# Bottleneck Processes Improvement for Food Industries by using an Integration of Lean Six Sigma and Risk Assessment Approach

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**Abstract.** Food industries, typically operating as Small and Medium Enterprise (SME) companies, are often susceptible to production waste and process risks that are concealed within the production line. Issues such as low efficiency, reduced productivity, and inconsistent daily production output are associated with bottleneck and unbalanced processes. Company A, which produces frozen foods like doughnuts, is experiencing similar challenges. The primary goal of this study is to enhance the bottleneck process by incorporating the Define-Measure-Analyse-Improve-Control (DMAIC) approach of Lean Six Sigma (LSS) and risk assessment (RA). Two identified bottleneck processes, stamping and frying, underwent an extensive work study analysis through cycle time (CT) measurements of Value-Added Activity (VAA) and identification of production waste Non-Value-Added Activity (NVAA). Additionally, hidden process risks were identified and improved using the risk assessment technique, which involved the application of Failure Mode and Effect Analysis (FMEA) and statistical analysis. Continuous improvement was pursued through process kaizen at the impacted processes. After the intervention, cycle time measurements were reassessed, which showed a notable enhancement. The culmination of Lean Six Sigma (LSS) integration led to the creation of Standard Operating Procedures (SOP) and Statistical Process Control (SPC), establishing a structure for enduring productivity. The results underscore the efficacy of LSS in boosting operational efficiency, cutting production costs, minimizing waste and variation, and enhancing product quality to meet customer satisfaction. This project not only aids in process optimization in the food industry but also emphasizes the potential for ongoing improvement and waste reduction through LSS and RA methodologies.

**Keywords** : Value-Added Activity (VAA), Non-Value-Added Activity (NVAA), Kaizen, bottleneck process, Lean Six Sigma (LSS), Risk Assessment (RA)

## 1. Introduction

The Lean idea, which aims to get rid of activities and actions that don't add value, is known by many names, such as Lean manufacturing, Lean production, Lean college, Lean office, and so on [3]. A semi-quantitative measurement method takes the best parts of both quantitative and qualitative methods. The semi-quantitative method is made up Failure Mode and Effect Analysis (FMEA). In FMEA, the Risk Priority Number (RPN) helps to identify which of the problem was the priority to solve[4]. Kaizen is a Japanese term that meaning "constant improvement." It emphasises improvement to enhance process parameters. It is a tool used to put a stop to another Japanese policy 3M- MUDA, MURA, and MURI, which stand for inconvenience, inconsistency, and waste, respectively [5]. Recently, a demand for frozen foods such as doughnut, mini murtabak and puff shows an increasing trend. A frozen food production at a selected SMEs company in Kedah, company A, is having few bottlenecks in the doughnut manufacturing process which leads to difficulty in achieving the maximum output. Hence, in this project LSS approach will be considered to achieve the product optimization through some improvement for the machine or equipment in the processes [1]. While using LSS as a main methodology, DMAIC approach which consists of five (5) phases (Define-Measure-Analyse-Improve-Control) is selected as a framework to solve the bottleneck process at the company A's production line [2]. The approach benefits from incorporating a risk assessment method to assess and improve the processes risks by using FMEA. Control phase is a final step in the DMAIC approach. It was primarily concerned with ensuring that the action item developed during the improvement phase was properly executed and maintained. Control charts such as SPC chart were used to assess performance before and after deployment [6]. In addition, SOP is prepared to visual representations help outline the step-by-step sequence of activities, providing a clear and accessible overview for users.

Company A encountered bottlenecks that significantly impact its overall performance. These bottlenecks are exacerbated by delays and inefficiencies caused by specific process cycle times. Additionally, there is a lack of a systematic approach to execute and measure the effectiveness of actions on the production line. Therefore, by using DMAIC approach, this study will define Value-Added Activities (VAA), Non-Value-Added Activities (NVAA) and risks, assess the performance of current bottleneck processes on the studied doughnut production line. Then, process cycle times is analysed using the Lean Six Sigma (LSS) approach and action plans are developed. Finally, the execution of the identified actions on the production line and implement effective control measures are performed. The analysis will be conducted by utilising Lean Six Sigma methodologies to enhance productivity specifically within the forming and frying stages of the doughnut manufacturing process. Implementation of the DMAIC approach, incorporating time recordings, cycle time measurements, FMEA, statistical analysis, and KAIZEN principles for continuous improvement. Finally, development of SOP and Statistical SPC measures to ensure sustained improvements in productivity [9].

## 2. Methodology

A cycle time (CT) is referred as a time taken to produce one unit of doughnut per shift, while takt time (TT) is a reference time for all processes at the production line measured by dividing total effective work time to number of outputs required per shift (equation (1)) [7].

$$\text{Takt time } \left(\frac{\text{Hours}}{\text{unit}}\right) = \frac{\text{Total daily effective production time (Hours)}}{\text{Total production demand (Units)}} \quad (1)$$

Figure 1 illustrates the application of the DMAIC approach and the explanation of each phase, aimed at addressing the issues encountered in doughnut production at Company A. During the define phase, there is a familiarization process for stamping and frying. A work study is conducted on the existing processes using a method of video recording analysis. Following this, in the measure phase, the Value-Added Activity (VAA) cycle time and Non-Value-Added Activity (NVAA) waste time for both processes under study are documented. The takt time, which is the time taken to produce a single doughnut, is also measured.

Next, during the analysis phase, a normal distribution graph was created to depict the Value-Added Activity (VAA) and Non-Value-Added Activity (NVAA) cycle times, showcasing the bell-curve nature of the statistical analysis. The Failure Mode and Effect Analysis (FMEA) method is employed for potential risk analysis, which aids in identifying, scrutinizing, and managing risks. The output from the

FMEA approach is the Risk Priority Numbers (RPN) for each risk, which can help management prioritize which risks need to be addressed first. The calculation of RPN numbers is done using equation (2) [8].

$$RPN = S \times O \times D \tag{2}$$

where S is a risk severity factor, O is occurrence level of each risk to happen and D is a current detectability in the production line if the risk happened. All the three factors scale range from one (1) to ten (10) and the RPN numbers will be ranked into four risk ranks, as illustrated in table 1.

**Table 1.** RPN numbers and risk rank

| Rank | RPN | Colour Code | Management Decision |
|---|---|---|---|
| 1 | 1-250 | Green | Monitoring and no action necessary |
| 2 | 251-500 | Yellow | Monitoring, Actions are optional |
| 3 | 501-750 | Orange | Action is recommended |
| 4 | 751-1000 | Red | Action Priority First |

In improve phase, KAIZEN tool is used to rectify the issue and execute the action plans decided as a result from a brainstorming session between researcher's and management's teams. After the improvement processes stabilized, another sets of CT data need to be collected to justify the effectiveness of VAA and NVAA actions. While for the risk improvement, the justification is done by remeasure the RPN values after actions took placed. The value of RPN should be dropped to a better risk rank. All the results from improve phase need to be validated before proceeding to a control phase. In a control phase, the finalized processes must be documented into a form of standard operation procedures (SOP) and all the processed required for statistical control need to be done by statistical process control (SPC) charts.

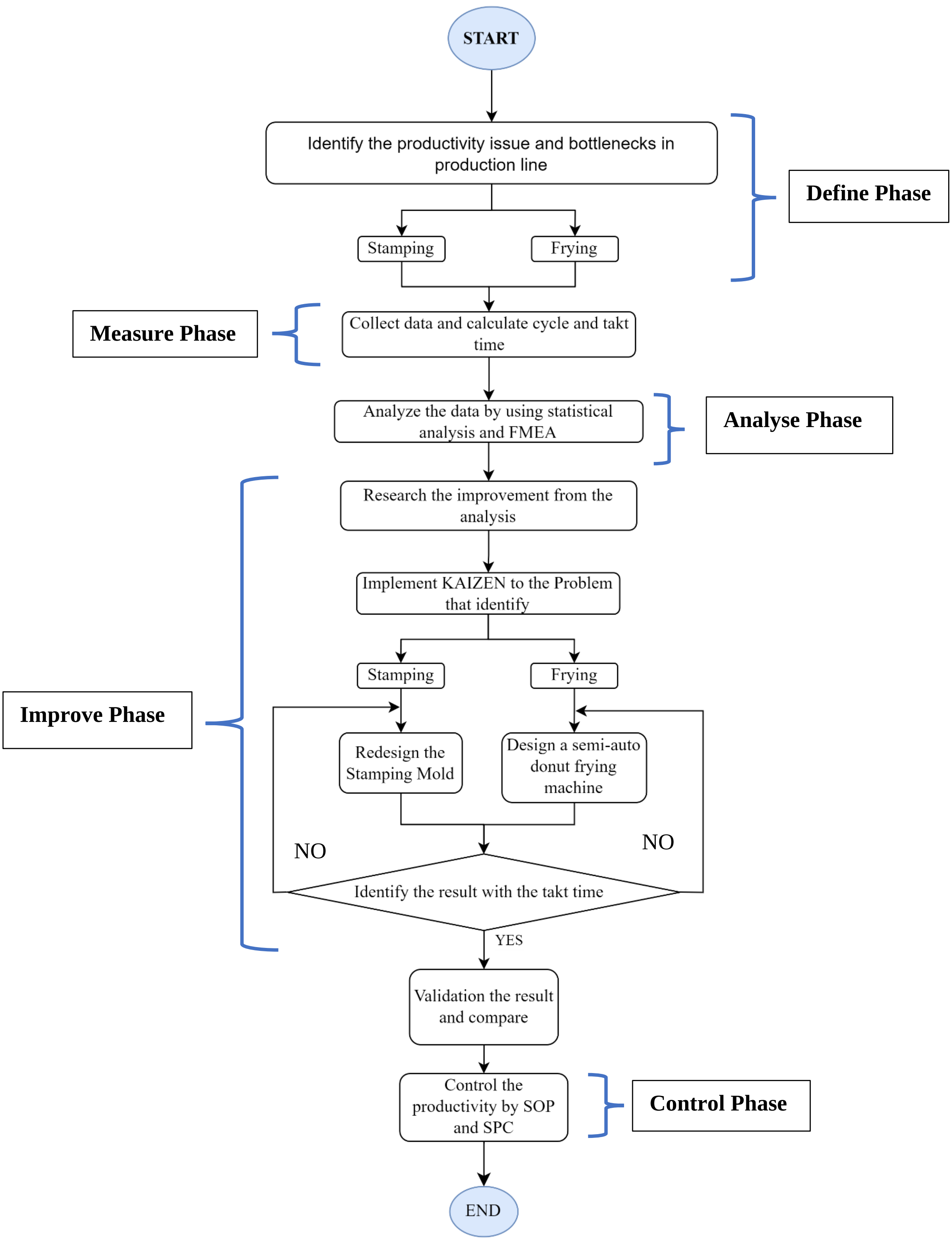


**Figure 1.** Methodology Flow

## 3. Result

*3.1 Define and Measure Phase*

From the production processes familiarization there are three main problems identified at pressing and frying stations, as illustrated in Figure 2.

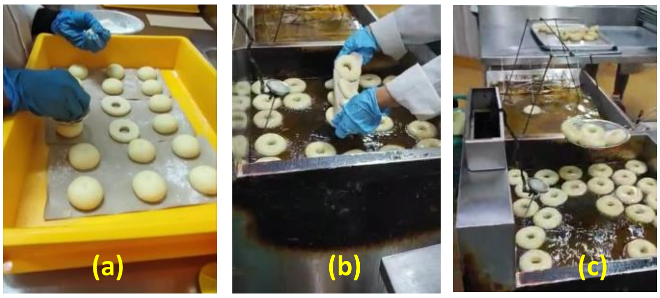


**Figure 2.** (a) Stamping: mould handle small. (b) Frying: inconsistent drop time of the doughnut. (c) Frying: small sieve to flip the doughnut from side A to side B

During a work study, a cycle time (CT) for one WIP tray (work in progress) of doughnut is recorded and then measured for CT per piece of doughnut. The 50 sets of CT data recorded is in term of VAA, NVAA and potential risks at the studied processes: stamping and frying.

### *3.2 Analysis Phase*

The before improvement data is plotted in the normal distribution graph as shown in figure 3. By using equation (1), the doughnut production takt time is equal to 5.4s/pc. From the overall distribution of data in figure 3, it shows a wide distribution of data for both stamping and frying processes due to a big variance and standard deviation. This is due to inconsistency of current processes caused by production wastes and potential risks hidden in the production line.

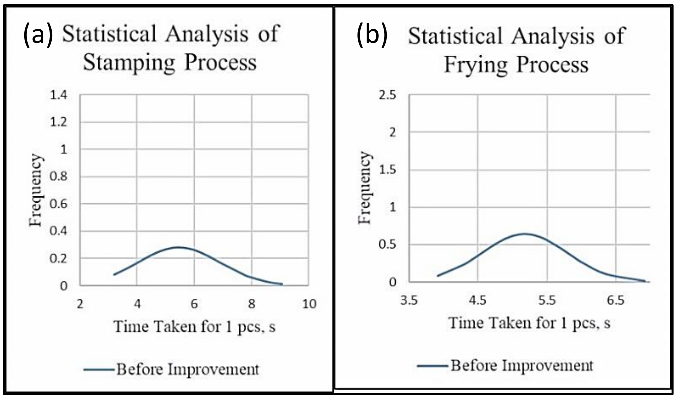


**Figure 3.** (a) Normal Distribution Graph for Stamping Process and (b) Normal Distribution Graph for Frying Process

The potential risks at the studied processes are then identified and summarized in a risk registered table (Table 2). The RPN numbers is measured for each risk by using equation (2) for before and after actions taken. From table 2, the highest RPN numbers are improper (inconsistent) frying time at frying station causing uneven frying time at side A and B, and uncomfortable of holding the stamping mould at stamping process.

### *3.3 Improve Phase*

Based on the analyse phase finding, the focused kaizen could be prioritized by the management which will be explained in improve phase. Figure 4 shows the kaizen sheet for design improvement carried out at the stamping mould. There are three main improvements carried out for the mould design illustrated by A, B and C points in figure 4 ('After' column). Design improvement point A was by adding a radius curve to avoid the crack at doughnut, point B was sharpened the cutting doughnut area for easy cutting the dough and point C was adding notches at the hole so it could catch the dough when pressing. The fabrication was done by using 3D printing. The effects from this kaizen are an improvement in pressing process CT, eliminating production motion waste and operator finger pain risk, besides improve the appearance quality of the doughnut.

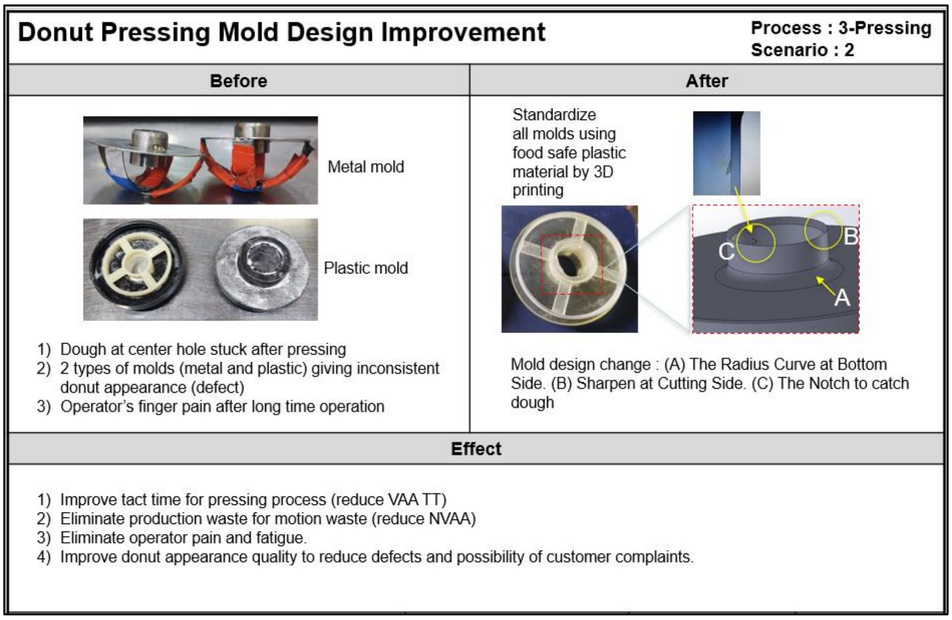


**Figure 4**. Design improvement of a doughnut stamping mould kaizen

The next improvement carried out was at frying station by an introduction of semi-automated fryer in order to make the even frying time at both sides of the doughnut. Figure 5 shows the kaizen sheet for the introduction of semi-automated fryer. The effects from this kaizen are improving the VAA CT of frying process, eliminating the inconsistent frying time risk and eliminating motion waste of flipping from side A to side B.

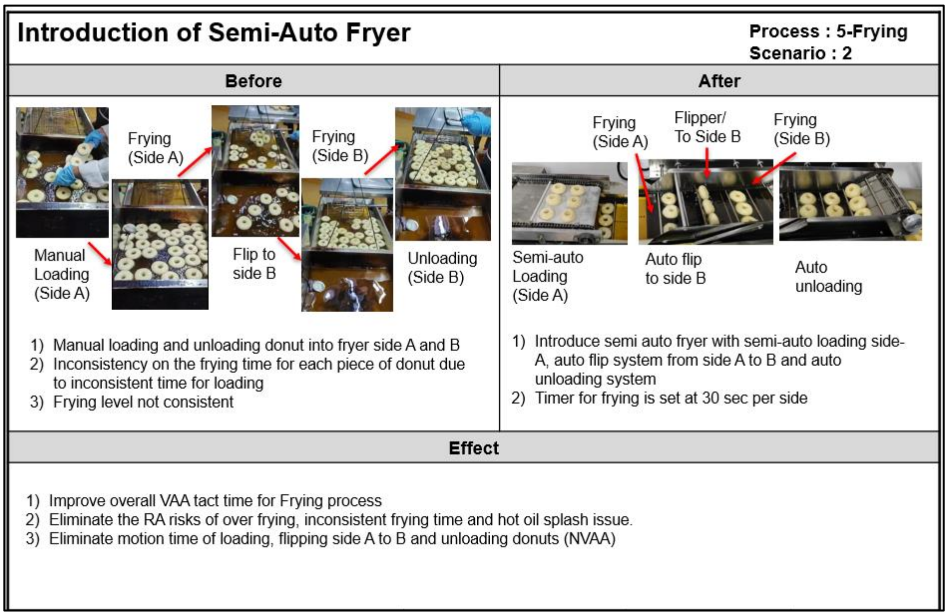


**Figure 5.** Semi-automated fryer machine kaizen

After the kaizens' actions executed at stamping and frying processes, the CT for both stations is remeasured. Figure 6 shows the improvement in the CT data distributions. CT data shows a big improvement in the data variation for after actions taken where the distribution is narrower towards the centre value of takt time (5.4s).

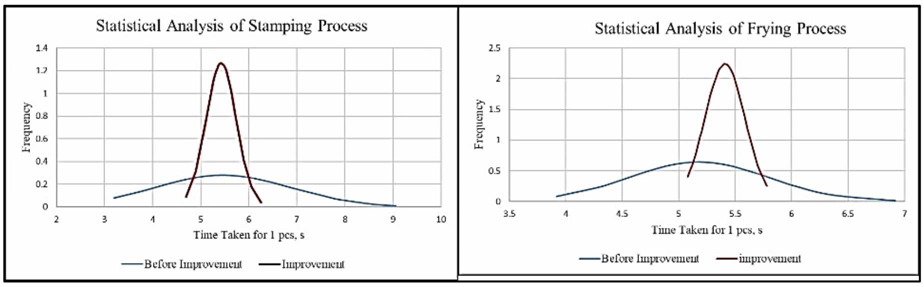


**Figure 6.** Normal Distribution Graph for Stamping and Frying Processes after Improvement

The improvement could also be seen for the RPN value after actions taken, where all the risks' RPN reduced to rank 1 as shown in table 2.

**Table 2.** Risk Registered Table for before and after improve phase

| Process | Potential Risk Mode | Potential Risk Effects | S | Potential Causes | O | Current Control | D | RPN | Recommended Action | Responsible | Action Taken | Sev | Occ | Det | RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stamping | Unconsistency Donut Shape | Irregularly shaped donuts | 7 | Worn-out or misaligned stamping mold | 6 | Take out and rework | 6 | 252 | Design the mould that can align the donut to center | Lee | The mould had change to transparent material | 7 | 4 | 3 | 84 |
| | Non-utilized talent, Motion, Transport | Slow down the process | 6 | Slow in doing the pressing process | 7 | None | 6 | 252 | Giving training program | Lee | Making SOP and training | 6 | 3 | 2 | 36 |
| | Non-utilized talent, Motion, Transport | Don't know use the mould correctly | 8 | Not familiar with the mould | 7 | None | 9 | 504 | Giving training and teach them how to use it correctly | Lee | Giving Training | 8 | 3 | 2 | 48 |
| | Non-utilized talent, Motion, Transport | It will over the cycle time of the process | 5 | Extra time to adjust the oil paper and transfer the tray and rework dough | 7 | None | 5 | 175 | Make a fix base | Lee | The tray is improve with another material | 5 | 2 | 2 | 20 |
| | Mould handle not comfortable | Finger will pain when using in long time | 10 | The handle is too small | 8 | None | 9 | 720 | Redesign the handle of the mould | Lee | The handle is added in the design. | 10 | 2 | 2 | 40 |
| | Extra Processing | Need to take the dough from the donut | 6 | The dough will not catch up at the mould | 7 | None | 6 | 252 | | Lee | Extra added a notch on the mould to catch the dough | 6 | 3 | 3 | 54 |
| Frying | Improper frying time, Extra Processing | Overcooked or undercooked | 10 | The time of the donut drop in the first frying pan not equal | 9 | None | 9 | 810 | Modify the tray that can drop in 1 times | Lee | A manually had change to Automated Frying Donut Machine and Monitoring the Takt time by SPC | 10 | 1 | 2 | 20 |
| | Improper frying time, Extra Processing | Overcooked or undercooked | 10 | The sieve is too small to flip the donut to another frying pan in one time | 9 | None | 8 | 720 | Design a big wire mesh to flip the donut in a big quantity | Lee | In the machine, the component can automatic to flip | 10 | 1 | 1 | 10 |
| | Frying more than 2 tray of donut | inconsistent donut texture and colour | 7 | Too many of donut cannot control | 9 | None | 9 | 567 | Create a SOP to follow the instruction | Lee | Making SOP and training | 7 | 1 | 1 | 7 |

## *3.4 Control Phase*

Once the processes were fine-tuned and had undergone the required learning period, they were recorded in the SOP and SPC chart. The SPC kept a close watch on the cycle time to ensure it remained within the boundaries established by management. The SOP was designed to provide comprehensive instructions, enabling both seasoned and new employees to adhere to the rules and guidelines with ease.

The emphasis on these regulated processes was further heightened through managerial training, leading to an overall enhancement in the consistency of operations.

## 4. Conclusion

This study successfully addressed bottleneck issues in the frozen food industry using Lean Six Sigma (LSS) employing FMEA and statistical tools. The DMAIC method was applied as a framework to resolve identified bottlenecks. The main actions were executed at the production line through focused kaizens, introducing a new stamping mould and a semi-automated frying machine. Post-improvement, cycle time was reassessed and compared to the doughnut production initial performance resulted in the improvement on the process variation (for VAA and NVAA cycle time) and the production risk (for RPN numbers improvement). SOP and SPC were implemented to ensure sustained control of production efficiency.

## 5. Acknowledgement

The authors would like to acknowledge UniPRIMA 2022 internal grant (Project code: 9001-00727) awarded by Universiti Malaysia Perlis for carrying out this project.

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