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Enhancement of Productivity by Using Line Balancing in Manufacturing Production

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Abstract

Nowadays, the manufacturing industries are trying to increase their productivity because there are too many challenges from competitors in similar sectors especially when their products are the same. The purpose of this study is to understand the lean waste that always happens in assembly processes and how it can be reduced by applying line balancing into assembly processes. This research is beneficial to industry practitioners, and companies that are willing to enhance productivity at the same time can reduce the takt time and cycle time of a product in an assembly line. This study will allow industry practitioners to have a greater grasp of the implementation of the line balancing method to reduce cycle time as well as increasing productivity..

Keywords: lean waste, line balancing, cycle time, takt time, assembly line.

1. Introduction

Nowadays, productivity is a very important aspect of manufacturing industries. Therefore, increasing productivity is important to improve gross income and sustain profitability. Productivity for manufacturing industries relies upon a balance of effective workers, facilities, and systems. Improvement in many of these fields includes reviewing the existing procedures in place and making changes to processes, education for workers, and also the facilities used to produce products and parts. To make these changes, a suitable strategy or tool is needed to help improve productivity in manufacturing industries.

Many strategies can help to improve productivity but the most common in manufacturing industries is lean manufacturing (LM). Lean is applied to meet the interrelated goals of maximising efficiency, recognising and removing “wasteful” instructional activities, and minimising or reducing excessive costs. Hence, it is important to implement LM in manufacturing industries to recognise and remove the waste that happens in the production line to increase productivity and also optimise cost.

1.1 Issue of Studies

Productivity can be defined as the amount of work that can be accomplished per time using the available resources. By increasing productivity, manufacturers can attain production targets at optimum cost. To increase productivity, manufacturers need to implement a good strategy or method to reduce waste that happens in production. The fundamental issue faced by manufacturing organisations is the manufacturer does not realise the type of waste that happens during production, which can impact the cost of the product. Normally, manufacturing companies always focus on one issue, which is defects of the product.

Many manufacturing companies have tried to reduce waste and several of them have been successful in doing so. Hence, knowing the type of waste that happens in companies does not guarantee that the industries can successfully reduce it. Therefore, suitable lean strategies or tools are needed to accomplish the objective. Normally, small manufacturing companies do not have employees with experience in lean studies to help the companies implement it. As a result, many small companies failed to implement a lean strategy to reduce waste. Besides, manufacturing companies need to implement appropriate LM tools to reduce waste as well as achieve optimal costs for production. As a result, the more reduction can be made, the higher productivity will increase.

1.2 Purpose of Studies

The general purpose of this study is to improve productivity by using a lean manufacturing concept in production assembly. The specific objectives of this project are:

i. To identify the type of waste in the manufacturing industry.

ii. To study line balancing that can be implemented in the manufacturing industry.

iii. To propose an appropriate solution to the manufacturing industry.

2. Understanding of Lean

[1] synthesis has many techniques and tools to produce goods for sustainability in manufacturing industries. Besides, the globalisation cycle helps manufacturers to automate their production processes so that they can produce high-quality goods in a short time [2]. Subsequently, [3] claims that many sectors reveal that increasing innovation has driven many firms to introduce manufacturing processes that can offer improved prices and efficiency. Although improvement is very important to industries, manufacturing industries face difficulties in reducing labor costs, industry fluctuations, uncertainty, and endless demands [1]. Therefore,, it was agreed that time, effort, and cost are the essential elements that needed focus to preserve or improve the productivity of the assembly line.

2.2 Productivit

According to [4], productivity is defined as the ratio between the output value and the input value used to obtain the output. Likewise, [5] also stated that productivity is characterised as the ratio of outcomes and resources, in which the outcome value is also crucial. In manufacturing industries, productivity shows the price rate of product per the use of input resources such as labour, equipment, and materials.

Efficient work would use fewer input resources and would achieve high work efficiency. [4] highlighted that a higher rate of productivity makes process expense and time more valuable, as it means fewer production resources are being used. Besides, organisations have sought to maximise the productivity of their workers by defining work activities and improving work processes [5].

2.2.1 Lean Manufacturing

[6] identifies LM as an integrated socio-technical system which aims at eliminating waste by reducing or minimising supplier, customer, and internal variability at the same time. Besides, [7] claimed that LM is described as a “systematic approach to identifying and eliminating waste through continuous improvement, promoting the customer's product pull in pursuit of perfection”.

Similarly, [8] defined LM as a strategy for removing different waste, so it involved a matrix of waste interactions with lean approaches to assess their effect on waste before disposal. Based on the previous study, this method has been proven as an effective method to successfully eliminate waste in manufacturing while increasing productivity. Figure 1 below shows the lean principle.

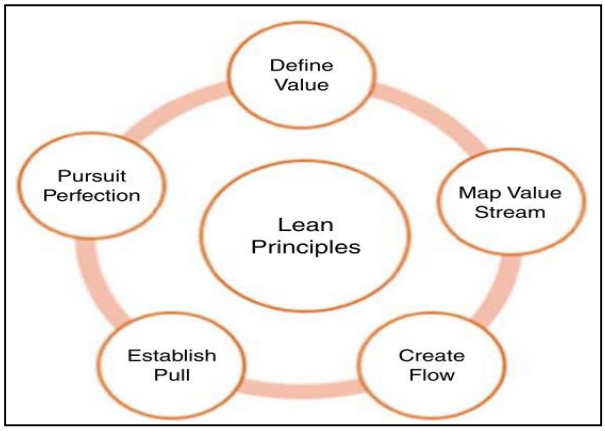

Figure 1: Lean Principle

However, to implement LM in manufacturing industries, the manufacturer needs to understand the lean principle, which is basic knowledge for lean. Thus, the manufacturer needs to define value from the customer's perspective. [9] stated that identifying the value stream which is an organisation of procedures from products to end users according to consumer experience can identify the type of waste that happens in manufacturing. The next step provides value-creating moves in a short series, such that the output flows efficiently to the customer [10]. [11] claimed the create flow concept removes overproduction by simply relying on what consumers want or use. Finally, the pursuit of perfection is a repetition step until a state of perfection is reached.

2.3 Type of Waste

The importance of lean practices in industries typically lies in the potential to enhance the manufacturing line by recognising waste, non-value-added activities, and ensuring the flow of value activities to customers [1]. Therefore, "waste" is any step or event in a process not needed to effectively complete a task (called non-value-adding). If waste is eliminated, only the measures necessary to provide a suitable good or service to the consumer called value-adding remain in operation.

By recognising waste, manufacturers can constantly analyse and make improvements. According to [12], waste can be divided into eight areas that are due to overproduction and excessive storage. Figure 2 below shows the types of waste.

Figure 2: Type of Waste

2.4 Lean Tools

Lean manufacturing is a manufacturing strategy where resources are expended on any method in the industry rather than generating value for the end-customer [13]. According to [14] lean ideals are targeted at waste management, thus, capital gain outcomes and the different methods and concepts of lean are also accomplished with sustainability benefits. The various sustainable benefits from the lean tools are shown in Table 1.

Lean principle / tools	Sustainable benefits
Pull approach	Reduction of work-in-process, elimination of potential waste from damaged products, lesser floor space utilization
Cellular manufacturing	Reduction in set-up times and change over time hence low energy and resource usage, reduction in defects
Value stream Mapping	Reduction in waste through fewer defects, less scraps, low energy usage, etc.
5S	Reduction in lighting requirements due to clean windows, leaks attended to immediately, reduced consumption of materials and chemicals
Total preventive maintenance	Less hazardous waste due to decreased spills and leaks, increased longevity of equipment
Six-sigma	Fewer defects hence less waste, improvement in product durability and reliability hence increase in product lifespan
Pre-Production planning	Reduction of waste at design stage, usage of right sized equipment, reducing the complexities of production processes and product design

Table 1: Environmental benefit of lean tools

2.4.1 Visual Stream Mapping (VSM)

According to [15], VSM provides the possibility of classifying value-adding events according to LM values. In addition, the value stream covers all activities involving both value-adding and non-value-adding to turn raw material into a product [16]. Therefore, [16] has defined value stream as the flow of all value items during the production cycle during which a service is rendered or a product generated through the transformation and combination of primary factors, as well as the processing of targeted information, thereby increasing the value of the item at each stage.

VSM is used as an invaluable tool for strategic planning, which helps to identify the weaknesses and strengths of the production process and flow. Based on VSM, this approach provides a suitable framework for the drawing, analysis, and design of quality control measures across the production process chain [15]. Moreover, there are four phases in VSM which are preparation, analysing value stream quality, designing an inspection process, and implementation. [17] suggested identifying the product family and description of the current state VSM as a guideline for defining the future state VSM as the key problem was found in manufacturing.

2.4.2 Tools of 5S

One of the basic tools in lean manufacturing is 5S and it is the first lean tool that is needed to start the implementation process. It can be considered as the foundation stone of lean because it is applicable in service operations and manufacturing processes. Implementing 5S is one of the crucial moves for quality growth in a company [18]. Its implementation ensures continuous improvement in a standardised and organised environment. Figure 3 below shows the stages of 5S.

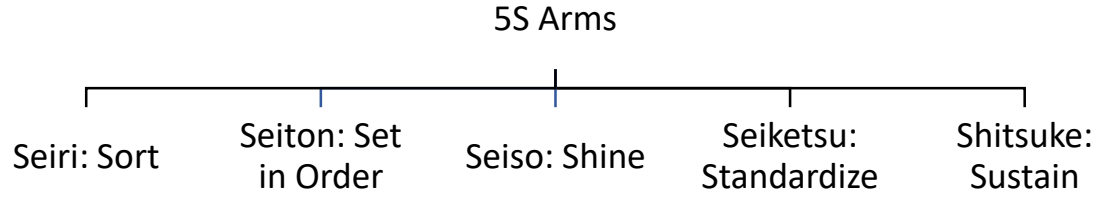

Figure 3: Stage of 5S

[18] said the 5S is the English meaning of five Japanese words which stand for Seiri (sorting), Seiton (set in order), Seiso (sweep), Seiketsu (standardize), and Shitsuke (sustain). The first “S” is Seiri or sorting, which is to separate the items that are actually needed within the work area. Any products that are rarely needed are transferred outside of the work area to a more centralised storage area [18].

Next is Seiton (set in order), which is to take the required items after being separated and arrange them in an efficient order. The activities used for this include marking each object, using color to mark it easily, placing related items together, bringing together specific things, bringing names and numbers on it, painting walls, and using a rack or shelf and tool frames [18]. The third “S” is Seiso (sweep), which depends on the organisation’s

cleaning practices [18]. This process involves cleaning thoroughly the working area, tools, machines, and other equipment to ensure that everything is cleaned as new.

The fourth "S" is Seiketsu (standardise), which is the process of ensuring the first three stage are standardised. It to ensure that there is a common standard and ways of working. [18] quoted that every employee knows his/her responsibilities, and housekeeping duties are performed regularly. The final stage for 5S is Shitsuke (sustain), which is to ensure the company continues maintaining the previous stages of 5S. [18] claimed that this "S" is considered to be the toughest to implement because it needs proper discipline from all employees to maintain it. The 5S system should become part of the organisation's culture and everyone has a responsibility to it.

2.4.3 Total Productive Maintenance (TPM)

The evolution of quality has become a top priority in many manufacturing industries and is mainly due to world trade globalisation and competitive competition. However, besides selecting the right strategy, [19] said that one must be vigilant with the job scope under which the equipment has been configured, operating mistakes, and also the maintenance approach, by selecting the type of maintenance and choosing when and how to do it. Similarly, [17] also supported the statement quoting that maintenance plays a vital role in various industries, such as the utility industry, the railroad, and the oil and gas processing industry.

TPM is a theory for increasing the efficiency of an enterprise and delivering products of high quality by eliminating waste and thereby reducing costs [20]. Based on a study [17], the idea of effective and reliable maintenance in the modern industrial sector has recently taken a new position to keep machines in good working condition to achieve the desired result. [20] also agreed that the key focus in TPM is to encourage the administrative staff to conduct routine everyday maintenance while the repair crew conduct advanced repairs, enhancements, and alteration jobs to reduce failures, thereby increasing system performance, lowering costs, and enhancing organisational productivity.

2.5 Lean Implementation in Assembly Line

The fundamental thinking behind lean is that consumers pay for things but not for mistakes or waste [13]. Therefore, manufacturers need to increase their services or products to maximise profit. There are two types of lean, namely lean management and lean manufacturing. Lean management provides opportunities for performance enhancement and quality development, while lean manufacturing is a business strategy in which the industry invests money on a method other than value development for the end-customer.

The implementation of lean will affect the production line because productivity and profit are based on production line costs. According to [13], lean waste in manufacturing can be reduced in terms of energy, time and movement, as well as enhancing ergonomically safe operations and discontinuing the use of environmentally hazardous materials.

2.5.1 Line Balancing

Once the management understands the time taken for the raw materials to be processed into finished products, they will try to balance the operator-to-computer time to minimise the loss of waiting time between operations. In addition to maintaining the workstations in assembly lines, material management processes such as the transport of raw materials, work-in-process, parts, and components to workstations are important in manufacturing environments [21].

Line balance is a management technique involving matching the operator and production time with the output rate to the average time. [21] quoted that the aim of balancing the assembly line is to delegate tasks to the workstations in a balanced way such that all workstations are charged evenly.

There are many benefits of implementing line balancing in the manufacturing industry but the most common is reduce waiting waste. [22] stated that the line-balancing method aims to assign an equivalent amount of time in each cycle for workers, ensuring that output processes can be consistent and without long waiting periods. Waiting waste is one of the types of waste of lean manufacturing. It refers to the idle time when a process is not coordinated with equal time.

Other than that, it reduces inventory waste because it corresponds to excess of raw materials, unfinished products, or finished products. [22] claims that the material flow is quicker and leads to shorter processing time and decreased inventory. Furthermore, using line balancing will reduce the waste that will automatically affect the cost and profits. Therefore, to ensure a smooth manufacturing process and a total cost reduction, an effective line balancing system in the production system must be established [21].

2.5.2 Work Layout Production Assembly

[22] stated that an efficient layout of the facility not only minimises the expense of material handling, but can also help to reduce the ongoing work and the throughput time (Chan & Tay, 2018). However, the problem of assembly line balancing deals with the distribution of activities between workstations, leading to the full utilisation of human resources and facilities without disrupting the work sequence [23]. Based on an existing study, a proper layout strategy is needed to achieve full utilisation of human resources.

The simplest line is a straight line and its conventional layout type is as shown in Figure 4. [24] explained that workstations are serially placed in a line and can join one another, and employees can operate on one side of the line. It also has one entrance and one exit that are situated at different locations.

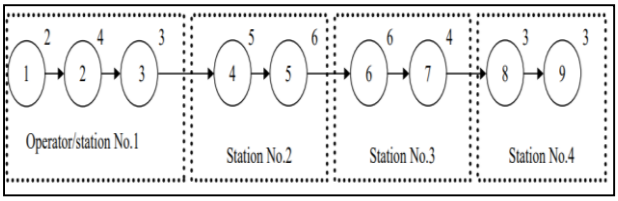

Figure 4: Work Layout Straight-Type (Ağpak, 2010)

Next, the U-type was developed to eliminate these drawbacks as shown in Figure 5. It is an ideal layout for just-in-time and team technologies that will also result in reduced cost, cycle time, and the number of [24]. The key advantage occurs when multiple operators are inside the "U" line. All the workers are in the "U" area while the content is supplied outside the "U". Moreover, this style of structure helps workers to execute U-type activities. Unlike the straight line, the entry and exit are located at the same spot.

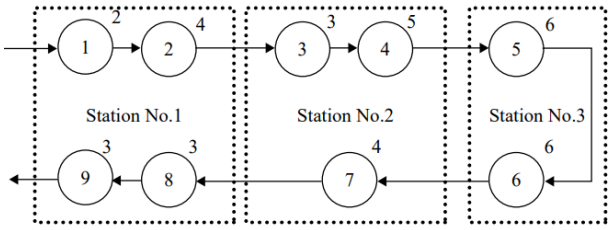

Figure 5: Work Layout U-Type (Ağpak, 2010)

2.5.3 Workflow Assembly Process

[25] stated that companies continue to expand their variety of products to satisfy their consumers' requirements for a greater degree of product customisation. Therefore, customers also expected manufacturing process requirements to have shifted tremendously. However, several measures need to be taken into consideration such as optimal utilisation of human and other resources in the assembly or fabrication process [26]. However, proper management of manpower was needed to accomplish optimal utilisation.

For a production line, efficiency is enhanced in various operating domains by removing or reducing non-value-added activities [26]. However, [27] stated that failure to satisfy consumer demand is to be carefully calculated in terms of manpower requirements for performing a specific task which may result in a surplus or human capital shortage in achieving the output goal. Besides, [26] quoted that a reasonable explanation for the manpower requirement for an operation or function is necessary for a systematic review of the time needed to complete all the basic tasks.

2.5.4 Time Study

In the manufacturing industry, time is a critical factor because it affects the productivity and efficiency of the product. Time measures the processes that are required from the beginning until delivery to the customers. Besides, [28] defines cycle time as the total time taken to get from one end to another, which is measured from the moment the job begins until before the object is shipped, corresponding with the lead time of output. In the assembly line, productivity is very important for customer demand but it depends on the cycle time of the product.

Cycle time reduction has emerged as a significant improvement in customer satisfaction [29]. Cycle time is the time taken for a single unit to be processed from start to finish. Similarly, cycle time is defined as the

time required to complete a cycle [29]. According to [26], reducing cycle time involves the number of workstations as well as line balancing and modifications of work method with minimal investment.

3. Methodology

3.1 The Detailed Process Flow of Methodology

The detailed process flow of the methodology is shown below in Figure 6. In proposing improvement, 7 QC tools were implemented to show the fundamental cause, which has a proclivity to be the problem in industries.

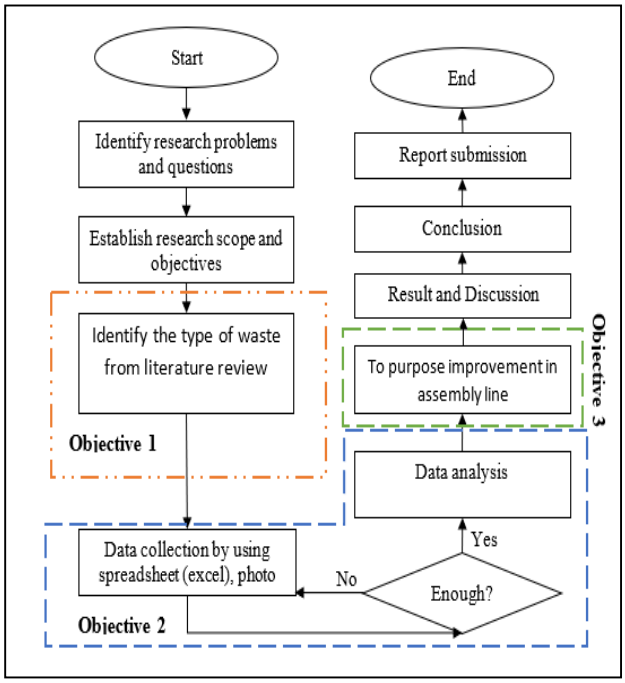

Figure 6: Detailed Process Flow of Research Methodology

3.2 7 QC Tools

The 7 QC tools is a proposed solution for resolving an issue that happens frequently in the manufacturing industry. The 7 QC tools include the check sheet, Pareto chart, cause and effect diagram (Fishbone diagram), histogram, flow chart, and control chart.

All these methods are important tools that are commonly used in the manufacturing sector to evaluate the overall and continuous process improvement. These tools are used to define the root cause, thereby strengthening the manufacturing process. For this study, just one quality control tool was utilised, which is the 5 Whys Analysis.

3.2.1 5 Whys Analysis

The 5 why analysis is a very successful tool created by Sakichi Toyoda. The 5 whys are an iterative inquiry strategy used to investigate the relationship between cause and effect that underlies a specific issue. The purpose of this analysis is to find the root cause by repeating the "why" questions. After all, the answers to the 5 whys solve the "why"' problem. Besides, this tool is simple and very effective for finding the root cause of a problem.

4. Result & Discussion

The main purpose of this chapter is to elaborate on the problem definition of the project. In addition, after the problem had been recognised, data were collected based on the main purpose of the study. Then, the data were analysed to propose improvements that can be used to increase the productivity of the company.

Furthermore, the data collection was performed by using primary and secondary data for the production process that was focused on. The method that was used for collecting the primary data for this study was the interview method, where workers were interviewed about the process of production, while the process of gathering cycle time was performed using the observation method. The secondary data were collected from the previous database of the industries.

4.1 Data Collection

Table 2 shows the data collected through observation and records of the time at the machine.

TIME / PROCESS	1 (s)	2 (s)	3 (s)	4 (s)	5 (s)	6 (s)	7 (s)	8 (s)	9 (s)	10 (s)	AVERAGE (s)
CLEANING	21	22	24	20	21	23	20	21	24	24	22
FILLING	20	21	18	21	19	20	22	20	17	18	19.6
CAPPING	16	16	15	14	15	17	13	16	15	16	15.3
LABELLING	11	10	13	11	10	8	9	11	9	8	10
COOLING	16	11	12	14	11	15	12	14	13	13	13.1
ARRANGE	25	28	27	30	26	31	22	23	29	21	26.2
TOTAL	109	108	109	110	102	114	98	105	107	100	106.2

Table 2: Process Timetabl

4.2 Data Analysis

Figure 7 shows the bottleneck process that happens in a production line. A bottleneck is a process that can interrupt or slow down a whole operation. This situation occurs because of the checking process. In this process, the workers need to check the quality of the products before arranging them into a box. Thus, it affects the cycle time of the process, making it longer than other processes.

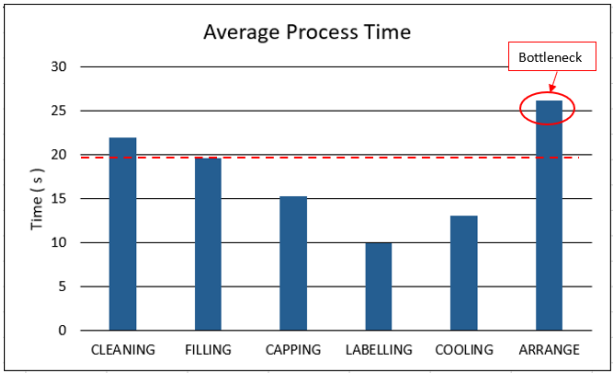

Figure 7: Bar Graph of Process Time

4.3 Proposal for Improvement

Impovement is the process of a factor moving from one step to another step to be better, usually through some action that is supposed to bring about that better state. In order to maintain the improvement, five proposed improvement ideas could be executed in the related industry to gain higher productivity. The first improvement idea is to create a standard operating procedure (SOP) that focuses on balancing the production line cycle time.

The second is to create an optimise-the-machine setting to reduce the defect as well reduce the production cost. The next improvement idea is to make a specific monthly schedule for maintenance. Then, the workstation is added or redesigned. The last improvement idea is to provide a reward if the industries achieved a target goal.

4.3.1 Standard Operating Procedure (SOP) for Production Line

The SOP as shown in Figure 8 depicts a series of instructions created by an industry and carried out to guide the personnel performing the tasks. The importance of this SOP is to ensure that manufacturing runs smoothly and that workers are properly trained. Besides, the SOP can assist the industry in reducing training expenses and ensuring the quality and consistency of manufacturing processes. It is vital to note that this SOP focuses on the right manufacturing line procedure.

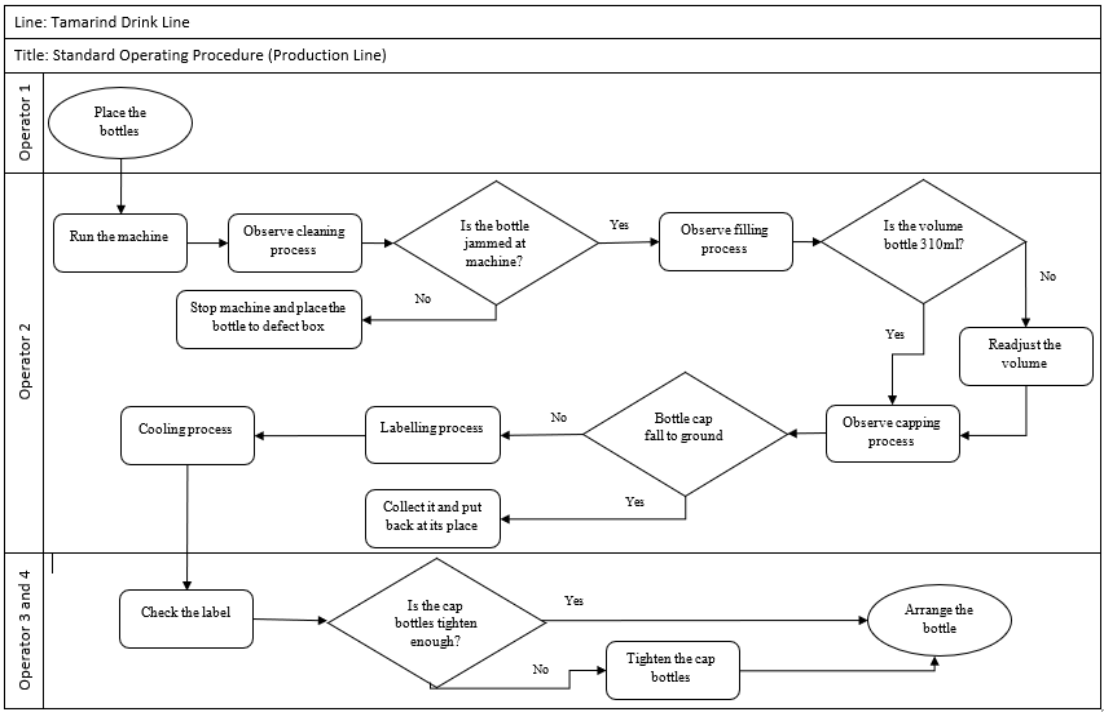

Figure 8: Standard Operating System

4.3.2 Optimization Setting

Optimisation setting is important for the production line because it can maximise the capabilities of the machine and avoid errors. Previously, there was no specific speed for machine operation. Hence, the number of defects were randomly based on the speed that was used, which can also affect the whole process time.

Therefore, using an optimisation setting can help to improve production time as well as control the defective products. The optimisation is created by comparing the time and defect between each operating speed, as shown in Table 4.10. Then, the setting is determined by choosing the minimum defect with efficient time taken for the whole process.

4.3.3 Add or redesign the workstation

Production time is a very important aspect to be considered in a production line. A production line with a high production time affects the productivity and cost for the industries. As such, using a suitable workstation is important to determine the production time for the whole process. Therefore, redesigning a suitable workstation is necessary to reduce waste and also increase productivity.

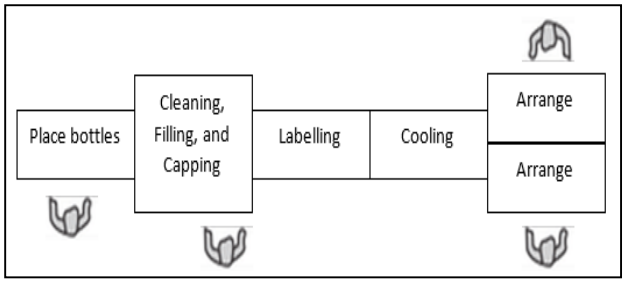

Figure 9: Redesign Production line

Based on Figure 9, the workstation was added to reduce the cycle time for this workstation. The arranged workstation was the bottleneck for the whole production line, thus, dividing the cycle time between two workstations can reduce the duration as well balance the production line

4.3.3 Maintenance Schedule

A maintenance schedule represents the routine services and or inspections that are to be performed on a plant item. Each maintenance schedule consists of multiple intervals which are assigned a service or inspection procedure. Therefore, the workers are required to constantly check that the machine is in good working condition. Therefore, constant maintenance can ensure a better-performing machine and can reduce the machine problem.

5. Conclusion

In conclusion, lean tools are very convenient to be applied to any company. This is because the lean tool is really useful to increase productivity with minimal cost. Furthermore, it is crucial to know how to implement the relevant lean tools to the corresponding problems in a company. Upon the completion of this study, the first objective of this project which is to study the type of waste in the manufacturing industry is achieved.

As mentioned before, the lean tools are used for reducing waste in the manufacturing process as it changes the internal activities to become external activities. The external and internal activities had been differentiated and identified in the production line. Therefore, the second objective which is to study line balancing in the production line at the manufacturing industry is met. In addition, several tools such as the 5 why analysis had been used to determine the problem's fundamental cause and solution.

Finally, the last objective of this project which is to propose the lean analysis for enhancing productivity is also achieved. Line balancing had been proposed as one of the lean manufacturing tools that can be used in the industry to reduce waste in the production line. The proposal for improvement is made from the analysis of the data and the root cause that could be identified from those applied tools. Then, the proposal for improvement will be presented to the company to help solve the problem.

6.Acknowledgments

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