CHAPTER II

LITERATURE REVIEW

This chapter will be elaborations of the literature studies which are in the form of inductive and deductive study. There will be also the general description of the company as well as the research framework. Inductive study is the previous studies which will be the basic of research. While deductive study is the theoretical basis for supporting the problem solving in the research. Inductive study was obtained from the journal and proceedings are published periodically. While deductive study was obtained from the study of textbooks related to the theory.

2.1 Inductive Study

This study discusses about assembly line balancing. Generally, it defines how tasks are to be assigned to workstations so that the assembly line can be balanced (Morshed & Palash, 2014). In the real world, the development of the assembly line revolutionized manufacturing and contributed to the higher level of Industrial Revolution (Micieta & Stollmann, 2011). Assembly line defines that manufacturing technique in which a sequential organization of workers, tools or machines, and parts are performed. It is designed to exploit a high specialization of labour and the associated learning effects (Adeppa, 2015). Balancing assembly lines is a very important mission for manufacturing industries in order to improve productivity and a cost-efficient mass production of standardized products (Dwivedi 2012).

Bryton (1954) stated that assembly line balancing problem (ALBP) aims to assign tasks to workstations in order to balance the workload of the workstations. Since different tasks might have different processing times, the task times associated with different workstations are rarely equal and so workstations may encounter idle times. The first published scientific study belonged to Salveson (1955). For more than 45 years, many studies were made on this subject. During this period various ALB problem concepts were explained by (Ghosh & Gagnon, 1989) and (Miltenburg & Wijngaard, 1994). They classified ALB problem as problem types in line configuration that are a number of products such as single-model, multi-model and mixed-model lines. The types of layout production are also considered such as serial, U-shape, parallel and two-sided lines (Bartholdi, 1993).

In this research will be focused on the problem of mixed–model two-sided assembly balancing (MTALB). Simaria & Vilarinho (2009) and Özcan & Toklu (2009) stated that MTALB problem which is recently recognized to be crucially important, especially in manufacturing systems with large-sized products such as cars, buses and trucks.

The researcher tries to review the literature of MTALB. However not many studies that discussed about MTALBP. the first MTALBP research presented by Simaria & Vilarinho (2009). Mathematical programming model approach is developed to solve MTALBP Type I. Due to the makes it imposible to be solved optimality. Therefore, the ant colony optimization algorithm (ACO) named 2-ANTBAL as optimization procedure is purposed to get optimal solution. The approach developed to find solutions for the 2-MALBP. However, it is still not expected procedure. For further research, change the other algorithm is purposed to improve the procedure. Still the same year, Özcan & Toklu (2009) develop a new mixed integer programming (MIP) model to solve the MTALBP Type I problem. They presented mathematical model is based on the mathematical formulation of TALB Type II presented by Kim et al. (2009). There are several constraints which added in the model. However, a new mathematical model for the problem and solved it for small-sized problems. But large-sized problems were solved by the simulated annealing (SA) algorithm. It is proposed approach as optimization procedure. To measure the performance of assembly line, the test problem considers with two goals. It is maximize wighted line efficientcy (WLE) and minimize weighted smoothnes index (WSI). The experimental result shows that the procedure get the better solution than previous research. To make complete the problem solving, MTALBP Type II can be reference for further research. It can use another metaheuristic approach to get the optimum solution.

In the next research still focused on MTALBP Type I, there are three researches still continues. They consider the results with MIP and SA from Özcan & Toklu (2009). Started from Taha (2012), due to exact and mathematical methods fail to find optimal solutions for large-size problems. Modified genetic algorithm adopted in this paper was able to obtain the best-known solution for all of the test problems. It is adopted from single model TALBP by (Taha et al. 2011). The test problem shows that WLE has increase 81.93%, when compared with SA that has 75.39%. This algoritm has the better solution in a number of iteration. Furthermore, Delice et al. (2014) stated that MTALBP is difficult to solve in a reasonable computational time. So it is necessary for researchers to find some efficient approaches to address this problem. A modified particle swarm optimization algorithm with negative knowledge is proposed. These new procedures enhance the solution capability of the algorithm while enabling it to search at different points of the solution space. The experimental results show that the proposed approach obtains better solution within a short computational time for every test problem. Then, the result is more better than SA. In the last research, Yuan et al. (2015) stated that also comparing the algorithm performance of Hybrid honey be mating optimization with MIP and SA. In terms of the number of mated-stations, total number of stations and WLE. The procedure achieves the same results. Moreover, HHBMO outperforms MIP and SA in terms of the weighted smoothness index (WSI). The result show that HHBMO find better combinations of tasks in the same or less number of stations compared with SA. In the future, HHBMO can be applied to solve other combinatorial optimization problems. The encoding and decoding scheme proposed in this paper can also be modified to solve other two-sided assembly line balancing problems. However, they stated that MTALB problem is difficult to solve in a reasonable computational time. So it is necessary for researchers to find some efficient approaches to address this problem.

On the other hand, only Qi et al. (2015) that solve the MTALBP II. They presented a new mathematical for random mixed-model two-sided assembly line balancing. In random mixed-model two-sided assemble line, processes are usually arranged on the right-side or left-side assembly lines and the longer operation time which adding all processes time in a work position on each side determines the cycle time of this work position. And the longest operation time position among all work positions determines the cycle time of the whole assembly line. Automobile manufacturing company C is their target study. Random assembly line is that each process time is an uncertain value in the entire assembly procedure, and usually can only be used to express in a randomly distribution function. In other words, the influence of random factors on all the assembly line can be converted to impact on the process time. For example, they stated that each process time is an uncertain value in the entire assembly procedure, and usually can only be used to express in a randomly distribution function. In other words, the influence of random factors on all the assembly line can be converted to impact on the process time. Therefore, the poisson distribution is the specific data processing in this paper. MATLAB is used to calculate the integrated time process according to the distribution of each process. As a result, the conversion of each product's of process time i (in this case there are three types of products) to be the one process time. Exactly, the conversion takes into account demand uncertainty and different process time variations. In this research, the optimization procedure using genetic algorithm. The result shows the cycle time can be minimized by using this procedure. However, this is the only research that completed the MTALBP type I and still has flaws. Firstly, the conversion data method that they used, only for their research. It is a way that has never been done by other researchers who discussed about mixed-model assembly line. These never happened in the previous research which also discussed the mixed-model assembly line. In other words, it can not be guaranteed that it is concrete data. The solution of this problem is to solve the MTALBP type I without converting the process time data of each product into one process time. This is to ensure the validity of data to be used. Secondly, although the cycle time can be minimized, they show assembly line performance with the percentages of assembly line balancing level. They don’t explain the parameter more clearly and of course, it is standard performance or not. On other hand, the previous researcher who tested the assembly line performance by using test problem. Exactly, the test problem that has become a standard performance assessment on the assembly line.

MTALBP become an interesting topic as actually there are a lot of things can be considered in this topic. In other side, there are still a lack of research concerning about their procedures. Researches solve the problem only focus toward one approach such as mathematical model that combinated by metaheuristic procedures. Although its find the better solution but they purpose that their procedures must be improve to get the optimal solution. Moreover, what Simaria & Vilarinho (2009) said about high complexity in MTALBP, it makes the difficulty to obtain optimal solution is proved. Therefore, it needs find alternative approach with proper procedure and more practical to resolve the problem.

Again, it is possible to see how the researcher agrees with Huang et al., (2012). They stated that generally, the traditional assembly line simulation is based on mathematical model, which is time-consuming. In this situation, they proposed the computer simulation is arise at the historic moment, which can quickly and accurately finish simulation, as a result of shortening the production cycle, reducing manufacturing costs. It is simulation approach based. For example, by using computer simulation make the technique are quick generate with no complex calculations involved whatsoever. There are many computer simulation software especially Tecnomatix Plant Simulation. It is object oriented, graphical, integration of modeling, simulation tools, which used to call eM-Plant until the takeover of Siemens. They proposed the method of assembly line modeling. The simulation operation of the simulation model can only provide feasible scheme in certain conditions.

For example, Jamil & Razali (2016) develop modelling simulation with the software. The purpose is reducing the task time or processing time that have been assigned to all workstations to suit and not exceed the cycle time that has been given. Through simulation modeling, it can improve the assembly line performance compared to the traditional way of trial and error on the actual production system. The result, idle time can be reduced by increasing the part’s arrival frequency after balancing out the production line. Nevertheles, what they suggest still limitation. They must be run a trial for every combination of input parameters that they want to explore. It also spends a lot of time to trial and not giving the optimal solution of the problem.

Based on the previous researches mentioned, there is still no previous paper discussing about problem solving of MTALBP using simulation approach. In this research, Tecnomatix Plant Simulation is the computer simulation software to support the problem solving. In addition, the researcher wants to improve the flaws in Qi et al research that presented MTALBP Type II in automobile company.

2.1.1 Comparisons of Previous Research

The comparison table of previous researches and the research proposed can be seen in Table 2.1. All of the researches conducted already focused on mixed-model two-sided assembly line balancing problems, but they focused on different objectives and methodology.

Table 2.1 Comparisons between Previous Researches and Research Proposed

No	Author	Year	Objectives	Methodology
1	Simaria & Vilarinho	2009	MTALBP Type I	Ant colony optimization algorithm
2	Özcan & Toklu	2009	MTALBP Type I	Simulated annealing algorithm
3	Taha	2012	MTALBP Type I	Modified genetic algorithm
4	Delice et al.	2014	MTALBP Type I	New modified particle swarm optimization algorithm
5	Yuan et al.	2015	MTALBP Type I	Hybrid honey bee mating optimization algorithm
6	Qi et al.	2015	MTALBP Type II	Genetic Algorithm with a new mathematical for

No	Author	Year	Objectives	Methodology
				random MTALB problem
7	Research proposed	2018	MTALBP Type II	Simulation approach

2.2 Deductive

Deductive study is the theoretical basis for supporting the problem solving in the research. Inductive study was obtained from the journal and proceeding are published periodically. While deductive study was obtained from the study of textbooks related to the theory. In this chapter, there will be an elaboration of the theory used.

2.1.2 Production System

Assembly line balancing becomes one important thing in the production system aspect. Panneerselvam (2005) mentioned that classifications of the production system are:

a. Mass production system, manufacturing facility is geared up to produce the products of interest in large volume, a flow line may be used for the mass production system, which produces the same product over a long period of time.
b. Batch production system, manufacturing facility is geared up to produce the products in much smaller volumes. The batch production is realized through job shop implementation.

2.1.3 Mass Production system

In the mass production process, there is a production line in which assembly operations that carried out on sequential stations is called assembly line. In there, the production follows in a predetermined sequence of steps which are continuous. The product moves from workstation to other workstation at a controlled rate following the sequence needed to build the product and as the network relationship, some of the tasks will be processed in serial order and some of them will be processed in parallel.

Competition motive between enterprises has created a need to ensure mass production and flexibility in the product range. In this case, Mercan (2012) stated that assembly lines reached various shapes and capacities by growing and developing over time in order to meet demands. Assembly line can be designed to achieve balance at each workstation in order improve to make better performance.

2.1.4 Assembly Line Balancing

Managing and designing assembly lines become one important thing in the production managerial aspect. Line balancing is the balancing the assignment of task elements from assembly lines to a workstation (Gasperz, 2004). In this concept, the elements of operation will be combined into several workstations (Biegel, 2002), which is the main purpose to minimize total waiting or idle time in all stations for a given level of output (Baroto, 2002), until obtaining a smooth production flow in order to obtain high utility over facilities, labor and equipment through the balance of work time between workstations (Herjanto, 1999). Thus, assembly line balancing is a group of human or machines that perform sequential tasks in assembling a given product to each resource with balanced in each assembly lines, so that achieved high work efficiency in each workstation. The function of line balancing is to create a balanced process. According to (Gasperz, 2004), the main objectives of a balanced of assembly lines are:

a. Balancing the workload that is allocated to each workstation so it can be completed at a given time (balanced).
b. Prevent bottleneck (a process that limits the output and frequency of production.
c. Keeping the assembly line in order to smooth and running continuously.
d. Improve efficiency or productivity.

A. Basic Terms of Assembly Line Balancing

Here are the basic term of assembly line balancing that mentioned by (Mercan, 2012) as follows:

a. An Operation (Task) is the smallest part split logically of the all work content that carried out during the production process of the finished product.

b. Station is the space used by workers where the defined work is completed by using such tools on the assembly line. For an assembly line; there are constraints such as the smallest station number is one and the biggest station number determined during the station number balancing operation should not be exceeded.

c. Cycle Time can be defined as; the longest period of a product at a station on the assembly line or the necessary period of time for a worker at a workstation in order to complete the work to be done. The total time period of work items assigned to a station, cannot exceed the cycle time.

d. Processing (Task) Time is the required time for the realization of the smallest part split logically of the all work content that carried out during the production process of the finished product.

e. Idle or Waiting Time is a positive difference between the cycle time and the task time. The sum of idle or waiting times for all stations of the line is called balance delay time.

f. Takt Time is the time required for the assembly of a product to be produced on the assembly line or sum of standard durations of all work items at all workstations of the product.

B. General Steps of Assembly line Balancing

Accordance by Gaspersz (2004), there are the steps of the problem solving of line balancing. Here are the steps to problem solving as follows:

a. Identify individual tasks or activities to be carried out.

b. Determine the time required to perform each task.

c. Establish precedence constraints, if there is associated with each task.

d. Determining the output of the assembly line required.

e. Determine the total time available to produce the output.

f. Calculating the cycle time required, for example the time between the completion of the products needed to complete the desired output within the tolerance limits of the time (the time limit allowed).

g. Give the tasks to employees or machines.

h. Determine the minimum number of workstations needed to produce the desired output.
i. Assess the effectiveness and efficiency of the solution.
j. Find the solution to improve the process continuously (continuous process improvement).

C. Classification and Description of Assembly Line Balancing Problem

Generally, the assembly line is carried out in many industries. Especially, they are used to produce consumer goods such as automotive appliances. These products are rather different, and it is necessary to implement different production systems. Here are the classifications of ALB problems as follows:

1. Problem Type – Assembly Line Design

   One of the assembly line balancing classification criteria is a number of different products which can be produced on the same line can be shown in Figure 2.1.

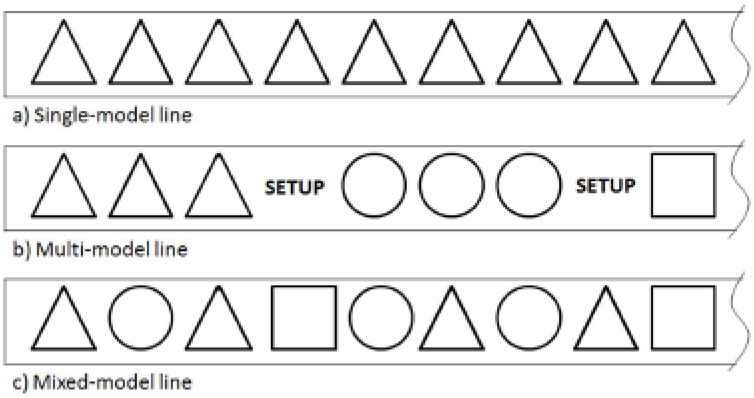

Figure 2.1 Assembly line types

Source: Becker & Scholl (2006)

a. Single-Model Lines

   One homogeneous product is continuously manufactured in large quantities. According to Merengo et al. (1999), single model lines are suitable for large-scale production, since they ensure quite low production costs. No operation changes are being made at any stations on this kind of lines and all stations repeat the same work. Thus, does not change in workloads of stations.

b. Mixed-Model Lines

It is the line system that provides sequential production by mixing more than one product on the same line. Product ranges produce on the same line are quite similar to the main product. According to Merengo et al. (1999), it is possible to produce very small batches (even one – unit batches.). Also when there is model change on the line, the set-up is carried out quite fast and cheap. For example, if option differences of the main product are produced sequentially mixed on the same line according to customer demand, this belongs to mixed-model assembly lines class.

c. Multi-Model Lines

Similar products with differences in production processes are produced on these lines. Due to differences in production processes, because of situations like operation processing times, the ergonomic need of workspace and so on, products are produced in batches. Even a lengthy set-up study is needed during product change. These changes cause an increase in costs and a decrease in productivity (Mercan, 2012).

2. Layout of the Production System

Layout of production systems in flow lines are partially determined by the material flow. In addition, some changes can be made in the system in order to use the line more efficiently.

a. Serial Lines

A traditional line organizes stations and the tasks that comprise them sequentially along a straight line (Ajenblit & Wainwright, 1998). Due to reasons such as being simple and systematic, placement is easy, conveyor system provides the applicability, cost reduction, and it does not contain transition difficulties that may occur in the angular lines; straight lines are preferred in the placement of lines. A serial assembly line is illustrated in Figure 2.2.

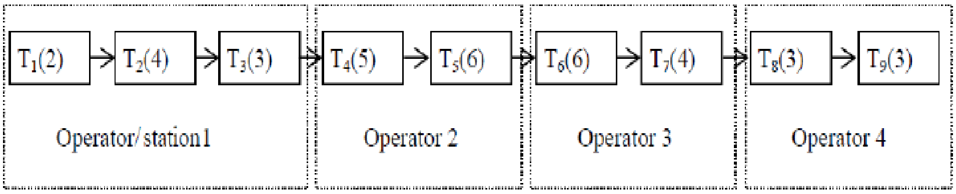

Figure 2.2 Serial Lines

Source: Mercan (2012)

b. U-Shaped Lines

In a U-shaped line, tasks are arranged around a U shape line and are organized into stations that can cross from one side of the line to the other. The assignment of the tasks to the stations on a U-line exploits the geometry of the line to keep the return and crossover distances as small as possible (Baykasoğlu & Dereli, 2009). The number of stations needed for a U-shaped line layout is never more than the number of stations needed for the traditional straight line (Ajenblit & Wainwright, 1998). A U-shaped assembly line is illustrated in Figure 2.3.

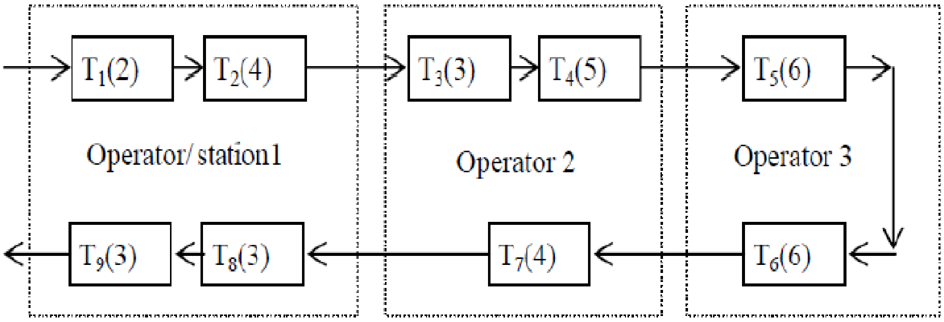

Figure 2.3 U-Shaped Lines

Source: Mercan (2012)

The most important advantage of the U-Shaped line placement is providing flexibility in a number of employees in order to adapt to optional and capacity changes in customer demands.

There are also many reasons for the current popularity of U-lines as an alternative to traditional batch production in shops with functional layouts. These include lower inventories, simpler material handling, easier production planning and control, opportunities for teamwork and problem solving, better control of quality, and so on (Miltenburg & Wijngaard, 1994).

c. Parallel Lines

In a modern production environment, the number of developing and flexible enterprises is rapidly increasing and these enterprises adopt JIT technique. Therefore, many traditional structures are unable to meet customer demands. The system in which more than one parallel and similar lines meeting customer demands oriented work synchronized is called parallel lines.

In practically, most production systems consist of one or more assembly lines. There are two cases in producing products on one or more assembly lines. In the first case, the demand is high enough and a single line is insufficient to meet it and a second line is needed to be formed. In other words, the same products are produced on multiple identical lines. In the second one, if each demand is large enough to form a line, similar products more than one are produced on separate assembly lines (Gökçen & Ağpak, 2004). A parallel assembly line is illustrated in Figure 2.4.

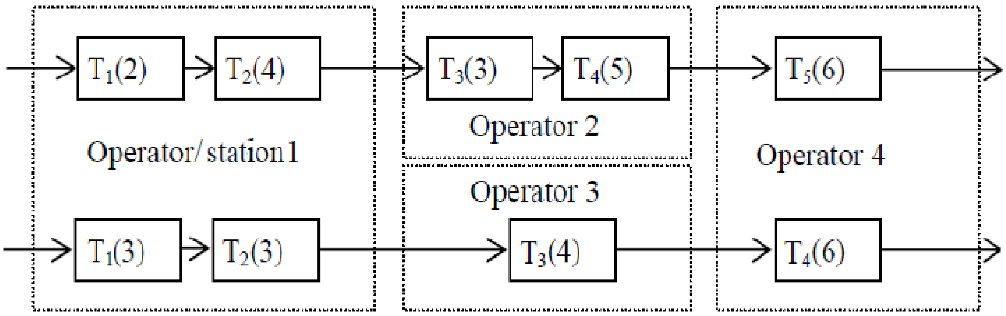

Figure 2.4 Serial Lines

Source: Mercan (2012)

d. Two-sided Lines

Two-sided assembly lines are typically found in assembling large-sized high-volume products, such as buses and trucks. In a two-sided assembly line, both left and right sides of the line are used and different assembly tasks are carried out on the same product in parallel at both sides (Wu et al., 2008). A two-sided assembly line is illustrated in Figure 2.5.

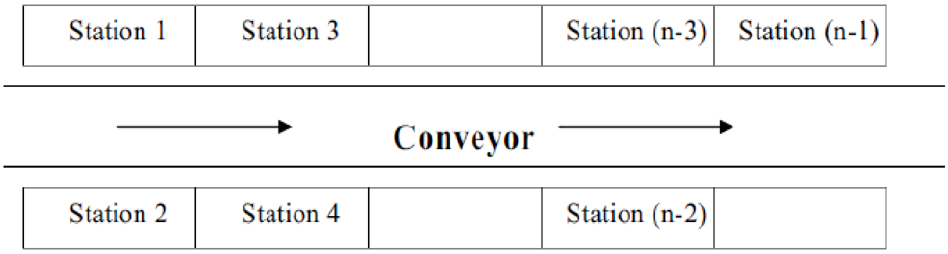

Figure 2.5 Two-sided Lines

Source: Mercan (2012)

The consideration of the preferred operation directions is important since it can greatly influence the productivity of the line, in particular when assigning tasks, laying our facilities, and placing tools and fixtures in a two-sided assembly line (Lee et al. 2001).

2.1.5 Mixed-Model Two-Sided Assembly Line Balancing Problem

The current market is intensively competitive and consumer centric. For example, in the automobile industry, most of the models have a number of features, and the customer can choose a model based on their desires and financial capability. Different features mean that different, additional parts must be added to the basic model. Due to the high cost to build and maintain an assembly line, the manufacturers produce one model with different features or several models on a single assembly line (Xu & Xiao, 2008). Under these circumstances, mixed-model two-sided assembly line balancing (MTALB) problem arises to smooth the production and decrease the cost.

MTALB are typically found in producing different models and large-sized products, such as trucks and buses are produced on the same line with the different models interspersed throughout a production sequence. In that case, often as a consequence of implementing just-in-time (JIT) principles into their operations. This helps manufacturers provide their customers with a variety of products in a timely and cost-effective manner. The consideration of the preferred operation directions is important since it can greatly influence the productivity of the line, in particular when assigning tasks, laying out facilities, and placing tools and fixtures (Bartholdi, 1993) and (Kim et al., 2009).

A. The Objective of Mixed-model Two-sided Assembly Line Balancing Problem

According to (Sly & Gopinath, 2007) ALBP that can be based on MTALB problems can be classified into two different types, as follows:

a. MTALB problem type I

Type I problem is minimizing a number of stations given cycle time. The cycle time (the time elapsed between two consecutive products at the end of the assembly line) and consequently, the production rate has to be pre-specified so it is more frequently used in the design of a new assembly line for which the demand can be easily forecasted.

b. MTALB problem type II

Type II problem is minimizing cycle time for given number of stations. It is deal with the maximization of the production rate of an existing assembly line.

B. Constraints and Restrictions of Mixed-Model Two-Sided Assembly Line Balancing Problem

1. Basic Constraints

a. Cycle time constraint: The total duration of operations assigned to a station (i.e. task times, the sum of lost times due to uncontrollable periods and pre-designed downtimes), cannot exceed the cycle time. When the sum of task durations in a work center exceeds the specified cycle time, either one or more tasks must be removed from the work center, or else duplicate workstations (and workers) can be included in the work center (Yilmaz, E., & Erol, 2005).

b. Precedence Constraints: The assignment of a task must follow the precedence constraint. This means that a task can only be assigned when its entire predecessors are finished (Purnomo et al., 2013).

2. Assignment Restrictions

In addition to the cycle time and precedence constraints, the following restrictions are commonly considered in the literature (Purnomo et al., 2013):

a. Zoning restrictions: there are two types of zoning restrictions; positive zoning and negative zoning. Positive zoning means a set of tasks must be assigned to the same workstation while negative zoning means a set of tasks must be assigned to different workstations. The restrictions might reflect a set of tasks that require expensive resources; thus they can share the same workstation (Dar-El & Rubinovitch, 1979) or a set of tasks that require different equipment, therefore they cannot share the same workstation (Scholl et al., 2010).
b. Distance restrictions: assembly process might require minimum distance or maximum distance between tasks. The distance can be measured in time, space, sequence or workstation positions (Buxey, 1974). An example, in which minimum distance should be considered, can be observed in the case where color has to dry before further tasks can be performed. The maximum distance, e.g., must be considered when the melted metal must be prevented from cooling down before a specific task is performed (Scholl et al., 2010).
c. Synchronous task restriction: synchronous task restriction can only be applied in TALBP. Two tasks are synchronous tasks if the tasks must be performed simultaneously, one at each side of the assembly line (Purnomo et al., 2013).
d. Resource restriction: the restriction might reveal inadequate space for allocating the required machines or containers at a workstation, therefore, the workstation feasibility is limited by its space availability (Pastor et al., 2013) and (Sawik, 2002).
e. Station restriction: this restriction means that specific tasks need to be assigned to specific workstations. For example, a task need to undergo position changes during the assembly, therefore the task can only be assigned to a workstation where the task is in the required position (Lapierre & Ruiz, 2004)

C. Advantages and Disadvantages of Mixed-Model Two-Sided Assembly Line Balancing Problem

Mixed-model Two-sided production systems are mainly used due to the following advantages resumed by (Bartholdi, 1993) and (Cao & Ma, 2008):

a. It provides a continuous flow of materials.
b. It reduces the inventory levels of final items.
c. It is very flexible with respect to model changes
d. It keeps up with customer demands.
e. It can shorten the line length, which means that fewer workers are required.
f. It thus can reduce the amount of throughput time.
g. It can also benefit from the lowered cost of tools and fixtures since they can be shared by both sides of a mated-station.
h. It can reduce material handling, workers movement and set-up time, which otherwise may not be easily eliminated. These advantages give a good reason for utilizing two-sided lines for assembling large-sized products.
i. Mixed-model two-sided assembly lines in practice can provide disadvantages over a single-model assembly line as follows:
j. One of the most important disadvantages is, it has more constraints than single model assembly line balancing problems due to much product range.
k. It needs more operators due to many tasks.
l. The flexibility of the mixed-model two-sided assembly line requires expensive equipment which reduces or even eliminates delays due to set-up activities.

2.1.6 Simulation Approach

To know the flow of material in the production process, the researcher can do the simulation to build the current model. Simulation is a tool that used to build a model from the problem (Lu & Wong, 207). By using simulation, is expected to create a system that represents the real situation occurring in the production. The more appropriate simulation model, thus indirectly also conducted an appropriate analysis. Also expected with the revision of the simulation model can provide improvements for enterprise production systems.

By doing simulation, allows researchers to draw conclusions without having to build it first. Researchers can also make changes to existing systems without disrupting ongoing activities. Simulation is a useful tool in the design stage of the system to assess design alternatives when used in evaluating policy alternatives.

Tecnomatix Plant Simulation can be used to create a simulation of the production line and optimization of production system during the process. Plant Simulation gives an easy way to perform a series of experiments that aim to make improvements to the system (Siemens, 2010). Basic abilities that need to be held at the base used in performing simulation using are good analytical skill, statistical knowledge, technical expertise and good communication skill. Some advantages of Plant Simulation are:

a. Detect and eliminate problems that require correction cost and takes a long time in production
b. Maximize the output
c. Optimizing the performance of existing production system by taking steps that have been verified in a simulated environment before being implemented.
d. Can simulate the production process easily
e. Many objects that can control the situation in the plant and include optimization tool as a genetic algorithm, bottleneck analyzer, programming method, etc.