So far, there were so many problems to resolve regarding assembly line balancing in the world as it was seen in BAI. Generally speaking, the target of this investigation was to achieve Lots of activities among the workstations which has led to the maximum utilization of human resources and facilities without disturbing the work sequence in bus production Factory.

This paper responsibly was concentrated at diminishing of total cycle time for the amount of prearranged work stations in the company; having better quality of production rate. For the sake of accurate results, the time required to accomplish four busses of the case company were registered independently; besides, average timings of these four buses was considered in this research.

Project 40720/, www.web/ (BAI) /about-us1/1, currently named Bishoftu Automotive Industry (BAI), established in 1984 to overhaul medium repair of armored and automotive parts, communication equipment's, maintain radar stations and anti-air craft guns. From 1991 up to 2008 the project works finalize and the industry started overhauling tanks and Ural military trucks. In 2008, the industry reorganized under Defense Industry Sector named as Bishoftu Motorization Engineering Complex Established in 1999. Later in 2010 it reestablished and re-named as Bishoftu Automotive Industry (BAI) while it incorporated into the Metals and Engineering Corporation. Located 45 km East of Addis Ababa, in the town of Bishoftu. BAI assembles public transportation buses, intercity buses, heavy duty trucks, pick-ups, small vehicles and multi-purpose military vehicles. In addition to producing and supplying automotive products it is also working on the expansion of modern automotive technology as well as related production facilities owned by private enterprises.

Vision of the company is to become a competitive automotive industry in the global market. Its Mission is also to lead the industrial development of Ethiopia in the automotive sector. Note that, to beat up the standard vision of the company and other inter related manufacturing industries, there must have been wise assembly line Balance during production. For that matter this paper has been done to come up with smart solutions on this issue. From financial information of the company, as Alemayehu Wondu, financial head officer of the company, (personal communication, May 16-2018) whispered that, the company has a credit of about 191,979.62 Birr per one school bus.

Figure 1 Sample produced (assembled) buses of the company

Bishoftu Automotive Engineering Industry is one of the subsidiaries under the state-owned Metal & Engineering Corporation (METEC), has set up a cabin manufacturing plant worth 35 million Br. The new facility has already started pilot production of a cabin, an enclosed space in a truck, for the vehicles which the company is manufacturing. Figure 1 shows some of the produced school busses of the company. The company has two sections of manufacturing plants which are designated to make cabins for pickups and trucks.

The first section has a production capacity of making 11,000 cabins for pickups annually, enrolling 190 workers. The second part manufactures 13,000 truck cabins annually with its 350 employees.

Now a days, Bishoftu Automotive Industry is one of the companies operating under METEC, specializing in designing and manufacturing automotive products and different types of machinery. It has been started making the vehicles in June 2011, by importing the parts from China and Europe. But this time most of the inputs including the cabins are manufactured locally, according to the company data, promotion and communications director at METEC.

This time again, the company adds 30pc to 55pc value on the vehicles depending on the type of car, according to the company data. The lowest addition is made to the trucks, and the highest is done on pickups. BAI manufactures public buses, construction vehicles, Solid and liquid waste disposal vehicles and cash-in-transit trucks.

Since its establishment, BAI has produced a total of 7,055 cars of which 1,957 were public buses. Out of the total public buses, 553 of them were supplied to Anbessa City Bus Service Enterprise, 410 for Public Service Employees Transport Service Enterprise, and 300 for Sheger Express Bus System. The other 490 buses were distributed to regions while the remaining were supplied to private companies and government institutions for different services including cross country transportation.

Currently, BAI works with 218 small and medium enterprises which are providing it input. It has a total of **3,600** employees. The company tolerates working about 16 hours per day. Its annual turnover has reached 2.2 billion Br, with a production capacity of manufacturing 16 pickups, 10 trucks and two buses on a daily basis.

The umbrella company, METEC, was incorporated in 2010, and presently has 15 companies operating under it, mainly engaging in the engineering sector. These companies consolidate 98 state-owned enterprises employing a total of 19,500 workers including the military base.

Besides the cabin, the company is currently sourcing various parts of vehicles locally including brakes, tires, seats, bodies and leaf springs.

The company has 29 maintenance centers scattered across the country, operating as exclusive maintenance centers. Beyond this, the company is highly criticized for delivering poor quality products, but the management of the company defends that saying they are improving their deficiencies gradually and now they are supplying better products.

Currently, the company has produced a little over 8,000 commercial and private vehicles for the local market.

But then again, to coup its vision, mission and values, it is better for the company to have its own balanced assembly line during production. For that reason, this paper is concerned on assembly line balancing for manufacturing industries which is the basic dispute of Bishoftu automotive industry.

1.2. Problem Justification

Earlier Assembly Line Balancing papers, Mathias A., (2000), were designed to have blameless productive way of manufacturing; but, they were dealing with a particular products only. They did not gone through complex manufacturing industries assembly lines. It is distinctly preferable to investigate for sophisticated manufacturing industries like Bishoftu Automotive Industry, which is the case company. Bishoftu Automotive Industry is one of the ongoing Ethiopian Automotive and manufacturing industries with eight chief factories which are performed by machinery and man power employees. One of these central factories is Bus production Factory (BPF). From the company information (BAI, 2018), Bus Production Factory is the most complex, crowded and unhinged factory having four interesting shops with each of about two sequential straight lines. Namely: Body production / trimming and welding line, Chassis line, Final line and Adjustment line. To develop wise assembly line balancing phenomenon, it was mandatory to link these lines with body and frame bending production factory lines as well as with painting and polishing production factory line. For that reason, the scope of this research has been vast; comprising these three functional production factories. The Company, (BAI) had not robotic production system. The straightforward assembly lines of these three factories; namely, Bus production Factory, painting and polishing production factory as well as body and frame bending production factory lines in BAI, consists of a set of totally forty (40) workstations arranged in a linear fashion, with each station associated by a material handling device.

Clearly, there were a total of about 28 binary stations in bus production factory. Figure 2 sows the plant layout of these lines in detail. Chassis production line, one of these shops, includes two serial parallel lines having seven stations each. There was a perceptible bottle neck in Chassis line with engine assembly and loading as well as the engine wing necked area. From the field observation, Chassis shop in general was able to bounce/give an Output of only two buses per day. With this in mind, there was great variations in production rate on each stations. Ato Tesfahun, the head of chassis line (personal communication Oct.26, 2017), identified that alternative solution for this tricky could be tallying one station. Similarly Body and frame Production line have two lines with each of ten stations. As Mr. Berhe, head of body and frame assembly (personal communication Oct.26, 2017), whispered that, Body and frame line was the finest balanced line with an output of three bus bodies per day. But again this line has been retested intentionally and shown that the universal output of trimmed and assembled school bus bodies per day was also two.

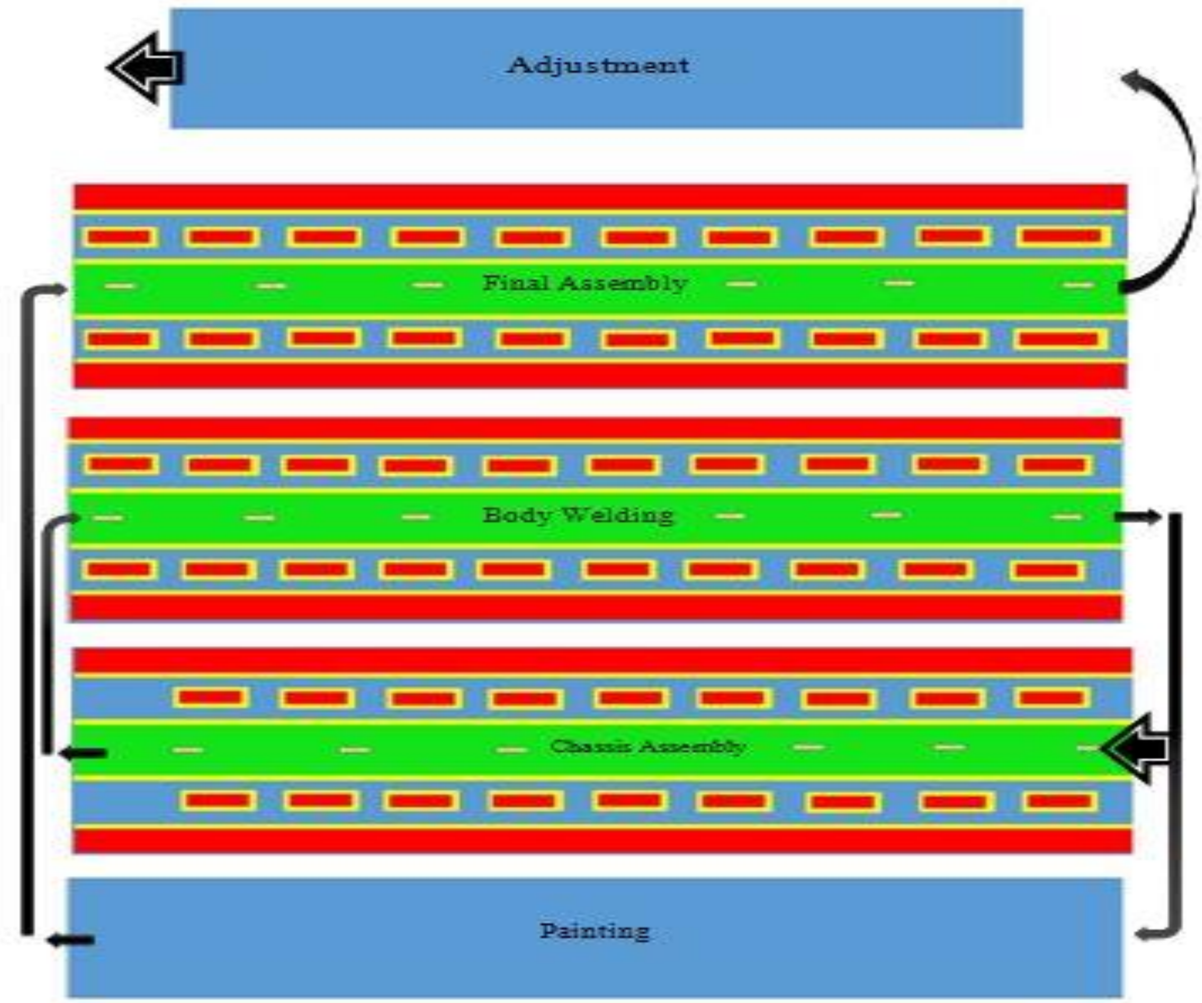

Figure 2 plant layout of Bishoftu Automotive Industry, Bus Production Factory

From the field observation, Painting and polishing shop having two mixed lines with three stations, has feed an Output of three school buses per day. It was predictable that this ought to be upgraded in to a minimum of four buses. As a product, the Output of finishing line was only one school bus per day; which is virtually observed in the field. But then again, it was expected that the final line must has been balanced with the other lines to provide an output of at least four buses per day. These issues has done by heuristic methods as well as mathematical models and grouping similar predecessor works into one. In view of that, let's see the Following back grounds and the organized problem Statement to clarify the core disputes of the given company and other relative manufacturing industries.

1.2.1. Location of bottlenecks in the factory

The main bottle necked locations in the company were;

Break down of cranes and fork lift, light switch off, Electrical power interruption, some times over heat crane break downs, Overhead break down, Sometimes Shortage of materials, No more Man power sometimes, co2 (gas cylinder) empire, Co2 gas cylinder change convertibleness, Sheet metal ride, Always oxygen cylinder change to man power, Sometimes power difficulty (heavy duties) man power, Oil leakage effects, There was no light in the Whole system, No enough man power in various stations, No enough wrenches for work, No more cutter blade, No more drilling bitt, Materials were not accessed quickly, Drill machine problem, no more drill bit with Dia. 3.5 mm, Pneumatic machine requirement, Drill machine over heat, Overlap of station, Luck of air, Breakdown of drill bit and taps. The bottle necks given away has been discussed in detail and solved by continuous contact with the respective chair persons and employers as well as by minimizing the cycle time to accomplish prearranged works.

1.3. Problem Statement

The problem of assigning tasks to workstations in such a way that some objectives are optimized is said to be assembly line balancing problem (ALBP). We can generally recognize two types of ALBP:

- Minimizing number of workstations for a given cycle time (TYPE 1 of ALBP) or
- Minimizing the cycle time for a given number of workstations (TYPE 2 of ALBP).

The occasion how to minimize working cycle time is the principal enquiry of instantly extra industries in the world. In the same fashion, the case company did have a big issue of how to minimize the idle time to improve its productivity. The result of field observation yet again displays that, Bus Production Factory (BPF) especially is the innermost complicated and instable factory; besides it devours supplementary idle time. Indeed, Bus production factory of BAI had noticeable problem of Assembly Line Balancing system for long period of time. In other words, there was unconditional wastage of delay time and man power; for the distribution. This also is the leading problem of the superficial assembly line balancing poise in supreme manufacturing industries as it was perceived in Bishoftu Automotive industry BPF soon.

1.3.1. Research Questions

So far, there were so many difficulties related with the problem of productivity Oriented ALB:

- Which bottle necks were affecting productivity of the case company? And what comprehensive mechanism has taken to control that issue?
- What mechanism should be taken to balance the number of work stations for a given task with respect to the cycle time?
- How to balance the number of operators and machineries with respect to their set-ups to do a given amount of work at a certain assembly line speed?
- How to improve the production rate of manufacturing industries?

Subsequently, this study had been carried on the problem of how to minimize the cycle time for a given number of workstations with the existing operators.

1.4. Objective of the Study

1.4.1. Main Objective

The goal of this paper has basically aimed at Productivity oriented Assembly Line Balancing System for Manufacturing Industries; especially School Bus; which was the rudimentary case of Bishoftu automotive Industry. Its role was to minimize the total amount of idle time that resulted on improvement of productivity rate with respect to work stations and workers load on the assembly line shop and enhance the required output.

1.4.2. Specific Objectives

- To identify the location of bottlenecks and minimize them.
- To balance and distribute the number of operators and work descriptions with respect to their set-ups to do a given amount of work at a certain assembly line speed.
- To compute the number of work stations for a given task
- To develop a systematic assembly line enhancing productivity of the given company as well as various related manufacturing industries by matching their operational work stations with respect to the intended cycle time.

Generally speaking, the target of this investigation was to achieve Lots of activities among the workstations which has led to the maximum utilization of human resources and facilities without disturbing the work sequence in bus production Factory.

1.5. Significance and Contribution of the Study

It is obvious that, Core subjects of Industrial manufacturing organizations deals with continuous improvement of productivity, customers' satisfaction, as well as reduction of production cost. The importance of this paper likewise was to achieve these bulls; by reducing the total amount of time required to crop numerous products. In addition to this, it was expected for the paper to react with the gaps from existing body of knowledge of the world. It also was expected to stretch farther feedbacks for Assembly Line Balancing journals with various recommendations. Definitely this was the current issue of Bishoftu Automotive Industry; especially bus production Factory. This investigation was also aimed to show general directions; such that, the result of its analysis be available even for companies other than BAI throughout the world. Accordingly, the importance of the thesis was to advance both continuous improvement on customers' satisfaction, as well as comprehensive reduction of production time and cost of the company; besides, other related manufacturing industries.

1.6. Scope of the Study

This paper primarily deals with **Assembly line balancing system of bus production factory** of **Bishoftu Automotive Industry** and gives farther emphasis for co - related manufacturing industries in detail. It was started by exploring the present system of bus production in Bishoftu Automotive Industry; beginning from body and frame bending factory, including bus production as well as painting and polishing factories. In addition to this, it had been annoyed to feed concrete acquaintance of assembly line balancing for other related companies.

The paper recovered so many things to beat up its objective well; Besides, it had been:

- Identified bottle necks of the company assembly lines and given away the gaps on why some machineries in bus production factory of the company was being idle with respect to their corresponding solutions.
- Exposed and lessen the basic factors for the delay of production system of the company; especially; Bus production factory,

- Driven improvements to advance production rate concerning Assembly Lines of the given company as well as other extra manufacturing industries.
- Moved out through general conclusion on how to realize the weighing scale of manufacturing industries assembly lines.

To develop wise assembly line balancing phenomenon, it was mandatory to link Bus Production factory with, Body and Frame Production Factory as well as painting and polishing factory. For that reason, the scope of this research has been vast; comprising these three functional production factories assembly lines.

1.7. Limitations of the study

Honestly speaking, it is so difficult to record over all the timing and the entire working condition of every stations during operation; no more related works yet. Great delay of input raw material stock also partaken its own impact for the paper not to finish with in the pre-planned schedule.

1.8. Organization of the thesis

This thesis is prepared in five chapters.

Chapter 1: describes the introduction part of the study mainly, the background of case company, general and specific objectives, problem statement, scope, significance and limitations.

Chapter 2: demonstrations about the literature review on Assembly Line balancing, regarding productivity from work descriptions, line efficiency, cycle time minimization, and man power distribution, as well as operational working stations. Previous features, research works, on Assembly line balancing, approaches to the determination of ALB, and their research gap are deeply reviewed and presented in this chapter.

Chapter 3: deals with the materials and methods, which focused on productivity oriented ALB, over view of ALB methodology, sources of data and their collection, data analysis methods and research frame work.

Chapter 4: entirely presents about ALB results and discussion of three factories of the case company and shows the possibility of attaining genuine productivity improvement from the research work focusing on presenting the work flow, manpower distribution, precedence, cycle time, line efficiency results.

Chapter 5: is dedicated to donate conclusions and recommendation

CHAPTER TWO

2. LITERATURE REVIEW

2.1. General clue

The concept of manufacturing assembly line (AL), Krzysztof F. and Khalil S., (2003), was first introduced by Henry Ford in the early 1900's. It was designed to be an efficient, highly productive way of manufacturing. However, this innovation was no more able for multiple products; it was about a particular product only. Researchers have studied the subject of balancing assembly lines in many different industrial areas. The first line balancing researches were applied to the automotive sector. Up to now, a number of assembly line balancing studies have been conducted in manufacturing industries.

2.2. Definition of Assembly Line Balancing:

Assembly line, Ana S. et al, (2009), stands for a manufacturing process in which interchangeable parts are added to a product in a sequential manner to create an end product. In most cases, a manufacturing assembly line is a semi-automated system through which a product moves. At each station along the line some part of the production process takes place. The workers and machinery used to produce the item are stationary along the line and the product moves through the cycle, from start to finish.

Line Balancing, Betul Y., (2011), is a classic Operations Research optimization technique which has significant industrial importance in lean system. Line balancing means balancing the production line, or any assembly line. The main objective of line balancing, Neda M. et al, (2013), is to distribute the task evenly over the work station so that idle time of man or machine can be minimized. **Line balancing,** Ghutukade et al, (2013), also aims at grouping the facilities or workers in an efficient pattern in order to obtain an optimum or most efficient balance of the capacities and lows of the production or assembly processes.

According to Surry. (1971), **Assembly Line Balancing (ALB)** is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods. The concept of **mass production** essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must.

2.3. Characteristics of Assembly Line balancing

2.3.1. Features of assembly line

There are three main types (Naveen K and Dalgobind M., 2013) of Assembly lines; namely: Single-Model Assembly Line, Mixed Model Assembly Line and Multi Model Assembly Lines. Look at figure 3 below:

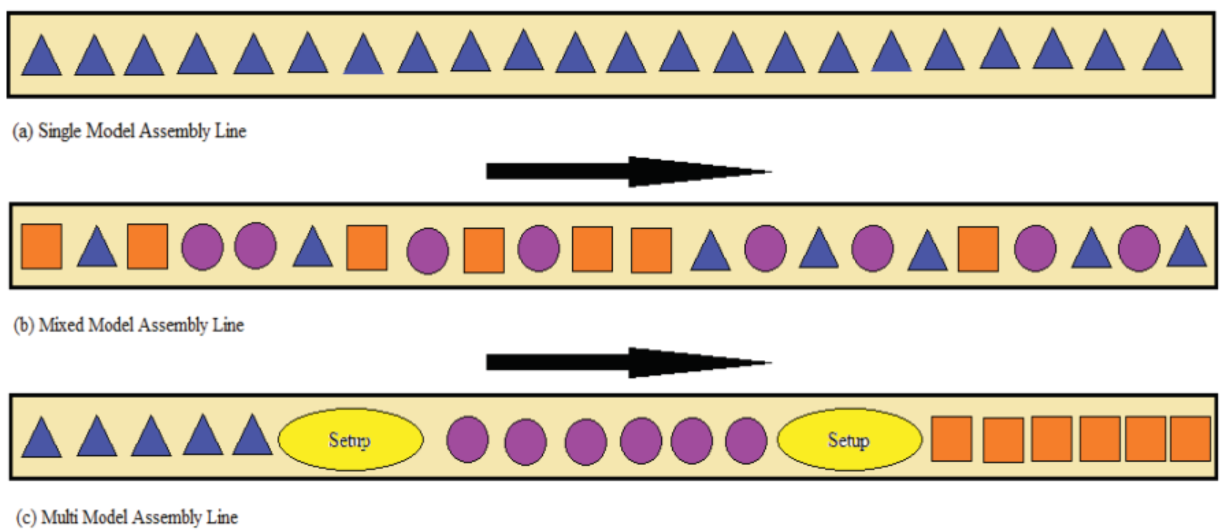

Figure 3 Assembly lines for single and multiple products

A. Single-Model Assembly Line

In early times, (Naveen K and Dalgobind M., 2013) assembly lines were used in high level production of a single product. But now the products will attract customers without any difference and allows the profitable utilization of Assembly Lines. An advanced technology of production which enables the automated setup of operations and it is negotiated time and money. Once the product is assembled in the same line and it won't variant the setup or significant setup and it's time that is used, this assembly system is said to be Single Model Line.

B. Mixed Model Assembly Line

In this model the setup time between the models would be decreased sufficiently and enough to be ignored (Naveen K and Dalgobind M., 2013). So this internal mixed model determines the assembled on the same line. And the type of assembly line in which workers work in different models of a product in the same assembly line is called Mixed Assembly Line.

C. Multi Model Assembly Line

In this model, (Naveen K and Dalgobind M., 2013), the uniformity of the assembled products and the production system is not that much sufficient to accept the enabling of the product and the production levels. To reduce the time and money this assembly is arranged in batches, and this allows the short term lot-sizing issues which made in groups of the models to batches and the result will be on the assembly levels.

2.4. Survey of Theories

There are so many heuristics exist in literature for LB problem. The heuristic provides satisfactory solution but does not guarantee the optimal one (or the best solution). As the Line balancing problems can be solved by many ways, out of those, the Longest Operation Time (LOT); Held M., (1963), approach had been used. It is the line-balancing heuristic that gives top assignment priority to the task that has the longest operation time. The steps of LOT are: LOT 1: To assign first the task that takes the most time to the first station. LOT 2: After assigning a task, to determine how much time the station has left to contribute. LOT 3: If the station can contribute more time, to assign it to a task requiring as much time as possible.

The operations in any line follow same precedence relation. For example, operation of super-finishing cannot start unless earlier operations of turning, etc., are over. While designing the line balancing problem, Krzysztof F. and Khalil S., (2003), one has to satisfy the precedence constraint. This is also referred as technological constraint, which is due to sequencing requirement in the entire job.

2.5. Approaches to Determination of the Performance of ALBP

(Mathias Amen, 2000) presented a work on an exact method for cost-oriented assembly line balancing. Rendering to Mathias Amen, Characterization of the cost oriented assembly line balancing problem had been shown by without loading the stations maximally the cost-oriented optimum. According to M. Amen (2000), there are two types of optimization problems for the line balancing problem (LBP). Assembly line balancing problems are classified into two categories. Type-I problems deals with the cycle time, number of tasks, tasks times and task precedence. The objective is to find the minimum number of workstations. A line with fewer stations results in lower labor cost and reduced space requirements. Type-I problems occurs when we have to develop a new assembly line. Type-II problem occurs when the numbers of workstations or workers are fixed. Here the objective is to minimize the cycle time. This will maximize the production rate because the cycle time is expressed in time units per part (time/parts) and if we can find the minimum cycle time then we can get more production per shift. This kind of problem occurs when a factory already has a production line and the management wants to find the optimum production rate so that the number of workstations (workers) is fixed.

According to him criterion two stations-rule had to be used. As a result, this journal is left with a number of research gaps such that, why not for single station? And also why not for three and / or even multiple stations? Definitely, this journal didn't use three and above station rules.

(Fleszar and Hindi, 2003) presented a work on enumerative heuristic and reduction methods for the assembly line balancing problem. They presented a new heuristic algorithm and new reduction techniques for the type 1 assembly line balancing problem.

On the other hand, that journal did not goes through type 2 ALBP. Hence, there was still a requisite for assembly line balancing to come up with the solution of production rate (type 2 ALBP). (Gokcen, 2005) presented a work on shortest route formulation of simple U-type assembly line balancing problem. A shortest route formulation of simple U-type assembly line balancing (SULB) problem was presented. This model was based on the shortest route model developed in for the traditional single model assembly line balancing problem. But then again, there is steel a request for solutions of mixed and multi model assembly line balancing problems.

A work on optimal piecewise-linear program for the U-line balancing problem with stochastic task times was published by (Urban and Chiang, 2006). The utilization of U-shaped layouts in place of the traditional straight-line configuration has become increasingly popular. This work examines the U-line balancing problem with stochastic task times.

Conversely, a cavity was seen that, there are so many Situations other than U-line type assembly line balancing problem. These are serial lines, parallel lines, parallel stations and also two-sided lines. A chance constrained, piecewise linear, mathematical model and software programs should be formulated to find the optimal solution. Various approaches must also be used to identify a tight lower bound. Computational results have a duty to show that the proposed method be able to solve practical sized problems of the company.

2.5.1. Approaches of ALB in developed countries

The introduction of the assembly line to American manufacturing, Krzysztof F. and Khalil S., (2003) floors in the early part of the twentieth century fundamentally transformed the character of production facilities and businesses throughout the nation. Thanks to the assembly line, production periods shortened, equipment costs accelerated, and labor and management alike endeavored to keep up with the changes. Today, using modern assembly line methods, manufacturing has become a highly refined process in which value is added to parts along the line. Increasingly, assembly line manufacturing is characterized by, Sener A., et al, (2013), "concurrent processes"—multiple parallel activities that feed into a final assembly stage. These processes require sophisticated systems of communications, material flow plans, and production schedules. The fact that, the assembly line system is a single, large system means that failures at one point in the "line" cause slowdowns and repercussions from that point forward. Keeping the entire system running smoothly requires a great deal of coordination between the parts of the system.

Computer power has enabled tracking systems to become more sophisticated and this, in turn, has made it possible to reduce the costs associated with holding inventories. Just-in-time (JIT) manufacturing methods have been developed to reduce the cost of carrying parts and supplies as inventory. Under a JIT system, manufacturing plants carry only one or a few days' worth of inventory in the plant, relying on suppliers to provide parts and materials on an "as needed" basis. Future developments in this area may include suppliers establishing operations within the manufacturing facility itself or increased electronic links between manufacturers and suppliers to provide for a more efficient supply of materials and parts.

2.5.2. Approaches of ALB in developing countries; BAI (Ethiopia)

Ethiopian Herald, (2017), reported that; this time, Bishoftu Automotive Industry (BAI) announced plans to establish 27 new automotive engineering zones that will be assembling and manufacturing motorcycles, bicycles, light and heavy trucks and other vehicles in different parts of Ethiopia. Along with assembling and manufacturing different civil and military vehicles, the Industry is providing professional training in neighboring countries. The Industry assembles and manufactures pick-up, station-wagon, light and medium trucks, minibus and buses. Bishoftu has already signed an agreement with Uganda, Kenya and Rwanda to build motor production factories. Kenya has also placed orders to purchase 400 buses from Bishoftu.

Yet, the company (BAI), do not partake well balanced assembly line as crucial as it is running. Rather heuristic methods only. Especially, bus production factory is too complex and is working without balanced assembly line. This shows that there is a need to upgrade it’s over all features continuously. This difficulty is perceived all over the world manufacturing industries; rather than Bishoftu Automotive Industry only. Hence, the new study has built up with numerous solutions on these issues.

Consequently, the tricky of assembly of final products is still very common and we can find it in many companies throughout the world as it is seen in Bishoftu Automotive Industry. The basic assembly line consists of a set of workstations arranged in a linear fashion, with each station connected by a material handling device (transfer lines, roller conveyors, cranes etc.). In order for the assembly line to maintain a certain production rate, the sum of the processing times at each station must not exceed the stations’ cycle time. If the sum of the processing times within a station is less than the cycle time, idle (delay) time is said to be present at that station. This idle time must be controlled using various mechanisms.

2.6. Research Gap

It’s observed that, previous studies, M. A. Hannan et al, (2011); were recording timings of three shift or three busses only; On the other hand this paper was considered average timings of four buses. This was perceived for the sake of accurate results. In addition to this, various journals, for instance Naveen Kumar (2013), didn't consider to balance Assembly lines with the help of learning phases (levels) of operators with respect to immense difficulty of each working areas and (staff leaderships and stations). They also had not efficient results. For farther information, (Mahmut Kayar, 2014); look at table 2.1 that remits the previous assembly line balancing journals methods and found the following efficiency:

Table 2. 1 Comparison of the lowest workstation efficiency values of the line balancing methods.

Methods	The lowest workstation efficiency values, %
Ranked positional weight	28.88
Moodie & Young	28.88
Largest Candidate Rule	28.88
Kilbridge & Wester	17.77
Hoffman	73.33
Comsoal	73.33

In case of high prerequisite of efficient Assembly line balancing singularities, this research title, productivity oriented assembly line balancing: A case of Bishoftu Automotive Industry had come in to the front. Unlike to this study, Naveen Kumar (2013), most former ALB projects were merely paper reviews and were without flawless confirmations. Others were done using heuristic methods, Grzecha (2016), Kayar (2014), and genetic algorithm for robotic assembly line balancing algorithms, Levitin (2006) other than compromising mathematical models, as this study had possess. Advances in assembly line balancing methods have been carried out regularly as new and more efficient ways of achieving the goal of increased throughput. The number of crops produced in a given period of time had been achieved from two busses yielding to finalizing four busses and semi finishing of additional one bus per day from this research. During application of various assembly line methods, it is expected for the case company as well as other interrelated manufacturing industries, to smear this paper in real world; and manufacturing processes, professional experts will have also been known to apply these principles to other areas of business, from product development to management.

CHAPTER THREE

3. Materials and Methods

3.1. Methodology over view

Even though multiple projects regarding Assembly line Balancing has done before, their methodology was not same with this paper. Productivity slanted towards Assembly Line of industries must be balanced with the help of compromising or inter linking various methods. In view of that, this paper is done using heuristic methods with the help of mathematical modeling system and grouping comparable functional operations. In other words, group technology sensations has been introduced here.

3.2. Sources of Data and their collection

The main source of data for this research was primary and secondary data. This includes;

- **Primary and secondary data in general:**
  - ✓ BAI, Bus production factory Working conditions, employees direct observation
  - ✓ Incessant contact with the Industry’s unit/department managers and coordinators
  - ✓ Available Bishoftu Automotive Locomotive Industry’s (BALI’s) daily reports and documents remark
  - ✓ Journals and Literatures reviewed at national and international level concerning Assembly line balancing systems
- **Primary data**

The Primary data has been obtained from the Industry by means of interviewing production manager of the company, other related staffs, technicians and employees. The paramount source of primary data remained field observation and activities including measuring time, man power and other related parameters. There was consistently continuous contact with 40 production managers of each stations to find crucial data of these parameters.

♦ **Secondary data**

The basic source of secondary data to accomplish this paper was Bishoftu Automotive Industry’s working documents, especially bus production factory, body and frame production factory as well as painting and polishing factory’s reports and manuals.

3.3. Data analysis

Each and every operational time had been controlled to give emphasis of the parameters like material tooling types, number of work stations, the time taken (cycle time), number of employees and type of sequential processes. These parameters sort out analyzed heuristically and took reactions to minimize basic factors affecting idle time to come up with latest productivity rate. There was also continuous outgoings or communications with the project advisor, production employers, designers, as well as with administrative persons, of the case company. Alternatively, grouping similar work descriptions of every stations in the company was applicable for the thesis to beat up its objective.

3.4. Research frame work

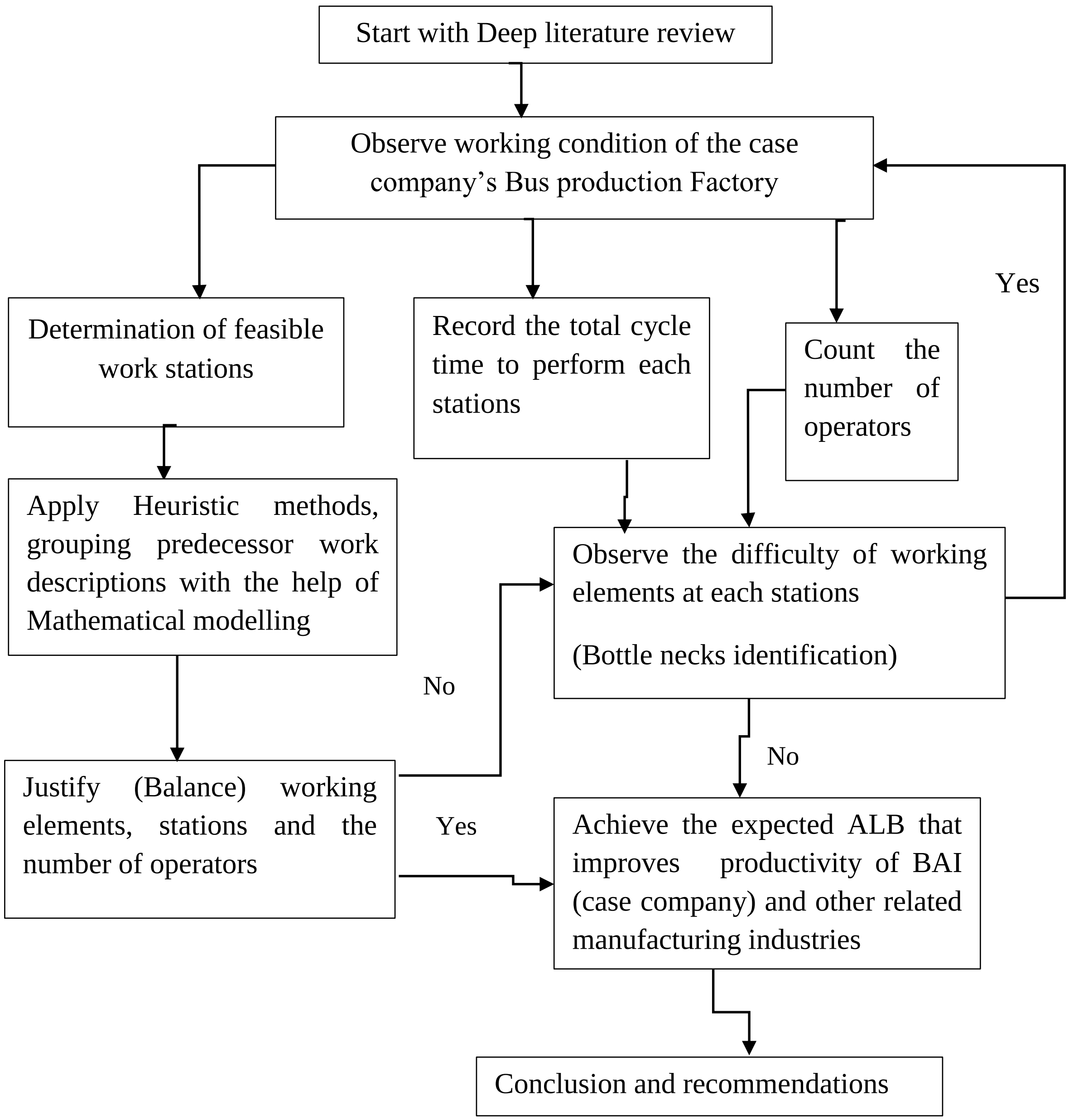

Figure 4 Research frame work

Generally speaking, (figure 4); the thesis had been started with deep literature review and gone to observe working condition of the case company's Bus production Factory, body and frame production as well as painting and polishing production factories. There were a total of forty stations in three production factories of the case company. Five stations in body and frame production factory, seven in painting and polishing as well as about 28 stations in bus production factories in BAI. Waged conditions and total timings of these stations and also the number of operators in the case company has been detected entirely. Especially, bus production, body and frame bending as well as painting and polishing factories procedures been perceived and heuristic methods, grouping predecessor work descriptions with the help of Mathematical modelling situated at that juncture. Once again Feasible work stations, the number of operators and total cycle time to perform each stations grasped well. Bottle necks of the case company has been identified and their respective solutions also took over with the help of grouping predecessor works. Advancements of parallel work descriptions as well as mathematical modelling methods of assembly line balancing system has been arranged well. Later on, the discussion results of Working elements, stations and the number of operators has been justified (balanced); Achieved the expected ALB that improves productivity of BAI and other related manufacturing industries. Lastly, there had been general summary of these discussions through conclusion and some recommendations and future works had been stated well.

3.4.1. Methods of ALB Analysis Overhaul

I. **Work Element,** M. A. Hannan et al, (2011) **(i):** The job is divided into its component tasks so that the work may be spread along the line. Work element is a part of the total job content in the line. Let TV be the maximum number of work element, which is obtained by dividing the total work elements into minimum rational work elements. Minimum rational work element is the smallest practical divisible task into which a work can be divided. The time in a-work element, *say* (TjN), is assumed as constant. Also, all TiN are additive in nature. This means that if "assume that if work elements, 4 and 5, are done at any one station, the station time would be (T4N + T5N). Where N is total number of work elements.

II. Work Stations (w), M. A. Hannan et al, (2011); is a location on the assembly line where a combination of few work elements is performed.

III. Total Work Content (TWC): M. A. Hannan et al, (2011); this is the algebraic sum of time of all the work elements on the line.

Thus, $Twe = \sum_{i=1}^{N} \mathrm{TiN}$; ………………………………………..……………………….……. (1)

IV. Station Time (Tsi) M. A. Hannan et al, (2011): It is the sum of alternatively all the maximum parallel work elements (i) time on work station (s).

Tsi = TAmax + TBmax + TCmax + … + TNmax………………………………………….. (2)

Where; 'N' is the number of alternatively much more time of sequential parallel work.

V. **Cycle Time (c)** M. A. Hannan et al, (2011)**:** This is the time between two successive assemblies coming out of a line. Cycle time can be greater than or equal to the maximum of all times. If, c = max {Tsi} ……………………………………………………..…………… (3)

Then there will be ideal time at all stations having station time less than the cycle time.

VI. **Delay or Idle Time at Station (Tds)** M. A. Hannan et al, (2011)**:** This is the difference between the cycle time of the line and station time.

Tds = c – Tsi ………………………………………………………..…………….….. (4)

VII. **Precedence Diagram,** M. A. Hannan et al, (2011) is a diagram in which the work elements are shown as per their sequence relations. Any job cannot be performed unless its predecessor is completed. A graphical representation, containing arrows from predecessor to Predecessor have the successor work element. Every node in the diagram represents a work element.

VIII. **Balance Delay or Balancing Less (d),** M. A. Hannan et al, (2011)**:** This is a measure of line-inefficiency. Therefore, the efficient is done to minimize the balance delay. Due to imperfect allocation of work along various stations, there is idle time to station. Therefore, balance delay:

D = nc - Twe / nc = nc - ∑Ni=1 TiN / nc ………………………………………………….. (5)

Where: c = Total cycle time; Twe = Total work content; n = Total number of stations.

Where; Tsi = Station time at station i, n = Total number of stations, c = Total cycle time

IX. **Target time,** M. A. Hannan et al, (2011)**:** Target cycle time (which must be greater than or equal to the target task) or define the target number of workstations. If the $\sum \mathrm{ti}$ and n are known, then the target cycle time ct can be found out by the formula:

$\mathrm{Ct} = \sum \mathrm{ti/n}$ **. ………………………………………………………………..…………… (6)**

X. **The Total Idle time,** M. A. Hannan et al, (2011)**: The total idle time** for the line is given by: $IT = \mathrm{nc} - \sum_{i=1}^{k} \mathrm{ti}$; …………………………………..……………………………….. (7)

A line is perfectly balanced if IT = 0 at the minimum cycle time. Sometimes the degree to which a line approaches this perfect balance is expressed as a percentage or a decimal called the balance delay. In percentage, the balance delay is found given as $\mathrm{D} = 100\frac{(\mathrm{IT})}{\mathrm{nc}}$ Where; IT = Total idle time for the line. n = the number of workstations, assuming one worker per workstation **c** = the cycle time for the line ti = time for the ith work task k = the total number of work task to be performed on the production line. The total amount of work to be performed on a line broken into tasks and the tasks assigned to work stations so the work is performed in a feasible sequence within and acceptable cycle time. The cycle time for a line (time between completions of successive items on the line) is determined by the maximum amount of time required at any workstation. If one workstation has a great deal of more work than others, it is desirable to assign some of this work to stations with less work so that there will exist no bottlenecks in the line.

CHAPTER FOUR

4. DISCUSSION, WORK FLOW ANALYSIS AND ASSEMBLY LINE BALANCING RESULTS

4.1. BAI Bus Production and other allied Factories Work flow investigation

4.1.1. Introduction

To bargain the total time of each stations in every lines, it is better to start with calculating the summation of interval period documented during maneuver of Stations of body and Frame production line. There was sequentially straight work descriptions during operation of accumulating various assemblage mechanisms rather than this research based appliance of grouping parallel work descriptions in to one. The total time of body and frame bending production factory was premeditated as the summation of all stations work timings.

That is, $T_{bf} = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}$

$\Rightarrow T_{s1} = T_{s2} = T_{S3} = T_{S4} = T_{S5} = 480$ minutes, then

$\Rightarrow T_{bf} = T_{S\ tot} = (480*5)$ min $=$ **2400** min.

Average of time for body and Frame production line = 2400/5 = 480 min. = 8 hrs.

Total time of Stations of chassis line, $T_c = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}$

$T_c = (320 +360+142+458+210+135+441)$ min.

$\Rightarrow T_c =$ **2066** min.

Average of time for chassis line = 2066/7 = 296 min. = 4.93 = 5 hrs.

Summation time of Stations of body line = $T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}+T_{S8}+T_{S9}+T_{S10}$

$T_b = (270+270+328+295+290+400+233+275+285+240)$ min.

$\Rightarrow T_b =$ **2886** min.

Ordinary time for body production line = 2886/10 = 288.6 min. = 4.81 hrs.

Rundown time of Stations of painting production line, $T_p = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}$

$$T_p = (180+390+390+120+60+160+100) \text{ min.}$$

$$\Rightarrow T_p = \mathbf{1400} \text{ min.}$$

Average of time for painting production line = 1400/7 = 200 min. = 3.33 hrs.

Synopsis time of Stations of Final line, $T_f = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}+T_{S8}+T_{S9}$

$$T_f = (320+230+270+235+252+360+480+260+360) \text{ min.}$$

$$\Rightarrow T_f = \mathbf{2767} \text{ min.}$$

Average of time for Final production line = 2767/9 = 307.44 min. = 5.124 hrs.

Summation time of Stations of adjustment line, $T_a = T_{s1}+T_{s2}$

$$T_a = (120+270) \text{ min.}$$

$$\Rightarrow \quad T_a = \mathbf{390} \text{ min.}$$

Average of time for adjustment line = 390/2 = 195 min. = 3.25 hrs.

Total time of production per one bus ($T_{tot} = T_{bf}+T_c+T_b+T_p+T_a+T_{f.}$)

Whereby:

- $T_{bf} =$ total time of body and frame production line
- T_c = total time of chassis production line
- T_b = total time of body production line
- T_p = total time of painting and polishing production line
- T_a = total time of adjustment line
- T_f = total time of final line.

$$\Rightarrow \; T_{tot} = 2400+2066+2886+1400+2767+390$$

$\Longrightarrow T_{tot} =$ **11,909** minutes. = 198.483 hrs. ; say, 198.5 hrs.

Over-all number of enduring stations, $N_s = S_{bf}+S_c+S_b+S_p+S_f+S_a$.

Where;

- S_{bf} = stations located on body and frame production.
- S_c = Chassis line stations
- S_b = stations of body line
- S_p = stations of painting and polishing production line
- S_f = stations of final line

$\Longrightarrow$ SA = stations of adjustment line = 5+7+10+7+9+2 = **40** stations.

The rate of durable production (r) can be calculated as the rate of total time of production with respect to the entire sum of stations.

i.e. (r) = 11,909 min/40 stations. = 297.725 minutes/St. = 4.962 Say, r= **5 hr. /St.**

Note that, this is the ideal rate of production for each stations. This shows, one bus can be finished within 5 hrs.' in each of the production lines. Meaning that, the industry can produce three (3) buses with in a day.

But, this must also be farther balanced with the help of grouped predecessors of sequential work elements. In view of that, let's grasp each stations of the given lines one by one:

Note that: components which can assembled in parallel precedence were assigned by the same letter.

4.2. Body and Frame production factory line; Work flow inquiry

A total of 74 employees has been assigned for body and frame bending production factory. Each station of body and frame bending factory has spent about 8 hours to accomplish the given work. Figure 5 below shows one of the basic operations of body and frame production factory; overhead welding. Right side, frontal as well as left and rear frames are assembled in this production factory line. There were five main stations in this factory line and balanced distribution of each operational work stations is given in detail.

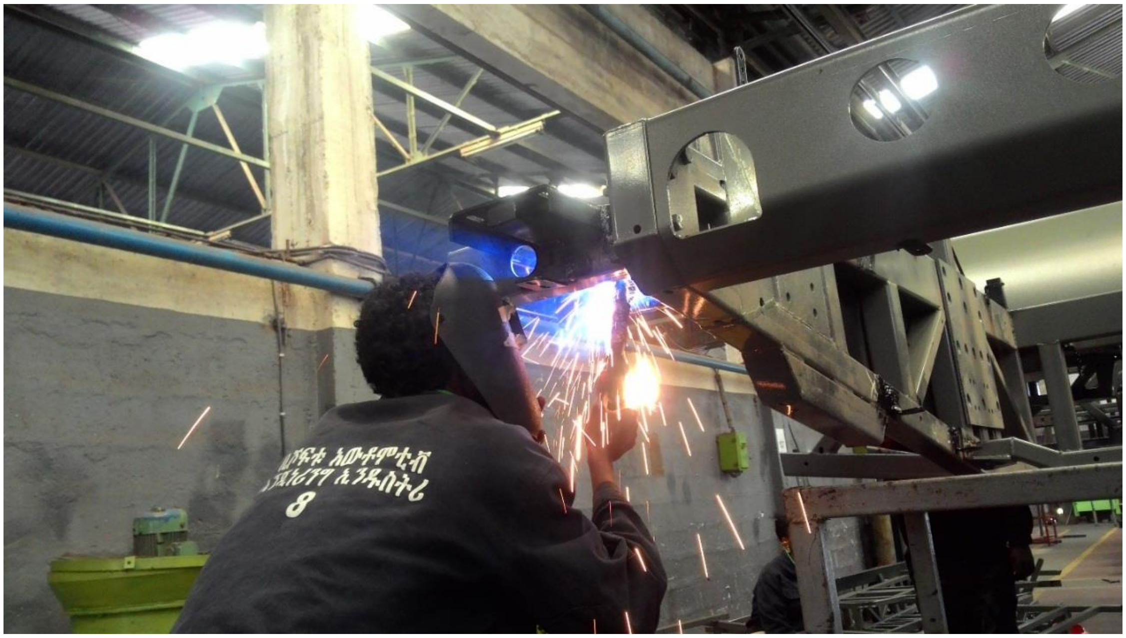

Figure 5 Body and Frame production factory line overhead welding assembly

Denote that, the total time of body and frame bending production line time, “T”, and Average of time for this line to be Tave.

i.e., T = Brief time of Stations to complete every operations in body and Frame production line

$$T = Ts1+Ts2+T_S3+T_S4+T_S5$$

$\Longrightarrow$ T = (480*5) min. = **2400** min. In this case, the time taken was 2400 min. That is about 40 hours. Since there was five stations in body and Frame production line, Average of time for this line was T_{ave} = 2400/5 = 480 min. = 8 hrs. Consequently, bodies and frames of only two buses has been completed per day.

This shows that, there must had been a fundamental reduction of time delay in body and frame bending production factory for the bus production to provide exigent and fast product yields. In view of that, let’s see the central solutions for each of the prearranged stations:

4.2.1. Frame alignment welding

Assigned man power in this station for one shift were about 24 employees. Their balanced distribution were given below in table 4.1 with respect to their timings.

Typical time taken to accomplish relative components of one bus in station1, i.e.; measured time to assemble Frame alignment welding was 480 minutes. But, it can be finished within 345 minutes by combination of the same work descriptions; subsequently, there was about 135 minute's idle time. Which totally gives eight o'clock.

Table 4. 1 Frame alignment welding

Work Sequence	Pred.	Mp	t1	t2	t3	t4	t ave
Cross member assembly	A	8	28	32	28	32	30
Frame assembly	B	8	13	17	13	17	15
Welding each parts	C	6	63	57	63	57	60
Grinding scraps	D	6	31	29	31	29	30
Opposite side cross member strengthen	E	8	29	31	29	31	30
Assemble different sides of plates	F	4	26	34	26	34	30
Grinding scrap parts	G	2	29	31	29	31	30
Welding skin covers	H	8	87	93	87	93	90
Grinding scraps	I	2	17	13	17	13	15
Polishing	J	1	8	22	8	22	15

From the given data in table 4.1, sequential work of this station can be finished simply within 345 minutes; that is by adding all timings of sequential works:

$$T = 30+15+60+30+30+30+30+90+15+15 = 345 \text{ minutes.}$$

On the other hand, by taking maximum of parallel work, it was already minimized into **180** minutes. In other words, Cross member assembly, Frame assembly, welding each parts, grinding scraps, opposite side cross member strengthening can be done in parallel with Assemble different sides of plates, Grinding scrap parts, Welding skin covers, Grinding scraps, and Polishing.

$$T_1 = 30+15+60+30+30 = 165 \text{ minutes; } T_2 = 30 +30+90+15+15 = 180 \text{ minutes.}$$

$$\Longrightarrow (T1 = 165 > T2 = 180) \text{ minutes.}$$

Hence, it is optimized into **180 minutes** of average total time by taking Parallel works maximum spell. 180/60 = 3 hrs.

This shows frame alignment welding of five buses can be completed and again half of a buses' alignment can be started and partially finished in one day (16 hrs.).

4.2.2. Right side frame Assembly

Right side frames are assembled in this station. A total of 10 employees were assigned to fulfill the described work for one shift in 405 minutes and their distribution was seen in table 4.2.

Table 4. 2 Right side frame Assembly

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
primary welding (preparation of Rm)	A	1	28	29	30	33	30
Set the appropriate level	B	1	31	30	29	30	30
Checking time	C	1	30	29	30	31	30
Welding to appropriates	D	2	45	47	43	45	45
Grinding	E	1	60	61	60	59	60
Painting	F	1	30	32	30	28	30
Inside and out part Welding process	G	1	90	92	90	88	90
Inside and out part grinding	H	1	61	62	60	57	60
Inside and out part Painting	I	1	31	28	30	31	30

In the same manner, table 4.2, primary welding (preparation of Rm), Set the appropriate level, Checking time and Welding to appropriates as well as grinding operations takes about 195 minutes That is, T_{s2} = 30 +30+30+45+60 = 195 minutes.

These operations again can be processed in parallel with Painting, inside and out part welding process, Inside and out part grinding and Inside and out part Painting that can be accomplished within **210** minutes.

i.e. T_{s2} = 30 +90 +60+30 = 210 minutes. Now, 210 >195 minutes.

So, the thoroughgoing time needed to finish Right side frame Assembly of a bus is about 210 minutes.

210/60 = 3.5 hrs. Likewise, Right side frame of four buses can be assembled and again half of a buses' Right side frame Assembly can be started and partially finished within day.

4.2.3. Left side frame assembly

Typical time taken to accomplish relative components of one bus in station3 was 410 minutes working time and about 70 minutes idle time; i.e.; measured time to assemble left side Frame has taken nearby 480 minutes. This existed work done by fourteen (14) assigned employees.

Table 4. 3 Left side frame assembly balancing distribution

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
Outer part Raw material preparation	A	1	35	27	32	30	31
Set the appropriate level	B	1	29	28	31	28	29
Checking time	C	1	33	27	32	28	30
Welding to appropriately	D	2	79	77	80	76	78
Grinding	E	1	60	60	53	55	57
Painting	F	1	30	31	28	31	30
Inside outer part Welding	G	1	79	88	85	80	83
Inside outer part Welding	H	1	41	43	39	45	42
Painting	I	1	30	27	33	30	30

Once again there is an opportunity for the progressions like: Outer part Raw material preparation, Set the appropriate level, Checking time, Welding to appropriately have consumed total additional time of 168 minutes. And these progressions can be done in parallel with Grinding, Painting, inside outer part welding, inside outer part welding, inside outer part welding, inside outer part Welding and again Painting which comprises about 242 minutes; (Refer table 4.3). In this case, it is conceivable to take the maximum concentrated time which is **242** minutes.

4.2.4. Frontal frame assembly

Frontal frames are assembled by twenty one (21) assigned man power in this station and measured working time for the station was about 480 minutes. Out of which there was 108 minutes idle time.

Table 4. 4 Frontal frame assembly distribution

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
Left front frame	A	4	83	87	82	88	85
Right font frame	B	4	87	91	93	89	90
Assembling both	C	5	63	62	57	58	60
Board sheet metal cover	D	4	87	83	80	82	83
Finishing	E	3	56	60	52	48	54

In the same fashion as table 4.4 shows, Left front and Right front frames of **Frontal frame** can be assembled in parallel with assembling both, Board sheet metal cover and Finishing; As a result the supreme yield time to gloss these issues should be about **197** minutes. From table 4.4, the total possible time was 480 minutes and now it is optimized into 197 minutes.so, 283 minutes was idle time.

4.2.5. Rear frame assembly distribution

Rear frame is done by five operators in 480 minutes at station five.

Table 4. 5 Rear frame assembly

Work Sequence	Pred.	Mp	t1	t2	t3	t4	t
Select the material and put it on the jig	A	3	58	57	62	63	60
Welding	B	2	39	40	41	40	40
Grinding and finishing	C	1	31	30	29	30	30

From table 4.5, the total time needed to accomplish this work is **130** minutes. 350 minutes or about 6 is shiftless time. The overall time taken to finalize body and frame production line is given by:

$T_{bf} = T_{s1}+T_{s2}+T_{s3}+T_{s4}+T_{s5} = 180+210+242+197+130 = \mathbf{959}$ minutes; 959/60 = 15.98 hrs.

Now, the average time to accomplish all stations of body and frame production line is calculated as: 15.98/5 = 3.196 = 3.2 hrs. Per each station.

Line efficiency

E = 15.98 / (5*3.5225) = 90.73%

4.3. BAEI; Chassis line work flow

There are about seven dualistic stations in Chassis line.

Chassis line includes a total of 45 employees. These employers has explicitly been assigned for chassis production line.

Denote, the total time of a chassis line, 'T_c'; i.e., T_c = Summation time of Stations of chassis line

$$T_c = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7} = (320 +360+142+458+210+135+441) \text{ minutes}$$

T_c = **2066** minutes = **2066/60 =** 34.43 hours.

Since there was seven stations in chassis line, Average of time for this line was = 2066/7 = 295.14 minutes = 4.92 hrs. Each station of chassis line has spent about 4.92 hours to accomplish the given work. But, this was expected to be minimized into three and half hours. This also shows that, there must had been a fundamental reduction of time delay in chassis production line for the bus production to provide exigent and fast product yields. Accordingly, it is farther balanced with the help of grouped predecessors of sequential and parallel work elements.

Next tables' (table 4.6 – 4.12) shows detail data of each stations' processes delay time with their corresponding man power and resultant discussions in facet.

4.3.1. Axle assembly

Man power required per bus in a shift for Station one were 6, and their balanced distributon were given in line with their amount of time taken for axle assembly of one school bus again in one shift was 320 minutes. Note that, components which can assembled in parallel precedence were assigned by the same letter.

Table 4. 6 List of processes for Axle assembly

Work Sequence	Pred.	Mp	t1	t2	t3	t4	t.ave
front and rear axle to assemble	A	2	116	117	118	119	120
front and rear axle to assemble on chassis	A	3	90	90	90	90	90
Front and rear bracket Assemble on chassis	A	2	30	30	30	30	30

Rear differential Assemble with chassis	A	3	30	30	30	30	30
Front and Rear wheel Assembly	A	2	20	20	20	20	20
Front and Rear stopper Assemble on chassis	B	1	10	10	10	10	10
Rear and front pin bolt tighten	B	2	10	10	10	10	10
Rear and front guider bolt tighten	B	1	10	10	10	10	10

In chassis line, axle assembly, (table 4.6) has two groups of work; namely Group A and group B. The all-out or maximum expanse of time taken for group A was about 120 minutes. And for group B was 10 minutes. This shows, **130** minutes is enough to assemble axle assembly. That is by applying equation 2 rather than the previous consecutive working principles.

$T_{s1} = T_{A\,max} + T_{B\,max} = 120 + 10 = 130$ minutes. But, primarily it was 320 minutes.

So, this technique results on great minimization to the task time from 320 to 120 minutes.

4.3.2. Small parts assembly distribution

Allocated Man power per bus in a shift for Station two were 5, and the Amount of time taken for axle assembly of one school bus was about 360 minutes.

Table 4. 7 Small parts assembly

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t. ave
Tanker assembly	B	2	30	30	30	30	30
Valve assembly	D	1	50	50	50	50	50
Supporter on the tanker	A	2	40	40	40	40	40
All adapters assembly	B	2	55	55	55	55	55
Breather	B	1	15	15	15	15	15
Front and Rear Wing assembly	A	4	113	113	113	113	113
Stabilizer assembly Front and rear	C	2	53	53	53	53	53
Shock absorber assembly	C	2	53	53	53	53	53

Alternatively, there were four groups of work (see table 4.7) to bring together Small parts which vigor after axle assembly. Group A; Front and Rear Wing assembly can be done in parallel with Supporter on the tanker assembly takes maximum of **113** minutes. Group B also includes Tanker, Breather and All adapters' assembly; can be going on thorough **55** minutes. Again group C; Stabilizer assembly Front and rear as well as Shock absorber assembly can be finished within **53** minutes. Lastly, Group D, Valve assembly can be amassed in **50** minutes. Therefore the total time to combine small parts of station2 was calculated to give:

T_{s2} = (113 + 55 + 53 + 50) = **271** minutes.

When you compare with the previous, 360 -271 = 90 minutes variation.

4.3.3. Steering and AC line

Man power per one bus for Station three were assigned to be four in number (4); and the Amount of time taken for one school bus to assemble its Steering and AC line was 142 minutes. Look at table 4.8 which shows the work description of steering and Ac line.

Table 4. 8 Steering and AC line

Work Sequence	Pred.	Mp	t1	t2	t3	t4	t.ave
-Steering gear	B	2	15	35	15	30	24
-toroid	B	2	10	20	5	10	11
-pitman arm	B	2	5	15	3	10	8
-steering column gear	B	1	5	15	5	10	9
Shaft	B	1	5	15	5	10	9
steering Supporter	A	2	10	12	10	20	13
-Power steering oil tank	C	2	5	15	10	20	13
-Air tank	C	1	10	10	5	10	9
-Air dryer	B	1	5	10	5	10	8
Condenser	B	1	7	15	5	10	9
-High oil pressure hose	C	1	10	20	5	10	11
- Low oil pressure hose	C	1	10	20	5	10	11
AC Compressor	B	2	15	35	20	40	28
-Steering oil pump	A	1	20	40	20	40	30
-Pulley belt AC	C	2	35	80	30	60	51

Air dryer support	A	1	5	10	5	10	8
Condenser support	A	1	5	10	5	10	8
Steering column gear Supporter	A	1	10	20	5	10	11

Similarly, as table 4.8 shows, there were three groups of exertion in Steering and AC line which was prepared in station three. Applying equation 2; let's find out the maximum requirement of time to complete this station (Steering and AC line).

$T_{s3} = T_{A\ max} + T_{B\ max} + T_{C\ max}$; Ts3 = 30+28+51 = 109 min.

Observe that it was 142 minutes in the previous.

4.3.4. Installation of pipe

About seven technicians (man powers) were assigned to install various pipes of school bus in Station four. And the Amount of time taken to assemble one bus in this station was 458 minutes.

Table 4. 9 Installation of pipe

Work Sequence	Pred.	Mp	t1	t2	t3	t4	**t.**ave
Installation of galvanized pipe	B	2	80	60	80	60	70
Installation of fuel line pipe	A	1	60	60	60	60	60
Mounting of cooler system with pipe	B	1	30	30	30	30	30
Installation of front and rear flexible hose	B	1	20	20	20	20	20
Installation of front pipe	A	2	90	90	90	90	90
Installation of rear pipe	A	2	60	60	60	60	60
Mounting of galvanized pipe front and rear adapter	B	1	30	30	30	30	30
Installation of suspension system pipe	D	1	20	20	20	20	20
Precutting and ready to work front pipe	C	2	40	40	40	40	40
Precutting and ready to work rear pipe	B	2	30	30	30	30	30
Foot brake and hand brake adapter	B	1	15	20	15	20	18

In the same fashion taking crucial data from table 4.9, the thoroughgoing time invested in station 4 can be set up by taking equation2, i.e. $T_{s4} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max}$

$\Rightarrow T_{s4} = 90 + 70 + 40 + 20 = 220$ min. Now, 458-220 = 238 minutes.

Guise that, there is about 238 minutes variation from the previous one.

4.3.5. Chassis Engine line

Chassis Engine of a school bus has done by ten (10) operatives in 210 minutes.

Table 4. 10 Chassis Engine line

Work Sequence	Pred.	Mp	t1	t2	t3	t4	tave
Engine and gearbox ass	B	3	60	40	20	35	39
Chassis support (front and Rear)	A	2	30	20	10	15	19
Air filter	F	2	60	50	30	40	45
All upper hose ass	E	1	30	25	15	20	23
Muffler ass	C	2	30	40	5	10	21
All lower hose assembly	D	2	30	30	30	40	33
Clutch assembly	A	2	30	30	20	30	28
Front and Rear engine support Assembly	B	2	30	30	15	20	24
Engine and chassis integrate	B	4	30	30	15	20	24
Tightening of front and rear Chassis assembly	B	1	60	40	10	15	31
Muffler chassis support assembly	E	2	17	21	10	16	16
Exhaust pipe Assembly	E	2	26	27	23	24	25
Tail pipe assembly	D	1	10	10	5	10	9
pulley assembly	C	1	20	20	10	15	16
Fun assembly	D	1	20	20	5	10	14
Radiator bracket guider assembly	E	2	10	10	10	15	11
Sherwood assembly	D	2	30	30	5	5	18
Radiator Chassis support assembly	C	1	10	10	5	5	8
Radiator and cooler assembly	C	2	30	30	15	20	24
Radiator coup assembly	D	1	10	15	10	15	13
Radiator and Chassis assembly	C	2	60	60	30	35	46
Air intake pipe assembly	D	1	30	20	10	15	19
All air and water assembly	F	2	30	30	15	20	24

Deforester and compressor adapter assembly	G	2	20	20	10	15	16

The table above (table 4.10) gives the detail work flow data of Chassis engine line.

Likewise inserting equation two into the given table 4.10, maximum yield time required to accomplish chassis engine line can be calculated as:

$$T_{s5} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} + T_{E\ max} + T_{G\ max}$$

$$\Rightarrow T_{S5} = 28+39+24+33+40+45+16 = 225 \text{ minutes.}$$

Remind that, No change is made to this station. This is because of its safe work descriptions.

4.3.6. Installation of chassis harness

Chassis harness of a school bus has completed by six (6) machinists in 135 minutes.

Table 4. 11 Installation of chassis harness

<table>
<tr><th>Work SequenceA8A88:J104</th><th>Pred.</th><th>Mp</th><th>t1</th><th>t2</th><th>t3</th><th>t4</th><th>t.ave</th></tr>
<tr><td>Main harness, ABS harness and Retarder harness assembly</td><td>A</td><td>6</td><td>40</td><td>40</td><td>40</td><td>40</td><td>40</td></tr>
<tr><td>-ECU harness</td><td>A</td><td>1</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>Retarder control harness</td><td>A</td><td>1</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td></tr>
<tr><td>-Battery ground</td><td>B</td><td rowspan="8">5</td><td rowspan="8">40</td><td rowspan="8">40</td><td rowspan="8">40</td><td rowspan="8">40</td><td rowspan="8">40</td></tr>
<tr><td>-Engine ground</td><td>B</td></tr>
<tr><td>-Starter wire</td><td>A</td></tr>
<tr><td>-Alternator wire</td><td>A</td></tr>
<tr><td>-Alternator ground</td><td>A</td></tr>
<tr><td>-Engine additional wire</td><td>B</td></tr>
<tr><td>starter cover</td><td>A</td></tr>
<tr><td>-Mounting alternator with engine</td><td>A</td></tr>
<tr><td>-Hand brake sensor</td><td>C</td><td rowspan="3">2</td><td rowspan="3">15</td><td rowspan="3">15</td><td rowspan="3">15</td><td rowspan="3">15</td><td rowspan="3">15</td></tr>
<tr><td>air pressure sensor</td><td>C</td></tr>
<tr><td>-Low pressure sensor</td><td>C</td></tr>
</table>

Fuel float sensor	C	1	5	5	5	5	5
Heat cover	C	1	5	5	5	5	5

In the same case, table 4.11 above perceived well. Here, Chassis harness was taking about 135 minutes, but now, let's find out the preferable working time to finish this station, chassis harness installation

$$T_{s6} = T_{A\ max} + T_{B\ max} + T_{C\ max}$$

$$\Longrightarrow T_{s6} = 40+40+15 = 95 \text{ minutes.}$$

Notice that there is good reduction of time in this section. (135 -95 = 40 minutes minimized).

4.3.7. Retarder & Drive shaft assembly

About seven Hands were given to accumulate Retarder & Drive shaft assembly. This task was ended in 441 minutes.

Table 4. 12 Retarder & Drive shaft assembly

Work Sequence	Pred.	Mp	t1	t2	t3	t4	tave
Retarder assy.	A	2	20	40	30	60	38
Retarder chassis assy.	B	4	30	60	40	140	68
Marsh cable	B	1	20	40	20	40	30
Servo pipe	B	1	20	40	20	40	30
Tire holder	B	2	15	30	20	40	26
propeller shaft	B	5	60	180	165	180	146
Filter	C	2	15	30	10	20	19

The supreme timing of the last station (retarder and drive assembly) was also calculated in such a way that; from the given table above, (table 4.12) spread on equation 2 gives:

$$T_{s7} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} + T_{E\ max} + T_{G\ max}$$

$$\Longrightarrow T_{s7} = 38+146+19 = 203 \text{ minutes.}$$

So, 441 – 203 = 238 minutes variation.

From these seven stations, the total time to finalize chassis line can be calculated to stretch the following value:

$$T_c = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}$$

$$\Longrightarrow T_c = 130+271+220+225+95+203 = \mathbf{1253} \text{ minutes} = 20.88 \text{ hrs.}$$

Since it was 2066 minutes previously; then,

2066 – 1253 = 813 minute. So, great reduction of working time (about 813 minutes) is sanctioned to chassis line.

Now, the average time to fix specific work for a given station of chassis line is planned to be responsible for:

$$T_c = 1253/7 = 179 \text{ minutes} = 3 \text{ hrs. Per each station.}$$

$$\text{Line efficiency; } E = 20.88 / (7*3.5225) = 84.69\%.$$

4.4. BAEI; Body production line Work flow

The Aggregate or total time 'T' which was registered to complete each process of every Stations in body line had set to be:

$$T = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}+T_{S8}+T_{S9}+T_{s10}$$

$$\Longrightarrow T = (270+270+328+295+290+400+233+275+285+240) \text{ minutes;}$$

$$\Longrightarrow T = \mathbf{2886} \text{ minutes.}$$

Hence, Average of time taken to accomplish each station for body production line = 2886/10 = 288.6 min. = 4.81hrs; which is approximately 5 hrs. Per bus. This shows that three busses can be assembled in a day. But this must again be upgraded into five buses.

Remember that, components which can assembled in parallel precedence were assigned by the same letter. Let's see each station one by one. Figure 6 below, displays the partial view of body production line:

4.4.1. Frame alignment welding

Body frames are aligned in this station. A total of 14 personnel were assigned to fulfill the described work for one shift in 270 minutes.

Table 4. 13 Frame alignment welding

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
Floor	A	5	98	95	93	97	96
Side hole	B	4	101	103	97	99	100
roof alignment	C	5	60	62	56	67	61

As you can see from table 4.13, there is no parallel work in frame alignment welding so the total time for tis station will be calculated to give the summation of all respective operations. That is, $T_{s1} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 96+100+61 = 257$ minutes. But, not that there is about 13 minutes idle time simply.

4.4.2. Side hole welding, roof with side wall, alignment side hole

Seven (7) personals are assigned to fix Side hole welding, roof with side wall, alignment side hole; and they accomplished this work within 270 minutes. Keep an eye to table 4.14 below:

Table 4. 14 Side whole welding, roof with side wall, alignment side hole

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
U channel	A	5	120	90	180	150	135
firm alignment	B	4	90	60	120	90	90
Display sit front and Rear re-enforcements	C	4	120	90	120	90	105

Similar to station one, this station of Side hole welding, roof with side wall, alignment side hole has only sequential works, so its total time will be:

$$T_{s2} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 135+90+105 = 330 \text{ minutes.}$$

In this case, some internal components can partially be done in parallel at a time. But here, for the sake of quality production, it is better to go for straight fore warred step by step assembly. That is the cause for why 330 minutes is greater than that of the previous production system, 270 minutes.

4.4.3. Floor partition welding

Assigned man power to assemble floor partition were nine (9). A total of about 328 minute's time has taken here. For farther clarification let you see next table 4.15 below:

Table 4. 15 Floor partition welding

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t. ave
floor welding	B	2	60	50	90	85	71
-engine welding	B	1	40	45	40	45	43
u-channel	B	1	35	30	35	30	33
-drive door frame	B	2	45	40	60	55	50
-welding floor portion RHS & U	B	1	55	50	80	70	64
-Chassis -welding	A	1	55	55	90	85	71
pipe welding	B	1	35	30	15	10	23
Grinding	C	1	30	25	15	10	20
Roof welding	D	5	150	120	210	180	165
Painting	D	1	15	15	10	10	13
Cutting Support pipe	B	1	35	25	10	75	36

There are four groups of work to assemble floor partition. Involving equation 2 into this section:

$$T_{s3} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max}$$

$$\Longrightarrow T_{s3} = 71+71+20+165 = 327 \text{ minutes;}$$

Which is the same with the previous production time.

4.4.4. Sealed board welding

About 10 man powers were assigned here; and they accomplished sealed board welding within 295 minutes. Look at table 4.16 to abate the production time.

Table 4. 16 Sealed board welding

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
L-shaped angle iron	A	4	45	55	40	50	48
-right sealing angle iron	A	4	60	35	55	45	49
-side sealing panel	A	4	60	55	60	55	58
-step sealing panel	A	2	25	25	25	25	25
-left corner s.p	A	2	25	15	25	15	20
L- pipe welding	A	2	35	20	35	20	28
Driver chair fix	A	2	40	45	40	45	43
Inner rear sheet metal welding	A	2	30	25	30	25	28

As you shown the above data in table 4.16, all components of sealed board welding can be done alternatively and paralleled. Meaning that it is able to finalize this graft within 58 minutes.

$$T_{s4} = T_{A\ max} = 58 \text{ minutes.}$$

This shows that, sealed board welding can be accomplished within 58 minutes, almost an hour.

Now, 295 -58 = 237 minutes idle time. This result was computed by grouping similar work descriptions into one and minimized by rejecting the sequential operations.

4.4.5. Ceiled Board assembly (CLD)

Nine (9) labors were assigned to assemble ceiled board and total time taken was 240 minutes.

Table 4. 17 Ceiled Board assembly

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
-Engine cover	A	2	78	79	75	76	77
-r/l sheet metal	A	4	89	92	91	88	90
-Luggage cover	B	2	79	86	77	90	83
Roof angle	B	2	58	61	59	62	60

Likewise, from the given table, (table 4.17) there are two groups of work in CLD assembly; namely, group A and B. Applying equation two in to this gives:

$T_{s5} = T_{A\ max} + T_{B\ max} = 90 + 83 = 173$ minutes 240 – 173 = 67 minutes idle (reduced) time.

4.4.6. Fender & step down fender

A total of ten (10) hands or personnel were assigned here to assemble Fender and step down fender in the interior 400 minutes. See next table 4.18:

Table 4. 18 Fender & step down fender

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t ave
Step rear and front	A	2	35	40	35	30	35
Wheel cover	A	2	35	40	30	35	35
Inner floor sheet metal	A	1	25	30	20	25	25
Mud guard	A	1	30	35	30	35	33
Left and right hungers	A	2	35	40	35	40	38
Battery bon	A	2	40	45	40	45	43

Similar to station four of this line, as it is prearranged in table 4.18, all components of fender and step down fender can be done alternatively and in parallel.

$$T_{s6} = T_{A\ max} = 43 \text{ minutes.}$$

You can notice that 400- 43 = 367 minutes was extra time in this section.

4.4.7. Fender & step down fender Driver compartment & passenger door welding

There were about eight (8) hands to carry out Fender & step down fender Driver compartment & passenger door welding 233 minutes.

Table 4. 19 Fender & step down fender Driver compartment & passenger door welding

Work Sequence	Predecessor	**Mp**	**t1**	**t2**	**t3**	**t4**	**t ave**
-driver door	A	2	120	60	120	60	90
-half left & right edge=6	B	1	60	60	60	60	60

-pin left & right =12	B	1	50	40	50	40	45
-left & right side frame=8	A	3	60	40	60	50	53
-bolt =13	B	2	60	38	60	40	50
Emergency door	B	2	90	90	90	90	90
Box frame	A	1	50	40	50	40	45
Compartment door left side	C	2	60	70	60	70	65
Passenger door	C	3	109	111	108	112	110

Fender & step down fender Driver compartment & passenger door welding includes three group of work (table 4.19) and its total time taken can be calculated as:

$$T_{s7} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 90 + 90 + 110 = 290 \text{ minutes.}$$

Perceive that 290 minutes is greater than 233 minutes. Once again this is because of quality consideration during fabrication.

4.4.8. Skill cover welding

Total man power 12 and total time taken (min): 225 minutes

Table 4. 20 Skill cover welding

Work Sequence	Predecessor	**Mp**	**t1**	**t2**	**t3**	**t4**	**t ave**
R/L frame welding (door frame)	C	1	50	50	50	50	50
Left and Right side sheet metal welding	A	8	210	210	210	210	210
Oil door welding	B	2	40	40	40	40	40
Sponge mask and Renting postiche	C	1	20	20	20	20	20

In this position (table 4.20), there was a probability to take part three groups of work, Group A, B, and C. Once again spread on equation two here, gives:

$T_{s8} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 210+40+50 = 300$ minutes. Note that 300 minutes is higher than 235 minutes. But, it is mandatory to take 300 minutes to go through eminence production system.

4.4.9. Front and rear cup cover

Total man power assigned for this section, (table 4.21) was 12, and the total time taken was 285 minutes.

Table 4. 21 Front and rear cup cover

Work Sequence	predecessor	**Mp**	**t1**	**t2**	**t3**	**t4**	**t ave**
All mirror frame	B	1	10	10	10	10	10
Front and Rear welding	A	4	120	120	120	120	120
Rear cup cover welding	B	3	60	60	60	60	60
Grinding and painting	D	2	30	30	30	30	30
Bummer welding	C	3	40	40	50	50	45

Front and rear cup cover is done by four corresponding groups of operations; Groups A, B, C, and D. Comprising equation 2 in this section will gives:

$$T_{s9} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 120+60+30+50 = 250 \text{ minutes.}$$

(285 – 250 = 35 minutes) is commercially savable time.

4.4.10. Integrating body with chassis

To integrate body with chassis, a total of 9 man power: are needed. And they can accomplish it contained by 240 minutes. Grasp table 4.22 below and apply equation 2 to compromise this issue:

Table 4. 22 Integrating body with chassis

Work Sequence	predecessor	**Mp**	**t1**	**t2**	**t3**	**t4**	**t ave**
pamper welding and tighten	A	4	61	58	59	60	60
-Door key welding and tightening	C	1	55	53	51	57	54
Engine door welding	A	4	69	65	62	61	64
Remark and grinder	B	4	78	75	79	76	77
Painting	D	1	41	40	42	39	41

There is an availability to clutch or group the integrating mechanism of body with chassis; in to four groups. That means, groups A, B, C, and D was needed to integrate body with chassis.

$$T_{s10} = T_{A\,max} + T_{B\,max} + T_{C\,max} + T_{D\,max} = 64+77+54+41 = 236 \text{ minutes.}$$

Four minutes has saved here during body and chassis integration.

Now, lets' discover the total variation in between the previous working cycle time of body production line with respect to the latest one:

Remember that, the total time to get done bring out body production line was, 2886 minutes.

But, the newly intended production time was calculated to give:

$$T_b = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}+T_{S8}+T_{S9}+T_{s10}$$

$$\Rightarrow T_b = 236+250+300+290+43+173+58+327+330+257 = \mathbf{2264} \text{ minutes}$$

$$\Rightarrow T_b = 2264/60 = 37.73 \text{ hrs.}$$

$$\Rightarrow T_b = 3.77 \text{ hrs. Per each station.}$$

Note that, 2886 – 2264 = minutes being saved.

Line efficiency; E = 37.73 / (10*5) = 78.44%

4.5. BAEI; BPF; School bus, Final line work flow

There were about nine stations in final line; figure 7 shows over view of this line. Basic operations of final production line were; Air conditioner Assembly, Ply wood, Roof decoration, Mirror assembly, Floor mate assembly, General component, Door assembly, Passenger seat and handrail as well as Electrical components Assembly.

Do not miss that, components which can assembled in parallel precedence were assigned by the same letter.

Rundown of every Stations working time “T” to finish each process of final line were

$$T = Ts1+Ts2+T_S3+T_S4+T_S5+T_S6+T_S7+T_S8+T_S9$$

$$\Longrightarrow T = (320+230+270+235+252+360+480+260+360) \text{ min.}$$

$$\Longrightarrow T = \mathbf{2767} \text{ minutes.}$$

Since there was nine stations in this line, Average of time taken to accomplish each station for final line is calculated as:

$$T_{ave} = 2767/9 = 307.44 \text{ minute} = 5.12 \text{ hrs.}$$

Figure 6 Final production line

4.5.1. Air Conditioner (AC) Work

Man power (Mp) to complete air conditioner was 12 and the total time taken (t) was 320 minutes. The work flow distribution is stated in table 4.23 below:

Table 4. 23 Integrating body with chassis

Work Sequence	predecessor	Mp	t1	t2	t3	t4	tave
1.Air conditioner assembly	A	3	50	50	50	50	50
2 battery assembly	C	2	45	45	45	45	45

3. high and low pressure pipe	A	2	25	25	25	25	25
4. AC harness pipe with hose	B	3	15	15	15	15	15
5. water dry hose	B	1	10	10	10	10	10
6. Air refrigerant	D	2	10	10	10	10	10
7. AC Fuse	B	1	10	10	10	10	10
8.all accessory mudguard,	C	2	20	20	20	20	20
9.Engine cover ,	C	2	30	30	30	30	30
10.spooky hole	B	2	40	40	40	40	40

Four groups of predecessor were available in station one of final line (table 4.23). Using equation 2: $T_{s1} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} = 50+40+45+10 = 145$ minutes.

Now, 320 – 145 = 175 minutes distinction left.

4.5.2. Ply wood

Allowance man power for ply wood assembly were 10 and they had finished ply wood of four buses with in average of 230 minutes in the previous. Look at table 4.24 to verify the alternative.

Table 4. 24 Ply wood

Work Sequence	predecessor	Mp	t1	t2	t3	t4	tave
1.Play wood prepare	A	9	194	194	194	194	194
2.inner roof prepare ,	B	3	32	32	32	32	32

From table 2.24, using equation 2; $T_{s2} = T_{A\ max} + T_{B\ max} = 194+32 = 226$ minutes.

When you compare this value from the previous, 230 – 226 = 4 minutes can be saved wisely.

4.5.3. Roof Decoration

Similarly, total man power to décor roof was 21 labors and is done in 270 minutes.

Table 4. 25 Roof Decoration

Work Sequence	predecessor	Mp	t1	t2	t3	t4	tave
-roof harness	A	3	60	60	60	60	60

-gage harness	A	2	20	20	20	20	20
-wind guarded	B	3	30	30	30	30	30
-roof decoration	B	6	180	180	180	180	180
- roof lamp	C	2	30	30	30	30	30
-speaker	C	2	30	30	30	30	30

From table 4.25, $T_{s3} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 60+180+30 = 270$ minutes.

This value is the same with the previous one. In other words, it is better to go through the prior working situation.

4.5.4. Mirror assembly

About fourteen employers has been employed for mirror assembly to finish in 235 minutes. Let's compare that with the give values in table 4.26:

Table 4. 26 Mirror assembly

Work Sequence	predecessor	Mp	t1	t2	t3	t4	tave
1.Side mirror assembly	C	9	90	90	90	90	90
2.Front mirror assembly	D	4	22	22	22	22	22
3.Celli glass	C	5	61	61	61	61	61
4.Curtain frame	E	3	46	46	46	46	46
5. Pre pair	A	3	25	25	25	25	25
6. Celli gas pre pair	B	4	28	28	28	28	28
7. Front celli gas	D	2	42	42	42	42	42

From table 4.26, Using equation 2; the latest crucial time has been calculated to give

$$T_{s4} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} + T_{E\ max} = 25+28+90+42+46 = 231 \text{ minutes.}$$

Compare contrast this value with the previous gives: 235 – 231 = 4 minutes.

4.5.5. Floor mate assembly

Here, a total of 18 labors has been distributed to assemble floor mate in 252 minutes.

Table 4. 27 Floor mate assembly

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
1. side decoration assembly	A	5	60	100	70	80	78
2.glass frame assembly	B	4	55	70	60	50	59
3.hole cover assembly	F	2	5	5	5	5	5
4.glue painting	D	2	10	10	10	10	10
5, Stack painting	D	2	10	10	10	10	10
6. Floor mat ass.	E	5	80	80	80	80	80
7. Frame ass.	E	3	60	60	50	50	55
8. Frame molding	F	1	10	10	10	10	10
9. Lather preparation	C	4	20	20	10	10	15

$T_{s5} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} + T_{E\ max} + T_{F\ max} = 78+59+15+10+80+5 = 247$ minutes.

But, since it was primarily 252 (see table 4.27) minutes, alternatively, the change is; about 5 minutes

4.5.6. General component

In this case there were eighteen (18) technicians to assemble general components in final line. This process has done in 360 minutes. Let s compare the value by taking table 4.28 in to consideration:

Table 4. 28 General component

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
1. dash board	B	2	90	120	90	120	105
2. All electrical switch assy.	C	2	85	90	85	90	88
3. deforester	B	1	90	80	90	80	85
4. sun visor	B	1	15	10	15	10	13
5. rear view mirror	B	2	10	10	10	10	10
6. fuse box electrical	C	2	60	85	60	85	73

7. driver handle cover	C	2	45	50	45	50	48
8. safety hammer	C	2	60	60	60	60	60
9. fire extinguisher	C	1	10	10	10	10	10
10. water gutter	D	1	60	60	60	60	60
11. hand brake	C	1	5	10	5	10	8
12. air cutting valve	C	1	10	10	10	10	10
13. front grille	E	2	90	60	90	60	75
Gear box cover	C	2	90	120	90	120	105
14. dash board cover	B	1	80	90	80	90	85
15. front side décor and side frame	A	2	100	110	100	110	105
16. brake pedal	A	2	90	120	90	120	105
17. acceleration pedal	A	2	90	110	90	110	100
18. shim block	A	2	90	110	90	110	100
19. Driver plate	A	2	90	110	90	110	100
20. Steering column cover	A	2	90	110	90	110	100
21. Spooky left and right	C	2	105	120	105	120	113
22. First head	C	1	50	90	50	90	70
23. Internal spooky	B	1	30	40	30	40	35
24. Marsh leveler	B	1	60	85	60	85	73
25. Clutch pedal	A	1	60	80	60	80	70
26. Engine Cover lock	B	1	30	50	30	50	40
27. Fork Exchanger	C	1	40	47	40	47	44
28. Dash board sticker	B	2	100	110	100	110	105
29. Explosion tank	A	1	50	70	50	70	60
30. Frisian pose	D	1	30	40	30	40	35
31. Air cover	D	1	40	30	40	30	35

$T_{s6} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} + T_{E\ max} = 105+105+113+60+75 = 458$ minutes.

For the sake of safety, it is better to take the final average timing, 458 minutes.

4.5.7. Door Assembly

Doors assembly had required 12 man power to finish in 480 minutes of a total time taken.

Table 4. 29 Door Assembly

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
1. door frame and Rubber	A	3	90	90	90	90	90
2. door frame cover	B	2	90	90	90	90	90
3. Door assy.	A	2	120	120	120	120	120
4. emergency valve	B	2	60	60	60	60	60
5. door adjustment	C	2	150	150	150	150	150
6. Side compartment	B	2	30	30	30	30	30
7. Back door lock	A	2	90	90	90	90	90

From the table above, (table 4.29), applying equation two; the newly required time be;

$$T_{s7} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 120 + 90 + 150 = 360 \text{ minutes.}$$

In this case about 120 minutes being saved. That is 480 – 360 = 120 minutes vary.

4.5.8. Passenger seat and handrail

A total of seventeen (17) man power were assigned to assemble passenger sit and handrail and total of about 260 minute's time has taken here. For farther clarification let you see next table 4.30 below:

Table 4. 30 Passenger seat and handrail

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
1. curtain	A	2	60	80	90	150	95
2. handrail	A	8	90	105	120	150	116
3. passenger seat	B	7	240	280	210	300	258
4. driver seat	B	1	30	50	60	90	58

$$T_{s8} = T_{A\ max} + T_{B\ max} = 116 + 258 = 374 \text{ minutes.}$$

In this situation, was better to go through the previous working principles.

4.5.9. Electrical components Assembly

Entirely assigned man power = 9 and mean time taken: t. ave. = 360 minutes. (Table 4.31)

Table 4. 31 Electrical components Assembly

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
1. CCTV camera	B	2	30	60	30	60	45
7. MDVR	C	1	30	60	30	60	45
8. CCTV monitor	C	1	20	30	20	30	25
9. stop light	A	1	15	30	15	30	23
10. Head lamp	B	2	40	60	40	60	50
11. Tail lamp	A	2	30	60	30	60	45
12. Front fog lamp	A	1	10	20	10	20	15
13. Rear fog lamp	A	1	10	20	10	20	15
14. Marker lamp	A	2	30	60	30	60	45
15. Front and rear display	A	1	15	30	15	30	23
16. Wiper ass.	A	2	45	90	45	90	68
17. Stop	A	1	40	90	40	90	65
18. Fire Extinguisher	A	1	10	40	10	40	25
19. horn	C	1	10	30	10	30	20
20. Refrigerator	C	1	5	10	5	10	8
21. Side turn signal	B	1	10	20	10	20	15

$$T_{s9} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 68+50+45 = 163 \text{ minutes.}$$

Once again, it was decided to apply 360 minutes to have tangible qualified product safely.

Now, lets' find out the overall discrepancy of time between the previous and newly presented time requirement to accomplish final line

First, it is better to find out the total constraint of time to finalize the newly introduced working condition.

$$\Rightarrow T_f = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}+T_{S8}+T_{S9}$$

$\Rightarrow T_f$ = 163+374+360+458+247+231+270+226+145 = **2474** minutes = 41.23 hrs.

$\Rightarrow$ 41.23/9 = 4.58 hrs. Per each station on final line.

Nut, previously, final line was done in **2767** minutes. Comparing these values:

2767 – 2474 = 293 minutes being saved.

Line efficiency; E = 41.23 / (9*5.124) = 89.4%.

4.6. BAEI; BPF; School bus, Painting and polishing line flow

Total time of all Stations activities during painting production line:

$$\Rightarrow T = Ts1+Ts2+T_S3+T_S4+T_S5+T_S6+T_S7$$

$$\Rightarrow T = (180+390+390+120+60+160+100) \text{ min.}$$

$\Rightarrow$ T = **1400** min.

Henceforth, the Consistent of time for painting production line = 1400/7 = 200 min. = 3.33 hrs.

Here, four buses can completely assembled in this line besides an additional of one bus is started and partially finished. Farther more, this line must be balanced later.

Bear in mind that, components which can assembled in parallel precedence were assigned by the same letter.

Look at figure 8 below:

Figure 7 partial view of painting and polishing line

4.6.1. Primary

Here, a total of 20 labors has been distributed to assemble floor mate in 180 minutes.

Table 4. 32 Primary

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Glue	A	5	20	20	30	30	25
Cleaning	B	15	120	120	90	90	105
Primary paint	C	4	40	40	50	50	45
Drying room	D	---	60	60	60	60	60

From table 2.32, $T_{s1} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} = 25+105+45+60 = 235$ minutes.

Comparing this result from the intended production system; it is mandatory to go for 235 minutes.

4.6.2. Putty

Total man power: 20 Total time taken (min): 390 min look at table 4.33 below:

Table 4. 33 Putty

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Putty	A	20	330	330	350	350	340
Drying room	B	--	60	60	60	60	60

$T_{s2} = T_{A\ max} + T_{B\ max} = 340+60 = 400$ minutes, ten minutes maximized.

4.6.3. Normal putty polishing

Over-all man power assigned to polish normal putty were 17 and the time taken to complete this exertion was 390 minutes. Look at table 4.34 below:

Table 4. 34 Normal putty polishing

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Normal putty polishing	A	17	40	40	50	50	45
Putty correction	B	7	60	60	120	120	90
Drying room	C	-	40	40	40	40	40
Putty correction polishing	D	7	20	20	15	15	18

$T_{s3} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} = 45+90+40+18 = 193$ minutes.

Now, 390 – 193 = 193 minutes being hold back.

4.6.4. Middle coat

Aggregate man power for middle coat were 20 and the mean time were 120 min

Table 4. 35 Middle coat

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Middle coat	B	5	50	50	40	40	45
Cleaning	A	15	30	30	25	25	28
Drying room	C	----	40	40	40	40	40

Table 4.35 shows, a number of three sequential works during middle coat painting with respect to their intended manpower as well as the average mean time required to accomplish that work.

$$T_{s4} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 28+45+40 = 113 \text{ minutes.}$$

In this case, 120 -113 = 7 minutes already hoarded or saved

4.6.5. Final polishing

Final polishing activity needed about 17 man powers and has been finished within 60 minutes.

Table 4. 36 Final polishing

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Final polishing	A	17	50	60	50	60	55
Putty correction	B	6	10	15	10	15	13

You can compare contrast the results from the given distribution in table 4.36, involving equation 2;

That is, $T_{s5} = T_{A\ max} + T_{B\ max} = 55+13 = 68$ minutes.

So, (68 > 60) minutes; at this juncture, it is compulsory to take 68 minutes.

4.6.6. Painting

Over-all, ten (10) man power were apportioned for painting in this line; and they accomplished this work 160 minutes. For further clarification let you stare at table 4.37 below;

Table 4. 37 painting

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Cleaning	A	15	40	30	40	30	35
Painting	B	4	60	60	60	60	60
Drying room	C	---	60	60	60	60	60

As you have seen above; table 4.37, we can find out the total requirement to time to finish painting by using equation 2:

$$T_{s6} = T_{A\ max} + T_{B\ max} + T_{C\ max} = 35+60+60 = 155 \text{ minutes.}$$

160 – 155 = 5 minutes idle time had to be saved.

4.6.7. External painting

Total man power involved in external painting were 15 personals and a total of 100 minutes time was taken here. See table 4.38 below:

Table 4. 38 External painting

Work Sequence	predecessor	Mp	t1	t2	t3	t4	t ave
Cover painting	A	10	60	60	60	60	60
Painting	B	3	40	40	40	40	40

From above data, (table 3.38) using equation 2 the total requirement of time for this station be: $T_{s7} = T_{A\ max} + T_{B\ max} = 60+40 = 100$ minutes; which is same with the previous time constraint. Now, the total time prerequisite to varnish painting and polishing line which is the summation of timing of all stations is calculated as follows:

$$\Longrightarrow T_p = T_{s1}+T_{s2}+T_{S3}+T_{S4}+T_{S5}+T_{S6}+T_{S7}$$

$$\Longrightarrow T_p = 100+155+68+113+193+400+235 = \mathbf{1264} \text{ minutes} = 21.06 \text{ hrs.}$$

$\Longrightarrow T_p$ = 3 hourrs per each station on painting and polishing production line.

Observe that, there is a great difference on necessity of time to finish painting and polishing production line between the aforementioned and the cutting-edge one:

That is, 1400 – 1264 = 136 minutes preserved.

Line efficiency; E = 21.06 / (7*3.5225) = 85.41%.

4.7. BAEI; bus production Factory; School bus, Adjustment line Detail data

Adjustment and over all checkups were held in this line. Figure 9 below shows the partial view of adjustment line.

Over-all time of each operations of every Stations for adjustment line

$$\Longrightarrow \quad T = Ts1+Ts2 = (120+270) \text{ min.} = \mathbf{390} \text{ min.}$$

Ordinary of time for adjustment line = 390/2 = 195 min. = 3.25 hrs.

Figure 8 Adjustment line

Next tables sows the detail balanced distribution of every operational work stations

4.7.1. Adjustment

Allotted man power (Mp) = 18. Aggregate time taken (t) = 90 minutes. Look at table 4.39 below;

Remember, components which can assembled in parallel precedence were assigned by the same letter.

Table 4. 39 Adjustment

Work Sequence	predecessor	Mp	t1	t2	t3	t4	Average

							time (tave.)
Clutch adjustment	A	2	30	20	50	40	35
Radiator (Water and other coolants filling)	B	2	18	22	40	50	33
Marsh Adjustment	A	2	19	21	47	53	35
Tire assembly	B	4	30	30	30	30	30
Fuel filling	A	2	40	40	40	40	40
Stirring oil filling	B	1	3	3	3	3	3
Fuel filter connection	A	3	15	15	15	15	15
Motor start	B	3	10	10	30	40	23

Remember equation two, $T_{s1} = T_{A\ max} + T_{B\ max} = 40+33 = 77$ minutes.

90 – 77 = 13 minutes can easily be saved in this station.

4.7.2. Over all checkup and adjustments

Dispersed man power: = 18, And Full time taken previously = 180 minutes. Next table 4.40 shoes the flow distribution of works:

Table 4. 40 Over all checkup and adjustments

Work Sequence	Predecessor	Mp	t1	t2	t3	t4	t.ave.
Intake and exhaust system	A	2	30	45	31	46	38
Engine area	A	1	15	30	15	32	23
Lubrication system	B	1	16	22	15	23	19
Brake check up	B	1	2	3	1	2	2
Clutch check up	B	1	15	30	17	30	23
Shift select adjustment	B	1	15	23	16	22	19
power system	B	2	31	38	30	37	34
Cooling system	B	2	15	23	16	22	19
Electric system	A	2	30	38	31	37	34
Steering system	C	2	8	15	9	16	12

Pneumatic system	A	2	15	23	16	22	19
Body check up	A	1	15	30	16	31	23
Rain test a	D	3	30	38	31	37	34
Driving road test Abs checkup, Retarder checkup, Oil leakage, Bolt and nut checkup, Km/hr, Steering angle checkup, gauges checkup, Ac checkup, Noise of engine, Marsh check up	E	4	30	60	30	60	45

$$T_{s2} = T_{A\ max} + T_{B\ max} + T_{C\ max} + T_{D\ max} + T_{E\ max} = 38+34+12+34+45 = 163 \text{ minutes.}$$

$$\Longrightarrow T_a = T_{s1} + T_{s2} = 77+163 = \mathbf{240} \text{ minutes} = 4 \text{ hrs.}$$

$$\Longrightarrow T_{a\ ave} = 2 \text{ hrs. For each station.}$$

Note that, in the previous it was 390 minutes; so, 390 – 240 = 150 minutes set aside.

Line efficiency; E = 4 / (2*3.3.25) = 61.54%.

4.8. Summary of Results on analysis of BAI, BPF; and other allied Factories productivity

The result of this study shows that, there was an aptitude to develop a systematic approach to attain a smart production; by means of correct balancing system of assembly lines. Distinctly, it had enabled to upgraded production rate of the case company bus production factory from two busses into four and half busses per day. Let's see following table to clarify the result:

Table 4. 41 Results of productivity rate

Lines	Tools (Machines)	No. of stations	time taken to finish all stations (Min.)	Average time per station (Min.)
Body and	Welding instruments and various types of	5	(T_{bf}) = 959	192

Frame production line	electrodes, jigs and fixtures			
Chassis line	Pneumatic and Allen key wrench, open wrench, box wrench, …flat screw, hammer, special tools, combination wrench	7	$(T_c) = 1253$	179
Body production line	Cutter disc125=2, grinder, disc180=2, shield=4, nozzle=1, Teflon=1, Tip=1, torch=1, Shield=4	10	$(T_b) = 2264$	227
Final line	Drill, pneumatic, Allen key, jigsaw machine, grinder machine, rivet gun, position gun, combination.	9	$(T_f) = 2474$	275
Painting	Painting and polishing instrumental rooms air conditioners	7	$(T_p) = 1264$	181
Adjustment	Various Adjusting tools, speed and lights testing machines, Rain test class,	2	$(T_a) = 240$	120

The Cumulative time of every stations is now calculated to give smart composition of well-balanced lines in such a way that:

$$\Rightarrow T_{tot} = \sum t = T_{bf} + T_c + T_b + T_p + T_a + T_{f.}$$

$$\Rightarrow \sum t = 959+1253+2264+2474+240+1264 = \mathbf{8454} \text{ minutes}$$

$$\Rightarrow \sum t = 8454/60 = \mathbf{140.9} \text{ hrs.}$$

Total number of currently enduring stations = 5+7+10+7+9+2 = **40** stations.

The rate of durable production (R) can be calculated as the rate of total time of production with respect to the entire amount of stations.

$$\Rightarrow R = 8454 \text{ min}/40 \text{ stations.} = 211.35 \text{ minutes/St.} = \mathbf{3.5225\ hr.\ /St. = 3.5225\ hr.\ /bus.}$$

Note that, this value is the production rate of time for each stations. This shows that, one bus can be finished within 3.5225 hrs.' in each station of the production lines. Meaning that, Production rate of the case company and other related manufacturing industries can be promoted to deliver four and half (4.5422) buses with in a day. Accordingly, Global discussion and results of the profound method displays, it is bright to avail a drastic modification (birr 191,979.62 *2.54 = 487,628 profit per day) variation on productivity of the case company and other related manufacturing industries. This shows, productivity oriented Assembly Line Balancing of the case company and other virtual manufacturing industries can be upgraded by the pre stated techniques.

4.9. Cycle time

Cycle time is the maximum time needed to produce a unit of bus at a station which is the inverse of desired output rate.

Desired output rate of the overall production is the rate of durable production per time taken.

Hence, **r = 3.5225 /16 hrs**. = 0.2202 unit of bus per hr.

So now, the cycle time can be premeditated as

$$\Longrightarrow C = 1/0.2202 = 4.542 \text{ hr. /unit.}$$

Where, r = Desired output rate of production.

C = Cycle time, the maximum time needed to produce a unit of bus at a station.

Theoretical minimum (number of stations required)

The theoretical minimum is a bench mark or goal for the smallest number of stations possible

$$\Longrightarrow TM = \frac{\sum t}{c} = \mathbf{140.9} \text{ hrs. / } 4.542 = 31.02\text{; say, 32 stations.}$$

The result of this study shows that, there was an aptitude to develop a systematic approach to attain a smart production; by means of correct balancing system of assembly lines. Distinctly, it had upgraded to line of attack production rate of the case company bus production factory from two busses into a minimum of four and half busses per day which was done by minimizing the cycle time.

4.10. Line Efficiency

Efficiency can be defined as the state or quality of being able to accomplish something with the least waste of time and effort. Efficiency in this research is calculated to give the ratio of the total timings of all tasks (stations) to the product of the number of total work stations and cycle time.

$$\Rightarrow \text{Efficiency} = \text{summation of task times} / (\text{work stations}^* \text{ cycle time})$$

$$\Rightarrow E = 140.9 / (40*4.542) = 140.9 / 181.689 = 77.55\%.$$

Remember that there had been a big variation on the efficiency in the previously stated ALB methods of the given journals. But, efficiency of the newly intended productivity Oriented ALB paper had already been upgraded into 77.55 %. Note that, this result is highly efficient than that of the previous research based ALB methodologies.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The basic concern of this paper was to solve a query dealing with how to minimize the cycle time and pass through well-defined assembly line balancing methods to maximize the productivity of BAI and other allied bus production manufactories. A total of forty stations in three factories of the case company; bus production factory, body and frame production factory as well as polishing production factories had been considered in this research. About 514 required operators were distributed correspondingly to assemble one bus in a shift. Balanced distributions of the work elements with respect to their timings and employers were given in the form of tables. Heuristic methods with the help of grouping parallel work descriptions and mathematical modelling and Excel was used to answer the ALB concern. Availability of producing three and half (3.5225) buses per day have also been perceived in the case company; on the other hand, it was two buses per day at the beginning. Meaning that, there was a variation of one and half buses assembly per a day. This resulted on 75.55% efficiency. Accordingly, a profit of about four hundred eighty seven thousand six hundred twenty eight (191,979.62 * 2.54 = 487,628) Birr can be saved by applying the exploration in place of the case company and other related manufacturing industries production system. This enquiry paper has done with great consideration of quality product, cycle time minimization and efficiency approval. As a result, capability of applying these methods enables to solve associated industries incident by place in relative standards or numbers.

5.2. Recommendation

The company postponements to import raw materials from its allied companies. For instance starting from May 15 up to June 30 – 2018, for one month and two weeks there was no raw material, no more other engagements; meanwhile, the company was idle all over from work. Because the raw materials was late. Definitely, this results on minimal of the company’s profit. Subsequently, it is highly recommended for the case company, and other linked manufacturing industries to full fill strategic plan of pre and post production undertakings. But then again, to coup its vision, mission and values, it is better for the company to have its own balanced assembly line during production. It is also recommended to acquaint with this paper work into central activities of their assembly lines. BAI; the case company, and correlated supplementary enterprises must also have to upgrade the learning curve of their internal labor efforts to gain excessive yield on their rate of production. Once again it is recommended for these companies to introduce robotic and just in time system of production to reward great throughput.

5.3. Future works

- How to minimize the number of personals, work stations and the global safety of production making an allowance for cost and quality of manufacture functionally?
- How to integrate assembly line balancing system with Just in time production spectacles?
- How to simulate and introduce accurate assemblage system in to blatant manufacturing industries of the modern biosphere?

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