

EFFICIENCY IMPROVEMENT OF ASSEMBLY LINE:  
CASE STUDY OF BUS SEAT MANUFACTURER

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## **ABSTRACT**

In this era of globalization, competition is becoming ever more intense. Manufacturing companies must not only compete locally but also on a global basis. Reducing manufacturing costs without sacrificing product quality is vital for the survival of manufacturing companies in a global market. With the increasing of market competition, the line balancing problem especially the assembly line balancing plays an important role for the industries to obtain the high quality and lowest cost. Assembly line plays a critical role in enabling a factory to deliver on time and at the right quantity and quality. This project main purpose is to assist in making an assembly line more efficient and productive through improving its line efficiency. The focus is on a bus seat assembly line. A manufacturing company faces difficulties in delivery on time. The core cause is the inefficiency of assembly line in the bus seat manufacturer. Therefore, the study will concentrate on manufacturer's problem, which is efficiency of assembly line balancing for VIP seats. This research will attempt to overcome the problem by balancing its line and improved its efficiency. It also involves minimizing the number of stations and minimizing the balance delay time (sum of idle time).

## **ABSTRAK**

Dalam era globalisasi ini, persaingan menjadi semakin sengit. Syarikat pembuatan bukan sahaja perlu bersaing di pasaran tempatan tetapi juga di peringkat antarabangsa. Mengurangkan kos pengeluaran tanpa mengorbankan kualiti produk adalah penting untuk menyelamatkan syarikat-syarikat pembuatan di pasaran antarabangsa. Dengan peningkatan persaingan pasaran, masalah keseimbangan barisan terutama pengimbangan barisan pemasangan memainkan peranan yang penting bagi industri untuk mendapatkan kualiti yang tinggi dan kos terendah. Barisan pemasangan memainkan peranan penting dalam membolehkan sebuah kilang untuk menyiapkan produk pada masa dan kuantiti yang betul serta kualiti. Tujuan utama projek ini adalah untuk membantu dalam menghasilkan barisan pemasangan yang lebih cekap dan produktif melalui peningkatan kecekapan barisan. Tumpuan adalah pada barisan pemasangan kerusi bas. Sebuah syarikat pembuatan menghadapi kesukaran dalam menyiapkan produk pada masa yang tepat. Punca utama adalah ketidakcekapan barisan pemasangan dalam pengeluaran kerusi bas. Oleh itu, kajian ini akan menumpukan perhatian kepada masalah, pengilang yang merupakan kecekapan mengimbangi barisan pemasangan untuk kerusi bas VIP. Kajian ini akan cuba untuk mengatasi masalah ini dengan mengimbangkan barisan pengeluaran dan meningkatkan kecekapan barisan tersebut. Ia juga melibatkan mengurangkan bilangan stesen dan meminimumkan masa kira-kira kelewatan (jumlah masa terbiar).

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## LIST OF EQUATIONS

- 2.1 **Average observed time**  

$$= \frac{\text{Sum of the times recorded to perform each element}}{\text{Number of observations}}$$
- 2.2 **Normal time**  

$$= (\text{Average observed time})(\text{Performance rating factor})$$
- 2.3 **Standard time**  

$$= \frac{\text{Total normal time}}{1 - \text{Allowance factor}}$$
- 2.4 **Cycle time**  

$$= \frac{\text{Production time available per day}}{\text{Units required per day}}$$
- 2.5 **Theoretical minimum number of workstation**  

$$= \frac{\text{Total task time}}{\text{Cycle time}}$$
- 2.6 **Line efficiency**  

$$= \frac{\text{Total task time}}{(\text{Actual number of workstation})(\text{Largest assigned cycle time})}$$

## LIST OF SYMBOLS AND ABBREVIATIONS

AL	Assembly line
ALB	Assembly line balancing
ALBPs	Assembly line balancing problems
CT	Cycle time
d	Balance delay
Dd	Daily production
DLBPs	Disassembly Line Balancing Problems
DTS	Direct Time Study
Dw	Daily working hour
E	Efficiency
GALBP	General assembly line balancing problem
K-W	Kilbridge and Westers method

LCR	Largest Candidate Rule
LFT	Least Following Tasks
LOT	Longest Operation Time
M	No. of workstation
MAL	Methods of Assembly Line
MALBP	Mixed model assembly line balancing problem
MFT	Most Following Tasks
MSP	Mixed model sequence problem
NT	Normal Time
POM	Production and Operation Management
PU	Polyurethane
QM	Quantitative Methods
RPW	Ranked Positional Weights Method
SALBP	Simple assembly line balancing problem
SALBP-E	Simple assembly line balancing problem – Efficiency

SALBP-F	Simple assembly line balancing problem – Feasibility
SOT	Shortest Operation Time
ST	Standard Time
TC	Cycle Time
TNT	Normal Time
TST	Standard Time
TTS	Total Station Time
UALBP	U-line assembly line balancing problem
WS	Workstation
$W^*$	Workstation

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.0 Introduction**

According to Mikell P. Groover (2007), the word manufacture is derived from two Latin words “manus” (hand) and “factus” (make). The English word manufacture is several centuries old, and “made by hand” accurately described the fabrication methods that were used when the English word “manufacture” was first coined around 1567 A.D. Most modern manufacturing operations are accomplished by mechanized and automated equipment that is supervised by human workers.

Manufacturing can be defined in two ways, which are technology and economy. For technology, manufacturing is the application of physical and chemical processes to alter the geometry, properties, and appearance of a starting material to make parts or products. Economically, “manufacturing is the transformation of materials into items of greater value by means of one or more processing and/or assembly operations” (Mikell P. Groover, 2007). Manufacturing will add value to the material by changing its shape or properties, or by combining it with other materials. Manufacturing is the industry that consists of enterprises and organizations that produce or supply goods and services. Industries can be classified as primary, secondary, and tertiary. Primary industries cultivate and exploit natural resources, e.g., farming, mining, any natural resources. Secondary industries take the outputs of primary industries and convert them into

consumer and capital goods. Tertiary industries constitute service sector-like post, telephone, or government sectors.

Manufacturing processes can be divided into two basic types, which are processing operations and assembly operations. A processing operation transforms a work material from one state of completion to a more advanced state that is closer to the final desired product. It adds value by changing the geometry, properties, or appearance of the starting material. In general, processing operations are performed on discrete work parts, but some processing operations are also applicable to assembled items. An assembly operation joins two or more components in order to create a new entity, called an assembly, subassembly, or some other term that refer the joining process. Components of new entity are connected either permanently or semi-permanently. Permanent joining processes include welding, brazing, soldering, and adhesive bonding. Mechanical assembly methods are available to fasten two or more parts together in a joint that can conveniently disassembled.

## **1.1 Background of the study**

In this era of globalization, competition is becoming ever more intense. Manufacturing companies must not only compete locally but also on a global basis. Reducing manufacturing costs without sacrificing product quality is vital for the survival of manufacturing companies in a global market. The automotive part industry is not spared from the effects of globalization. The local Malaysian automotive part manufacturers are faced with this tough competition as the selling price is not much different from foreign brands especially with the implementation of the ASEAN Free Trade Area (AFTA). Demand for foreign bus seats will probably soar; more so for bus seats that are assembled locally as the cost becomes cheaper. Increasing productivity will be important to ensure survival of the numerous players in the automotive part sector. Late delivery of bus seats can cause companies to lose customers as well as resulting in dissatisfaction.

With the increasing of market competition, the line balancing problem especially the assembly line balancing plays an important role for the industries to obtain the high quality and lowest cost. According to Bhattacharjee T. K. (1988), an assembly line

consists of a sequence of stations performing a specified set of tasks repeatedly on consecutive product units moving along the line at constant speed. “Assembly Line Balancing (ALB) problem is to determine the allocation of the tasks to an ordered sequence of stations such that each task is assigned to exactly one station, no precedence constraint is violated, and some selected performance measure is optimized like minimize the number of stations” (Ponnambalam, S.G. Aravindan, P. and Naidu G. M., 2000).

## **1.2 Problem statement**

Assembly line plays a critical role in enabling a factory to deliver on time and at the right quantity and quality. This project main purpose is to assist in making an assembly line more efficient and productive through improving its line efficiency. The focus is on a bus seat assembly line. According to the production manager of a bus seat manufacturer (Personal communication, August 21<sup>st</sup>, 2012), the manufacturing company faces difficulties in delivery time issue. The core cause is the inefficiency of assembly line in the bus seat manufacturer. In this line, majority of the production workers manually sews and built the seat. Customers’ choices of patterns and color also affect the flow of the assembly line. In local bus industry, they have several types of seats provided by the bus seat company such as commercial seats, VIP seats, and VVIP seats. The design will be change accordingly each type is of different sizes and frames as required by the customers. All this procedures will cause the process of assembly line to become rigid and laborious. The study will concentrate on manufacturer’s problem, which is efficiency of assembly line balancing for VIP seats. This research will attempt to overcome the problem by maximizing the productivity as well as efficiency. It also involves minimizing the number of stations and minimizing the balance delay time (sum of idle time).

### **1.3 Research question**

1.3.1 What is the current line efficiency rate of each method for assembly line in bus seat manufacturer?

1.3.2 What is the optimized method that can provide efficient line for assembly line of this bus seat manufacturer?

### **1.4 Research objective**

1.4.1 To determine the efficiency of the assembly line in bus seat manufacturer.

1.4.2 To propose the optimum efficiency of assembly line in bus seat manufacturer.

### **1.5 Scope of the study**

The study scope will involve a bus seat manufacturing factory in Telok Gong, Port Klang, Selangor. It will focus on the efficiency of assembly line and make improvement to the line efficiency through the line balancing process. The study will concentrate on manual line of assembly line and only VIP seat will considered in this study. The study will use Direct Time Study (DTS) method and Methods of Assembly Line (MAL) to obtain the final result.

### **1.6 Significance of study**

Based on the research objectives, the final result will help the company solve the inefficiency of assembly line. Production Manager will receive the optimized line efficiency of assembly line and implement it into the production line. It also helps the bus

seat manufacturer improve their assembly line with optimum workstation as well as optimized line efficiency.

## **1.7 Summary**

For a bus seat manufacturer, efficiency of assembly line is very important especially for their daily production. Assembly line balancing will help the company solve existing problem with inefficiency of assembly line and five methods of assembly line system which will be introduced on Chapter 2.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 Introduction**

This chapter explore and provide information about line balancing. The information comes from literatures, journals and thesis. The literature review structure of this chapter is as shown in Figure 2.1. These sections are mainly concern about knowledge in Line Balancing. Manufacturing company has become very important and the area selected is a manual assembly line and it is focus on its efficiency. In the middle part of the literature reviews, detailed explanation regarding terminology of assembly line balancing, classification of assembly line balancing problems, line balancing, types of assembly line, methods of assembly line, work measurement, and efficiency.

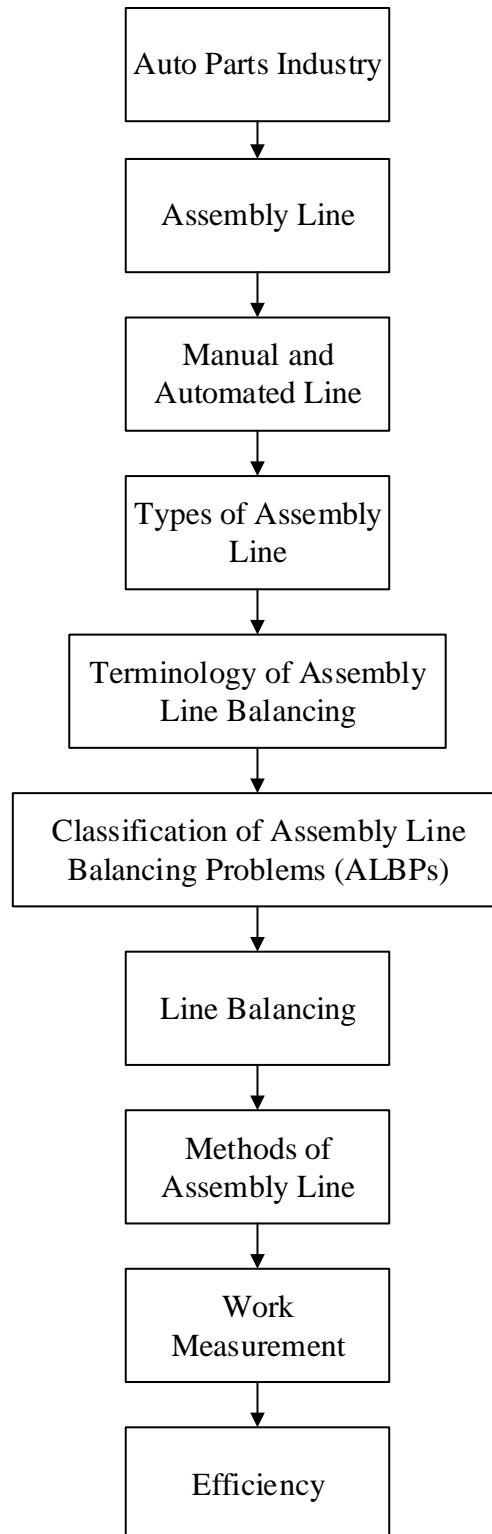


Figure 2.1: Literature review structure

## **2.1 Auto parts industry**

According to Economy Watch (2010), auto parts industry in Malaysia is a booming industry which encompasses areas of activities from car manufacturing to dealing with auto business with foreign countries. Auto parts industry in Malaysia is one of principal producers and exporters of vehicle parts, components and accessories, which are widely accepted to most of the leading countries of world. Foreign countries like Japan, UK, Thailand, Taiwan, Singapore, Indonesia, are major importers of Malaysian auto parts. Leaders of automotive manufacturing companies like Mercedes, Suzuki, Ford, General Motors, Mazda, Nissan and Mitsubishi are using Malaysian automotive products and accessories such as seats, springs, and absorbers because of their high quality and competitive prices.

Market survey conducted by Business Times, reveals that during 2007, sales of Malaysian vehicle reached 487,176 units with an overall growth of 13.8% and is expected to increase in coming years. During period of slowdown, government of Malaysia surmounted other competitive economies by controlling inflation and eventually kept costs down. In year 2000, Malaysian auto industry exported US\$274.2 million worth of automotive parts.

## **2.2 Assembly line**

According to Becker and Scholl (2006), assembly lines are flow oriented production systems which are still typical in the industrial production of high quantity standardized commodities and even gain importance in low volume production of customized products. Among the decision problems which arise in managing such systems, assembly line balancing problems are important tasks in medium-term production planning.

According to Becker and Scholl (2006) again, an assembly line consists of work stations arranged along a conveyor belt or a similar mechanical material handling equipment. The jobs are consecutively launched down the line and are moved from station to station. At each station, certain operations are repeatedly performed regarding the cycle



time (maximum or average time available for each work cycle). The decision problem of optimally partitioning (balancing) the assembly work among the stations with respect to some objective is known as the assembly line balancing problems (ALBPs). Manufacturing a product on an assembly line requires partitioning the total amount of work into a set of elementary operations named tasks. Performing a task takes a task time and requires certain equipment of machines and skills of workers. Due to technological and organizational conditions precedence constraints between the tasks have to be observed. These elements can be summarized and visualized by a precedence graph.

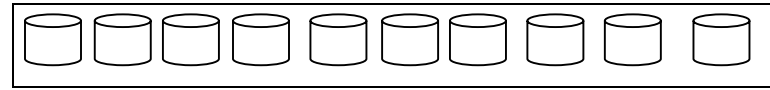
Scholl (1999) originally define assembly line as “assembly lines were developed for a cost efficient mass production of standardized products, designed to exploit a high specialization of labor and the associated learning effects”. Under the term assembly line balancing (ALB) various optimization models have been introduced and discussed in the literature, which are aimed at supporting the decision maker in configuring efficient assembly systems. “Subsequent works however, more and more attempt to extend the problem by integrating practice relevant constraints, like u-shaped lines, parallel stations or processing alternatives” (Becker and Scholl, 2006).

### **2.2.1 Types of assembly line layout**

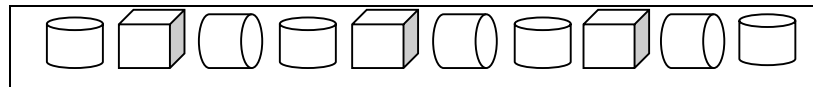
According to Sumichrast and Russel (1990), if only one product is assembled, all jobs are identical and a single-model line is present. If several products or models are manufactured on the same line, the ALBPs is connected to a sequencing problem which has to decide on the sequence of assembling the model units. The sequence is important with respect to the efficiency of a line, because the task times may differ considerably between the products.

“A mixed-model line produces the units of different models in an arbitrarily intermixed sequence” (Bukchin, 2002), whereas a multi-model line produces a sequence of batches (each containing units of only one model or a group of similar models) with intermediate setup operations. The different line types are characterized in Figure 2.2, where different models are symbolized by different geometric shapes. Depending on these

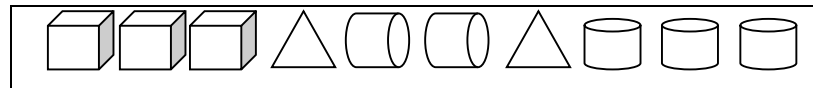
line types, single-model, mixed-model and multi-model versions of ALBPs have to be considered and solved.



a. Single-model line



b. Mixed-model line



c. Multi-model line

Figure 2.2: Types of assembly line layout

According to Scholl and Klein (1999), the layout of flow-line production systems is partially predetermined by the flow of materials. Nevertheless, some layout possibilities exist. Traditionally, an assembly line is organized as a serial line, where single stations are arranged along a straight conveyor belt. Such serial lines are rather inflexible and have other disadvantages which might be overcome by U-shaped assembly line. Both ends of the line are closely together forming a rather narrow “U”. Stations may work at two segments of the line facing each other simultaneously (crossover stations). Besides improvements with respect to job enrichment and enlargement strategies, a U-shaped line design might result in a better balance of station loads due to the larger number of task-station combinations.

According to Geoffrion and Graves (1976), further improvements in flexibility and failure sensitivity of an assembly line system may be achieved by introducing some type of parallelism. In a multi-model context installing complete parallel lines each

designed for one product or family of related products often allows better balances and increased productivity. Then the ALBPs is accompanied by the additional decision problems concerning the number of lines to be installed and assigning products and work forces to lines. Even with a single line the advantages of parallelization can be utilized by installing parallel stations such as the work pieces are distributed among several operators who perform the same tasks. As is the case with parallel lines, the equipment has to be installed several times. “Parallel stations allow the reduction of the global cycle time of the system if certain tasks have task times longer than the desired cycle time” (Buxey, 1974). “Another possibility of reducing the global cycle time below the largest task time is the concept of parallel tasks” (Inman and Leon, 1994). Respective tasks are assigned to several stations of a serial line which cyclically perform them completely on different jobs.

## **2.3 Manual and automated line**

### **2.3.1 Manual line**

In spite of the major advances in the automation of assembly processes, there are still many assembly systems which mainly or completely rely on manual labor. According to Abdel-Malek and Boucher (1985), manual lines are especially common, where work pieces are fragile or if work pieces need to be gripped frequently, as industrial robots often lack the necessary accuracy. In countries where wage costs are low, manual labor can also be a cost efficient alternative to expensive automated machinery.

So far, “The level of cohesiveness of a task set has been roughly measured by the number of direct precedence relationships between included tasks” (Agrawal, 1985). According to Shtub and Dar-El (1989), the lack of motivation and the low level of satisfaction, which is typically caused by the high repetitiveness of elementary operations, have been considered as a major disadvantage of assembly production. It is therefore desirable to assign packages of cohesive tasks to workers, like the total assembly of a particular product option. “Task times under manual labor are often subject to stochastic

deviations, as the performance of human workers depends on a variety of factors, like motivation, work environment or the mental and physical stress” (Tempelmeier, 2003).

According to Carnahan (2001), the physical and psychological stress an operator has to face can be modeled as additional node weights in the precedence graph. To each task a certain stress indicator is assigned, which may not exceed or fall below a certain total level over all tasks assigned to a worker. Another major factor influencing manual labor is the individual experience of a worker. That is why learning effects gain a special importance in manual labor as they might result to dynamic task times.

Due to their complexity and the problems in quantification it is questionable whether a detailed consideration of all mentioned aspects leads to meaningful ALB models. Another characteristic aspect of manual labor might be more easily utilized, which is the unmatched level of flexibility. Operators of adjacent stations might for instance support each other in case of an overload. This can be directly exploited by certain line layouts, like the “U-line” (Miltenburg and Wijngaard, 1994) or “n-U line” (Miltenburg, 1998). In such a line both wings are positioned close to each other to form a rather narrow U, so that workers can carry out tasks on both wings in the same production cycle.

### **2.3.2 Automated line**

According to Scholl A. (2006), fully automated lines are mainly implemented wherever the work environment is in some form hostile to human beings, as for instance in the body and paint shops of the automobile industry, or where industrial robots are able to perform tasks more economically and with a higher precision such as metal processing tasks. The higher precision of machines typically justifies the assumption of deterministic task times. If only specialized machinery (each task requires his own machine or tool) is employed, very little other particularities such as space restrictions arise merely from the fact that machines carry out tasks. However, the increasing differentiation of products, which share the same line, gives rise to flexibility even in automated assembly systems. This leads to flexible transfer lines where multipurpose machines with automated tool swaps can

perform a number of different tasks at varying speed. Due to the high investment costs of universal machinery, the objective of cost minimization considerably gains in importance.

## **2.4 Types of assembly line**

An assembly line and corresponding ALBPs are multifaceted and they also provide variation of problem accordingly.

### **2.4.1 Paced line**

According to Scholl A. (2006), in case of a paced assembly line, the station time of every station is limited to the cycle time (CT) as a maximum value for each job. Since tasks are indivisible work elements, CT can be no smaller than the largest task time. Due to the cycle time restriction, paced assembly lines have a fixed production rate (reciprocal of the cycle time). In a paced assembly production system typically a common cycle time is given which restricts process times at all stations. The pace is either kept up by a continuously advancing material handling device like a conveyor belt, which forces operators to finish their operations before the job has reached to the end of the respective station, or by a so called intermittent transport, where the job comes to a full stop at every station, but is automatically transferred as soon as a given time span is elapsed. If the transportation of jobs is continuous, station lengths need to be defined in accordance with the line balance. The length of a station might be subjected to technical restrictions such as space requirements of assigned machinery, but should also be considered from a planning point of view. If the length of a station (multiplied by the movement rate of the line) exceeds the cycle time, the resulting extra time can be used to compensate for deviations in task times either due to a mixed-model production or caused by stochastic variations. Accordingly, the cycle time should not always be observed strictly at a station. In the case of stochastic task times it is sufficient to fulfill the cycle time restriction with a certain probability.

### 2.4.2 Buffered line

“In the absence of a common cycle time like all stations operate at an individual speed, jobs may have to wait before they can enter the next station or stations may get idle when they have to wait for the next job” (Malakooti, 1994). These difficulties are partially overcome by buffers between the stations. In this case of a buffered or un-paced assembly line, the ALBPs is accompanied by the additional decision problem of positioning and dimensioning buffers.

## 2.5 Terminology of assembly line balancing

In assembly line balancing system, there are various term normally used. Each of them has their meaning and purposes. According to Rekiek in Springer Handbook Series in Advanced Manufacturing: Assembly Line Design (2006), there are several common terms found in assembly line balancing system was shown in Table 2.1.

Table 2.1: Terminology of assembly line. (Rekiek, 2006)

Terms	Definition
Tasks	This is a portion of the total work content in an assembly process. The necessary time to perform task is called the task process time. Tasks are considered invisible and they cannot be split into smaller work elements without unnecessary additional work.
Task precedence	The sequence or order in which tasks must be performed. Precedence of each task is known from a listing of tasks that must immediately precede it.
Task times	The amount of time required for a well-trained worker or unattended machine to perform a task. Task times are usually expressed in minutes.

Table 2.1 (Continued)

Cycle time	The time in minutes between products coming off the end of a production line.
Workstation	Physical location where a particular set of tasks is performed. Workstation is usually of two types: a manned workstation containing one worker who operates machines and/or tools, and an unmanned workstation containing unattended machines like robots.
Number of workstation working	The amount of work to be done at a work center expressed in number of workstations.
Minimum number of workstation	The least number of workstation that can provide the required production.
Actual number of workstations	The total number of workstations required on the entire production line.
Utilization	The percentage of time that a production line is working.
Lead Time	Summation of production times along the assembly line.
Bottleneck	Delay in transmission that slow down the production rate. This can be overcome by balancing the line.
Precedence	It can be represented by nodes or graph. In assembly line the products have to obey this rule. The product can't be move to the next station if it doesn't complete at the previous station. The products flow from one station to the other station.
Idle time	A period when system is not in used but is available.
Line Efficiency	The measurement of the capacity utilization of the line. The idle capacity is reflected by the balance delay time.

## 2.6 Classification of assembly line balancing problems

Scholl and Becker (2006) have detailed out the classification of assembly line balancing problems. They have classified the main characteristics of assembly line balancing problems and considered several constraints and different objectives as shown in Figure 2.3. Simple ALBP is a simple and straight single product assembly line and General ALBPs is a generalized and removed some assumptions from Simple ALBPs.

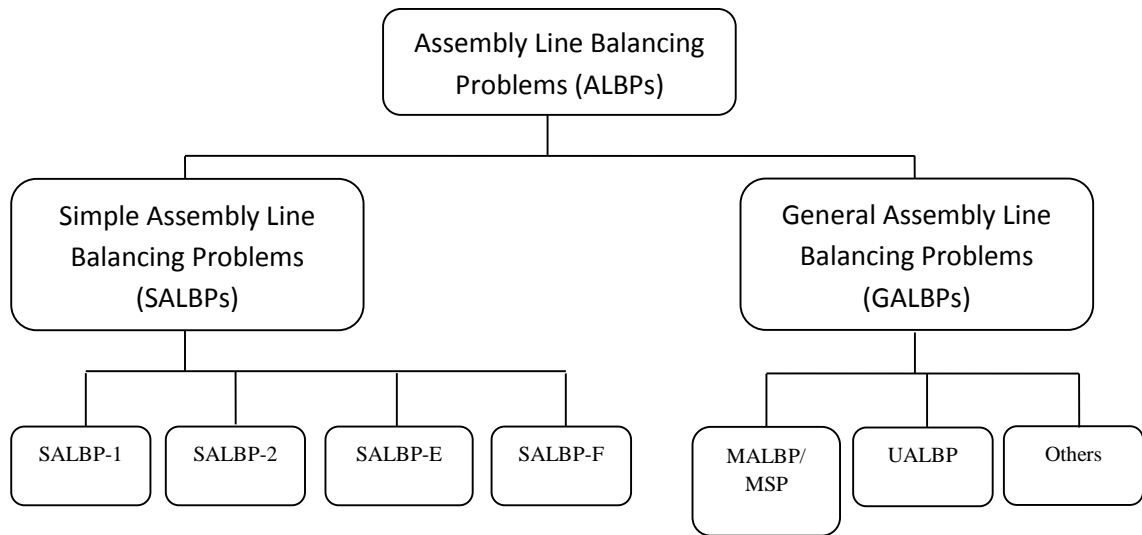


Figure 2.3: Classification of assembly line balancing problems (Scholl and Becker, 2006).

Table 2.2: Types of Assembly Line Balancing Problems (Scholl and Becker, 2006).

Types of ALBPs	Definition
SALBP	The simple assembly line balancing problem is relevant for straight single product assembly lines where only precedence constraints between tasks are considered.
SALB-1	This problem consists of assigning tasks to work stations such that the number of workstation (M) is minimized for a given production rate (fixed cycle time, CT).



Table 2.2 (Continued)

SALBP-2	This problem is to minimize cycle time (maximize the production rate) for a given number of workstation (M).
SALBP-E	This is the most general problem version maximizing the line efficiency (E) thereby simultaneously minimizing CT and M considering their interrelationship.
SALBP-F	This is a feasibility problem which is to establish whether or not a feasible line balance exists for a given combination of M and CT.
GALBP	In the literature, all problem types which generalize or remove some assumptions of SALBPs are called generalized assembly line balancing problems (GALBPs). This class of problems (including UALBP and MALBP) is very large and contains all problem extensions that might be relevant in practice including equipment selection, processing alternatives, assignment restrictions.
MALBP/ MSP	Mixed model assembly lines produce several models of a basic product in an intermixed sequence. Besides the mixed model assembly line balancing problem (MALBP), “which has to assign tasks to stations considering the different task times for the different models and find a number of stations and a cycle time as well as a line balance such that a capacity- or even cost-oriented objective is optimized” (Scholl, 1999). However, “the problem is more difficult than in the single-model case, because the station times of the different models have to be smoothed for each station” (Merengo, 1999). The better this horizontal balancing works, the better solutions are possible in the connected short-term mixed model sequencing problem (MSP). “MSP has to find a sequence of all model units to be produced such that inefficiencies (work overload, line stoppage, off-line repair etc.) are minimized” (Scholl, 1998).

Table 2.2 (Continued)

UALBP	The U-line balancing problem (UALBP) considers the case of U-shaped (single product) assembly lines, where stations are arranged within a narrow U. As a consequence, worker is allowed to work on either side of the U, i.e. on early and late tasks in the production process simultaneously. Therefore, modified precedence constraints have to be observed. By analogy with SALBP, “different problem types can be distinguished” (Scholl and Klein, 1999).
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## 2.7 Line balancing

Line balancing is an important tool to decrease production time, maximizing the output or minimizing the cost of a product. In other word, line balancing is one of the important aspect to the design stage for flow-line production systems (Martinich J.S, 1997).

In line balancing the important data is the details of the process flow and the cycle time at each workstation. The classical line balancing problem consists of assigning each task to a workstation such that the number of workstations are minimized and precedence constraints are satisfied. The sum of time for all operations of this workstation must not exceed the given cycle time. The difference between the cycle time and workstation time is called idle time. The balance delay time can only be minimal if the number of workstation is minimum. The dual problem are minimization of the cycle time for a given number of workstations.

Improving bottleneck workstation is the main objective the line balancing tool. To achieve the objective, the cycle time data at each workstation need to be taken in making the analysis. There are number of parameters that can be balanced at the workstations which are balance by time, balance by work content, balance material, and balance by inventory. Balance by time is referring to the cycle time of the workstation. In this term one need to utilize time study method for data collection. All the time that is

involved in the operation will be taken. After that a certain amount of allowance is given to the operation especially for the manually operated workstation.

The second parameter that can be balanced is the work content. Some workstations are balanced perfectly and should be left alone. Work content at others will need to be shifted around or taken out of its original sequence. New ways of operation will be created to make the line flow properly. Balancing by work content must utilize the knowledge and experience of operators and engineers.

Material is one the parameter that can be balanced. Example of this method can be referred to the individual work elements, focus to outsized parts that requires large workstation. Although in the ideal state, operators should stay in their workstations without having to leave for any reason, it may be necessary to allow time for lifting parts or a little walking to retrieve them from bins. Small bits of waste like these will remain in the operation for a while.

The last parameter that can be balance is inventory. While excessive inventory is waste, having some inventory can help in line balancing. To balance by inventory, the new design of the space a workstation to allow an operator to work on more than one unit.

Line balancing can be done in two methods, traditional and simulation. In the traditional method it will involve some algorithms to define the problem. In the modern world, simulation are used to define the problems and automatically solve the problem with the line balancing. Although there are different methods in line balancing tool but both of this method requires the same data collection process.

According to H. Jay and R. Barry (2008), line balancing is common technique to solve problems in assembly line. Line balancing is a technique to minimize imbalance between workers and workloads in order to achieve required cycle time. This can be done by equalizing the amount of work in each station and assign the smallest number of workers in the particular workstation. Line balancing operates under two conditions:

i. Precedence Constraint.

Products cannot move to other stations if it does not fulfill required task at that station. It should not skip stations because certain tasks need to be done before others according to the set sequence.

ii. Cycle time Restriction

Cycle time is maximum time for products spend in every workstation. Different workstation has different cycle time.

### **2.7.1 Objectives of line balancing**

Line balancing technique are used to:

- i) Manage the workloads among assemblers.
- ii) Identify the location of bottleneck.
- iii) Determine number of workstations.
- iv) Reduce production cost.

### **2.8 Methods of assembly line**

According to Heizer Jay & Render Barry (2008), they are five types of assembly line methods to calculate line efficiency for an assembly line.

### 2.8.1 Largest Candidate Rule (LCR)

It is a heuristic procedure which arranged work elements for assignment to stations according to longest operation time among the total amount of tasks.

Procedure:

Step 1: List all elements in descending order of task time value, largest task time at the top of the list.

Step 2: To assign elements to the first workstation, start at the top of the list and work done, selecting the first feasible element for placement at the station. A feasible element is one that satisfies the precedence requirements and does not cause the sum of the task time value at station to exceed the cycle time, CT.

Step 3: Repeat step 2.

Example for Largest Candidate Rule (LCR)

Step 1: Arrange work element based on LCR as shown below:

Table 2.3: Work elements arranged based on Largest Candidate Rule (LCR)

Work Element	Task Time (minutes)	Immediate Predecessor
3	0.7	1
8	0.6	3,4
11	0.5	9,10
2	0.4	---
10	0.38	5,8
7	0.32	3
5	0.3	2
9	0.27	6,7,8

Table 2.3 (Continued)

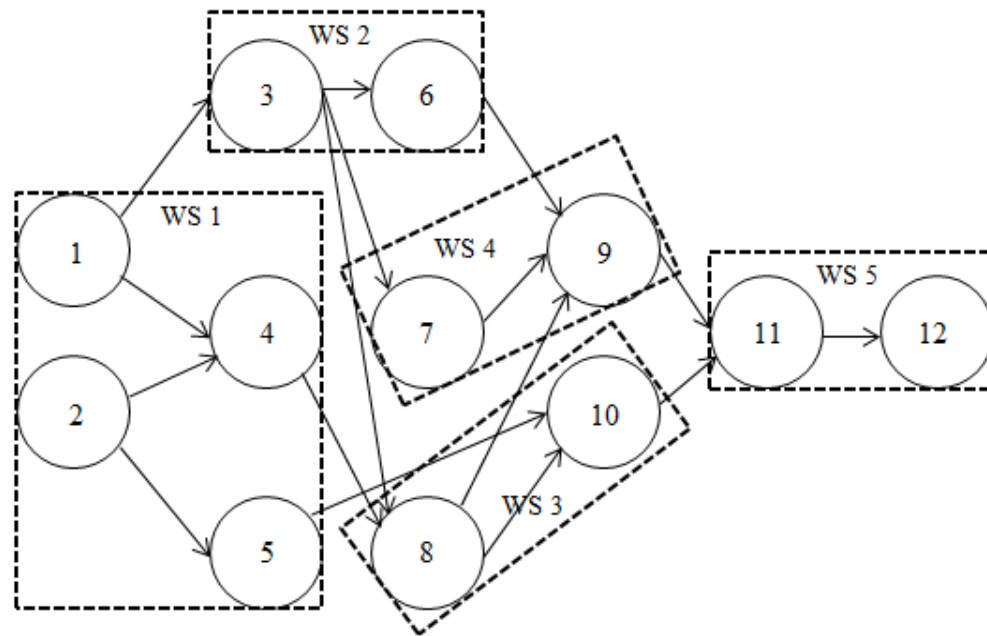
1	0.2	---
12	0.12	11
6	0.11	3
4	0.1	1,2

Step 2 and 3: Assign work element based on LCR as shown below:

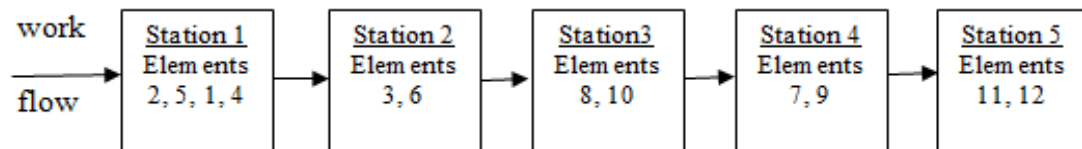
If we assume CT= 1.00 minute

Table 2.4: Work elements assigned to the stations based on Largest Candidate Rule (LCR)

Workstation	Element	Task Time (minutes)	Task Time at station (minutes)
1	2	0.4	1
	5	0.3	
	1	0.2	
	4	0.1	
2	3	0.7	0.81
	6	0.11	
3	8	0.6	0.98
	10	0.38	
4	7	0.32	0.59
	9	0.27	
5	11	0.5	0.61
	12	0.11	



(a)



(b)

Figure 2.4(a): Assignment of elements based on the Largest Candidate Rule (LCR)

(b): Physical sequence of station with assigned work elements

### 2.8.2 Most Following Tasks (MFT)

It is a heuristic procedure which arranged work elements for assignment to stations according to the highest number of following tasks in the sum of all tasks.

Procedure:

Step 1: List all elements in descending order of task time value, most following tasks at the top of the list.

Step 2: To assign elements to the first workstation, start at the top of the list and work done, selecting the first feasible element for placement at the station. A feasible element is one that satisfies the precedence requirements and does not cause the sum of the task time value at station to exceed the cycle time, CT.

Step 3: Repeat step 2.

Example for Most Following Tasks (MFT)

Step 1: Arrange work element based on MFT as shown below:

Table 2.5: Work elements arranged based on Most Following Tasks (MFT)

Work Element	Task Time (minutes)	Number of Following tasks
1	0.2	9
2	0.4	7
3	0.7	7
4	0.1	5
8	0.6	4
5	0.3	3
6	0.11	3
7	0.32	3
9	0.27	2
10	0.38	2
11	0.5	1
12	0.12	-

Step 2 and 3: Assign work element based on MFT as shown below:



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