Sustainable Production Flexible Improvement by Internal Activities Time Reduction in Manufacturing Industry

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Abstract. Nowadays, the manufacturing sectors are in the process of increasing their performance to extend productivity because there are so many challenges from competitors in the same sectors, especially in the food industry. The purpose of this study is to propose improvements to increase sustainability of food operation flexibility through secondary data collection, Cause and effect diagram analysis, and the Why-why Analysis tool. Besides, improving the understanding of Single Minute Exchange of Dies (SMED) factors in the production line can be applied by changing the internal activities to become external activities. This study is useful for manufacturing managers and companies who are willing to increase their flexibility and at the same time reduce the changeover time within their available resources without compromising the machine efficiency and cost. In conclusion, this study has provided a better understanding of reducing internal activities that cause high changeover time.

Keywords: Changeover, Internal Activity, Flexibility, Production Line, Sustainable

1. Introduction

Today, demands for goods and services are changing repeatedly and some companies are always facing greater challenges; thus, a new manufacturing system is needed to make the production proceed rapidly and more importantly to bring profit to respond to all the market changes. Therefore, the goal of each company in manufacturing is minimal cost and setup time. Due to these two main factors, the flexibility in the production line must be balanced or flexible as it will help to increase the productivity of the manufacturing companies.

It is also important to note that time, effort and cost are the essential elements that need more focus to maintain or improve flexibility in the production line. Based on research findings, it is very important to have rapid changeover while changing the product because it will give a huge impact to sustain the flexibility in industries.

Flexibility is the measure of performance of a firm in handling the production line. Being flexible means that the system carries out a good performance in order to reduce the time. The main problem that always happens in manufacturing companies is unnecessary activities or some internal activities which can drag the time to produce the product. Normally, small manufacturing companies have a difficult task to manage flexibility while performing changeover in the production line.
Other than that, the elements that are related to customer demands are the quality and the efficiency of the production itself. The reduction of internal activities in the company is one of the ways to produce better quality product and gain higher efficiency. Sometimes, poor services also tend to lower customer satisfaction. This is due to the slow production which may be caused by the slow changeover in the production line or unwanted activities. The higher the flexibility in the manufacturing companies, the higher the productivity. However, to achieve higher flexibility, food industries need to overcome many challenges. To face these challenges, the best way to overcome them is by practicing and applying lean manufacturing tools. Single-Minute Exchange of Die (SMED) is one of the Lean Manufacturing’s tools. In this study, the concept of SMED will be used to cater to sustainable flexibility improvement in the food industry.

2. Understanding flexibility

Mishra et al. [1] stated that the meaning of flexibility is the ability of firms to quickly change from one product to another without loss of efficiency and it is concluded as the main element of the manufacturing strategy. Besides that, [2] also wrote that flexibility is the capacity to change the surroundings or respond to unpredictability with minimum cost, time and effort and with maximum performances. Similarly, [3] claimed that the capability to change or react with little penalty in time, effort, cost or performances is known as flexibility. So, to sum up, it is agreed that time, effort, and cost are the essential elements that need more focus to maintain or improve flexibility in the production line.

2.1 Manufacturing Flexibility

Manufacturing flexibility refers to organisations which have the capability to change the levels of production quickly, to grow new products rapidly and more often and also to improve the organisations’ capability to face the challenge from competitors while at the same time gain the acceptable levels of cost and quality [4]. Fredriksson et al. [5] synthesised the reflection of manufacturing flexibility as the capability of a firm to respond to their customers’ need changes and unanticipated changes come from the pressure of the competitor. Complementary to this statement, with manufacturing flexibility, the level of production line of the product will run faster and can also reduce wastage of cost and time while further enhancing the effectiveness of the product.

[4] explained that machine flexibility, labour flexibility, material handling flexibility, and routing flexibility are the best ways to explain internal flexibility. In contrast, mix-based flexibility, volume flexibility, new product flexibility, and delivery flexibility are the major components of external flexibility [1].

Particularly, flexible processes guarantee a way to cope with the increasing demand for variety and uncertainty. Therefore, the topic of process flexibility has become the main focus from either commercial or research institutions, as an understanding of the requirement for processes is capable to adjust their behaviour to changes (Mejri et al.) [6]. The ability of a manufacturing system to produce a part without needing a major setup is known as process flexibility. This is useful in reducing the size of a batch and also lowering the inventory cost. Besides that, it would help to minimise the demands to duplicate the machines because it already allows the machines to share the same process. Sometimes, the time to produce or manufacture the product becomes longer because the time to set up the equipment is longer and extra time is needed to handle it. Otherwise, flexibility offers the process to be done without requiring a major setup as it can speed up the process and function efficiently. In order to improve process flexibility, it is important to have a flexible activity refinement (Jiang et al.) [7]. Thus, to achieve process flexibility, the machine in the production line has to manufacture the product as fast as lightning.

Process flexibility, or also classified as external flexibility in manufacturing, is mostly related to achieving customer requirements and also providing high competitiveness among firms. It is always more preferable by the customer as it directly seeks opportunity for a competitive advantage [8]. The main constituents of process flexibility are mix flexibility, new product flexibility, volume flexibility, and delivery flexibility.
2.1.1 Mix Flexibility
Mix flexibility is the ability to manage the product or its own variants by using equipment which needs a quick setup time. [9] argued that mix flexibility is when some products are being manufactured without a longer setup time. [8] asserted that mix flexibility is the capability of the machine to produce various combinations of products at certain capacity economically.

2.1.2 New Product Flexibility
The product is the main component because without the manufacture of a product, there is nothing to be controlled or changed. According to [3], product flexibility is the ability to produce new or exchange products and also to modify the product. In contrast, Lafou et al. [10] described product flexibility as the ability of the system in manufacturing to make various types of parts by using the same equipment. In terms of production, the aim of flexibility is lowering the amount and cost of the stock. Subsequently, the connections between product and plant group directly or indirectly are also relevant for the decisions of flexible production. There are three dimensions that defined new product flexibility operationally: range, mobility, and uniformity. Range means the number of new product parts, prototypes, and new products; mobility represents the ease when the company moves from one state to another state; and uniformity represents the manufacturing system’s ease of function under specific circumstances with several penalties in terms of time, effort, cost, and performances.

2.1.3 Volume Flexibility
[4] stated that when the organisation is managed to operate at numerous batch sizes and/or different production output levels profitably, it can be classified as having volume flexibility. Therefore, the implementation of this flexibility in the factory will help them to adjust or change the product within a big range. In other words, volume flexibility enables a firm to produce the production either above or below the capacity that had already been set to meet customer demand. [3] claimed that there are a few companies that had not invested in flexible technologies but using outsourcing for volume flexibility. In addition, volume flexibility is suitable to use for long term uncertainty, referring to customer demand of the products but it is inconvenient for the short term. This is because the implementation of this flexibility will affect some of the manufacturing elements such as the cost, productivity, and also performance of the machines. There are several reasons to implement volume flexibility due to unpredictable problems that could happen in a firm such as machine breakdowns, unbalanced cycle time, long setup time, and non-conforming products.

2.1.4 Delivery Flexibility
In a nutshell, customer satisfaction plays an important role for a firm to achieve success and become well known. The trust of the customers to a firm will be higher if the firm can provide fast and quick delivery after receiving orders. The tendency of customers to repeat their orders from the same company is also high. The saying “the customer is always right” is really meaningful. As customers, they do not think about the problem that a company will face if the customer demands already exceed its capacity limit. All they know are once the orders are submitted, they want to receive the product immediately or in a short time.
[11] stated that in order to assess the delivery flexibility, it is necessary to take into account the vehicle and the possibility of alternative routes in the network of transportation, palletising method, and transportation method. Other than that, the scheduling challenge that always occurs is the long term-capacity planning and the delivery process that needs to be scheduled and assigned based on available resources during operative delivery planning [12]

2.1.5 Variant Flexibility
Variant flexibility is the ability of a firm to produce the same product in a large number with various types of variants. The variant and inventory have a connection as a one-to-many relationship where the inventory has unique relations to every unique variant. All the products still use the same concept as the actual product, but there are some differences in terms of the materials and ingredients. The manufacturing process which manages to produce the product with multiple variants should be given
some credit and helped to improve customer satisfaction. Landahl et al. [13] suggested an adjustable manufacturing system that aids the variety of a product that can quickly change the customer requirement while the flexibility of the system itself serves the variation of the product family. Process flexibility in manufacturing is more focused on the operation of the product itself. As we can see, the product has various elements that need to be considered such as its designs, capacity, size, and market demands. All of these are big constraints before the product can be manufactured.

2.2 Single-Minutes Exchange of Die
SMED is a manufacturing lean tool that takes place when there is a changeover of equipment for reducing the time. The terms “single minute” or “single-digit minute” do not mean all changeovers and the startup time needs to be at least one minute, but should be below 10 minutes (Singh et al.) [14]. Rosa et al. [15] emphasised that SMED allows for the reduction of lot sizes and enables meeting of the variation of demand by focusing on the elimination of the waste connected to the changeover of the tool in the setup phase.

In SMED, there are two types of activities, namely internal and external. Internal activities can be conducted only when the machining process is stopped while the external activities can be done while the machining process is still running [16]. So, the main objective of the SMED system is to change the internal activity to external activity as much as possible. Furthermore, the process of SMED is more focused on external activity as it can help to reduce the time taken to change the equipment while the machine is still running. Figure 1 shows the visual application of the SMED process that has already been implemented in industries.

![SMED Process](image)

**Figure 1. SMED (Venugopal, 2018)**

2.2.1 Internal Activity
[17] also mentioned that internal activity can be carried out only when the machine is shut down such as when attaching or removing the dies. Similarly, Bevilacqua et al. [18] identified that the internal activities are carried out when the machine is offline and it must be reduced as it affects the production time. Karasu et al. [19], Maheswaran et al.[20] also claimed that all activities which cannot be done without the machine are stopped for an internal setup such as mounting-demounting the dies. From these three findings, it can be concluded that internal activities spend a lot of time that can actually be reduced or can be done while the machine is running as they do not involve the machine itself. The internal components need to be identified first as they will then determine whether it is suitable or not to be converted into an external activity.

2.2.2 External Activity
External activities can be performed when the machine is still running at its normal operation, for instance, equipment getting ready for the setup operation can proceed before the machine is shut down [17]. External setup includes the activities that can be performed while the machine is running, for
example in advanced mold transportation [16]. Sousa et al. [19], Maheswaran et al.[20] agreed with the previous explanation as they also concluded that external activities are designated as all the activities that do not involve directly with the equipment and can be carried out without discontinuing the production. Other than that, external activities can be described as an activity conducted while the machine is still running so that everything is done before reaching the last process of the current operation. As a suggestion, all the tools, equipment, and material are well prepared before starting the setup of the internal activity so that this will automatically remove all the time that should be needed while doing the internal activity. Thus, it will help the process of changeover between the equipment or tool.

In a nutshell, it is prominent to ensure the production time and the lead time of the product can be reduced for flexibility performance. Based on the overall findings, it can be concluded that in manufacturing, there is a lot of flexibility involved to improve the production line flexibility. Nevertheless, in this literature, only several flexibilities were focused on which are machine flexibility, labour flexibility, material handling flexibility, routing flexibility, customer flexibility, supplier flexibility, process flexibility, mix flexibility, new product flexibility, volume flexibility, delivery flexibility, and variant flexibility. All of these flexibilities give a huge impact on a firm to sustain and improve production and also reduce the changeover time to be more efficient and profitable through internal activities.

3. Identification of Issues

In order to propose an improvement, it is essential to identify the factors of issues. These factors of issues could be identified through literature studies. In this study, the selected company will undergo data collection. Relevant data are extracted from the assembly process. They are categorised into two types: (i) primary data and (ii) secondary data. Sources of data are mainly related to documents (i.e., Changeover Time Record and Monthly Quality Record). For analysis purposes, bar graph, 7 QC tools had been implemented in order to identify the root cause which has the tendency to be the issues in industries. Figure 2 shows the steps of the processes.

3.1 7 QC Tools

The 7 QC Tools is a suggested tool that is used to solve a problem that always occurs in the manufacturing industries. These 7 QC tools are fundamental instruments which can help to improve the product quality. Basically, the function of this tool is to analyse the process of production, identify major problems, control the fluctuations of product quality, and last but not least, suggest solutions to avoid any defect in future production. The 7 QC tools include the Check Sheet, Pareto Chart, Cause and Effect Diagram (Fishbone Diagram), Histogram, Flow Chart and Control Chart. In this study, there is one selected QC tool chosen to be more focused on as it is related to the project which is the Cause and Effect Diagram.

A Cause and Effect Diagram is a tool that studies the relationship between the effect and the possible causes that occur in certain problems. This tool is preferable to use in order to find the root cause of the problem before providing the solution or any improvement for the problem. Besides, the purpose of this tool is as a graphical representation of the trail leading to the root cause of any problems that happen in the industries. Moreover, this tool is very effective as it can help to generate ideas systematically about the problem’s cause and then present the details in a structure form that looks like a fishbone.
3.2 Why-why Analysis

Why-why Analysis is the ultimate root cause analysis tool that was developed by Sakichi Toyoda, a Japanese inventor and industrialist. This tool is part of the Toyota Production System and it has become an integral part of the Lean philosophy. Besides, this tool has a simple technique and is effective for solving problems. It is compulsory to find an exact reason that causes the existing problem by asking a sequence of “why” questions. It is very useful to help to identify the root cause and propose for the improvement of any problem.

4. Results and Discussion

Specifically, this section will elaborate on the problem definition of the studies. In addition, the definition of the problem was identified. The flexibility of production was not sustainable and the activity during changeover must be understood. This study will continue with the data collection from the case study through the factory itself. Then, data analysis is done to propose improvements that can be used by the company to increase their productivity.

4.1 Data Collection

Actually, this company has three main production lines which are carbonated drink line, soy bean drink line and tamarind drink line. In this study, the chosen production line is the carbonated drink line because the main focus of this study is to reduce the time in order to achieve flexibility in production. Thus, the carbonated drink production line is selected as a changeover occurs while changing the flavour in a day. It should also be highlighted that there are six types of carbonated drink flavours namely orange, ice cream soda, grape, sarsi, strawberry, and mixed fruits. In this study, the process of data collection was time consuming as secondary data were used. Table 1 shows the production record for carbonated products in March 2019.
Table 1. Carbonated Product for March 2019

| Product Carbonated | Volume | Production Date | Total Finish Goods |
|--------------------|--------|-----------------|--------------------|
| Strawberry, Sarsi, Grape, Soda, Orange, Fruit | 1.25 L | 3/5/2019 | 1416 |
| Strawberry, Orange | 2L | 3/12/2019 | 1956 |
| Strawberry | 2L | 3/13/2019 | 960 |
| Strawberry, Grape, Fruit | 2L | 3/14/2019 | 2772 |
| Strawberry, Grape, Fruit | 2L | 3/15/2019 | 2364 |
| Strawberry, Grape, Fruit | 2L | 3/16/2019 | 2316 |
| Fruit | 2L | 3/18/2019 | 1527 |
| Strawberry | 2L | 3/19/2019 | 2772 |
| Sarsi, Orange | 2L | 3/20/2019 | 1200 |

Based on the data above, the production activities did not receive consistent orders. The objective of this study is to eliminate unwanted internal activity to external activity to produce quick changeover.

4.2 Data Analysis

The data in Figure 3 are not consistent as no production occurred for several days in March 2019. This is because the production is based on customer demands and sometimes the workers did not record the data. In this Figure, flavour changeover occurred.

Figure 3 shows the changeover records in bar-graph for carbonated products in March 2019 based on Table 1.

![Flavour Change Graph](image)

Table 2. List of Internal and External Activities during Changeover

| Step No. | Description                                      | Activity |
|---------|--------------------------------------------------|----------|
| 1       | Taking out the raw material from storage         | External |
| 2       | Boiling of sugar                                 | Internal |
| 3       | Labelling process                                | External |
| 4       | Mixing the boiling sugar with the flavour        | Internal |
4.3 Propose Improvement
In order to identify the critical factor of the problems occurring in the company, Why-why Analysis was used. The Why-why Analysis is an iterative interrogative technique that was used to find the root cause of a certain problem. This technique was applied by repeating the question “why” as much as five times if possible. In this study, the focus was on the Man and Method factors because those two factors were related to changeover internal activities. Table 3 shows the Why-why analysis of the problems that occurred in the company’s operation.

![Fishbone Diagram](image)

**Figure 4. Fishbone Diagram**

| Why 1 | Why 2 | Why 3 | Why 4 | Why 5 |
|-------|-------|-------|-------|-------|
| **METHOD** | High Changeover time | Based on individual setting | No monitoring | Difficult to monitor | No provide SOP |
| | Lack of changeover activities | No review for internal activities | Excess of preparation time | Improper facility/equipment and layout |
| **MAN** | High Changeover time | Lack of changeover skill | Lack of talent | Lack of training | No specific training provided |

In Root Cause Identification, a tool was used to find the root cause which was the Fishbone Diagram. Based on Figure 4, it is shown that the cause is focusing more on the method and man, thus causing longer changeover time.

There are three proposed improvement ideas that could be implemented in this food operation company to reduce the changeover time through minimising or eliminating the time of internal activities. The first improvement idea is to provide appropriate standard operating procedure (SOP) that is focusing more on changeover that happens in the carbonated drinks production line. This is because it will meet the aim of this project to reduce the changeover time. SOP is described as a set of instructions compiled by a company that is done step-by-step to manage the workers to carry out their routine operations. The importance of SOP is so the production can be done by following the flows as well as to train the workers. Other than that, the SOP can also help the company to save on training costs and control the quality and consistency of the production of carbonated drinks. It is important to
note that this SOP focuses on the changeover that always happens in the production line. Thus, there are the main processes that were included in the changeover phase, namely the process of boiling sugar, mixing the sugar and flavour and the filling process.

Secondly, the idea is to design the mixture tank by adding one more tank intended to produce many flavours in a day quickly. Therefore, the total tanks went from two to three. Besides, after adding the tank, the layout of the mixture is redesigned to make sure it can be moved nearer to the filling machine in a short time. Thus, a new design is created that could help to improve production by reducing internal activities and at the same time can reduce the changeover time. The design is created by adding one more mixture tank and then designing a new tool named a rotary tool that might help to rotate the mixture tanks quickly to change the mixture tank before going through the filling process. Figure 5 shows the new design of the mixture tanks.

![Figure 5. The New Design of Mixture Tanks](image)

The last improvement idea is providing a changeover training with proper schedule in order to make sure the workers could carry out their task or operation with the appropriate skill. A training schedule is usually created to include the different activities involved in a company. The benefit of having a training schedule is it can provide a clear guideline for the process and also can help to manage the worker’s time, especially to ensure that changeover can be reduced to gain high flexibility in the production line.

5. Conclusion

As a conclusion, the company will gain new knowledge that can be used to reduce the changeover time during the process of manufacturing carbonated drinks through the application of 7 QC Tools and Why-why Analysis to identify and investigate the root causes and propose improvements. Thus, the company can also reduce the changeover time while increasing flexibility by applying SMED concept through reduction of internal activities. By the end of this study, the company will know how to execute the proper way to produce more products in the long term.

Hence, for future research, another type of operation involving any changeover in its production line should bestudied. It would bring more benefits to find a company that is highly competitive in the industries because the problems that will occur in that company will pose greater challenges to the researcher. There are several industries that could be chosen such as automotive industries, packaging industries, steel industries or plastic industries.

Acknowledgements

The author would like extend special thanks to the FRGS-RACER/2019/FTKMP-COSSID/F00412 grant, FakultiTeknologiKejuruteraanMekanikaldanPembuatan, UniversitiTeknikal Malaysia Melaka and the participating food company for the use of facilities and providing useful data in order to complete this study.
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