LINE BALANCLING BASED ON ECRS PRINCIPLE:

A CASE STUDY OF FROZEN BREADED FISH PRODUCT

NAMTIP INSALEE

AN INDEPENDENT STUDY SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN LOGISTICS AND SUPPLY CHAIN
MANAGEMENT
INTERNATIONAL COLLEGE
KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG
2017

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Independent Study Certification

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Place: International College, 8th floor, 55th Anniversary Chalermprakiat Building

KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG

(Assoc. Prof. Dr. Supat Kittiratsatcha)
Dean of International College
May 21st, 2017

RESEARCH TITLE	Line Balancing Based on ECRs Principle: A Case Study of Frozen Breaded Fish Product
STUDENT NAME	Ms. Namtip Insalee
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DEGREE	Master of Science
PROGRAME	Logistics and Supply Chain Management
ADVISOR	Asst. Prof. Dr. Wichitsawat Suksawat na Ayudhya

ABSTRACT

Agriculture products have been one of the pillar economic driver of Thailand since more than ten years ago. One of the agriculture products is exported fishery goods, which is the key to enhance economy. To become leader of the business, Thailand must improve production efficiency. Hence, the study picked up the case study of a seafood manufacturer to be a model for improvement. The purpose is to understand entire production process and improve line efficiency for the frozen breaded fish product. The study obtained the main data from two sources: on-site observation, and production records from the cooperated factory.

The problem of study was solved by using cause and effect diagrams, line balancing based on ECRs principle. After observation, the data showed that total cycle time was 108.15 seconds, and bottleneck was in workstation no. 7 which took 40.60 seconds per unit. Besides, the percentage of idle time and the line efficiency was 71.26 and 28.74 %, respectively. Then, the study implements proposed model and collects data after the implementation. As a result, the total cycle time decreases to 69.03 seconds per unit. Additionally, the number of operators reduced from 23 persons to 17 persons. Lastly, the line efficiency increased to 82.19%.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my research advisor, Asst. Prof. Dr. Wichitsawat Suksawat Na Ayudhya for his support, suggestion, and encouragement throughout the research progress. Additionally, I am grateful to all professors who support me with knowledge and useful advice.

Moreover, I appreciate the permission of the factory side that supports the information along with production process. Their effort to set production date to be studied and cooperate for production improvement also becomes a great support.

In addition, I would like to thank previous studies that provide useful methodology and models to be reference for my study.

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Namtip Insalee

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CHAPTER 1

INTRODUCTION

1.1. Introduction

Thailand has been exporting many kinds of commodities in global market for decades. The main goods for exporting in Thailand has been divided into 4 groups, industrial machinery, agricultural products, industrial goods and mineral products and fuel. The statistics of the Office of the Permanent Secretary Ministry of Commerce's reports in recently five years from 2012 to 2016 showed that agricultural products are the second-main product in this five year, it got about 10 percent of exported goods in Thailand (Office of the Permanent Secretary Ministry of Commerce, 2017).

The agriculture goods in the report included three kinds of goods which are agriculture products, livestock and fishery products. These have been exported to main markets around the world especially in The United States of America (USA), the People's Republic of China (PRC) and Japan which are three main exported markets. The other vital markets are such as European countries, Asian countries, and so on. Japan market is ranked as the third main exported market for Thailand in 2013 to 2016, which got about 20,563 million dollars in 2016. Additionally, Japan is ranked as number one for fishery goods such as frozen seafood, canned food, processed shrimp and processed fish in recently.

The statistics of the Department of International Trade Promotion, Ministry of Commerce in Thailand showed that Japan imported fishery goods about 728.29 million dollars in 2015 and 749.01 million dollars in 2016 (Ministry of Commerce, 2017). According to Japan Fishery department, amount of fishery catching in Japan' sea is decreasing for recently years. One kind of fish that is decreasing in these three years is "Meaji" (so called Big-eye scad), Japanese horse mackerel which has been consumed as a common dish in Japanese households.

The problem of catching in Japan then provide an opportunity for Thailand to increase exported value of products. The processed frozen fish is one of the best demand because recently Japanese households have been looking for processed food which needs to be easier and faster to be cooked.

There are many kind of fish products such as frozen whole round raw material, processed raw material, breaded fish, canned fish, and dried fish. These kinds of product have also been supplied from others exporter such as the People's Republic of China, the Socialist Republic of Vietnam. Recently, Thailand export situation is harder than that in the past because of high competitive pricing. Hence, Thailand must improve the quality of products and valued price to survive.

Enhancing the production efficiency is one of the way to reduce cost and create value of the products. Line balancing and ECRs principles have been commonly used to enhance production efficiency for more than fifty years.

1.2. Background and Problem Statement

One of supplier in Thailand is Siamchai International Food Co.,LTD. (so called SIFCO), the exporter and specialist for seafood products located in Southern Thailand, Ranong province. SIFCO is established in November 1986. This company produces many kinds of fishery goods such as surimi, soft shell crab, and shrimp business which mainly export to Japan market. SIFCO also own a fish port at Ranong province which catches variety of seafood.

This study focused on the supply of Breaded products which are one of the highly demand recently. Increasing of breaded product' demand made shipment delay possible, which the factory would like to avoid, to maintain their reliability. Thus, improvement of productivity is one of the way to solve their problem. The study decided to improve productivity in frozen breaded fish focusing on process after raw material pre-treatment which is value-added process, in coating or breading room by using ECRs principle and Line balancing method.

1.3. Objective of the Study

The study focused on improvement of production process for frozen breaded fish, Meaji in bulky pack as below objectives:

- To understand entire production process of the selected product
- To improve line efficiency for the selected product

The scope of the study is from Handing to weights process ~ Send to freezer process at breading room which is described production process in chapter 3.

1.4. Scope of the Study

This study is designed to collect data by on-site observation, interview related department in the scope of frozen breaded fish production in breading room, building no. 5 at Siamchai International Food Co., LTD. between 2016, October to 2017, March. The steps of study are showed in the table below

Table 1.1 Operation plan for the study

Operation plan	Oct-16				Nov-16				Dec-16				Jan-17				Feb-17				Mar-17			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1. Study the capacity and demand of the product																								
2. Study entire production process																								
3. Study previous study related production improvement																								
4. Collect and summary the data																								
5. Analyze the problem and investigate cause of problem																								
6. Create and implement improvement plan																								
7. Collect data after improvement and summary																								

1.5. Technical Term

Meaji (FAO names: EN- Bigeye scad **or Science name:** *Selar crumenophthalmus*): refers to Japanese horse mackerel which mostly live around the coast of Japan sea such as Okinawa Island. Meaji can also be found in Thailand coast, in both of Gulf of Thailand and Andaman Sea. The nature of habitat, finding in small to large schools mainly inshore at depth about 170 meter. The Characteristic of this fish is large eye, shorter than snout length. (Kent E., 1999) The recorded of standard size is about 27 centimeter length, commonly about 24 centimeter fork length and 0.23 kilogram. Characteristic of meaji is illustrate as Figure 1.1.

Figure 1.1 Meaji or big-eye scad

Breaded Product: Breaded product is the product before frying (such as shrimp, pork, fish) which is cover by breadcrumbs, waiting for frying before consumption.

Coating Percent: This word is commonly used in breaded products such as breaded shrimp and breaded fish. Coating percent is the ratio between breadcrumbs and meat (shrimp or fish).

CHAPTER 2

LITERATURE REVIEW

The chapter are divided into two main parts, which is literature reviews and previous study such as productivity, time study, fishbone diagram, line balancing and ECRS principle.

2.1. Literature Review

(Wajanawichakon and Srimitee, 2012) studied production improvement for drinking water factory. The researchers started the study by on site observation current production procedure and breakdown step of production. Then, collected operation time in each activity is based on the theory of work study and work measurement. After observation, the data showed that bottleneck was in process of placing process before packing. The researchers used fishbone diagram to identify cause of problem in bottleneck process. By analysis, the researchers found that the bottleneck process took time for placing or setting 16 bottles before packing it by shrink film. To reduce the processing time, the rack without bottom is used for easy to set bottle in one pack. This new tool was used to improve the productivity in bottleneck process. After the implementation of new tools, the cycle time of the process was collected again. As a result, the productivity dramatically increased from 80 packs per hour to 120 packs per hour.

(Ongkunaruk and Wongsatit, 2014) improved productivity for a large sized frozen chicken plant at one of leading poultry exporters in Thailand. The researchers selected frozen fried chicken product which is seem to be in high demand and short lead time as a case to be study. Firstly, the production process and supply chain of the product was studied. Because the production process of the product is in detail, the researchers scoped the production process and decided to study the process of raw chicken preparation (raw material treatment) before frying -including handling seasoned chicken, weighing chicken, weighting butter, buttering, and powdering.

After identifying the scope of study, job description and job relationship was studied. Then, the researchers collected the cycle time and analyzed the data. After an analysis, the researchers found that the bottleneck was in buttering and powdering process. The researchers applied theory of line balancing and ECRS principle to reduce cycle time in bottleneck process such as combining two task in same workstation, rearranged sequence of some production process. By implementing three models and collecting time after implementation, the performance of three methods were compared with previous model before improvement. As a result, the efficiency of production line increased to 94.18 percent, while the number of workers was reduced up to 14 persons.

(Chueprasert and Ongkunaruk, 2015) studied productivity and efficiency improvement technique based on line balancing and ECRS principle for the production process of pasteurized milk in small and medium size manufacturer which is located in the central region of Thailand. Firstly, the researchers studied production process and collected cycle time in each workstation. Then, they calculated standard time and identified bottleneck which was in filling and packing process. Next, they executed three models in production line and collected new cycle time for each model. Finally, they compared efficiency and analyzed advantage for each model. As a result, the line efficiency increased to 68.79% if the first improvement model has been executed for the production, to 88.33% if the second model has been executed for the production, and to 71.56% if the third one has been executed for the production, respectively. The researchers also suggested using the third model and recommended that manufacturers should replace the filling machines for more efficiency.

2.2. Productivity Measurement

Productivity is a common word used in various industries to measure performance for how resources, labor, energy, and materials are used. In highly competitive business, all player has been trying to improve their productivity for converting input to be output in lower costs per units.

There are two ways to measure productivity. One method is to compare similar business operation in the same industry such as comparing performance with competitors. Another method is to compare productivity in same operation in difference period time such as current usage and previous year usage. An equation for measuring productivity is showed as below.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \tag{2.1}$$

Productivity can specify scope to focus only some part of inputs which is called “Partial measure”. Partial measure can also focus on more than one input which is called “Multiple measure”, which can be calculated as below equation. (Jacobs and Chase, 2014).

Output stands for the goods or service, which depends on what kind of business it belongs to. Outputs are converted from input, energy, labors, materials, or any resources.

$$\text{Partial Measure} = \frac{\text{Output}}{\text{Energy}} \tag{2.2}$$

$$\text{Multiple Measure} = \frac{\text{Output}}{\text{Energy+Marterial}} \tag{2.3}$$

An equation 2.2 shows how to measure productivity of energy usage by defining energy input to producing output. This is the way to measure partial productivity or partial measurement. The equation can be used to measure other terms of input by changing from energy to the input to be determined.

By focusing on part of some usage resource, that result will represent performance or efficiency for using those part per output. Additionally, the result may give causes of the problem such as poor labor skills, waste material etc.

2.3. Work Study

Work study refers to Method Study and Work Measurement used to study work procedure and those elemental tasks used to improve standard of working and working time to enhance productivity. Work study is commonly used in many fields of business, including manufacturing and also service business. Normally, method study and work measurement are undertaken together, with both theories defined as below;

Method Study includes Process Analysis, Operation Analysis and Motion Analysis. It is use to improve working procedure and identify the standard of working procedure.

Work Measurement refers to the study to determine proper time or time standard for doing specified task along with working standard. The standard time which is defined by work measurement must produce qualified work in normal speed of work.

Time Study is the way to do work measurement, and the study to determine standard time for a job which is performed by trained or qualified employees in normal pace (Jacobs and Chase, 2014). The standard time is used to estimate the amount of qualified output rate when operators do the jobs in 100% of their performance. For doing time study, there are 3 types of time using for calculation as defined below;

- **Selected Time** refers to actual time usage for doing the job by operators.
- **Normal Time** refers to the working time of operators who do their task in normal speed and 100% of their performance. This normal time is defined by rating the performance of operator while doing their job computation with selected time. The calculation method will be explained in the next step.
- **Standard Time** refers to the time that should be taken to finish the task by trained or qualified workers, who work at normal pace in an arranged workplace.

2.3.1. The Ways to Do Time Study

- **Direct Time Study** (or Stopwatch Time Study) this method was developed by Frederick Winslow Taylor, American mechanical engineer. This method is the most common way to do time study for work measurement by collecting time at on site observation. Selected time collected from the observation will be applied for representative time of other operators who do the same task.
- **Predetermined Motion Time System (PMTS)** is the time which is suggested by previous researchers through calculated spreadsheet (Meyers, 1992). By identifying the motion of operators while doing their job, the researcher can calculate time spent for the job and decide the possible best working motion. With this method, waste motion can be identified and removed. An example principles of PMTS are Motions time study (MTA), Basic time motion study (BMT), Methods time motion time study (MTM), Master standard data (MSD).
- **Work Sampling** is the time study using statistical sampling methods to determine standard time. Researcher who works on the sampling will randomly observe operating interval and record activities operated at that time.

- **Standard Time Data and Formula** is the methods to use historical data and some equation to determine standard time.

2.3.2. Tools for Direct Time Study

Tools for time study are defined as below (Niebel, 1993);

- **Stopwatch:** One of the most important tool used for time study is stopwatch. This tool is used to measure actual time in each specified task when observed. There are two types of stopwatches; analog stopwatch and digital stopwatch. Currently, digital stopwatch is more commonly used because it would give more details and it is easier to be used at on site observation.
- **Observation Sheet:** It is the form to be recorded all observation's details such as the number of workers, operation time for each task, evaluation of worker's performance and so on.
- **Clipboards:** Clipboard will be used for attached observation sheet to simplify researchers who doing time study to collect and record time in observation form.

Table 2.1 Time study observation sheet

TIME STUDY OBSERVATION SHEET												
Process:		**Start - End Time:**					**Production Method:** Before / After improvement					
Division:		**Date of Observation:**					**Recorder:**					
Workstation	**Elemental Task**	**Cycle Time (CT)**										**Average CT**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	

2.3.3. Direct Time Study Procedures

Time study procedure are summarized as following steps (Meyers, 1992):

1. Determine Job or Process to be studied: To select the process to be case study, the researcher must study the entire business process first. Then, determine the scope of job or subject to be study.
2. Study Job Description: After deciding scope of job to be studied, starts to observe those jobs description and draws process flow chart, process layout and job precedence.
3. Breakdown a Job into Elemental Task: Split job activities into elemental tasks should not be too short or too long for time measurement.
4. Observation: Collect actual cycle time (selected time) of operators for doing their task at production line according to the elemental task which was breakdown from previous step.
5. Determine Sample Size (or Number of Cycle): Qualified sample size should represent actual situation. Two or three number of cycle time maybe too small to be accuracy sample size. Therefore, researcher must know how many number of cycle should be collected. After determining accuracy number of cycle, researcher may collect more selected time.
6. Rate Performance of operator in each activity.
7. Compute Allowance Time.
8. Compute Standard Time.

2.3.4. Determining Sample Size or Number of Cycle

There are several ways to determine qualified sample size for the study. This study used the technique that was created by Maytag Company in United States of America. The technique defines as below.

1. Collects Cycle Time in each Elemental Task by:
    a. 10 times, if the cycle time is less than 2 minutes
    b. 5 times, if the cycle time takes more than 2 minutes
2. Calculates $\frac{H-L}{H+L}$: H refers to maximum cycle time, and L refers to minimum cycle time which was collected from the first step.
3. Check required sample size (N) or number of cycle to be timed which is shown in Table 2.2.

For example:

Cycle time of Task A = 1.50 minutes – meaning that it should be collected for 10 times.

Maximum Cycle Time (H) = 1.52 mins.

Minimum Cycle Time (L) = 1.48 mins.

$$= \frac{H-L}{H+L} = \frac{1.52-1.48}{1.52+1.48} = 0.13$$

Thus, accuracy number of cycle based on Maytag Table (Table 2.2) is 11 times. Then, the researcher must collect cycle time for task A 1 more time to qualify Maytag standard

Table 2.2 Number of cycle at a 95 % confidence level

$\frac{H-L}{H+L}$	Number of cycle (N)		$\frac{H-L}{H+L}$	Number of cycle (N)		$\frac{H-L}{H+L}$	Number of cycle (N)	
	5	10		5	10		5	10
0.05	3	1	0.21	52	30	0.36	154	88
0.06	4	2	0.22	57	33	0.37	162	93
0.07	6	3	0.23	63	36	0.38	171	98
0.08	8	4	0.24	68	39	0.39	180	103
0.09	10	5	0.25	74	42	0.40	190	108
0.10	12	7	0.26	80	46	0.41	200	114
0.11	14	7	0.27	86	49	0.42	210	120
0.12	17	10	0.28	93	53	0.43	220	126
0.13	20	11	0.29	100	57	0.44	230	132
0.14	23	13	0.30	107	61	0.45	240	138
0.15	27	15	0.31	114	65	0.46	250	144
0.16	30	17	0.32	121	69	0.47	262	150
0.17	34	20	0.33	129	74	0.48	273	166
0.18	38	22	0.34	137	78	0.49	285	168
0.19	43	24	0.35	145	83	0.50	296	170
0.20	47	27						

Source: Kanjanapanyakom, (2009). Industrial work study. Bangkok: Top Publishing.

2.3.5. Westinghouse System

Westinghouse System is commonly the method of rating system which was developed by Westinghouse Electric Corporation. This technique is used to evaluate performance of workers by the consideration of 4 factors, including Skill, Effort, Condition, and Consistency. The evolution of operator is used to adjust cycle time of operation more correctly based on worker's skill, effort, condition and consistency. Because different operators have variable performance; thus, selected time (actual time) must be converted to normal time by rating performance. Evaluation of rating worker's performance should be done at on-site observation which is rated as shown in Table 2.3.

Table 2.3 Rating score of Westinghouse system method

Skill			Effort		
+0.15	A1	Super skill	+0.13	A1	Excessive
+0.13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0.08	B2		+0.08	B2	
+0.06	C1	Good	+0.05	C1	Good
+0.03	C2		+0.02	C2	
0.00	D	Average	0.00	D	Average
-0.05	E1	Fair	-0.04	E1	Fair
-0.10	E2		-0.08	E2	
-0.16	F1	Poor	-0.12	F1	Poor
-0.22	F2		-0.17	F2	

Source: Benjamin W. Niebel. (1993). Motion and time study (9th ed.). Sydney: R.R Donnelley& Sons Company.

Table 2.4 Rating score of Westinghouse system method (continued)

Condition			Consistency		
+0.06	A	Ideal	+0.04	A	Prefect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0.00	D	Average	0.00	D	Average
-0.03	E	Fair	-0.02	E	Fair
-0.07	F	Poor	-0.04	F	Poor

Source: Benjamin W. Niebel. (1993). Motion and time study (9th ed.). Sydney: R.R Donnelley& Sons Company.

For example:

Skill : Good = +0.06 C1

Effort : Good = +0.05 C1

Condition : Good = +0.02 C

Consistency : Good = +0.01 C

Total score = +0.14

Total score showed the performance of workers for doing their task. In this case, the rate of factor equals to +0.14, which means worker finished their task faster than usual for 14 percent. Hence, normal time would be;

$$\text{Normal Time} = \text{Selected Time} \times \text{Rating Factor}$$

$$= 0.50 \times 1.14 = 0.570 \text{ minutes}$$

2.3.6. Determining Allowances Time

Apart from rating factors of operator's performance, allowance time should be correctly cycle time for computing standard time. Everyone cannot maintain average pace for working every minute then they must have relaxed time (Niebel, 1993). Allowance time was categorized in 3 elements;

1. Personal Allowance: Every people must rest, and the personal time is such as talking, drinking, eating, etc. Normally, personal allowance is defined about 4.5-6.5%. However, in industrial field, personal allowance is defined to 5% of working time. For example, working time is 8 hours (or 480 minutes) per day, and personal allowance would be 0.05 x 480 = 24 minutes.
2. Fatigue Allowance: It is the time to allow worker to relax the stress from working. Normally, all workplaces give fatigue allowance in the pattern of break time or lunch time.
3. Delays Allowance: Delay is divided into two types, including avoidable delay, and unavoidable delay. Only unavoidable delay such as the breakdown of machine, reworking process, and transportation duration are counted in delay allowance.

An example of a system of rest allowance percent which is tabulated by International Labour Organization (ILO) is showed in Table 2.5. (Niebel, 1993).The table includes constant allowance, variable addition to basic fatigue such as workplace condition. Then, the percentage of allowance is based on the sex of the operator who does the job.

Table 2.5 Rest allowance given as percentages of basic times

	Men	Women
1. CONSTANT ALLOWANCES :		
Personal Needs	5	7
Basic Fatigue	4	4
Total	9	11
2. VARIABLE ADDITIONS TO BASIC FATIGUE ALLOWANCE :		
(i) Standing	2	4
(ii) Abnormal Position only Slightly awakward	0	1
Awakward	2	3
Very awakward (lying, stretching up)	7	7
3. Weightlifting or Application of force weight lifted (in kg)		
2.5	0	1
5	1	2
10	3	4
12.5	4	6
15	6	9
20	10	15
25	14	
30	19	
40	33	
50	58	
4. Light Conditions Slightly below recommended value	0	0
Well below	2	2
Inadequate	5	5
5. Air Conditions (all around)		
Well ventilated, or fresh air	0	0
Badly ventilated, but no toxic fumes or gases	5	5
Work close to furnaces severe, heat etc.	5-15	
6. Visual Stresses		
Fairly fine work	0	0
Fine work	2	2
Very fine or very exacting work	5	5
7. Aural Stresses Continuous	0	0
Intermittent, loud Intermittent, very loud	2	2
High-pitched loud	5	5
8. Mental Stresses		
Fairly complex process	1	1
Complex or wide span of attention	4	4
Very complex and complicated	8	8
9. Monotony: (Mental)		
Low	0	0
Medium	1	1
High	4	4
10. Monotony: (Physical)		
Rather tedious	0	0
Tedious	2	1
Very tedious	5	2

Source: International Labour Organization. (1969). Introduction of Work Study: Example of a system of rest allowances given as percentages of basic times. Bienne: Impression Couleurs Weber.

2.3.7. Determine Normal Time

An equation of normal time is defined as below:

$$NT = ST \times RF \quad (2.4)$$

Where NT = normal time

ST = selected time

RF = rating factor (Performance)

2.3.8. Determine Standard Time

An equation of standard time is defined as below:

$$\begin{aligned} ST &= NT + A(NT) \\ &= NT(1+A) \end{aligned} \quad (2.5)$$

Where ST = standard time

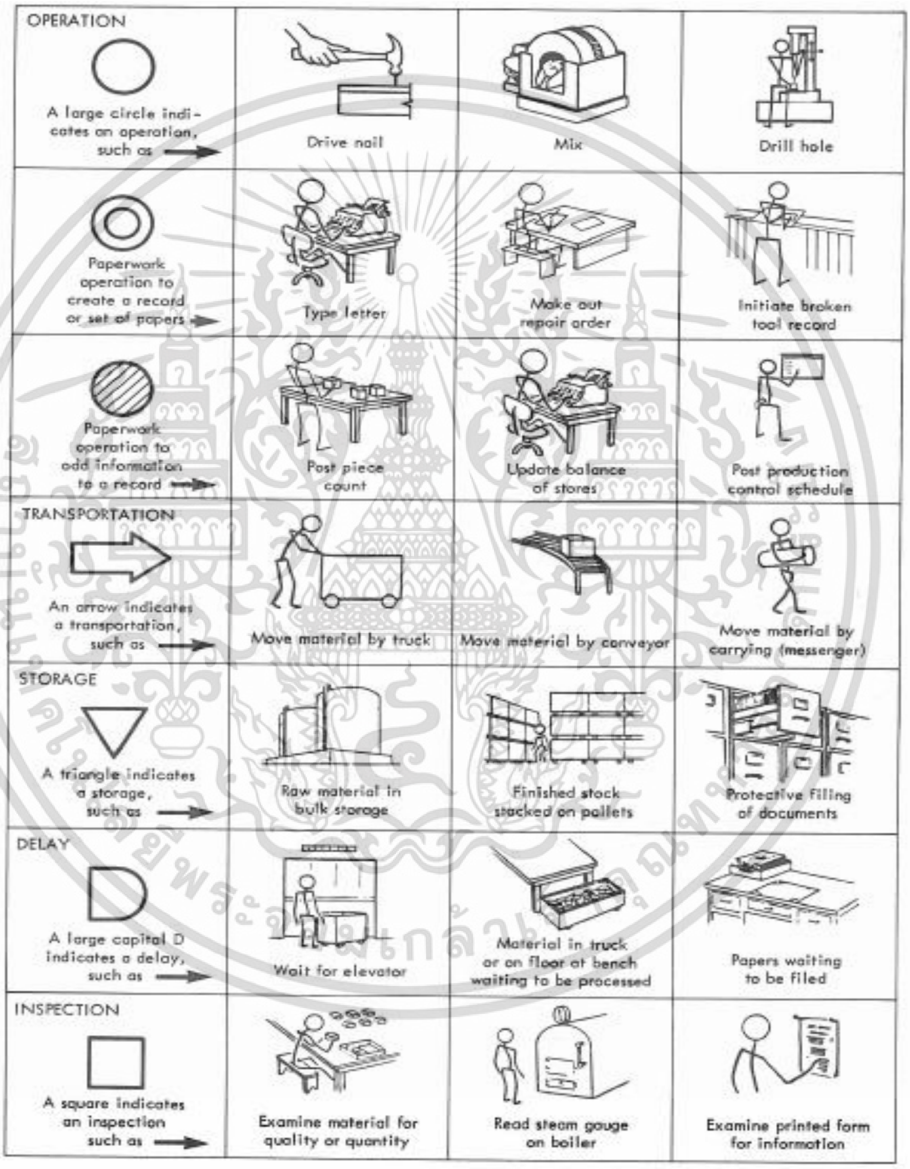
NT = normal time

A = allowance time

2.4. Flow Process Chart

Flow Process Chart is one of process analysis in method study principle which is commonly used to analyze the flow of product, materials, components, employees, machines, and equipment in the process along with activities which are shown in the pattern of symbol. The symbol of activities was created and set by American of Mechanical Engineers (A.S.M.E). The meaning of the symbol is shown in Table 2.5.

Table 2.6 Symbol characteristic of flow process chart



Source: Benjamin W. Niebel. (1993). Motion and Time Study (9th ed.). Sydney: R.R Donnelley& Sons Company. 1993.

2.4.1 Flow Process Charts Procedure

1. Set objective of the study. The flow process chart is normally used to reduce hidden cost such as handling cost because the symbols used in flow process chart show all activities including transportation, delay, and storage. Objectives for such symbols are to reduce transporting time, eliminate product handing distance, etc.
2. Determine the process to study. After scoping the process to study, collect all related details of the selected process, including process name, equipment, machine, start and end of process.
3. Determine the subject to be studied as below;
    - Manpower: flow, transport or movement of operator while working.
    - Product: flow of material or product along production process from start until finished product at production line.
4. Machine: flow, movement of equipment or machine in production line.
5. Start analyzing the flow of objective and record actual activities in pattern of symbols which is described in the table above.
6. Record the detail such as distance of movement between activities, cycle time, waiting time of objective.
7. Draw line throughout remarked symbols to link those activities from top to bottom. Then, summarize the number of each activities (operation, delay, transport, inspection) in summary table.

Table 2.7 Flow process chart record form

OPERATION

PAGE 1 OF 1	PRESENT METHOD [X]	PROPOSED METHOD [ ]	DATE 4/17
LOCATION Centre County, PA			By Russ Ruhf

SUMMARY	OPERATION	OPERATION CREATE A RECORD	OPERATION ADD INFORMATION	TRANSPORTATION	STORAGE	DELAY	INSPECTION
TOTAL NO.	7	1	1	5		2	6
TOTAL DIST.				375 ft			
TOTAL TIME	8.30 min	1.00 min	0.40 min	4.35 min		14.0 min	5.15 min

EVENT	EVENT SYMBOL	TIME (MIN)	DIST (FT)	METHOD RECOMMENDATION
Leave vehicle, walk to front door, ring bell,		1.00	75	Call home in advance to reduce writing
wait, enter home.				delays.
Walk to field reservoir.		0.25	25	
Disconnect field reservoir from unit.		0.35		
Inspect for dents, cracks in shroud, cracked glass		1.25		This can be done while walking back
or missing hardware.				to vehicle.
Clean unit with approved cleaner and disinfectant.		2.25		This can be done more effectively at vehicle.
Return to vehicle with empty tank.		1.00	75	
Unlock vehicle, place empty tank in fixture,		1.75		
connect hardware.				
Open valve, begin fill.		0.25		
Wait for tank to fill.		12.00		Clean unit while being filled.
Check humidifier for proper function.		0.50		Eliminate—no need to do this twice.
Check pressure (indicator).		0.20		
Check reservoir contents (indicator).		0.20		
Return to patient with filled tank.		1.10	100	
Hook up filled tank.		1.00		
Check humidifier for proper function.		.75		
Wait for patient to remove nasal cannula		2.00		
or face mask.				
Install new nasal cannula or face mask.		2.50		
Check flows with patient.		2.25		
Affix a dated, initialed		1.00		Perform this while unit is being filled.
inspection sticker.				
Return to vehicle.		1.00	100	
Unlock vehicle.		.20		
Log the odometer reading on the gas		.40		Perform this while unit is being filled.

Source: Benjamin W. Niebel. (1993). Motion and Time Study (9th ed.). Sydney: R.R Donnelley& Sons Company. 1993.

2.5. Line Balancing

Line Balancing is a technique to allocate the tasks or activities into workstation to balance cycle time. This technique aims to minimize idle time and balance activities in all workstation for the entire production process, because the output rate of production always relies on output from bottleneck process.

2.5.1. Principle of Line Balancing

1. All elemental tasks or activities must be allocated in workstation.
2. Balance tasks time in each workstation to be equal as much as possible.
3. Arrange tasks according to precedence diagram which is a sequence of production process.
4. The sum of cycle time spent in each workstation must be less or equal to takt time

2.5.2. Line Balancing Procedure

1. Draw precedence diagram to understand the relation of production process.
2. Calculate cycle time.
3. Calculate minimum number of workstation.
4. Allocate tasks into workstation under heuristics approach rule until all tasks are assigned in workstation.
5. Calculate idle time and efficiency of production line.

Cycle time is the time spending for production started from the beginning to finish of the specific activity in a repetition. Additionally, cycle time is used to determine minimum workstation and output rate of production line. Total cycle time refers to the production time from the beginning of the process until the end of the process to be a finished product.

An equation of **Desired Output Rate:**

$$\text{Output Rate} = \frac{\text{Operation time per day}}{\text{Cycle time}} \quad (2.6)$$

If the production knows the desired output rate, the cycle time required for each workstation, which is the goal to balance production time, can be determined as below.

An equation of **Cycle Time**:

$$\text{Cycle Time (CT)} = \frac{\text{Operation time per day}}{\text{Desired output rate}} \quad (2.7)$$

Takt Time is also the time allowed to finish production in order to meet customer demand. Besides, it also used to limit time allowed in workstation in the same way as cycle time.

An equation of **Takt Time**:

$$\text{Takt Time (t)} = \frac{\text{Net time avalaible per day}}{\text{Daily demand per day}} \tag{2.8}$$

For Example:

A car component manufacturer determines a work to be 8 hours per day and 25 days per month. Break time is 1 hour per day. The customer average orders are 2,000 pieces per month.

Daily Demand = 2,000 ÷ 25 = 80 pcs./day

Operation Time = 480 – 60 = 420 mins.

$$\text{Hence, Takt Time} = \frac{420}{80} = 5.25 \text{ minutes per piece}$$

An equation of **Minimum Number of Workstation**:

$$N\text{min} = \frac{\sum t}{CT} \tag{2.9}$$

Where N_{min} = theoretical minimum number of workstation

$\sum t$ = sum of task times

CT = cycle time

Percentage of Idle Time and Line Efficiency

Percentage of Idle is used to determine waste time in production line. This percentage shows the percentage of waste while the line efficiency shows efficiency for task allocation throughout the entire production. For line balancing, it is one of the tools to compare before and after improvement. The equation is shown as below;

An equation of **Percentage of Idle Time**:

$$\text{Percentage of idle time} = \frac{\text{Idle time per cycle}}{\text{N actual x Cycle}} \text{ x100} \quad (2.10)$$

Where N actual = actual time of stations

An equation of **Line Efficiency or Efficiency Rate**:

$$\text{Efficiency} = 100\% - \text{Percent Idle Time} \quad (2.11)$$

An equation of **Ideal Number of Operator**

$$\text{Ideal number of operator} = \frac{\text{Total cycle time}}{\text{Takt time}} \quad (2.12)$$

An Equation of **Ideal Number of Operator per Task**

$$\text{Ideal number of operator per task} = \frac{\text{Cycle time per task}}{\text{Takt time}} \quad (2.13)$$

The number of operators is one of the factors to reduce task time in any job. More operators in the same task means shorter cycle time for those jobs. However, there is direct and indirect cost occurred when increasing the number of operators such as wage cost and any necessities. Thus, ideal number of operators will be useful to determine the suitable number of operators needed in workstation based on requirement rate of production output.

For example:

Takt Time = 3.80 minutes, Cycle time in workstation 1 = 11.25 minutes, Cycle time in workstation 2 = 5.48 minutes

Ideal number of operator per task for;

$$\text{Workstation 1} = \frac{11.25}{3.80} = 2.96 \approx 3 \text{ persons}$$

$$\text{Workstation 2} = \frac{5.48}{3.80} = 1.44 \approx 2 \text{ persons}$$

Thus, the ideal number of workstation 1 = 3 persons, workstation 2 = 2 persons.

To identify the longest task time or the bottleneck of operation in case multiple operators working in same station, divide the number of operators with the cycle time per workstation as below;

An equation of **Average Cycle Time per Workstation**:

$$\text{Average cycle time per workstation} = \frac{\text{Cycle time per workstation}}{\text{Number of operators}} \qquad (2.14)$$

For example:

Last example shows the number of operators in workstation 1 = 3 persons, and cycle time = 11.25 mins. Number of operators in workstation 2 = 2 persons, cycle time = 5.48 mins.

Then, average cycle time for;

$$\text{Workstation 1} = \frac{11.25}{3} = 3.75 \text{ mins.}$$

$$\text{Workstation 2} = \frac{5.48}{2} = 2.74 \text{ mins.}$$

Thus, the longest cycle time of workstation is in workstation 1 and average cycle time is 3.75 minutes per units. In case this rate is inadequate for workstation 1, it can be solved by increasing number of operators, simplifying working methods, or rearranging some elemental tasks from workstation 1 to workstation 2 (Niebel, 1993).

2.5.3 Bottleneck Operation

Bottleneck Operation is the process which gives lower output than output from other operation (or workstation). The bottleneck operation limits the system output of entire production process. For example: there are five operations in the process.

Operation 1 to operation 4 takes 10 minutes per hour to produce one unit. However, the last operation take 30 minutes per hour for one unit. Consequently, the output of this production system is limited by 30 minutes per hour for one unit as shown in Figure 2.1.

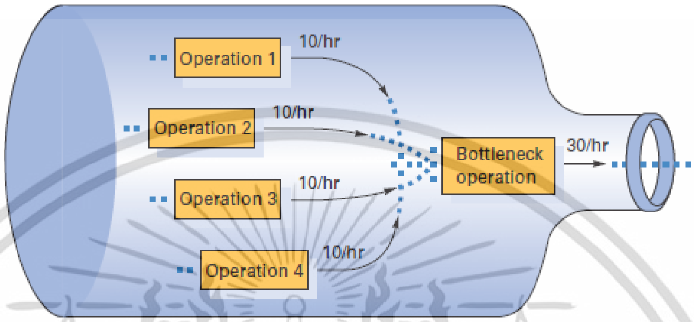


Figure 2.1 Example of bottleneck operation

Source: William J. Stevenson. (2012). Operation Management (11th global ed.). New York: McGraw-Hill Companies, Inc.

2.6. Fishbone Diagram

Fishbone diagram (also called Cause and Effect Diagram or Ishikawa Diagram) was developed by Kaoru Ishikawa, the professor in The University of Tokyo, in 1943. This method is mostly used in several industries to investigate plausible causes of problem by brainstorming. The diagram shows relationship between problems and all plausible causes of problem in the pattern of fish bone. (Stevenson, 2012)

2.6.1 Fish Bone Diagram Procedure

1. Group related persons in charge for brainstorming
2. Draw fishbone diagram and identify the problem at the head of the fish.
3. Discuss all factors that can be the cause of problem and write down on the bone of fish.
4. Classify and rearrange the cause of problem in the order of magnitude.

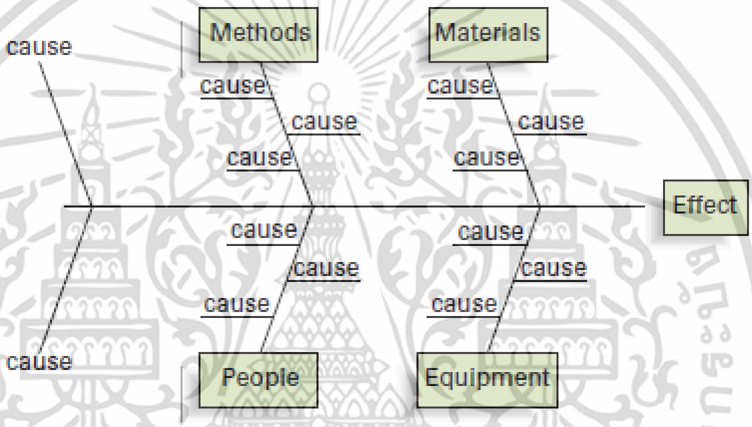


Figure 2.2 Fishbone diagram

Source: William J. Stevenson. (2012). Operation Management (11th global ed.). New York: McGraw-Hill Companies, Inc.

2.7. ECRS Principle

ECRs is one of the methods to improve productivity which refers to Eliminate, Combine, Rearrange, and Simplify. This method is commonly used to eliminate “Muda” (or “Waste”), the activities that do not add any value to the product (Stevenson, 2012). There are 7 types of waste based on lean philosophy which are defined as below;

1. Transportation
2. Inventory
3. Motion
4. Waiting Time
5. Over-Processing
6. Overproduction
7. Defects

The existence of waste means that there is a possibility to improve those processes. The way to reduce or remove those waste is ECRs principle which is defined as below;

E - Eliminate: Review all activities in the production process and identify unnecessary activities such as handling or any unvalued for product. Then, eliminate or remove those activities.

C - Combine: If eliminate cannot be applied for those tasks, the next step is to combine the tasks. Combine those tasks by splitting into elemental tasks and allocate them into other workstation. One advantage for combination is the reduction of transportation time between workstation.

R - Rearrange: Apart from elimination and combination, rearranging is the ways to adjust operation time in each workstation by changing the sequence of production process. However, rearrange method required understanding sequences of production process or precedence diagram before adjustment.

S - Simplify: If the task cannot be eliminated, combined, or rearranged, simplify those tasks to reduce task time. Regarding some uncomfortable production process or the process that required skills, try to make it easy, or use some support tools for those activities.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter devoted to research methodology includes on site observation, production data collection, and cause and effect diagram, which is divided into four steps as followed:

3.1 Study Current Process Flow Chart and Process Layout

3.2 Collect Current Cycle Time and Identify Standard Time

3.3 Cause and Effect Diagram

3.4 Propose Improvement Plan

3.1. Study Process Flow Chart and Process Layout

The process of Frozen Breaded Fish is divided into two sections, consisting of raw material preparation procedure and value added procedure (or coating process). The process description is described as below;

The raw material preparation procedure includes (1) De-head and de-guts, (2) Fillet cut, (3) washing, and (4) Smell check.

The value-added procedure includes (5) Sizing, (6) Cutting, (7) Dipping, (8) Draining, (9) Handing to weight, (10) Weighting, (11) Handing to powdering, (12) Pre-dust or powdering, (13) Breading, (14) Checking, (15) Arrange on pan, (16) Freezing, and (17) Packing. The production process is shown in Figure 3.1.

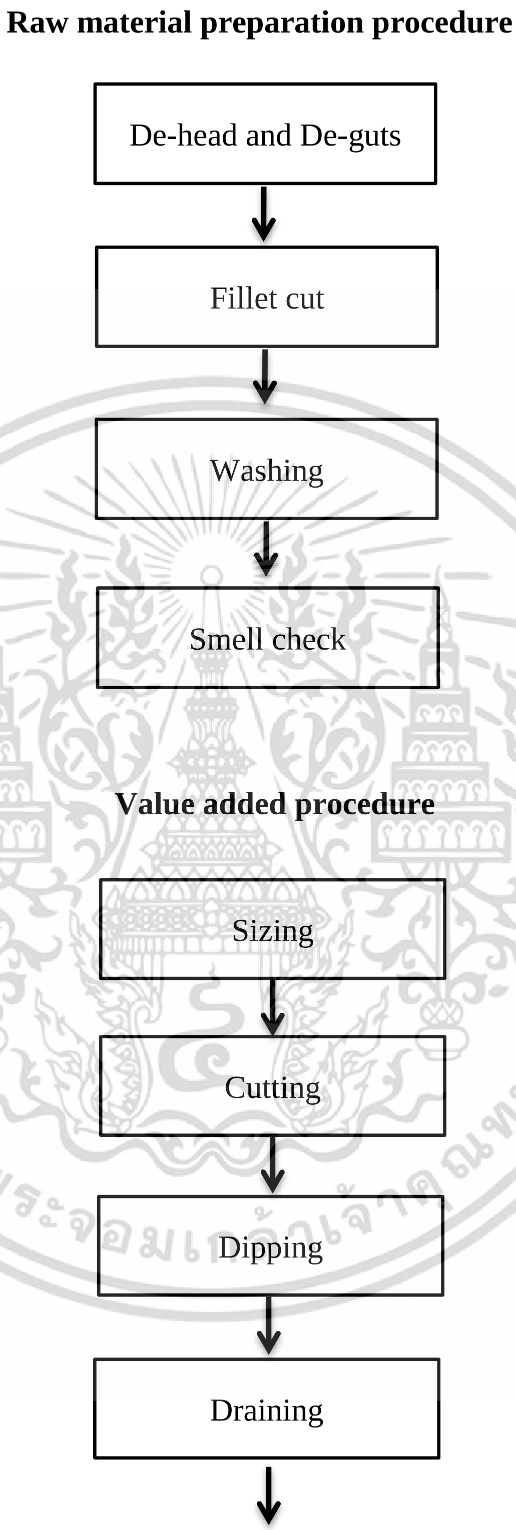


Figure 3.1 Flow chart of frozen breaded fish process

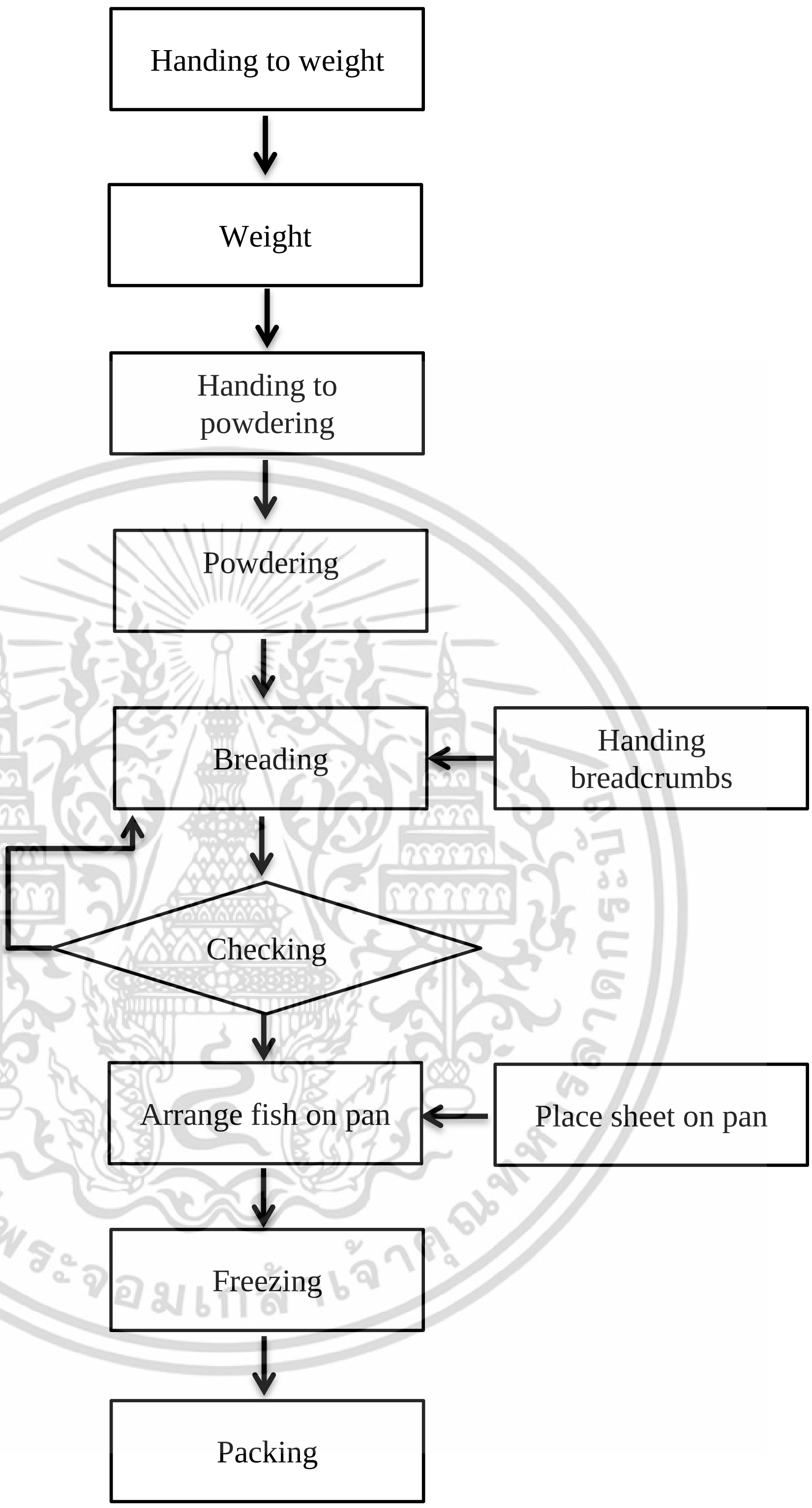


Figure 3.2 Flow chart of frozen breaded fish process (continued)

The flow chart can be explained as below;

After receiving, raw material will be checked for its freshness, species, and contamination risk such as scraps of wood. Then, decent quality of fish will be processed as following steps:

An explanation of raw material preparation procedure

1. De-head and De-guts process: The first step is to remove fish's head by manually cutting. Then, cut open the stomach and remove guts.
2. Fillet cut process: Place fish on the chop board, and start to cut fish along with dorsal fin until the knife reaches stomach. Repeat it again in the opposite side. The fish will be separated into three pieces, two pieces of meat and one pieces of bones.

Figure 3.3 Fillet Cutting

3. Washing process: Clean the fillet with chlorine water and fresh water to remove blood and some pieces of guts.

4. Smell check process: Screening at receiving process cannot reject all bad fish. This process aims to check the quality of fish by its own smell. Every piece of fillet would be checked by human.

An explanation of value added procedure

5. Sizing process: Correct size of fillet aims to minimize production cost. This process is for an inspection for quality of fillet by weighting scale. Unqualified weight will be separated to be adjusted in next steps.
6. Cutting process: Adjust weight of fillet by manually cutting before transferring to next steps.
7. Dipping and Draining process: This process aims to reduce the fish's smell and create a good texture by soaking fish in the water with specified recipes, then draining it on basket with holes to remove water remaining on the fillet before weighting it in next process.
8. Weighing process: One of the points to identify quality of breaded product is coating ratio, percentage of breadcrumbs covering on fish meat. To provide accurate coating ratio, the production must identify the range of meat's weight and breadcrumbs' weight. Hence, this process is an important process to control specified coating ratio by arranging correct meat (fillet) weight on the plate before being delivered to next steps.
9. Powdering process: Pre-dust or powdering process is the process to cover meat by flour (or pre-dust) to adhere between meat and breadcrumbs while breading.

10. Breading process: Dip the meat in liquid-mixed flours then place it on breadcrumbs. Press breadcrumbs on meat. Then check weight after coating and adjust weight of breadcrumbs until getting identified weight.
11. Checking process: After breading, all of the products must be checked for coating condition and weight.
12. Freezing: The final process before packing is freezing process to cool temperature of product in $\geq$ -18°. With frozen condition, it provides the product with longer expiration date.
13. Packing process: Pack the product in packaging and keep it in a cold storage.

Figure 3.4 Finished Product

After discussion with production manager, the researcher decided to learn the process of Handing to weights to the process of Sending to freezer, which is part of value added procedures. Because it is difficult to improve all processes, which are separated in many production areas. The researcher started to collect details of current methods such as process procedures, process layout, cycle time, and the number of operators in process that shows in Table 3.1 and Table 3.2.

Table 3.1 Description of process flow chart for frozen breaded fish

Company Name: SIFCO	**Summary**					
	Symbol		**Total**	**Not change**	**Decrease**	**Remark**
	Operation		5			
	Movement		5			
Process: Before/ After improvement	**Delay or wait**		0			
	Inspection		1			
	Storage		0			
Recorder: Namtip Insalee	**Distance (m.)**		7.35			
	Time (sec.)		108.15			

Task	**Elemental Task**	**Distance (m.)**	**Time (sec.)**	**Symbol**					**Remark**
A	Handing to weight	1.65	4.11						
C	Weight fillet fish	0.00	4.38						
B	Handing to powdering	1.00	4.00						
D	Powdering	0.00	3.88						
E	Breading	0.00	22.14						
	Transfer by conveyer	2.40	30.39						
F	Handing from conveyer	1.30	0.95						
G	Check weight, appearance	0.00	3.85						
I	Place sheet on pan	0.00	4.42						
H	Arrange fish on pan	0.00	26.48						
J	Send to freezer	1.00	3.55						
	TOTAL	**7.35**	**108.15**						

Table 3.2 Description of task in workstation and job precedence

Workstation	Elemental Task	Task Description	Job Precedence	Number of Worker
1	A	Handing to weight	-	1
	B	Handing to powdering	C	
2	C	Weight fillet fish	A	2
3	D	Powdering	B	2
4	E	Breading	D	12
5	F	Handing from conveyer	E	1
6	G	Check weight and appearance	F	2
7	H	Place sheet on pan	-	2
	I	Arrange fish on pan	E	
8	J	Send to freezer	I	1

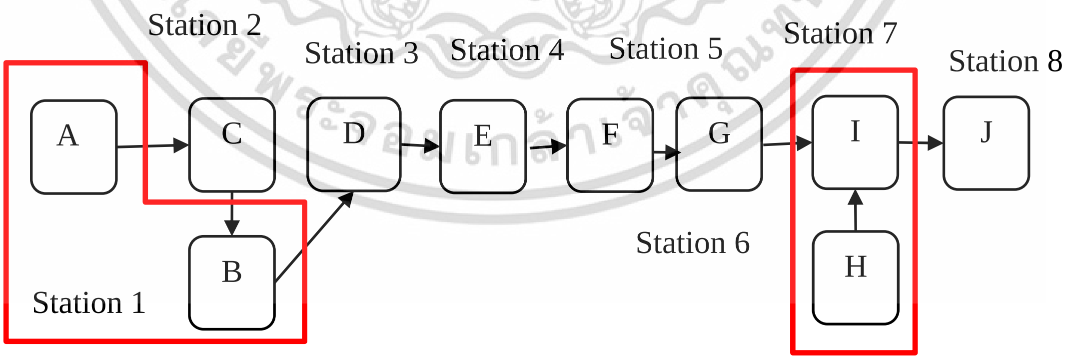


Figure 3.5 Production flow (before improvement)

Table 3.1 and 3.2 shows that the total operators are 23 persons with 10 elemental tasks from Task A to Task J allocated into 8 workstations. Total cycle time for the product was 108.15 seconds, including 6 operations, 5 movements, and 7.35 meters for product handing distance. The process layout and product flow is showed in Figure 3.6 and Figure 3.7.

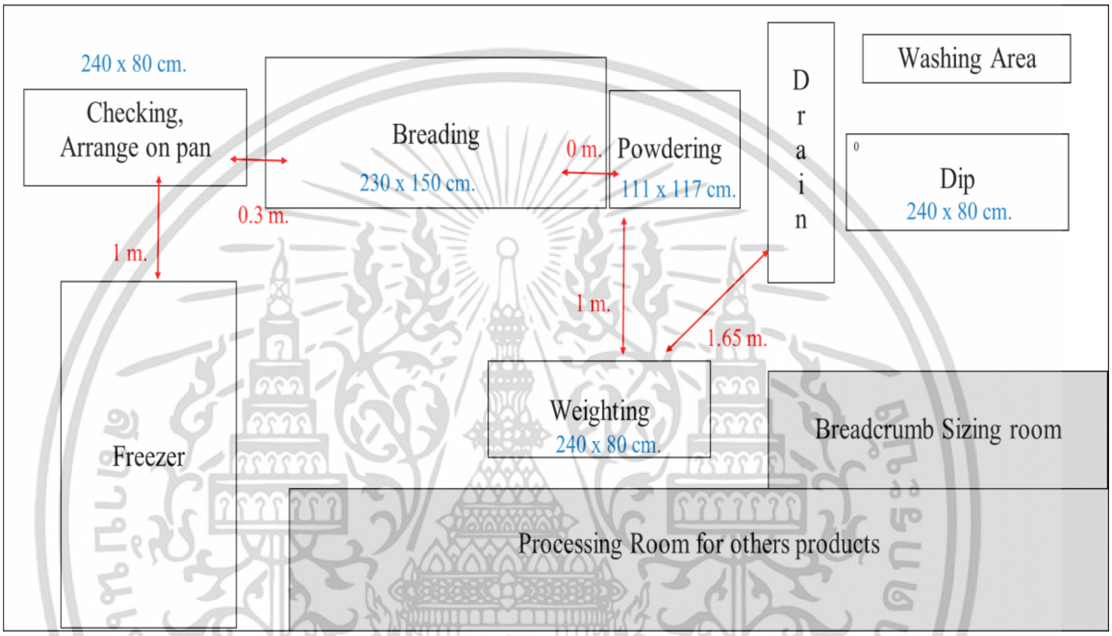


Figure 3.6 Process layout (before improvement)

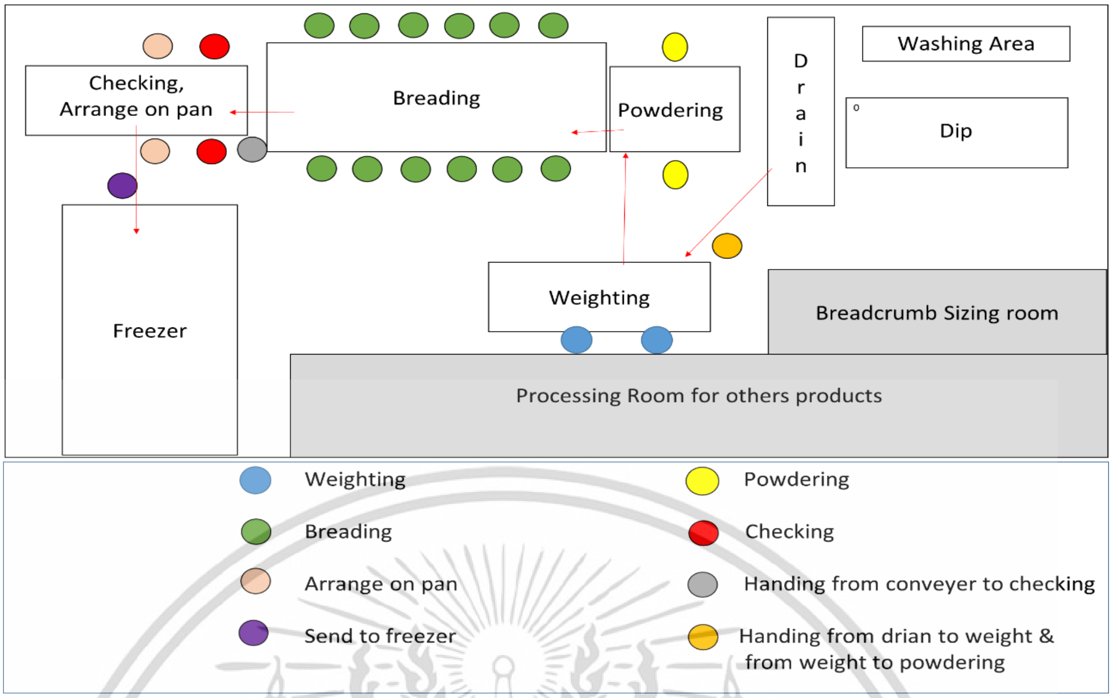


Figure 3.7 Product flow and number of operators (before improvement)

3.2. Record Cycle Time of Current Method and Compute Standard Time

The researcher recorded cycle time spending in selected process which are process of Handing to weight ~ Send to freezer, 10 times per each elemental task. There are several operators working in each workstation, which is hard to determine representatives to collect data. After discussion with production leader, it has been concluded that averaged-skilled operators are selected to be timed as the representatives of each activity. The cycle time of each activity are shown in Table 3.3 and Table 3.4.

After observation, the average cycle time and lowest-longest time of 10 repetitions per each activity was determined. The result is used to identify accurate number of cycle time to be collected based on Maytag table, which is $\pm$ 95% confidential level. The result is shown in Table 3.5.

Table 3.3 Cycle time in each activity before improvement

TIME STUDY OBSERVATION SHEET

Process: Value added process	**Date:** 2016/11/03~04, 2016/12/25	**Method:** Before / After improvement
Division: P17 at Factory 5	**Time:** 08.30 ~ 16.30	**Recorder:** Namtip Insalee

Workstation	**Task**	**Elemental Task**	**Cycle Time (CT)**										**Avg CT**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
1	A	Handing to weight	4.11	4.26	4.28	4.75	4.06	4.50	4.39	3.81	3.94	3.82	4.19
	B	Handing to powdering	4.00	3.74	3.55	3.49	3.88	3.61	3.83	4.07	3.57	4.09	3.78
2	C	Weighting	4.38	4.29	3.41	3.43	4.20	3.32	4.07	3.63	3.88	3.45	3.81
3	D	Powdering	3.80	3.88	3.80	3.95	3.74	3.80	3.88	3.68	3.61	3.76	3.79
4	E	Breading	24.24	23.04	24.44	19.41	25.12	21.18	20.33	23.64	19.33	22.14	22.29

Table 3.4 Cycle time in each activity before improvement (continued)

TIME STUDY OBSERVATION SHEET													
Process: Value added process			**Date:** 2016/11/03~04, 2016/12/25					**Method:** Before / After improvement					
Division: P17 at Factory 5			**Time:** 08.30 ~ 16.30					**Recorder:** Namtip Insalee					
Workstation	**Task**	**Elemental Task**	**Cycle Time (CT)**										**Avg CT**
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
5	F	Handing from conveyer	0.91	0.68	0.88	0.65	0.73	0.7	0.9	0.9	0.6	0.7	0.79
6	G	Check weight & appearance	3.27	3.60	4.36	3.36	3.07	4.4	3.1	3.8	4.0	3.5	3.67
7	H	Place sheet on pan	4.10	4.41	4.08	4.33	4.86	4.0	4.6	5.3	4.4	4.1	4.43
	I	Arrange fish on pan	34.3	35.7	36.4	35.9	36.7	40.1	37.2	39.4	40.2	37.8	37.4
8	J	Send to freezer	3.06	3.60	3.87	4.04	3.31	3.4	3.1	3.5	3.8	3.1	3.50

Table 3.5 Number of cycle time requirement (N) based on Maytag table

Workstation	Task	Task Description	Cycle Time (CT)					
			Avg. CT	High (H)	Low (L)	H-L	H-L/ H+L	N
1	A	Handing to weight	4.19	4.75	3.81	0.94	0.11	8
	B	Handing to powdering	3.78	4.09	3.49	0.60	0.08	4
2	C	Weighting	3.81	4.38	3.32	1.06	0.14	13*
3	D	Powdering	3.79	3.95	3.61	0.34	0.04	1
4	E	Breading	22.29	25.12	19.33	5.79	0.13	11*
5	F	Handing from conveyer	0.79	0.95	0.65	0.30	0.19	24*
6	G	Checking weight and appearance	3.67	4.44	3.07	1.37	0.18	22*
7	H	Place sheet on pan	4.43	5.30	4.04	1.26	0.13	11*
	I	Arrange on pan	27.43	30.24	24.35	5.89	0.11	8
8	J	Send to freezer	3.50	4.04	3.06	0.98	0.14	13*

The calculation result in column N shows that, except Task A, Task B, Task D, and Task I, others tasks (tasks with red star), need more samples to be collected to cover the criteria of Maytag Table such as Task C (weighting) in workstation 2, which requires 13 repetitions including 10 times collecting in Table 3.1. Therefore, Task C should be collected 3 times for additional cycle time. After collecting additional cycle time, computed average cycle time in each activity again.

While collecting cycle time, production leader advised a proper rating factor of each operator by evaluating their performance as shown in Table 3.6.

Table 3.6 Result of evaluation for operator performance

Workstation	Elemental Task	Task Description	Rating Score				Total
			Skill	Effort	Condition	Consistency	
1	A	Handing to weight	0.03	0.05	0.00	0.01	**1.09**
	B	Handing to powdering	0.03	0.05	0.00	0.01	**1.09**
2	C	Weight	0.06	0.05	0.04	0.03	**1.18**
3	D	Powdering	0.06	0.10	0.00	0.03	**1.19**
4	E	Breading	0.06	0.05	0.04	0.03	**1.18**
5	F	Handing from conveyer	0.03	0.05	0.00	0.01	**1.09**
6	G	Checking	0.08	0.08	0.02	0.01	**1.19**
7	H	Place sheet on pan	0.03	0.05	0.02	0.01	**1.11**
	I	Arrange fish on pan	0.03	0.02	0.02	0.01	**1.08**
8	J	Send to freezer	0.03	0.05	0.02	0.01	**1.11**

Evaluation of Time Allowance

Based on manufacturer's data, most of operators are women. Additionally, all operators are working mostly in the same condition: standing all day, with good air flow condition and good laminate condition. Hence, allowance time is identified as below;

Personal Allowance = 7 + 4 = 11%

Basic Fatigue = 4 %

Thus, Time Allowance is 15% per each activity.

Table 3.7 Calculation table of standard time (before improvement)

TIME STUDY OBSERVATION SHEET

Company Name: Siamchai International Food Company Limited

Date: 2016/11/03~04, 2016/12/26

Record Time: 08:30 ~ 16:30

Product Name: Frozen Breaded Fish

Division: P17 at Factory 5

Process of Production: Weighting process ~ Send to freezer

Production Method: Before/ After Improvement

Operators: Male / Female

No. of Operators: 23

Recorder: Namtip Insalee

Equipment: Stopwatch

Workstation	Task	Elemental Task	Avg. Time (sec.)	Rating Factor	Normal Time (sec.)	Allowance Time (sec.)	Standard Time (sec.)	CT/Workstation (sec.)	No. of Operators	Avg. CT/ operator
1	A	Handing to weight	4.19	1.09	4.57	0.15	5.38	10.22	1	10.22
	B	Handing to powdering	3.78	1.09	4.12	0.15	4.85			
2	C	Weight	3.81	1.18	4.50	0.15	5.29	5.29	2	2.64
3	D	Powdering	3.79	1.19	4.51	0.15	5.31	5.31	2	2.65
4	E	Breading	22.15	1.18	26.13	0.15	30.75	30.75	12	2.56
5	F	Handing from conveyer	0.78	1.09	0.85	0.15	1.00	1.00	1	1.00
6	G	Check weight, appearance	3.85	1.19	4.58	0.15	5.39	5.39	2	2.69
7	H	Place sheet on pan	4.41	1.11	4.90	0.15	5.76	40.61	2	20.31
	I	Arrange fish on pan	27.43	1.08	29.62	0.15	34.85			
8	J	Send to freezer	3.51	1.11	3.89	0.15	4.58	4.58	1	4.58

Table 3.7 shows the calculation result of standard time per each task based on previous data. According to the table, total cycle time is 103.15 seconds per unit and bottleneck operation time is 40.61 seconds. To find the bottleneck workstation, cycle time per workstation must be divided by the number of operators working at each workstation as shown in the last column on above table. The following figure shows cycle time per workstation before divided by number of operators.

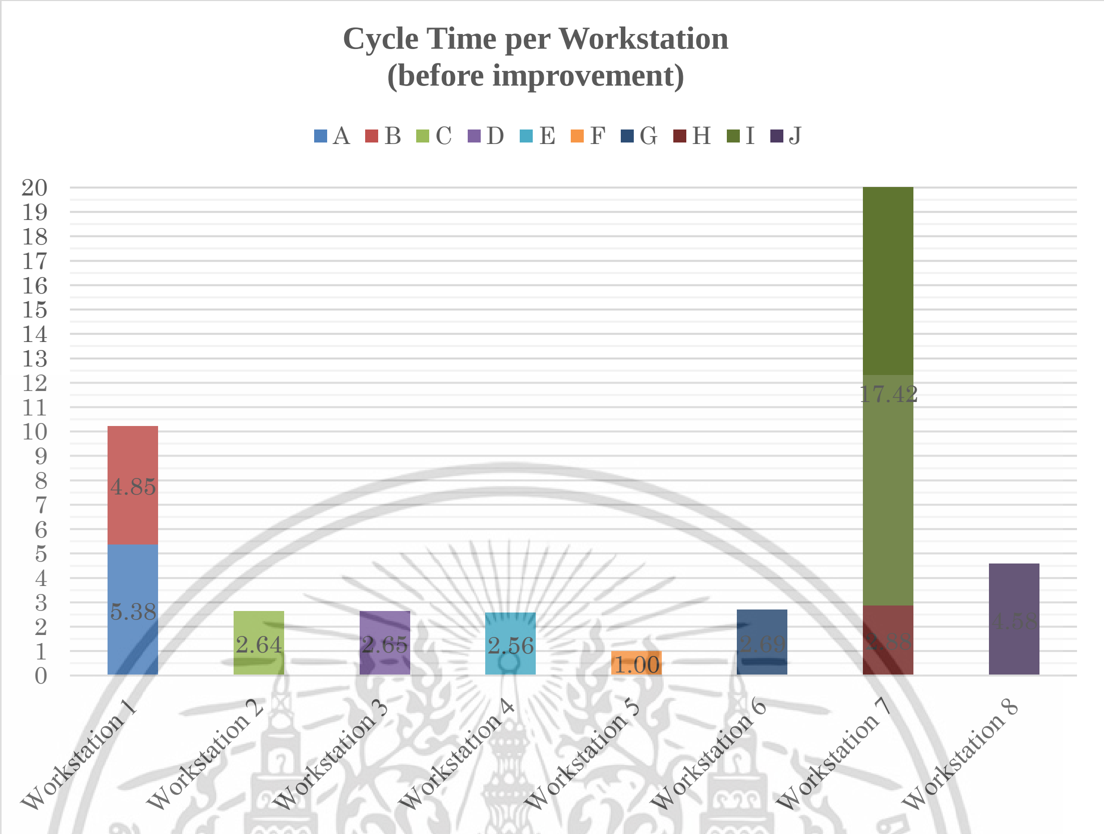


Figure 3.8 Cycle time per workstation (before improvement)

As Figure 3.8 shows, bottleneck operation is in workstation 7, which includes 2 elemental task working by 2 operators. Placing sheet on pan process (Task H) took 2.88 seconds to place a blue plastic sheet on pan (big stainless tray) to prevent breaded fish stuck with tray after freezing. Additionally, 17.42 seconds was for rearranging breaded fish from 11 small plates into big stainless tray.

Calculate Line Balancing (Before Improvement)

The operation time per day for selected product is from 08.00 am to 5.00 pm per day with one shift, 1 hour and 30 minutes of breaking time for production line setup. Hence, remaining operation time is 7 hours and 30 minutes. Total customer demand is 8,100 kilograms or 57,852 trays per month. Due to production line for the product is sharing with other products, the production day remains only 9 days per month. Then, designed output per day should be 57,852 trays /9 days = 6,428 trays/day.

Takt Time = ((8 hrs./day x 3,600 sec./hr.) – 1,800 sec.)) x (9 days ÷ 57,852 trays)

= 4.2 sec./tray

Cycle Time (CT) for bottleneck operation = 40.60 seconds

Theoretical Minimum Number of Workstations;

$$N\text{min} = \frac{\sum t}{CT}$$

$$= \frac{103.13}{40.60} = 2.54 \approx 3 \text{ workstations}$$

Cycle Time & Takt Time

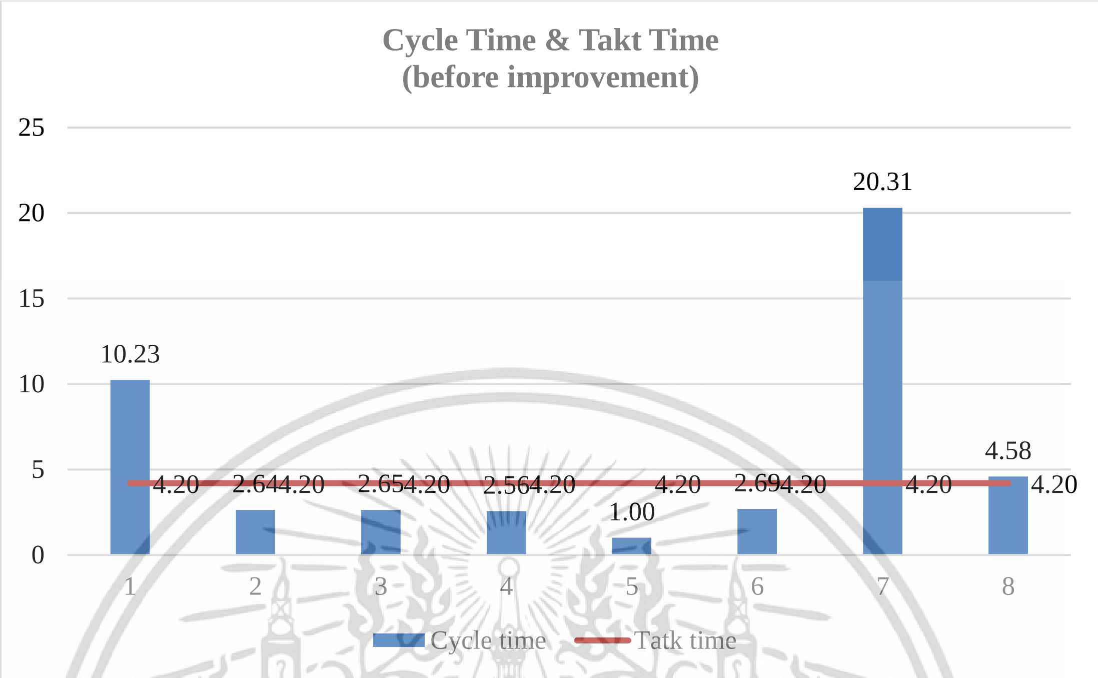


Figure 3.9 Comparison between takt time and cycle time (before improvement)

As explained in the previous chapter, takt time is the factor to limit cycle time in each workstation. Figure 3.9 shows that current cycle time in workstation 1, workstation 7 and workstation 8 over Takt time are 6.03 seconds, 16.10 seconds and 0.38 seconds respectively. Thus, those three workstations must improve productivity, especially workstation 7 which was the bottleneck of the process.

Percentage of Idle Time;

$$\text{Percentage of idle time}=\frac{\text{Idle time per cycle}}{\text{N actual x Cycle}}\ \text{x100}$$

$$=\frac{10.07+17.66+17.65+17.74+19.30+17.61+15.72}{(8)(20.30)}=71.26\%$$

The Line Efficiency or Efficiency Rate;

= 100% - Percentage of Idle Time

= 100 – 71.26 = 28.74 %

The above calculation result shows that in current operation method, the percent of idle time was 71.26%, line efficiency was only 28.74% in case takt time is 4.2 seconds per one tray of product.

3.3. Cause and Effect Diagram

The result of study shows that the bottleneck process in workstation 7, consisting of placing sheet and arranging fish on pan before sending to the freezer, took about 20.30 seconds per unit. Fishbone diagram is used to analyze possible cause of problem to find improvement method. The fishbone diagram analysis is shown in Figure 3.10.

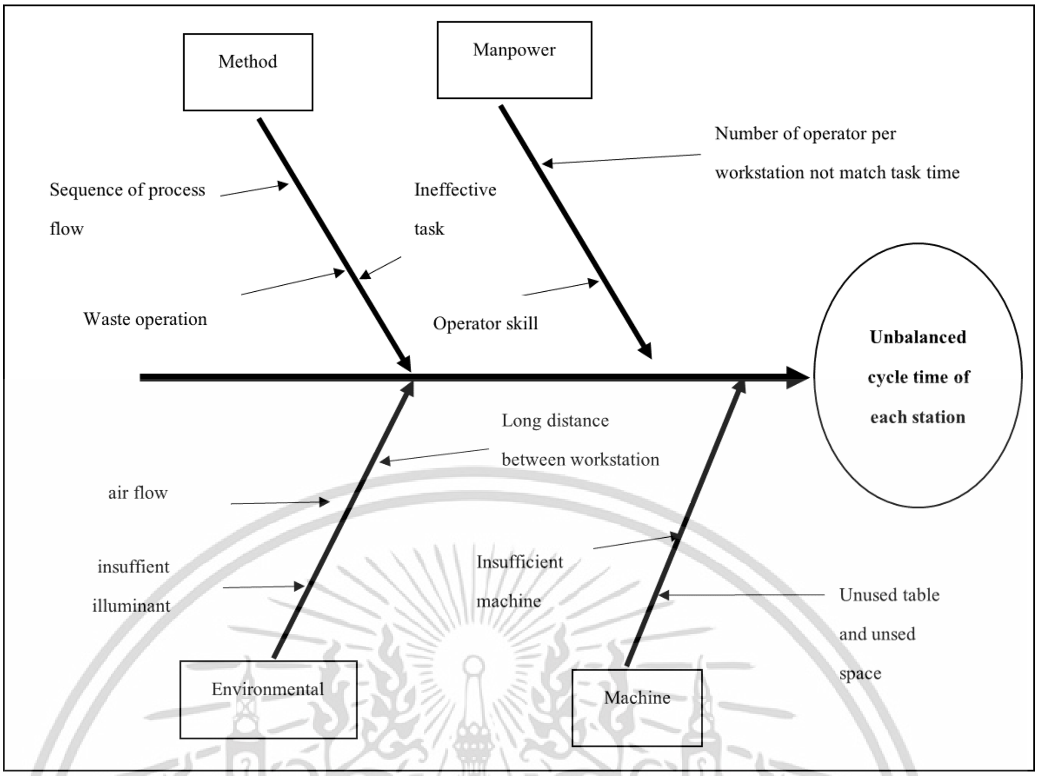


Figure 3.10 Fishbone diagram for problem analysis

According to Figure 3.10, the causes of problem are categorized as below;

- Method: Allocation of task into workstation is not efficient. Some of long cycle time is allocated into the same workstation which affects total cycle time of station. Additionally, some elemental task such as handing raw material to weight (Task B) in workstation 1 and rearranging in pan (Task I) in workstation 7 do not provide any value for product.
- Manpower: The number of workers does not match for the tasks in workstation. For example, there are only 2 operators in workstation 7 while taking care of long cycle time. Moreover, operators in some tasks need to improve their skills.

- Machine: The Number of weighting scale in workstation 4 and workstation 7 is not enough. Operators are sharing weight scales, which is a waste of time to wait for the scales to be available. Additionally, there is some unused space of the table, which causes a long distance between next stations.
- Environmental: Long distance between workstation which causes additionally process such as transportation or handing the product, which are Task A and Task B.

3.4. Propose Improvement Plan

After understanding the problem of current operation method, the researcher uses ECRs principle and line balancing (LB) to improve production process as following steps; Firstly, identify wastes and try to reduce those wastes based on ECRs principle by reduction and simplifying production process. Second, allocate elemental task into workstation based on line balancing. Next, implement proposed method and record cycle. Then, adjust the number of operators in each task by identifying ideal number of operator. Lastly, compare efficiency of current and proposed method and summarize the result of the study.

CHAPTER 4

ANALYSIS AND RESULTS

This chapter consist of improvement plan, following the situation of productivity after improvement, and the comparison in efficiency of production line between before and after the implementation of proposed improvement plan. The problem of research will be solved as following steps;

4.1 Improve Production Process Based on ECRS Principle

4.2 Collect Cycle Time, Identify Standard Time after Improvement

4.3 Adjust Ideal Number of Operator, Compare Average Cycle Time per Workstation

4.1. Improve Production Process Based on ECRS Principle

The study started improvement plan by analyzing the waste, which may occur in any activities such as waste from transportation, motion waste, and overproduction waste and so on as explained in chapter 3. By using cause and effect diagram, some transportation waste, inefficiency task allocation which should be improved based on ECRs principle were found, as explanation in Table 4.1 to Table 4.4.

Table 4.1 Propose improvement plan

Workstation	Elemental Task	Waste	Description	ECRs Principle	Improvement Plan
1 , 2 and 3	(A) Handing to weight, (B) Handing to powdering, (C) Weighting, (D) Powdering	Transportation waste	Waste Handing process because of long distance between workstation 1,2 and 3 which causes wasting transportation time and wage cost, one person responsible for handing raw material which is: 1. Task A: Bring raw material from workstation 1 to workstation 2 2. Task B: Bring raw material from weighting process in workstation 2 to powdering process in workstation 3 Total transportation distance was about 2.65 meter.	Combine	Rearrange table of workstation 2 to be next to workstation 3 as shown in Figure 4.1 and Figure 4.2. Hence, the total distance between workstation 1,2 and 3 is reduced to 0 meter. Then, group Task A in workstation 1 with Task C in workstation 2, and combine Task B in workstation 1 with task D in workstation 3. As a result, production can reduce wage cost for 1 person who is in charge of handing process.

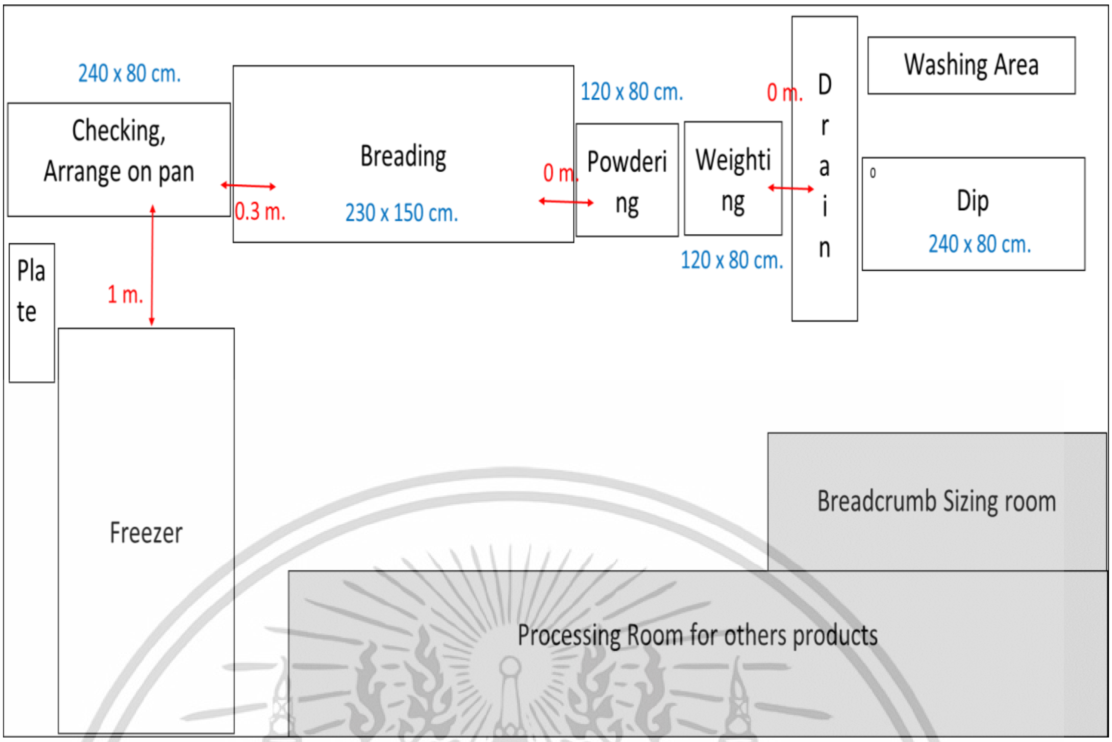


Figure 4.1 New product layout

Figure 4.2 After rearrange table of workstation 2 and workstation 3

Table 4.2: Propose improvement plan (continued)

Workstation	Elemental Task	Waste	Description	ECRs Principle	Improvement Plan
3	(D) Powdering	Motion waste	Operators at powdering process must turn fish's skin on top side every piece of fillet to make it easy for breading at the next station. However, it is difficult to determine which side is fish's skin after coating by flour.	Eliminate	To check and turn over fillet's skin on top side at Task C while weighting. Hence, there are no need to turn skin on at powdering process. The improvement is as shown in Figure 4.3.

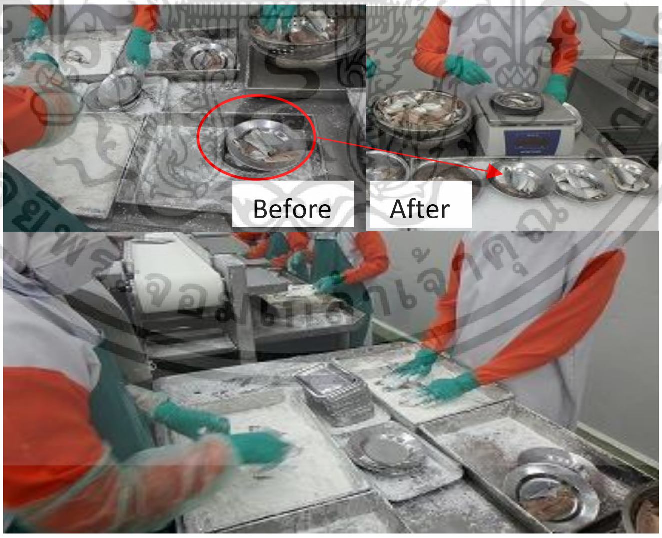


Figure 4.3 Weighting and powdering process after improvement

Table 4.3 Propose improvement plan (continued)

Work station	Elemental Task	Waste	Description	ECRs Principle	Improvement Plan
5 & 6	(F) Handing to check, (G) Check weight and appearance	Motion waste	There is an unbalance cycle time of Task F comparing with longer cycle time of Task G. which contain two steps of checking, which is (G1/2) weight checking and (G2/2) appearance checking in next station.	Rearrange	Rearrange Task G 2/2 with Task F in workstation 5, while workstation 6 maintains only Task G1/2 as shown in Figure 4.4, Figure 4.5 and Figure 4.8.

Figure 4.4 Workstation 5 after improvement, to handing and appearance checking

Figure 4.5 Workstation 6 after improvement, check weight of product

Table 4.4 Propose improvement plan (continued)

Work statio n	Elemental Task	Waste	Description	ECRs Principl e	Improvement Plan
7	(H) Place sheet on pan, (I) Arrange on pan	Motion Waste	This workstation was set to avoid breaded fish drop in freezer tunnel which does not make any value for product. The process contained two tasks, which are placing sheet on tray and rearranging breaded fish from small plate to big tray for freezing as in Figure 4.6	Eliminate	After discussion, production leader informs that this is old practice before changing new freezer. Currently, it is not necessary to do that. Hence, the leader accepted an elimination of workstation 7 as shown in Figure 4.7.

Figure 4.6 Task in workstation 7 before improvement

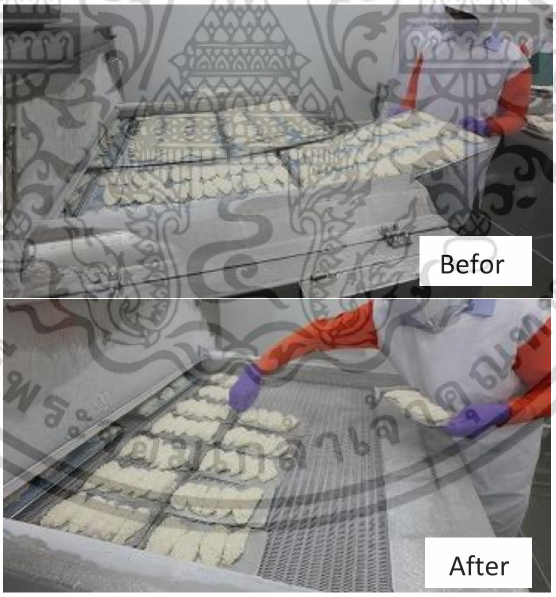


Figure 4.7 Task in workstation 8 before and after improvement

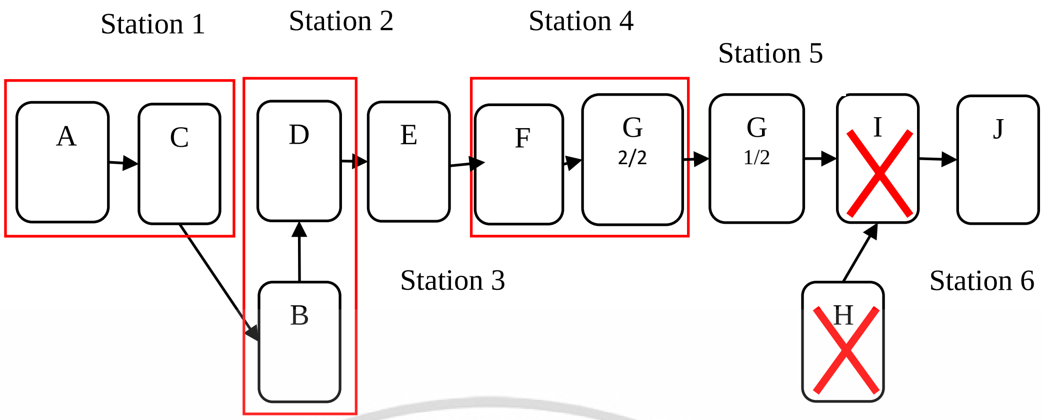


Figure 4.8 New model

The summary of improvement model was created as shown in Figure 4.8 and Table 4.5. The workstation is decreased from 8 workstations to 6 workstations, and tasks or activities also decrease from 10 tasks to 8 tasks. Therefore, the number of operators is changed from 23 persons to 19 persons.

The workstation 1 includes Task A and Task C. Workstation 2 includes Task B and Task D, while Task E is in workstation 3. Task G is divided into two activities, which are Task G 1/2 and Task G2/2. For workstation 4, it includes Task F, following with Task G2/2. Then, Task G1/2 is in workstation 5. Lastly, Task J is in workstation 6.

By Adjusting production layout and eliminating Task H and Task I in workstation 6, the bottleneck of the production was eliminated. Additionally, blue plastic sheets and big trays used in those workstation is also removed automatically. Besides, cooling time of the freezing process is decreased because the small plates can cool down the temperature of breaded fish more easily than big trays, which are thicker.

Table 4.5 Comparison number of workstation between before and after improvement

Before Improvement		Elemental Task	After Improvement	
Workstation	**Number of operator**		**Workstation**	**Number of operator**
1	1	(A) Handing to weight	1	2
		(B) Handing to powdering	2	
2	2	(C) Weighting	1	
3	2	(D) Powdering	2	2
4	12	(E) Breading	3	12
5	1	(F) Handing from conveyer	4	1
6	2	(G) Checking (G2/2) Check appearance		
		(G1/2) Check weight	5	1
7	2	(H) Place sheet on pan	-	0
		(I) Arrange fish on pan		
8	1	(J) Send to freezer	6	1
8	**23**	**TOTAL**	**6**	**19**

4.2. Collect Cycle Time, Identify Standard Time after Improvement

By changing of process flow and production layout, the data of the entire process such as process flow chart, cycle time should be collected again to confirm efficiency after improvement as shown below.

Table 4.6 Description of process flow chart (after improvement)

	Summary					
Company Name: SIFCO	**Symbol**		**Total**	**Not change**	**Decrease**	**Remark**
	Operation		**4**			
	Movement		**4**			
Process: Before / After improvement	**Delay or wait**		**0**			
	Inspection		**1**			
	Storage		**0**			
Recorder: Namtip Insalee	**Distance (m.)**		**4.70**			
	Time (sec.)		**69.03**			

Task	**Elemental Task**	**Distance (m.)**	**Time (sec.)**	**Symbol**					**Remark**
A	Handing to weight	0.00	2.03						
C	Weight and count 4-5	0.00	3.57						
B	Handing to predust	0.00	0.74						
D	Powdering	0.00	3.54						
E	Breading	0.00	19.89						
	Transfer by conveyer	2.40	30.39						
F	Handing & visual check	1.30	2.71						
G	Check weight	0.00	2.51						
J	Send to freezer	1.00	3.65						
	TOTAL	**4.70**	**69.03**						

Table 4.7 Cycle time in each activity after improvement

TIME STUDY OBSERVATION SHEET		
Process: Value added process	**Start ~ End Time:** 08.30 ~ 16.30	**Production Method:** Before / After improvement
Division: P17 at Factory 5	**Date of Observation:** 2017/03/17-20	**Recorder:** Namtip Insalee

Workstation	Task	Elemental Task	Cycle Time (CT) 1	2	3	4	5	6	7	8	9	10	Avg CT
1	A	Handing to weight	2.03	2.18	2.18	2.11	2.17	2.12	2.11	2.11	2.08	2.13	2.12
	C	Weight	3.57	4.21	3.92	3.57	3.84	4.07	4.10	3.81	4.06	3.92	3.91
2	B	Handing to powdering	0.74	0.66	0.63	0.65	0.71	0.64	0.68	0.71	0.66	0.63	0.67
	D	Powdering	3.54	3.94	3.22	3.17	3.86	3.35	3.93	3.82	3.87	3.80	3.65
3	E	Breading	19.89	19.30	19.52	19.50	19.18	19.19	19.30	19.35	19.35	19.80	19.44
4	F	Handing and visual check	2.71	2.65	2.81	2.42	2.51	2.50	2.57	2.67	2.57	2.55	2.60
5	G	Check weight	2.51	2.17	2.19	2.22	2.18	2.24	2.30	2.18	2.18	2.24	2.24
6	J	Send to freezer	3.65	3.87	3.60	3.99	3.76	3.89	3.90	3.84	3.86	3.82	3.82

Table 4.6 shows the process flow chart after improvement, which takes 69.03 seconds per unit - being less than flow chart before improvement in the previous chapter about 107.71 seconds per unit. Additionally, transportation waste in Task A and Task B is reduced from 1.65 meters to 0 meter because of the rearrangement of production layout.

Table 4.8 Number of cycle time requirement (N) Based on Maytag table

Workstation	Elemental Task	Task Description	Cycle Time (CT)					
			Avg. CT	High (H)	Low (L)	H-L	H-L/ H+L	N
1	A	Handing to weight	2.12	2.18	2.03	0.15	0.04	0
	C	Weight	3.91	4.21	3.57	0.64	0.08	4
2	B	Handing to powdering	0.67	0.74	0.63	0.11	0.08	4
	D	Powdering	3.65	3.94	3.17	0.77	0.11	8
3	E	Breading	19.44	19.89	19.18	0.71	0.02	0
4	F	Handing and visual check	2.60	2.81	2.42	0.39	0.07	3
5	G	Checking weight	2.24	2.51	2.17	0.34	0.07	3
6	J	Send to freezer	3.82	3.99	3.60	0.39	0.05	1

After 10 times of observation per each activity, the data are used to identify the number of cycle time to evaluate accuracy of the data. Based on Maytag Table in Table 4.8, it is not necessary to collect additional numbers of cycle time in any tasks because column N shows that all activities require the number of cycle time as less than 10 times, which is already collected in Table 4.7.

Table 4.9 Result of evaluation for operator performance (after improvement)

Workstation	Elemental Task	Task Description	Rating Score				Total
			Skill	Effort	Condition	Consistency	
1	A	Handing to weight	0.11	0.12	0.04	0.03	**1.30**
	C	Weight	0.11	0.12	0.04	0.03	**1.30**
2	B	Handing to powdering	0.06	0.08	0.04	0.03	**1.21**
	D	Powdering	0.06	0.08	0.04	0.03	**1.21**
3	E	Breading	0.13	0.12	0.04	0.04	**1.33**
4	F	Handing and visual check	0.06	0.05	0.02	0.01	**1.14**
5	G	Check weight	0.08	0.08	0.04	0.03	**1.23**
6	J	Send to freezer	0.06	0.08	0.02	0.03	**1.19**

The evaluation of operator performance is showed in Table 4.9. All data from Table 4.7 to Table 4.9 were used to identify standard time as shown in Table 4.10.

Table 4.10 Calculation table of standard time (after improvement)

TIME STUDY OBSERVATION SHEET

Company Name: Siamchai International Food Company Limited		**Date:** 2017/03/17~20
		Record Time: 08:30 ~ 16:30
Product Name: Frozen Breaded Fish	**Production Method:** Before/ <u>After Improvement</u>	**Operators:** Male / F<u>emale</u>
Division: P17 at Factory 5		**Number of Operators:** 19 persons
Process of Production: Value added process		**Recorder:** Namtip Insalee
		Equipment: Stopwatch

Workstation	Task	Elemental Task	Avg. Time (sec.)	Rating factor	Normal Time (sec.)	Allowance Time (sec.)	Standard Time (sec.)	CT/ workstation (sec.)	No. of Operator	Avg. CT/operator
1	A	Handing to weight	2.12	1.30	2.76	0.15	3.25	9.22	2	4.61
	C	Weight	3.91	1.30	5.08	0.15	5.98			
2	B	Handing to powdering	0.67	1.21	0.81	0.15	0.96	6.15	2	3.08
	D	Powdering	3.65	1.21	4.42	0.15	5.20			
3	E	Breading	19.44	1.33	25.85	0.15	30.41	30.41	12	2.53
4	F	Handing and visual check	2.60	1.14	2.96	0.15	3.48	3.48	1	3.48
5	G	Check weight	2.24	1.23	2.76	0.15	3.24	3.24	1	3.24
6	J	Send to freezer	3.82	1.19	4.54	0.15	5.35	5.35	1	5.35

Based on the number of operators in each workstation, the average cycle time of each workstation is determined in the last column in Table 4.10. For example, the average cycle time in workstation 1 is 4.61 seconds including total cycle time of Task A and Task B, 3.25 seconds and 5.98 seconds respectively. Then, total cycle time is divided by 2 persons which is = (3.25 + 5.98) ÷ 2 = 4.61 seconds. Average cycle time in each workstation is illustrated in the graph below.

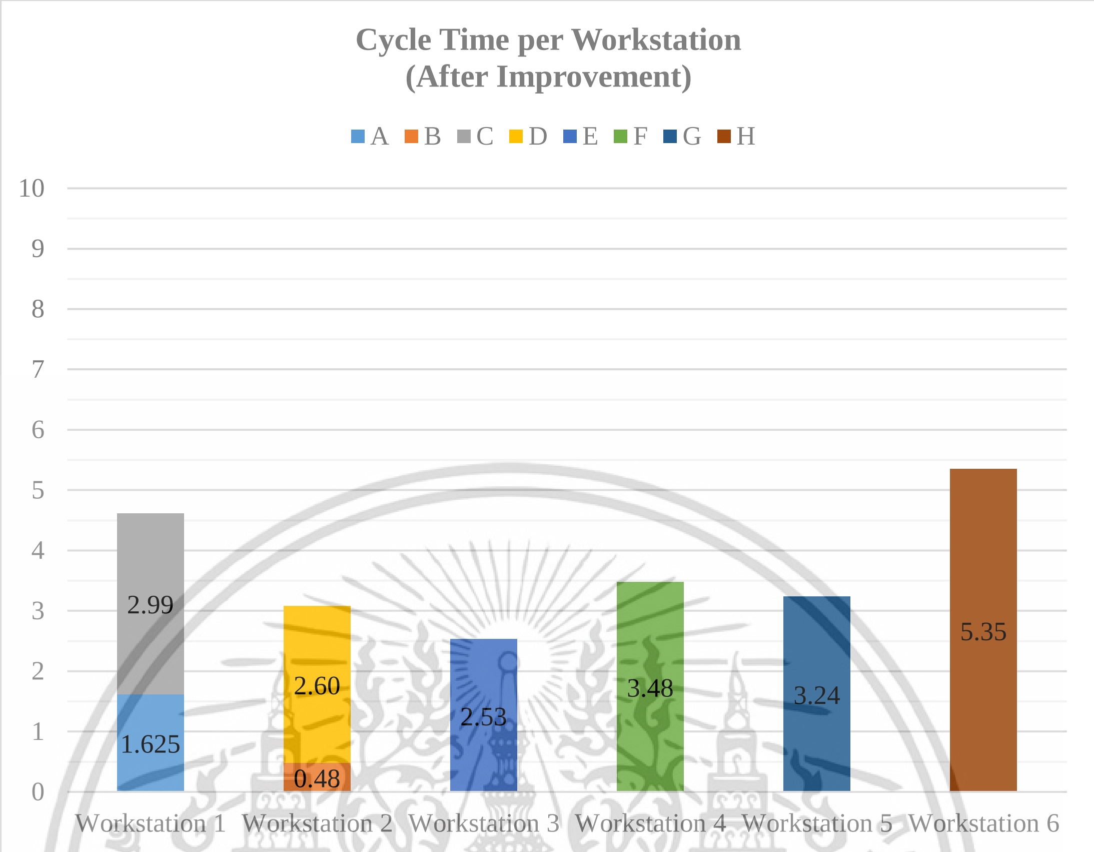


Figure 4.9 Cycle time per workstation (after improvement)

Cycle Time & Takt Time

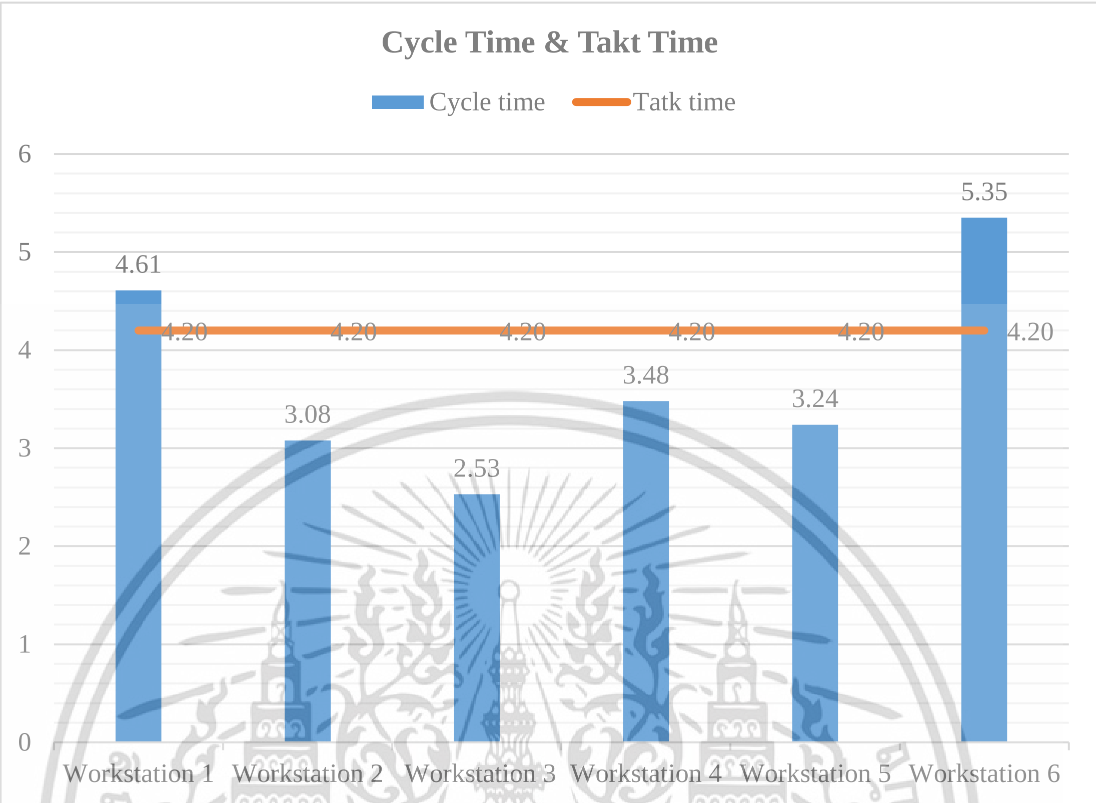


Figure 4.10 Comparison between cycle time and takt time (after ECRs principle)

Figure 4.10 illustrates the result of cycle time per workstation after adjusting activities based on ECRs principle comparing with takt time. The data shows that cycle time of 2 workstations, which is workstation 1 and workstation 6, is still over takt time, 0.41 seconds and 1.15 seconds respectively. Therefore, there is an attempt to adjust the number of operators to balance cycle time per workstation.

The overall cycle time in each workstation must be less than takt time to answer customer's required orders. Hence, takt time must be used to identify the number of suitable operators in workstation which is explained in the next step.

4.3. Adjust Number of Operator, Compare Average Cycle Time per Workstation

As explained in Chapter 2, the number of operators is a factor to adjust cycle time. In this part, below equation is used to adjust the number of operators in each workstation.

An equation of **Ideal Number of Operator**

$$\text{Ideal Number of Operator} = \frac{\text{Total Cycle Time}}{\text{Takt Time}}$$

Takt Time = ((8 hrs./day x 3,600 sec./hr.) – 1,800 sec.)) x (9 days ÷ 57,852 trays)

= 4.2 sec./tray

Table 4.11 Ideal number of operator per workstation

Workstation	**Cycle Time per workstation**	**Ideal number of operator**		**Average Cycle Time per Workstation**
		$=\frac{CT}{Takttin}$	= **persons**	
1	9.22	2.20	3	3.07
2	6.15	1.46	2	3.08
3	30.41	7.24	8	3.80
4	3.48	0.83	1	3.48
5	3.24	0.77	1	3.24
6	5.35	1.27	2	2.68

Table 4.11 shows the ideal number of operators in each workstation, including average cycle time per workstation in case of using amount of operator same as calculation. The number of operators reduces from 19 persons to 17 persons. For example, the result of calculation in workstation 1 = 9.23 ÷ 4.2 = 2.20 ≈ 3 persons. By using 3 persons, the cycle time will be 3.07 second per unit.

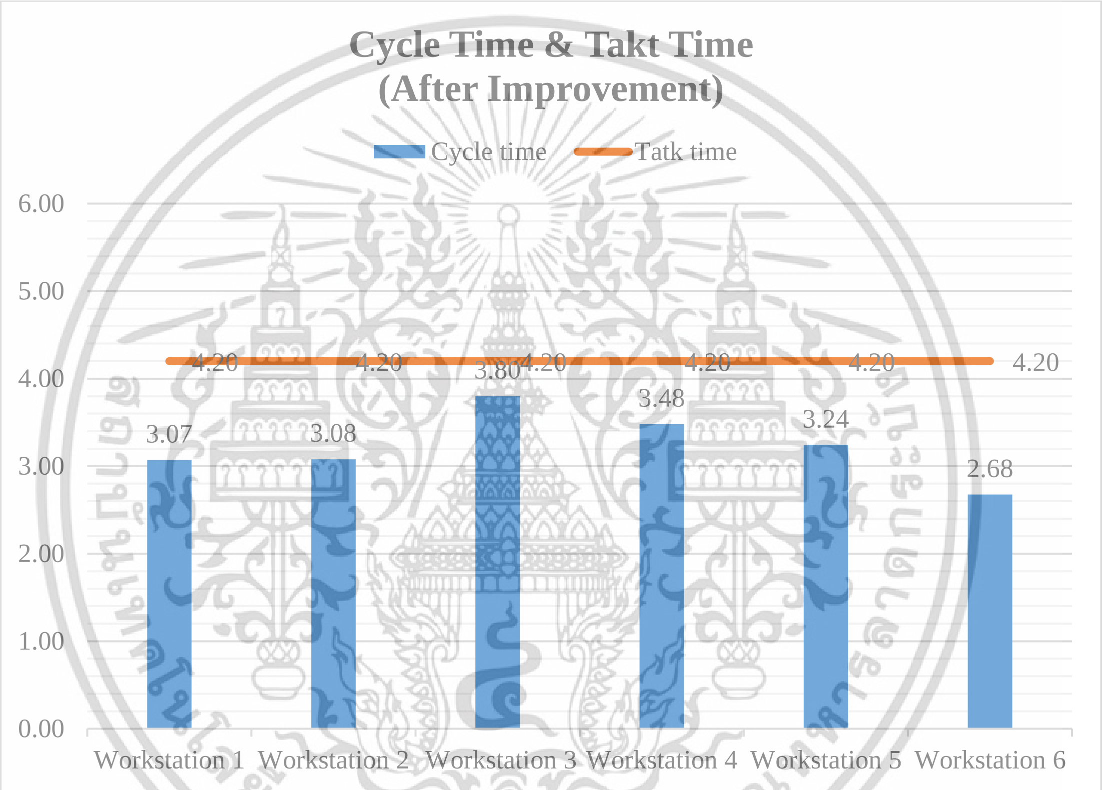


Figure 4.11 Comparison between cycle time and takt time (after improvement)

The above Figure shows the result after adjusting the number of operators. The graph illustrates average cycle time per workstation comparing with takt time by allocating ideal number of operators. The bottleneck of this model in workstation 3 contains one elemental task taking 3.80 seconds per unit. However, this task time is less than the takt time; then it has no problem for production.

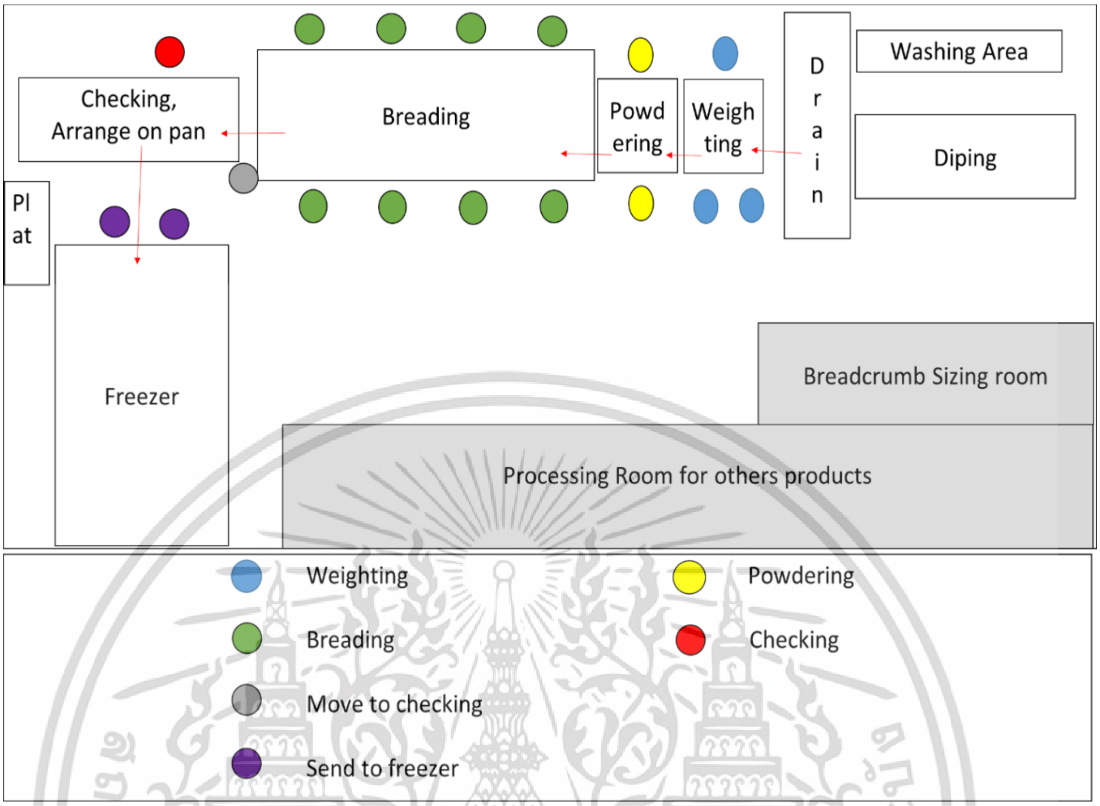


Figure 4.12 Product flow and number of operators (after improvement)

After the balance cycle time, the efficiency of production line should be calculated to compare between before and after improvement. The line efficiency can be identified as below;

Cycle Time (CT) for bottleneck operation = 30.41 seconds

Theoretical Minimum Number of Workstations;

$$Nmin = \frac{\sum t}{CT}$$

$$= \frac{57.86}{30.41} = 1.90 \approx 2 \text{ workstations}$$

Percentage of Idle Time;

$$\text{Percentage of idle time} = \frac{\text{Idle time per cycle}}{\text{N actual x Cycle}} \text{ x } 100$$

$$= \frac{0.72+0.72+0.32+0.56+1.13}{(6)(19.35)}$$

$$= 17.81\%$$

The Line Efficiency or Efficiency Rate;

$$= 100\% - \text{Percentage of Idle Time}$$

$$= 100 - 17.81 = 82.19\%$$

The calculation shows that Efficiency of production line increases to 82.19% and the overall number of operators reduces to 17 persons. The last chapter will be the conclusion of the study.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter devoted to summarize the result of the study after the implementation of the proposed improvement plan by comparing before and after improvement data. Additionally, the study provides recommendation for further research and to those who would like to conduct similar case studies. This chapter consists of two parts as below;

5.1 Result Evaluation and Conclusion

5.2 Recommendation

5.1.   Result Evaluation and Conclusion

The purpose of this study is to improve line efficiency by reducing waste and balancing cycle time in the production. After the improvement plan is implemented, the total cycle time per unit decreases by 39.12 seconds, from 108.15 seconds to 69.03 seconds. The number of workstation decreased by 2, from 8 workstations to 6 workstations. The number of operators reduces to 17 persons, decreasing wage cost for 1,800 bath per day. The distance between the workstation also deducted from 7.35 meter to 4.70 meter by rearrangement of production layout. Additionally, efficiency production line for frozen breaded fish increases to 82.19 %. As a result, this case study achieved the objective to improve production line efficiency and balance the production process. The brief conclusion of the study is shown in Table 5.1.

Table 5.1 Comparison between before and after improvement

Indicators	Before Improvement	After Improvement	Reduction Rate after Improvement
Total cycle time per unit (sec.)	108.15	69.03	39.12
Cycle time of bottleneck process (sec.)	20.3	3.8	16.5
Number of workstations	8	6	2
Number of operators	23	17	6
Total wage (estimate wage 300 bath/day)	6,900	5,100	1,800
Total handing distance (meter)	7.35	4.7	2.65
Line efficiency (%)	28.74	82.19	Increased by 53.45%

5.2. Recommendation

The factory is planning to expand ECRs principle and line balancing to other products which have production process close to the selected product, such as other breaded products. The study provided the recommend for further improvement as below;

1. Enhance labor's skill: Most of production in this case study is labor intensive. Additionally, there is some process which is rotated job. The operators' skill is important to keep stable productivity. Therefore, regular training from the

leader or skilled operators is recommended for those tasks. Additionally, incentive award is one of the way to motivate operator's performance.

2. Using predetermined motion time systems (PMTS): It is one of working measurement principles that is useful for intensive labor process such as breading process or powdering process. According to the research, there are a waste motion depending on the difference in skill of each operator. Hence, PMTS practice can be applied to study, analyze and classify operator' motion during working, and the waste motion can be removed after analyzing motion procedure. Besides, the study can design the feasible motion for doing each job better than existing practice.
3. Eliminate transportation waste for handing product along the production procedure. For example; after breading process, there is a conveyer belt to transport breaded fish to the next station. However, the height of the belt higher than the next station so the production leader must set person in charge of handing from the conveyer to the next station. If the production adjusts height of the conveyer to automatically send product to next station, there is no need to use person for handing.

For the recommendation, there was still a room for improvement the production process for the selected product such as studying the motion of operators, especially process which intensive labor and high motion. Currently, most of fishery factories are still labor intensive. Then, the motion study is one of the suitable way to enhance productivity in many ways. The incentive award is also commonly used to motivate operators.

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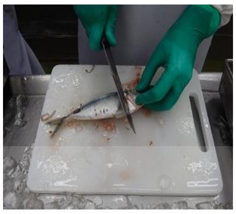
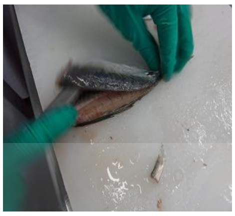
APPENDIX A

Appendix A: Picture of frozen breaded fish production

Raw Material Preparation Procedure



De-head and
De-guts



Fillet cut

Washing

Smell
check

Value Added Procedure

Sizing

Cutting

Dipping

Draining

Weight

Powdering

Breading

Checking

Arrange on pan

Freezing

APPENDIX B

Appendix B: Additional cycle time in each activity before improvement

Workstation		1		2	3	4	5	6	7		8
Task No.		A	B	C	D	E	F	G	H	I	J
Elemental Task		Handing to weight	Handing to powdering	Weighting	Powdering	Breading	Handing from conveyer	Checking weight, appearance	Place sheet on pan	Arrange on pan	Send to freezer
N		8	4	13	1	11	24	22	11	8	13
Cycle Time (CT)	1	4.11	4.00	4.38	3.80	24.24	0.91	3.27	4.10	24.35	3.06
	2	4.26	3.74	4.29	3.88	23.04	0.68	3.60	4.41	25.78	3.60
	3	4.28	3.55	3.41	3.80	24.44	0.88	4.36	4.08	26.48	3.87
	4	4.75	3.49	3.43	3.95	19.41	0.65	3.36	4.33	25.98	4.04
	5	4.06	3.88	4.20	3.74	25.12	0.73	3.07	4.86	26.73	3.31
	6	4.50	3.61	3.32	3.80	21.18	0.72	4.44	4.04	30.15	3.45
	7	4.39	3.83	4.07	3.88	20.33	0.95	3.18	4.61	27.25	3.14
	8	3.81	4.07	3.63	3.68	23.64	0.95	3.85	5.30	29.46	3.55
	9	3.94	3.57	3.88	3.61	19.33	0.66	4.03	4.42	30.24	3.81
	10	3.82	4.09	3.45	3.76	22.14	0.78	3.53	4.18	27.83	3.14
	11			4.29		20.75	0.61	4.16	4.18		3.42
	12			3.27			0.96	4.03			3.30
	13			3.94			0.89	4.84			3.92
	14						0.74	4.00			
	15						0.85	4.24			
	16						0.82	4.99			
	17						0.78	4.03			
	18						0.95	3.31			
	19						0.64	3.03			
	20						0.65	3.77			
	21						0.62	3.27			
	22						0.75	4.29			
	23						0.77				
	24						0.84				

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