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LOSS ANALYSIS IN BREAD PRODUCTION PROCESS USING MATERIAL FLOW COST ACCOUNTING TECHNIQUE

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Abstract

The case study factory manufactures a range of bread and bakery products for distribution in the North of Thailand. Losses from the production process were recently discovered, which besides being lost costs, also impacted the environment. This research is conducted under the concept of Material Flow Cost Accounting (MFCA) to analyze the losses from each process of the case study bread factory. This is to pinpoint where most of the losses occur and suggest methods for future improvement. This research is conducted with the principle of Plan Do Check Action (PDCA). The "Plan" was to determine a target product, which in this case was raisin bread, as it accounted for the largest proportion of production. Subsequently, a study was conducted of the production *process, and a scope under the "Do" stage of the procedure was determined. Input and output factors were identified for each Quantity Center (QC) in both physical units and financial units. Subsequently at the "Check" stage, an analysis of costs was conducted for each QC with the MFCA technique. This was divided into positive product, meaning costs generating revenue, and which were manifest in the product, and negative product, which were costs not generating revenue and were losses from each production stage. Finally, at the "Action" stage, negative products were ranked using Pareto diagram to identify and evaluate opportunities for improvement. The research found that the total costs to produce one production lot of raisin bread were 2,935.55 THB, which were divided into materials costs of 2,270.79 THB (77.35%), system costs of 500.30 THB (17.04%) and energy costs of 164.46 THB (5.60%). Overall, negative product was 25.19%, of which negative product in material costs was 19.41%. This negative product was wastage and losses from dough and fillings being deposited in the machinery, and the failure of packaging films when they were being installed in the packing machine. It was also found that negative materials costs arose maximum in the QC of packing. The conclusions from this research are that it has informed about losses arising in the production process and evaluated them in the form of costs, which should help in proposing methods to reduce this wastage in the future.*

Keywords

Material Flow Cost Accounting, Bread Production, Material Flow, Material Costs, System Costs, Energy Costs

1. Introduction

Although consumption levels of bread among the Thai public are considered low compared to other countries, the Thai bread and bakery industry shows clear ongoing growth trends. Consumer demand is increasing from urban consumer behavior preferring convenience foods and snacks. Production in Thailand's bread and bakery industry is expanding. As an industry, technology is being applied to production with the introduction of modern machinery enabling more efficient production. There is also a constant state of product development adding value to the products, to make their attributes more outstanding and diverse. Coupled with a more modern transportation system, the shelf life of products has been extended, all of which are factors supporting growth in the bread and bakery industry (Food Intelligence Center, 2016).

However, the bread industry also has an environmental impact. Bread is a food made from wheat flour mixed with water and yeast. Other ingredients are added to provide color, taste and aroma for each category of bread. The ingredients are integrated into dough which is then formed into shapes and proven at the appropriate temperature and humidity to get the yeast working, before baking. The industrial production of bread requires efficient flour milling machines and kneading machines, and large ovens with temperatures of over 230°C, which require a lot of energy. The transportation of raw materials and the finished bread to stores also require gas and oil. Moreover, to produce flour, 66% or 2/3 of greenhouse gas emissions come from growing the wheat crop, which is the key raw material for flour and bread. Another impact on the environment is waste from the production process and consumption, such as expired products which must be discarded in large volumes, compared to total production volumes (Green News, 2017).

Research of the literature discovered that many studies had the target to reduce waste from the production process and evaluate environmental impacts from the production of industrial bakeries, such as Laurence, Hartono and Christiani (2018) evaluated the life cycle of bread production process using life cycle analysis framework in ISO 14040. The research shows that the most important factor contributing to environmental impact is electricity use.

The case study factory conducted the production and distribution of a diverse range of bakery products in the north of Thailand. The factory is currently facing issues similar to other factories in the same industry, such as waste and losses from the production process. For instance, at the forming stage there is dough which was formed, but did not pass the size, shape or weight standards which had been specified, making it a waste product. However, in some cases it was possible to rework the product, or sell it as animal feed. Still, it is a lost cost and also impacts the environment. This research is therefore applying the technique of Material Flow Cost Accounting, (MFCA) to analyze the costs lost from each stage of the factory's bread production process, to pinpoint where the most losses occur, and seek methods for improvement in the future. Compared to other productivity improvement tools and techniques such as Lean Manufacturing, Six Sigma or Kaizen, etc. (Sharma, Sharma & Singh 2015; Shrivastava, Krishna, Sharma & Sharma, 2015), MFCA has the advantage that it can be used to simultaneously reduce losses and environmental impacts (Nishitani, Kokubu, Kitada, Guenther & Guenther, 2022). In addition, material flow model in MFCA can be used to trace and quantify the flows of materials in the process in physical and monetary units. This information can be used to find solutions to reduce material losses, as well as negative environmental effects, and related expenses (Kokubu & Tachikawa, 2013).

2. Literature Review

MFCA is one of a number of tools used to evaluate environmental impacts which originated in Germany (Wagner, 2015). It was seriously adapted in Japan and from there MFCA has been applied in many countries and specified as ISO-14051 (Nakajima, 2006; Schmidt & Nakajima, 2013). MFCA is a technique to characterize and indicate losses from work processes, systems or inefficient production technology, or to improve a system. Volumes of production are analyzed to compare them with volumes of raw materials brought in. When the production obtained has a weight or amount lower than the amount of raw materials brought in, this illustrates loss arising in the production process. Losses of material are evaluated in the form of costs. Costs are divided by costs generating revenue or manifest in the product which are called *"positive product"*, and costs not earning revenue as well as losses in the production process, which are called *"negative product"* (Nakajima, 2006; Chattinnawat, Teeratanasombut & Kammoon, 2015).

From studying past research studies, there were few studies that analyzed material flow in the bread or pastry production industry, but not many used the MFCA technique. For example, Kheiralipour and Sheikhi (2021) analyzed material and energy flow in different bread baking types in Iran. The results can be used for reducing the energy and material consumption in the bakery production, as well as decreasing environmental impacts. Furthermore, in the study by Amicarelli, Lombardi, Varese and Bux (2023), the material flow analysis was used to evaluate the sustainability of Italian artisan bread production by comparing a baseline and war scenario. This could assist artisan bakers in managing resources, waste and associated impacts from an economic and environmental point of view.

Although the bakery industry has not had MFCA applied to it very much, MFCA has been applied to a wide range of other industries including ceramics, timber and furniture, textiles, metallurgy and plastics, as well as the food industry. For instance, in order to improve process effectiveness, eliminate wastes, and reduce production costs, Chattinnawat et al. (2015) applied MFCA in conjunction with Lean manufacturing technique to the production of canned sweet corn in Thailand. It was found that the overall cost per unit decreased with higher proportion of positive product cost. Furthermore, Amicarelli, Roe and Bux (2022) used MFCA to evaluate food loss and waste costs in the Italian Potato Chip Industry before and during the COVID-19 lockdown. The results could improve company efficiencies and contribute to the sustainable resource and waste management. In addition, Bux and Amicarelli (2022) applied MFCA to the beef, pork and poultry industries of Italy. The research indicated that MFCA was of benefit in making business decisions focused on quantity, quality and cost, which is different from general considerations of the financial statement, while enabling analysis and management of waste in the factory.

3. Research Methodology and Results

This research made analysis of costs of losses arising in the production process of bread by applying the MFCA technique according to the PDCA cycle (ISO, 2011; Chompu-inwai, Jaimjit & Premsuriyanunt, 2015; Walz & Guenther, 2021) with the methods of research shown in Figure 1. Details and results of this research are as follows:

PLAN

-Determine target product

- Study steps of the production process, determine the scope of evaluation, and specify Quantity Centers (QCs)

DO

- Identify inputs and outputs for each QC
- Specify flow volumes of materials in physical units and in financial units

CHECK

Analysis of costs with MFCA technique to allocate positive product and negative product arising in each QC.

ACTION

Ranking negative product of each QC to identify and evaluate opportunities for improvement.

Figure 1: *Research methodology*

(Source: ISO, 2011)

The main objective of this research is to present loss analysis. For more information about loss analysis including techniques for reducing losses, please refer to Chompu-inwai et al., (2015). In the aforementioned article, the research was divided into two main parts. In the first part, MFCA was applied to identify resource consumption inefficiencies in the production process and determine the sources of these inefficiencies. This part followed MFCA implementation steps constructed in accordance with a PDCA cycle. In the second part, the tools and techniques required to improve process and reduce losses were then explored and proposed.

3.1 Determining the target product, studying of production process, and determining a scope and Quantity Centers

After consultation with the case study factory, the factory wanted to study its raisin bread product first, as it had the highest proportion of production, as high as 50% of the same category of bread products. Total production is 700 to 800 items daily (1 production lot). This was therefore determined to be the target product for this research. The bread bun with a raisin filling (depicted in Figure 2) had a central circumference of 6.4-6.8 cm with a weight per item of 35-39 gram, containing averagely 17.15 gram of filling. This research studied the data of one production lot.

Figure 2: *Target product (raisin bread)*

(Source: Authors' Own Illustration)

Researchers performed a study of the raisin bread production process with steps shown in Figure 3. This starts from mixing the dough and extruding the dough, then forming the pieces of dough, with weight tested there of 23-26 gram. If the weight is up to standard, the dough is sent for decoration and then to the next step of the process. If the weight is not to standard, the dough is returned to the extrusion machine once more. The buns are then placed on racks holding 24 buns each. The decoration involves an egg glaze and sprinkling white sesame seeds for decoration.

When decoration is complete, employees put the racks on a truck and push them to the Proving Room.

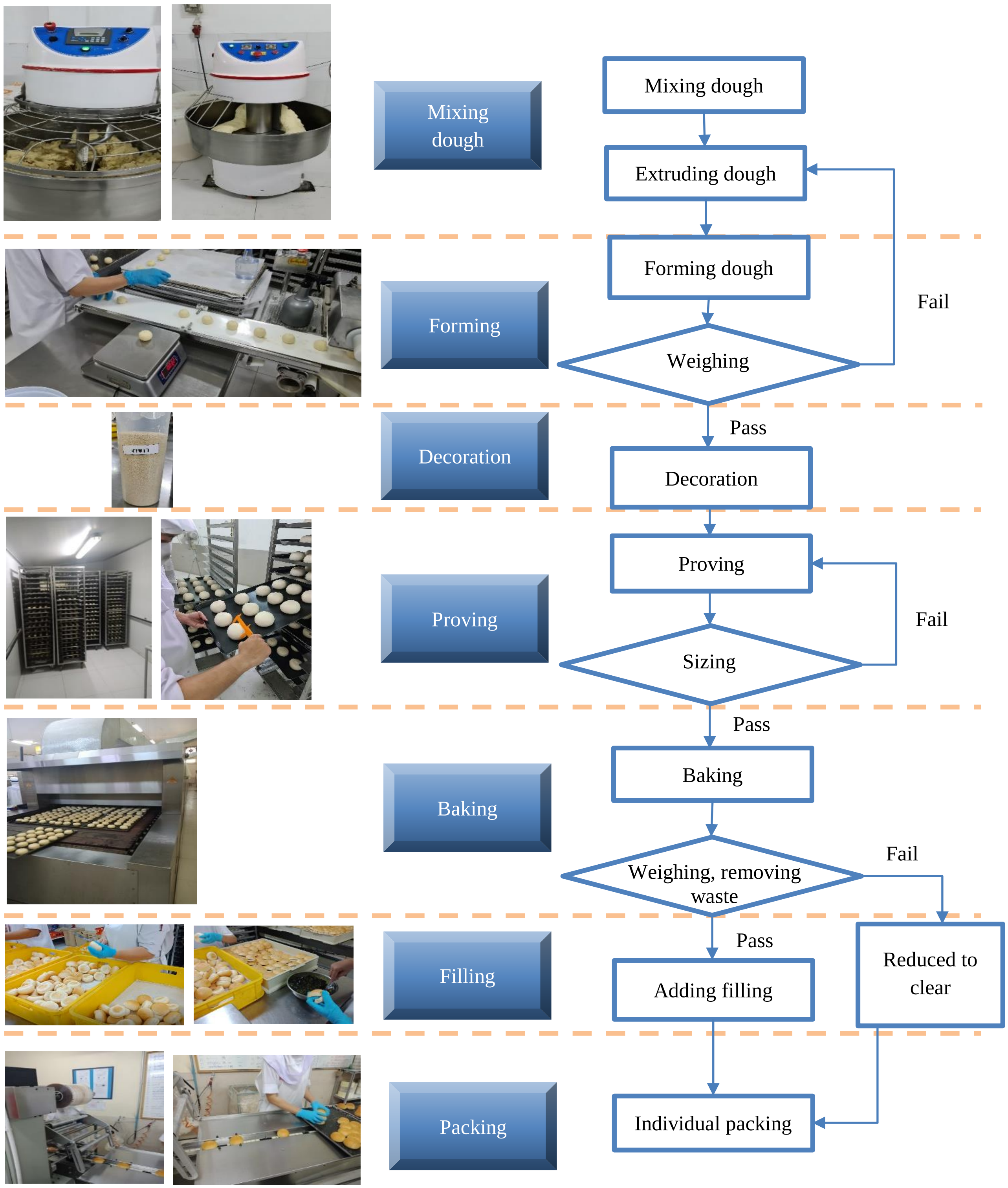

Figure 3: *Steps of producing raisin bread*

(Source: Authors' Own Illustration)

The proving processes the dough to rise. In this room, the temperature and moisture are controlled for the yeast to work fully and enable the dough to rise fully. From there the dough is left for a specified period of time. The next check is that if the dough is not yet standard size, the proving process will continue. Once the desired size is obtained, the racks are removed from the trucks to enter the baking process, where the baking is in a large tunnel oven, for 25-30 minutes. After baking is complete, the employees bring the racks back to the trucks, at which stage, they are inspected by weighing, and waste product is selected out and discarded. Waste at this stage of the process finds customers who are willing to buy it at a reduced price and use it to make fish food. The good product is sent for packing. The packing process is automated packing machines, with film cut at 132 mm intervals at a speed of 87 packs per minute. This is the end of the production process.

The next step of specifying the scope of evaluation means specifying a start point and end point of the production process, and specifying Quantity Centers (QC) which have volumes of material passing through in the manufacturing process. QCs are specified according to steps in the production process, so QC1 is the Mixing Dough stage, QC2 is the Forming stage, QC3 is the Decoration stage, QC4 is the Proving stage, QC5 is the Baking stage, QC6 is the Filling stage, and QC7 is the Packing stage respectively.

3.2 Identifying Inputs and Outputs for each Quantity Center

This stage has the objective to identify amounts of production factors entering and exiting each QC. The inputs are materials and energy while the outputs are product, waste and energy waste. Data was collected at the work stage of the raisin bread process at the case study factory. The inputs and outputs for each QC are connected throughout the scope of consideration.

This stage started from specifying amounts of material flows in physical units, in which all amounts of inputs and outputs were studied in units of weight (kilogram, kg). This enables a study of the balance of materials at each QC, in which inputs should equal outputs and waste. Table 1 is the Material Balance Table of QC1, Mixing Dough. It can be seen that at this stage, the material was dough, with a weight of 18.220 kg, which gave product weighing 18.043 kg. Waste dough attached to the machine weighed 0.177 kg, which was a 0.98% proportion of negative product by weight. As for the material balances of other QCs, they are not shown here, but were prepared in the same way.

Table 1: *Material Balance Table at QC1, Mixing Dough*

Material Balance Table, QC1					
Input: Material		***Output: Waste***		***Output: Product***	
Material	***Amount (kg.)***	***Waste***	***Amount (kg.)***	***Product***	***Amount (kg.)***
Dough	18.220	Waste dough in machine	0.177	Good dough	18.043
Total (kg.)	18.220	Total (kg.)	0.177	Total (kg.)	18.043
% weight	100%	% weight	0.98%	% weight	99.02%
Cost input		***Cost of loss (negative product)***		***Cost of product (positive product)***	
Total (THB)	477.22	Total (THB)	4.68	Total (THB)	472.54
% of cost	100%	% of cost	0.98%	% of cost	99.02%

(Source: Authors' Own Illustration)

As already mentioned, inputs and outputs at each QC are connected throughout the scope of consideration. Therefore, it is possible to create a Material Flow Model which is shown in Figure 4. It is a diagram showing the flow of materials or the details and amounts of materials entering and exiting each QC connected throughout the scope of consideration. Total inputs are identified at each QC, from all categories of inputs, both currently occurring, and positive product flowing from the previous QC.

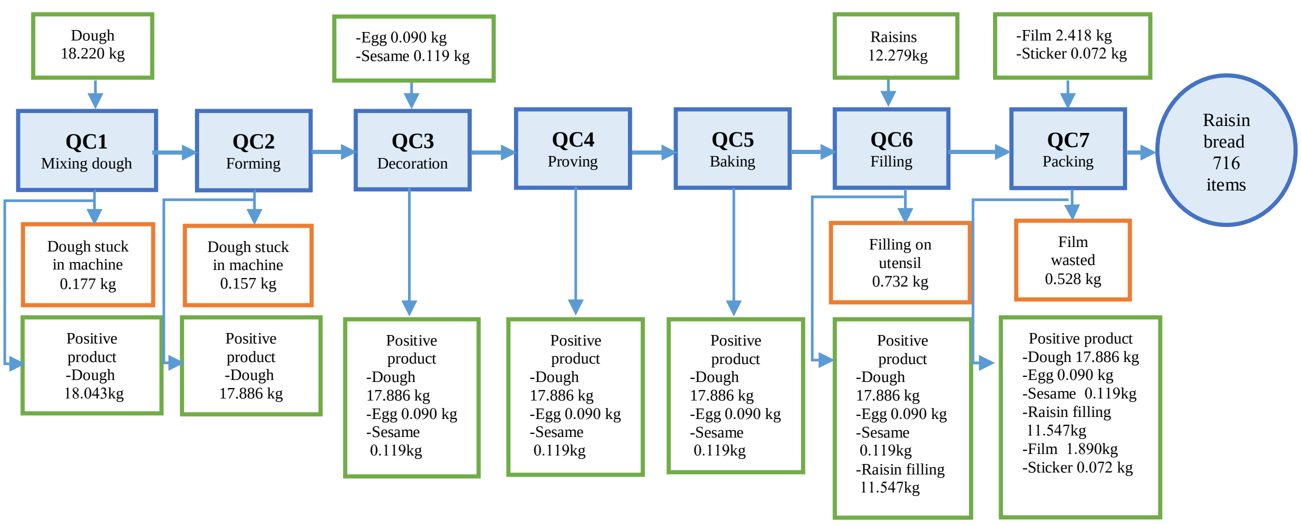

Figure 4: *Material Flow Model*

(Source: Authors' Own Illustration)

For instance, in Figure 4, considering QC2 Forming, the remaining 18.043 kg of positive product or material flew from the previous QC1 Mixing Dough into QC2 Forming, as some parts stuck to the machines and wasted in the mixer and the extrusion machine at QC1. There was no new additional material being added to QC2 Forming. There were additional losses of dough stuck in the machine at QC2 of 0.157g, with a remaining positive product (dough) of 17.886 kg flowing to the next QC. Information for other QCs can be explained in the same way.

Subsequently are determination of amounts of material flow in units of money. In each QC, data is collected on costs in 4 areas which are, material cost (MC), energy costs (EC), system costs (SC) and waste management costs (WC), detailed as follows.

Material costs are material inputs and outputs (product and waste) at each QC which can be identified from determining the product and waste in physical units of material (in this study, weight), and the unit price of that material. For instance, in the Material Balance Table at QC1 in Table 1, the Dough Mixing stage, the material being input was dough with a weight of 18.220 kg, which had a price of 26.192 THB/kg. THB means Thai baht; which 1 US dollar was approximately 35 baht on the day of the research. Therefore, the costs for the inputs at QC1 were calculated to be 477.22 THB, of which 472,54 THB was positive product and 4.68 THB was negative product.

Energy costs are the costs or expenses for energy used at each QC, with the data collected directly from the machine or electrical equipment being used, which is then timed, to calculate the energy cost.

System costs are expenses arising in the process that are extraneous to material costs, energy costs and waste management costs, such as labor, maintenance, depreciation and transportation. Labor costs were calculated from employees' real work times at each QC. The company has completely deducted depreciation on machinery according to accounting procedure, and so this parameter was not considered.

Waste management costs are costs concerned with the disposal of waste arising at every QC, including waste disposal charges and transportation. Waste management costs are all determined to be negative product. However, this research did not have a waste management cost, as waste at every stage of the process was sold as a discount to make into animal feed, so there was no need for disposal.

3.3 Analysis of costs with the MFCA technique (allocating positive product and negative product in each QC)

Positive product or previous input costs from previous process (classified into MC, SC and EC) are combined with new input costs at the QC under consideration to become total or combined costs before allocation. Analysis of proportions of positive product and negative product uses the "Law of Mass Balance" in which input mass must equal output mass plus waste in the process, considering material flowing from the previous QC. The total or combined material costs, as well as total system costs and total energy costs can be allocated into positive product and negative product using the proportions of positive product and negative product by weight that is obtained from the previous step.

Table 2: *Material Flow Cost Matrix at QC1*

Cost	**Material Flow Cost Matrix QC1**				
	MC	***SC***	***EC***	***WC***	***Total Cost***
Previous input	-	-	-	-	-
(new) input	477.22	56.67	27.15	-	561.04
Total	477.22	56.67	27.15	-	561.04
Positive product	472.54	56.11	26.88	-	555.54
Negative product	4.68	0.56	0.27	-	5.50

(Source: Authors' Own Illustration)

Table 2 shows the Material Flow Cost Matrix at QC1, in which QC1 was the starting QC, so there was no input of positive product from the previous QC (or previous input). Total MC, SC and EC before allocation were 477.22 THB, 56.67 THB and 27.15 THB respectively. Allocation of positive product and negative product of the materials was as previously explained. The allocation of SC and EC could use negative product proportion by weight which was equal to 0.98%. Therefore, the positive product and negative product of SC were equal to 56.11 THB and 0.56 THB respectively. The positive product and negative product of EC were equal to 26.88 THB and 0.27 THB respectively. Calculating costs on the principles of MFCA at other QCs was done in the same way. For instance, in the calculations at QC2, the positive product of MC, SC and EC from QC1, which were 472.54 THB, 56.11 THB and 26.88 THB, were combined with new input costs at QC2 to become total or combined costs before allocation.

When calculating costs from QC1 to QC7 in series, reports of costs arise according to category of positive product and negative product, separated into MC, SC, EC and WC, as shown in Table 3, Combined Material Flow Cost Matrix of all QC. It can be seen that combined costs to produce one production lot of raisin bread were 2,935.55 THB, which was divided into materials costs of 2,270.79 THB (77.35%), system costs of 500.30 THB (17.04%), energy costs of 164.46 THB (5.60%), while there was no waste management cost. Negative product was calculated at 25.19%, of which negative product in material costs was 19.41%. The highest was waste product getting deposited in the machinery, and failed packing film, which were not generating revenue.

Table 3: *Combined Material Flow Cost Matrix of all QC*

Cost	MC	SC	EC	WC	Total cost
Combined result	2,270.79	500.30	164.46	0.00	2,935.55
	77.35%	17.04%	5.60%	0.00%	100%
Positive product	1,701.09	373.19	121.93	0.00	2,196.21
	57.95%	12.71%	4.15%	0.00%	74.81%
Negative product	569.70	127.11	42.53	0.00	739.34
	19.41%	4.33%	1.45%	0.00%	25.19%

(Source: Authors' Own Illustration)

3.4 Ranking the importance of negative products from each QC using a Pareto diagram

This stage of the procedure is to rank the importance of negative products from each QC to identify and evaluate opportunities for improvement. The Pareto diagram was used as shown in Figure 5. It can be seen that negative product for materials costs at QC7 had the highest value, which was film wastage in packing at amount of 0.528 kg, or a value of 457.65 THB. Therefore, the case study factory should focus on remedying the cause of this issue first.

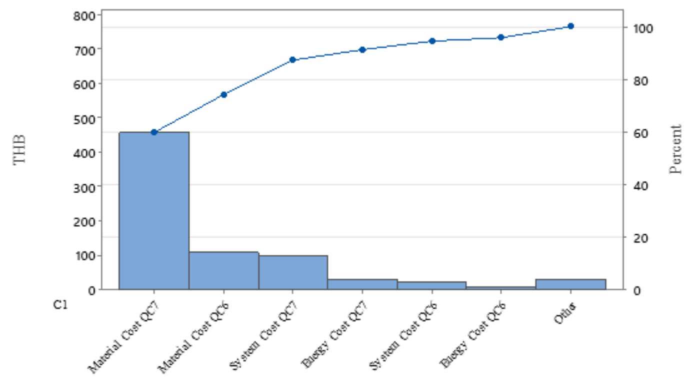

Figure 5: *Pareto Diagram Showing Negative Product from Each QC*

(Source: Authors' Own Illustration)

4. Conclusions and Suggestions

This research implemented the technique of MFCA to analyze losses from each stage of the production of raisin bread at the case study factory. This went through the process stages of mixing dough, forming, decoration, proving, baking, filling and packing. The methodology followed the principles of Plan Do Check Action (PDCA), and the procedures of MFCA. The Plan phase involved determining the target product, studying the production process, and determining a scope of evaluation and QCs. The Do phase involved identifying inputs and outputs for each QC and specifying flow amounts of materials in physical units and financial units. The Check phase involved analyzing of costs with MFCA technique to allocate positive product and negative product arising in each QC. The Act phase involved ranking negative product of each QC to identify and evaluate opportunities for improvement.

The research showed how total costs to produce one production lot of raisin bread could be divided into which proportions of material costs, system costs and energy costs. It was also possible to distinguish positive product costs, meaning costs generating revenue and manifest in the product, and negative product costs, meaning costs not generating revenues and which were waste at each stage of production. This informed of the waste arising at each stage of production, evaluated in the form of costs. This pinpointed the stages of greatest waste, assisting parties concerned to propose methods to reduce this wastage in the future.

In addition, the research discovered that the greatest waste was at the packing stage, by wasting film used for packing the raisin bread, a result of employees setting the packing speed to be too fast. As a result, employees stationed at the end of the packing machine could not insert the bread in time, with a result of empty packs coming out. There was also wastage of film in the initial phase of setting the machine. When the roll of film was exhausted, it had to be replaced with a new roll. Therefore, to reduce waste and negative product, the research is proposed to pack products with film of the same kind in large volumes, in a single instance, for continuous production until the roll of film was exhausted, so film would not be wasted while making the initial settings for the machine on several occasions. Also, there should be studies to specify an optimal packing speed, in line with the work-rate of the employees.

This research focuses on demonstrating loss analysis using MFCA. Although proposed methods to reduce losses were presented, no actual implementation of the suggested methods has taken place in the case study factory. Therefore, this research has not yet presented results for reducing losses. For future research, various simulation methods may be conducted to predict the improvement results (Chattinnawat et al., 2015). After that, MFCA may be used to analyze loss in the production process again to compare the results before and after improvements.

The benefits from this research of analyzing waste and loss in the production process of raisin bread at the case study factory, are that this research methodology can also be applied to other products of the case study factory. Also, the research methodology is useful to other entrepreneurs and particularly those at a similar level to the case study factory, which would be Small and Medium-sized Enterprises (SMEs). SMEs have the greatest proportion in Thailand, and have a key role in developing the national economy. This gives the SMEs capabilities to compete and be more resilient by reducing their costs and increasing their profits. Eventually, this will improve the country's macro economy.

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