APPLICATION OF LEAN MANAGEMENT CONCEPT TO A FROZEN FOOD MANUFACTURING

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งานวิจัยนี้มีจุดประสงค์เพื่อปรับปรุงความสามารถในการผลิตอาหารแช่แข็ง โดยสายการผลิตเนื้อปูหิมะแช่แข็งได้ถูกเลือกในการปรับปรุงในงานวิจัยนี้เพราะเป็นสินค้าที่มีความสามารถในการผลิตต่ำที่สุดเมื่อเทียบกับการผลิตสินค้าชนิดอื่น โดยค่าเฉลี่ยของความสามารถในการผลิตก่อนการปรับปรุงอยู่ที่ 60 กล่องต่อวัน

เครื่องมือและเทคนิคของลีนถูกประยุกต์ใช้ในการปรับปรุงความสามารถในการผลิตในงานวิจัยนี้ โดยวิธีการวิจัยจะใช้วิธีการวิเคราะห์แผนภูมิสายธารแห่งคุณค่า (Value Stream Mapping) ซึ่งประกอบด้วย 4 ขั้นตอน ได้แก่ เลือกชนิดของสินค้า, วาด สถานะปัจจุบัน (current state map), ออกแบบสถานะหลังการปรับปรุง (future state map), และ สร้างแผนการดำเนินงาน

โดยในขั้นตอนแรก การเลือกชนิดของสินค้าจะมีการวิเคราะห์มุมมองต่างๆที่เกี่ยวข้อง ได้แก่ คุณลักษณะของสินค้า, คุณค่าของสินค้าจากมุมมองลูกค้า, และ กระบวนการการผลิตเนื้อปูหิมะแช่แข็ง ขั้นตอนวิเคราะห์สถานะปัจจุบัน ประกอบด้วย การสังเกตุ, การวาดสถานะปัจจุบัน, การวาดแผนผังเส้นสปาเกตตี้, การทำแบบสอบถาม, และ การสัมภาษณ์ โดยผลลัพธ์ที่ได้จะอยู่ในรูปของกลุ่มปัญหาของสายการผลิตก่อนการปรับปรุงแสดงในรูปแผนผังก้างปลา (cause and effect diagram) หลังจากนั้นสถานะหลังการปรับปรุงจะถูกออกแบบเพื่อทำให้เห็นภาพโดยรวม แต่การเปลี่ยนแปลงสายการผลิตในปัจจุบันไปสู่สายการผลิตหลังการปรับปรุงที่ถูกออกแบบไว้จำเป็นที่จะต้องสร้างแผนการดำเนินงานที่เหมาะสม

จากการปรับปรุงความสามารถในการผลิตของสายการผลิตเนื้อปูหิมะแช่แข็ง พบว่าความสามารถในการผลิตในแต่ละวันเพิ่มขึ้น 10% จาก 60 กล่องต่อวันเป็น 66 กล่องต่อวัน ในขณะเดียวกันรอบการผลิตถูกปรับปรุงขึ้น 7.58% หรือ ลดลงเหลือ 2,908.87 วินาที และ ระยะเวลาในการผลิตปรับปรุงขึ้น 28.33% หรือ ลดลงเหลือ 1.804 วัน

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต	....
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The objective of this research is to improve productivity of frozen cooked snow crab production line. The manufacture of Combination (200g) product was chosen because its productivity yield was the least comparing to other product families. The average of current productivity before process improvement was 60 batches a day.

Lean tools and techniques were applied to improve the productivity in this research. Value stream mapping was used as a methodology which consists of four steps; selecting product family, drawing a current state map, developing a future state map, and constructing a work plan. The product characteristic, customer’s values, and production processes of Combination (200g) product were analyzed in the product family selection step. The necessary information of current production was gathered and analyzed using current state mapping, observation, spaghetti diagram, questionnaire, and interview. From these, the problems in the current production were analyzed by using cause and effect diagram. After the analysis of current production was completed, the future state map was developed to visualize the improved production line. In addition, the work plan was established in order to transform the current production line to be the designed one.

The results shows that the daily productivity is improved by 10%, 66 batches. In the meantime, the total cycle time and lead time are reduced to 2,908.87 seconds (7.58% improvement) and 1.804 days (28.33% improvement) respectively.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Engineering Management		
Academic Year:	2014		

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CHAPTER 1: INTRODUCTION

1.1. Background of the Research

The competition in frozen food business becomes intense since the behaviours of consumers have changed. Ready to eat products are chosen instead of fresh food because it is faster and delicious. Therefore, in the marketing point of view, the company has to produce the product to serve the need as quick as possible in order to gain market share. However, in the manufacturing point of view, many aspects have to be concentrated such as quality, inventory, and production process. Hence, the production efficiency should be enhanced in order to serve the right customer's values to the market and be able to compete and survive in long-term. The knowledge from Engineering Business Management degree could be used to help the case study company improve its production efficiency and achieves the company's goal.

1.2. Company Background

The case study Company is a small and medium sized enterprise (SME) which provides frozen and dried food. The company is located in eastern province of Thailand and close to Thailand's largest port, Laem Chabang Port. It was established in 1983 as a family business and has good manufacturer practice (GMP), hazard analysis critical control point (HACCP), and halal standard.

There are currently 250 employees including 188 production operators, 7 quality controls (QC), 18 raw materials, packaging, and finished products operators, and 37 staffs who work in an office and other employees. The company consists of 2 buildings which are office and production building. The production building is a three-story building.

1st floor: frozen production area, packing area, and stores (Figure 1-1)

2nd floor: storage of packaging area (Figure 1-2)

3rd floor: dry production area (Figure 1-3)

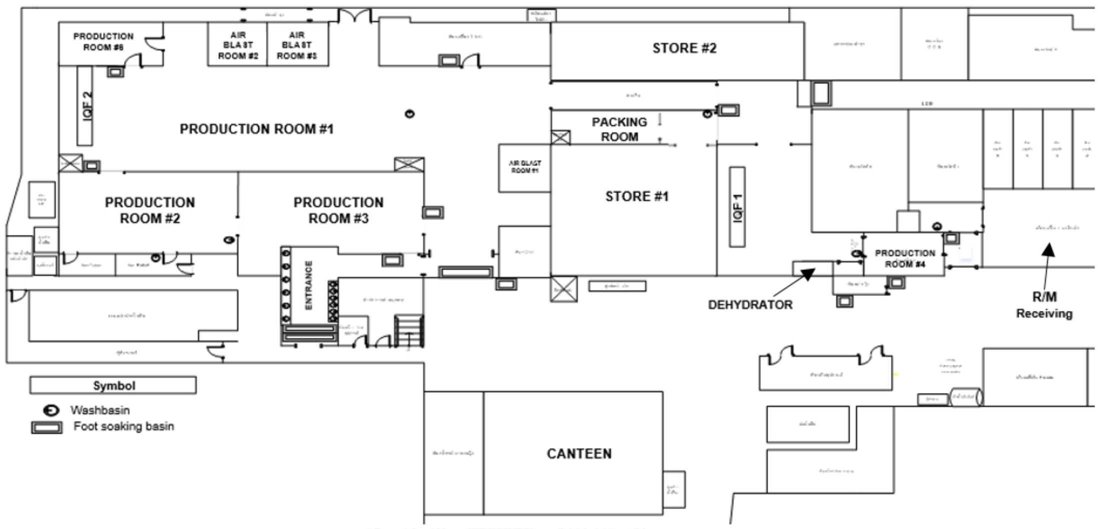


Figure 1-1: Layout of 1st Floor

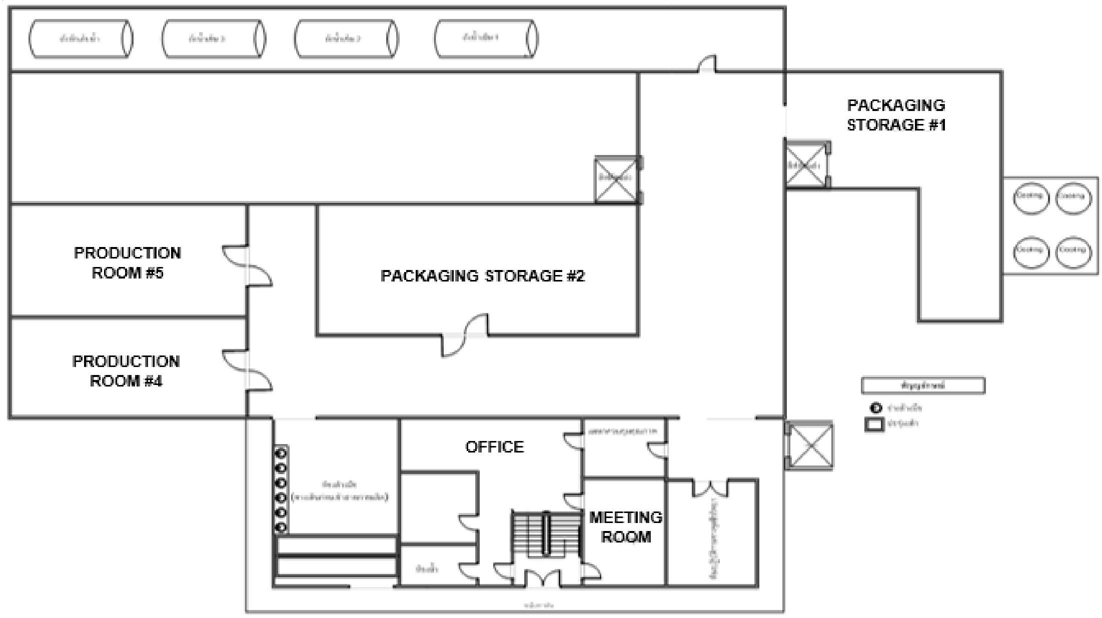


Figure 1-2: Layout of 2nd Floor

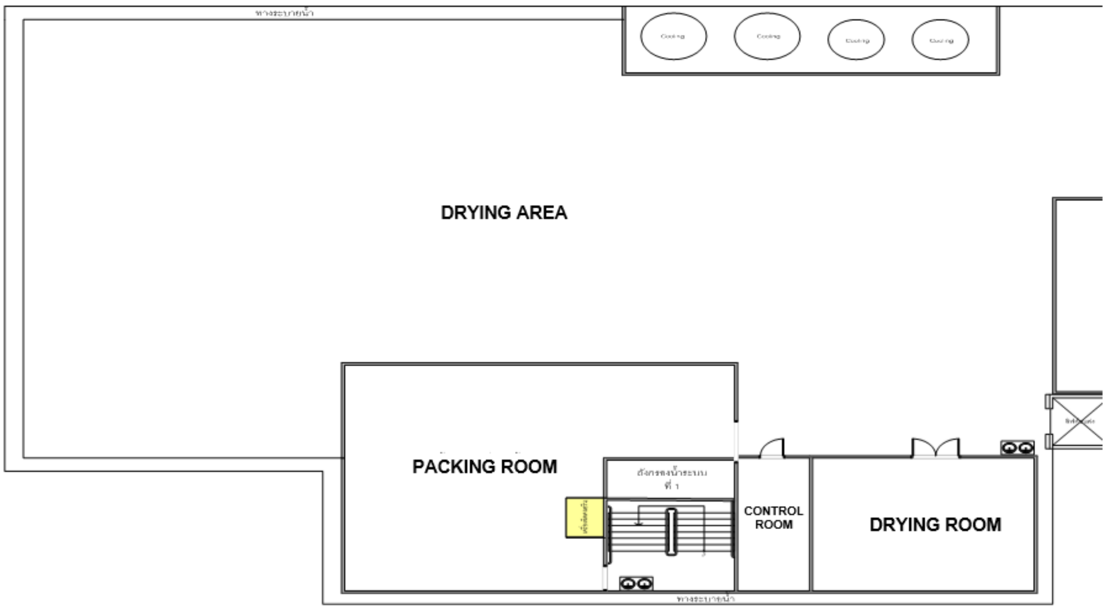


Figure 1-3: Layout of 3rd floor

1.2.1. Current Products

The main products of case study factory are seafood products which consist of dried fish (Figure 1-4), frozen fish (Figure 1-5), and frozen snow crab (Figure 1-6). The production of this factory is based on make-to-order principle. Customers are responsible for raw material ordering and inventory. Presently, there are 6 main customers from Thailand, Japan, Russia, and Europe.

Figure 1-4: Dried Fish

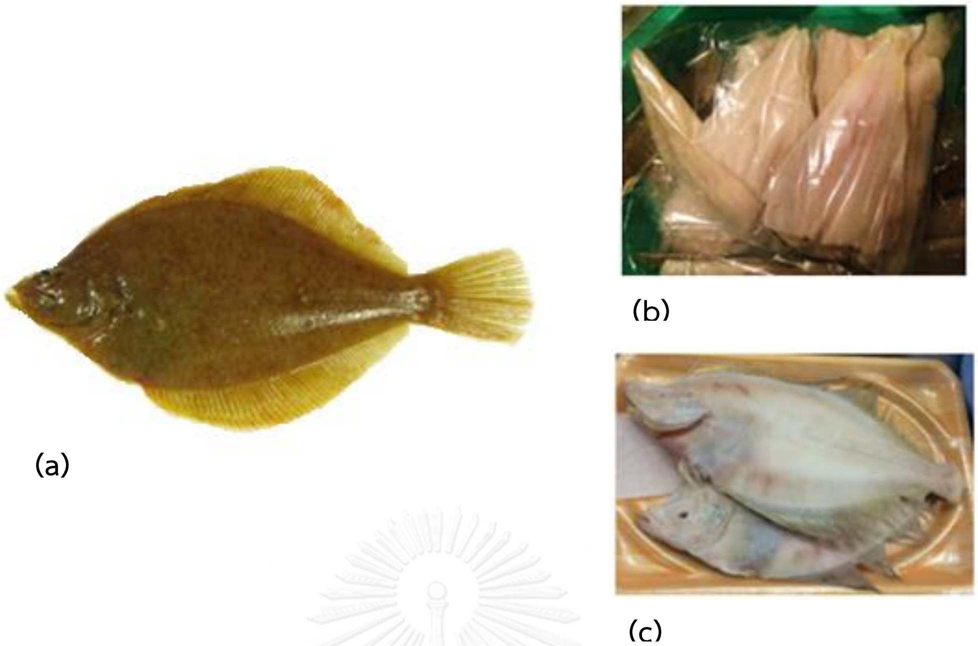


Figure 1-5: Frozen Fish

(a) Fish Raw Material (b) Frozen Fish Fillet (c) Frozen Fish

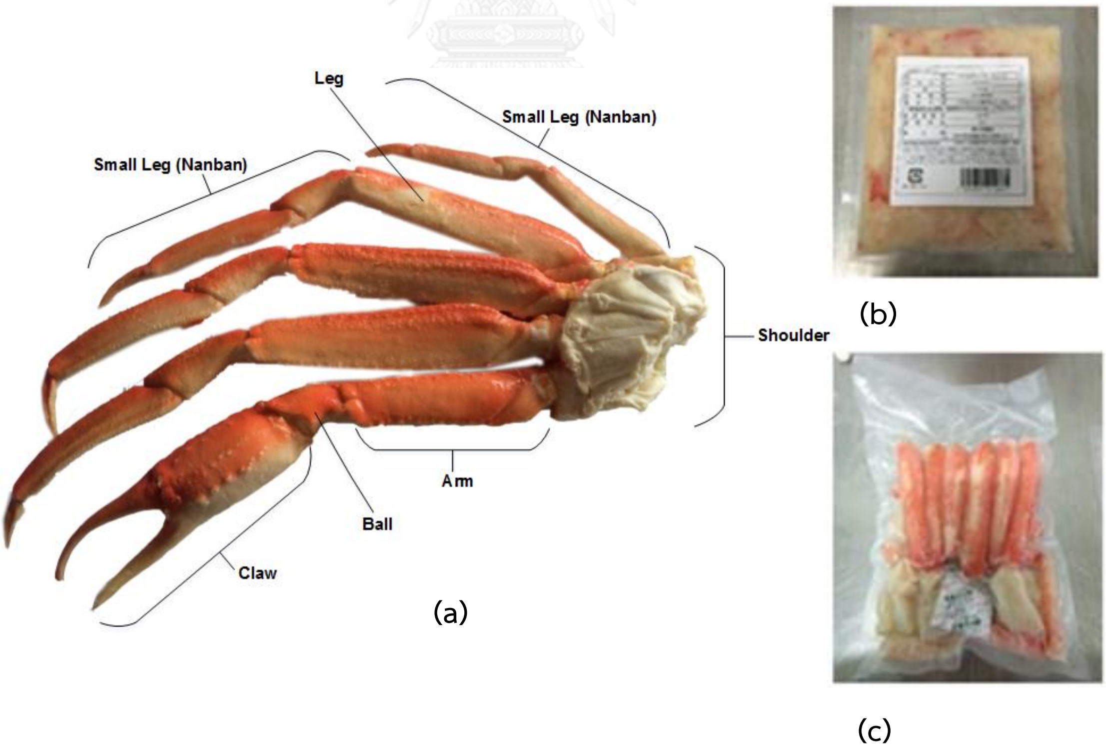


Figure 1-6: Frozen Snow Crab

(a) Cooked Snow Crab Raw Material (b) Combination (200g) (c) Mix Meat (500g)

1.2.2. Production Volume

Figure 1-7 shows the total production volume of the major products in a year since April 2013 to March 2014. It was fluctuate throughout the year depends on customers' orders. The products were produced about 750,000 kilograms in total. The majority of production were dried fish product which is approximately 450,000 kilograms or 61% of total production. The production of frozen snow crab is the secondary volume of the factory which is 176,506.82 kilograms or 25 % of total production. The least production volume of this period is frozen fish products, 122,841 kilograms or 14% of total production. Figures 1-8 and 1-9.

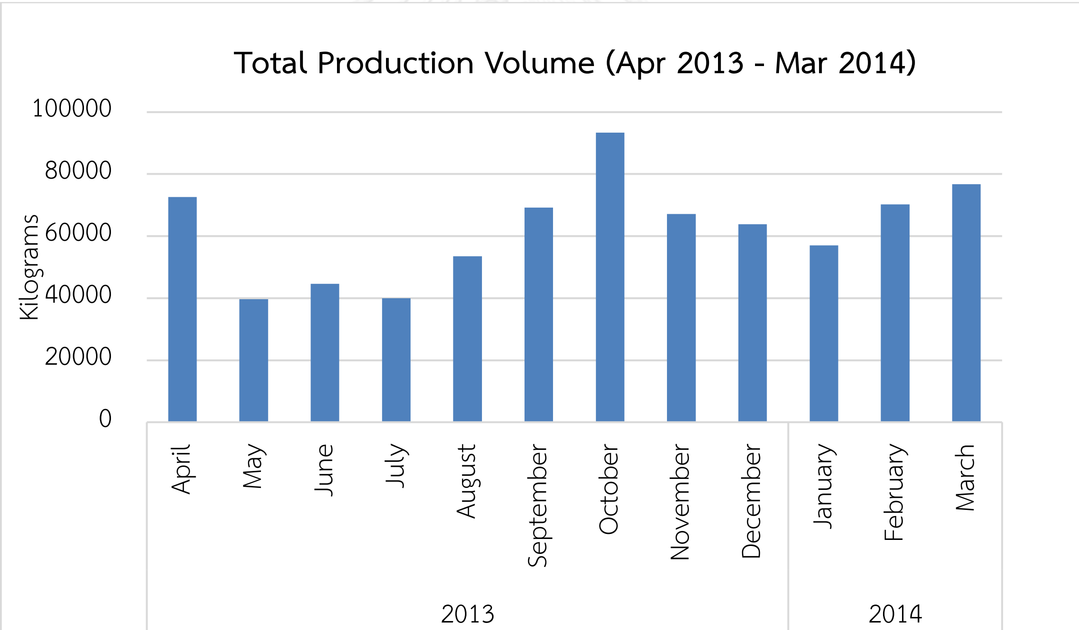


Figure 1-7: Total Production Volume (Apr 2013 – Mar 2014)

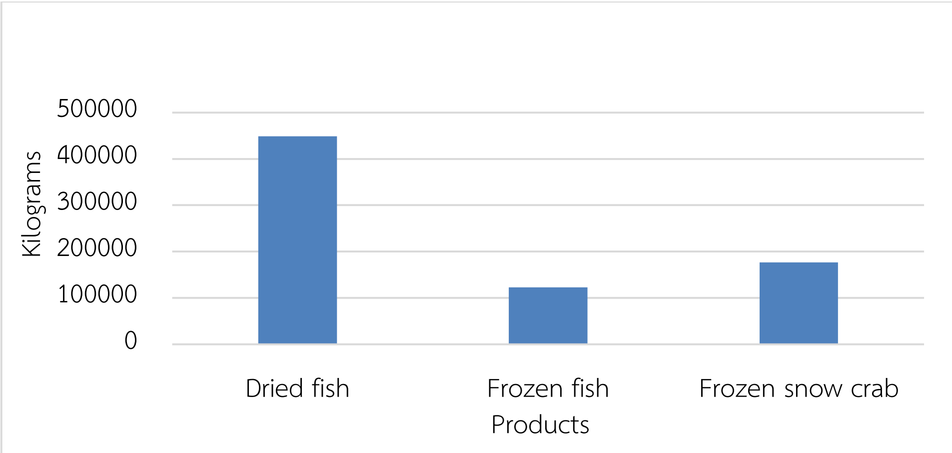


Figure 1-8: Production Volume by Products (Apr 2013 - Mar 2014)

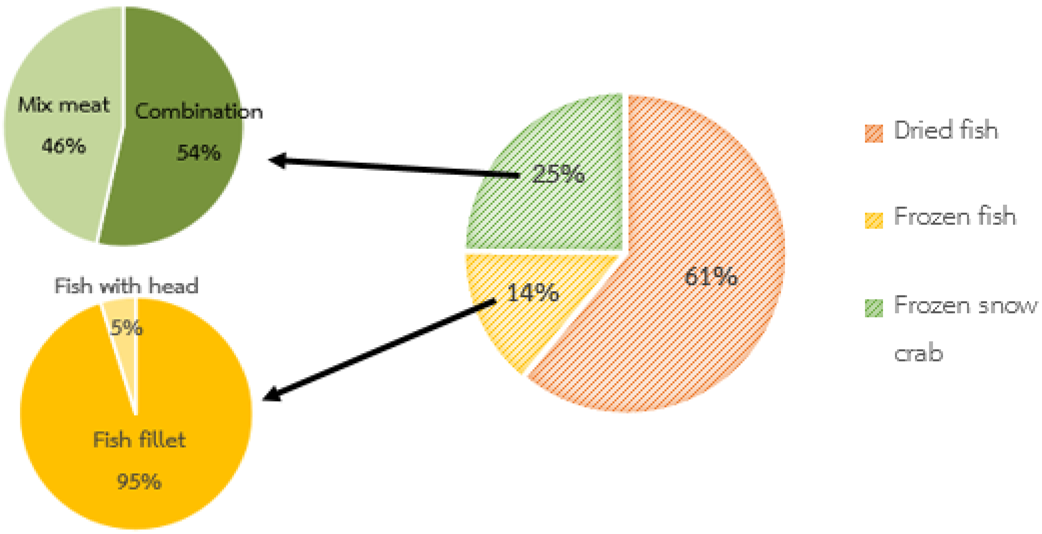


Figure 1-9: Production Proportion

1.2.3. Overall process

The following steps are the overall process of the case study factory. The process flow is shown in Figure 1-10.

1. Raw materials (R/M) are sent from supplier to keep in the cold storage. However, store staffs has to check R/M quality and quantity before receiving. If the quality is unacceptable, they will be sent back to supplier.
2. Factory receives the customer orders for each R/M container
3. The production plan will appropriately be prepared
4. Before the production day, the R/M withdrawal form will be sent to store so that R/M will be prepared properly. The fist in first out (FIFO) principle is used in the store.
5. In the morning of production day, operators withdraw the requested raw material from store and transport to production line
    a. For dried product, raw materials are sent to the 3rd floor
    b. For frozen product, raw materials are sent to the 1rd floor
6. Production process
7. Quality checking. If finished products are unqualified, QC will consider whether they can be reworked or rejected.
8. Packing process
9. Keep the finished goods in cold storage
10. Ship to customer

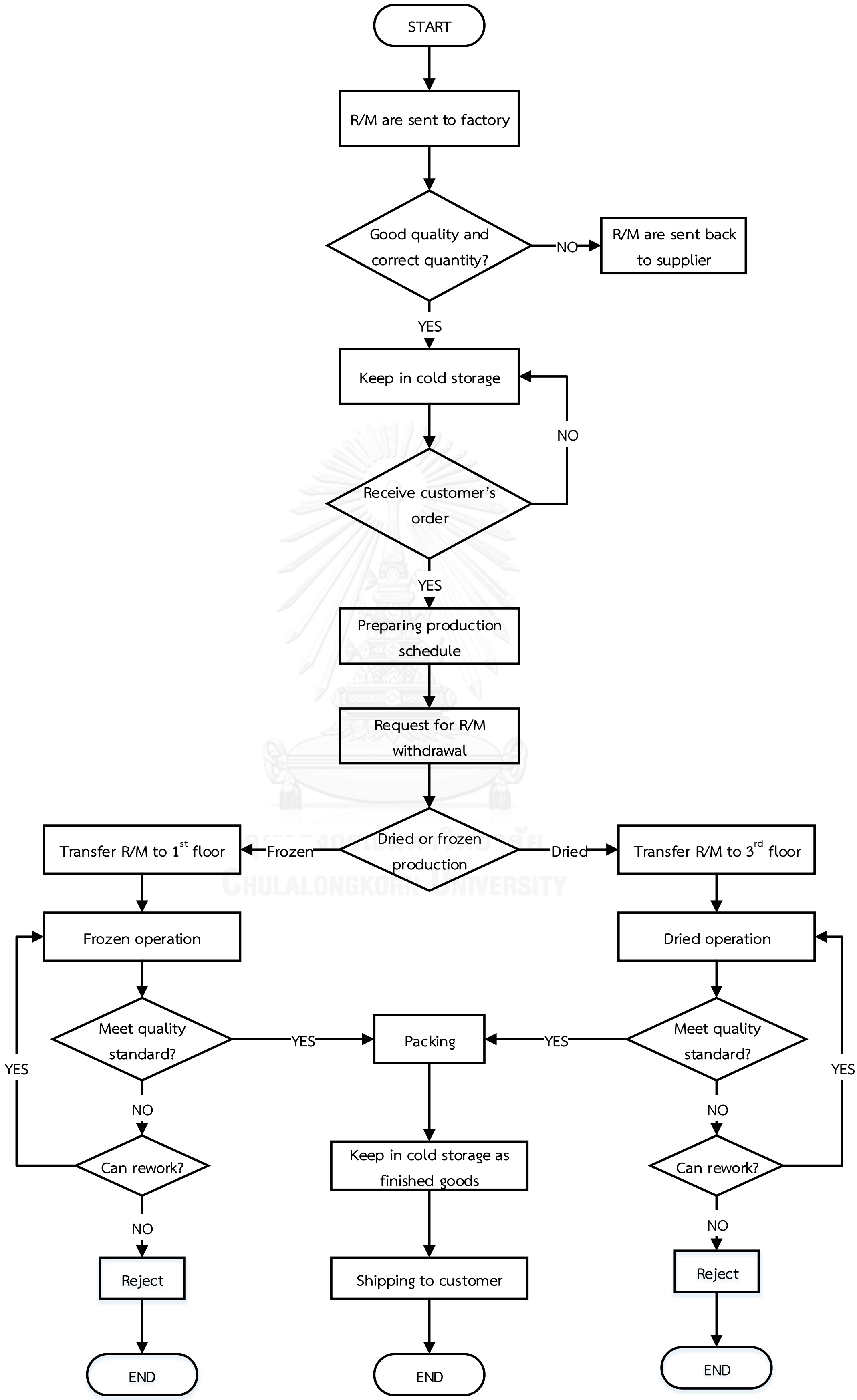


Figure 1-10: Overall Process of the Case Study Factory

1.3. Statement of Problem

Transparency Market Research (2013) reported that the value of global frozen food market will be reached approximately $290 billion by 2019 which is around 30% increase from 2012. The main factor contributed the market growth is the increasing consumer demand and preference of frozen food. Therefore, the frozen food manufacture could gain more income from this opportunity but the case study factory finds the difficulty of receiving new order from new customer dues to the limitation of productivity. It has no ability to produce the minimum orders that customer requested so the maximum capacity of the factory should be the first priority aspect which is needed to be analyzed. If current productivity is lower than maximum capacity, the factory productivity could be improved.

The frozen production of case study factory involves two main products which are frozen fish and frozen snow crab which produced at the different production line. Moreover, in each production line, each product is produced separately for instance, there is no production of Mix meat product at the day of Combination (200g) product production. Thus, it can be assumed that the maximum capacity of the factory is measured from the most time-consuming process or bottleneck process. It is noted that cycle time of fish and snow crab operation was calculated from the bottleneck process. For the freezing process (IQF) of both product families, the cycle time were average because the product was not continuous loading to the machine.

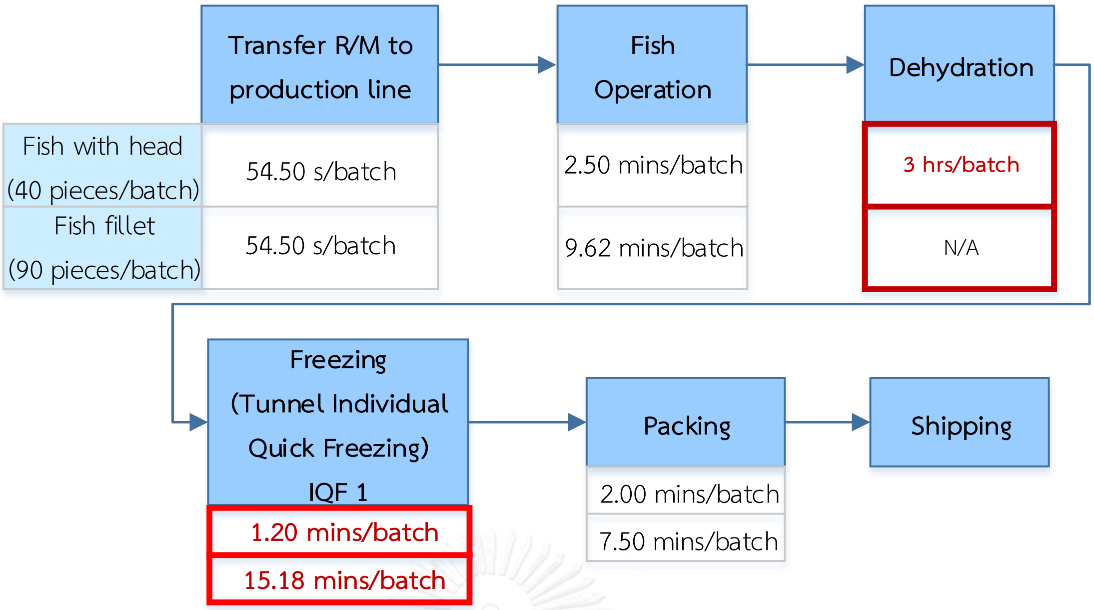


Figure 1-11: Overall Process of Frozen Fish Production

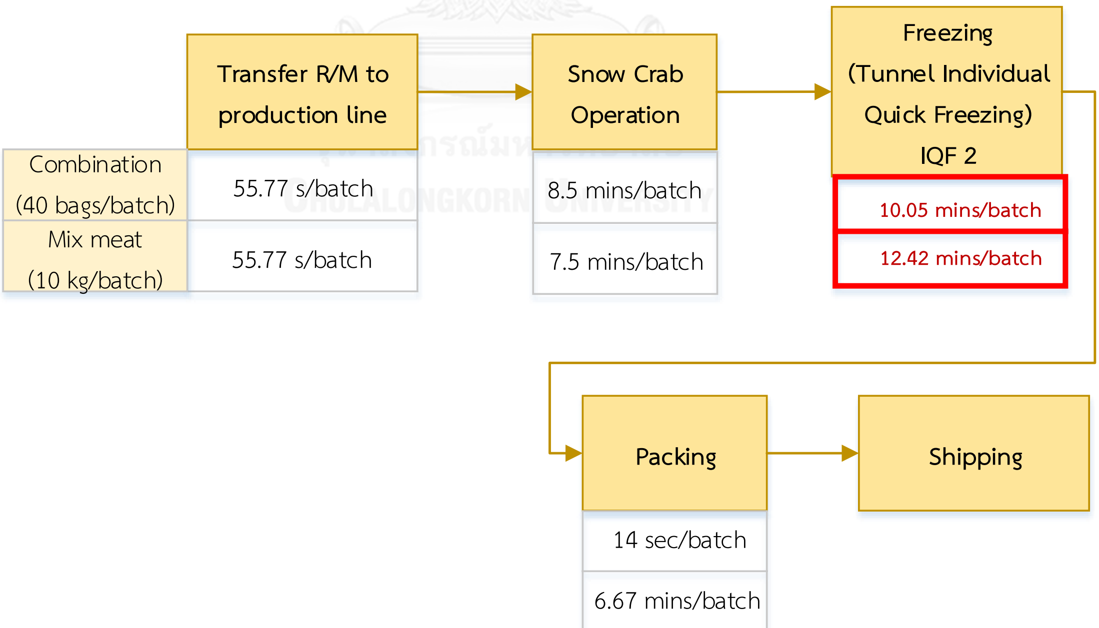


Figure 1-12: Overall Process of Frozen Snow Crab Production

As a result, IQF machine in Figure 1-13 consumes the highest amount of production time of frozen snow crab products and frozen fish fillet. For frozen fish with head, the majority of production time spends on dehydration process. Figures 1-11 and 1-12. Thus, the maximum capacity of factory could be measured at IQF and dehydration process. To calculate the maximum capacity, it could be assumed that these machines are able to produce finish goods since they are started and the products are continuously loading to the machine.

Figure 1-13: Tunnel Individual Quick Freezing (IQF) Machine

<u>IQF machines</u>

The machines are started at 8 am to 5 pm so loading time is 9 hours or 540 minutes

- *IQF 1 for fish products*

  Machine speed is 0.644 meters/minute

  Tunnel long 15.4 meters

  So the production of the first batch takes 23.91 minutes

Maximum capacity = (Loading time - Production of the first batch) / Cycle time

- Fish fillet (90 pieces/batch)

  Cycle time is 148 seconds

  So the maximum capacity of frozen fish fillet production is

  = (540 – 23.91) * 60 / 148

  = 209 batches/day

- IQF 2 for snow crab products

  Machine speed is 1.073 meters/minute

  Tunnel long 16.4 meters

  So the production of the first batch takes 15.28 minutes

  Note: The raw material of frozen snow crab product is needed to be separated parts at the beginning of operation and these parts have to be frozen by IQF machine before peeling the shell off. Since the capacity of the machine is shared, the maximum capacity of this product family should be half.

- Combination (200g) 40 bags/batch

  Cycle time is 41 seconds

  So the maximum capacity of Combination production is

  = (540 – 15.28) * 60 / 41

  = 768 batches/day

  = 768/2

  = 384 batches/day

- Mix meat 10 kilograms/batch

  Cycle time is 74 seconds

  So the maximum capacity of Mix meat production is

  = (540 – 15.28) * 60 / 74

  = 425 batches/day

  = 425/2

  = 212.5 batches/day

<u>**Dehydration**</u> (Figure 1-14)

The machine is started at 6 am to 6 pm so loading time is 12 hours

A cart contains 168 pieces of fish with head

14 carts are loaded per round so 2,352 pieces are loaded per round

The dehydration process takes 3 hours per round

So the maximum capacity of frozen fish with head production is

= 2,352 * (12 / 3)

= **9,408 pieces/day (235 batches/day)**

Figure 1-14: Cold Dehydrator

After calculation the maximum capacity of each product, the current productivity had been analyzed in order to compare for overviewing the current performance of the factory. As a consequence, the current productivity of frozen products were much lower than the maximum capacity besides, this factory could be improved the productivity to support the increased demands of frozen food.

As can be seen from Figure 1-15 and Table 1-1, the current productivity at IQF machine was under 50% because in the actual production, the finished products had not been loaded continuously since the machine was started. Moreover, the more complexity of production process, the less productivity. For instance, the productivity of frozen snow crab products was lower than the productivity of frozen fish products because each portion of snow carb was needed to be separated and peeled in order to be the finished products. Moreover, the Combination product which involves the most complexity of production process had the least productivity of 15.74% so the research is mainly focused on the production of this product.

Table 1-1: Productivity (Unit: batch)

Product	Maximum Capacity	Avg. Current Productivity	Productivity
Combination	384	60	15.74%
Mix meat	212.5	68	31.91%
Fish with head (Dehydration)	235	204	86.73%
Fish fillet	209	53	25.52%

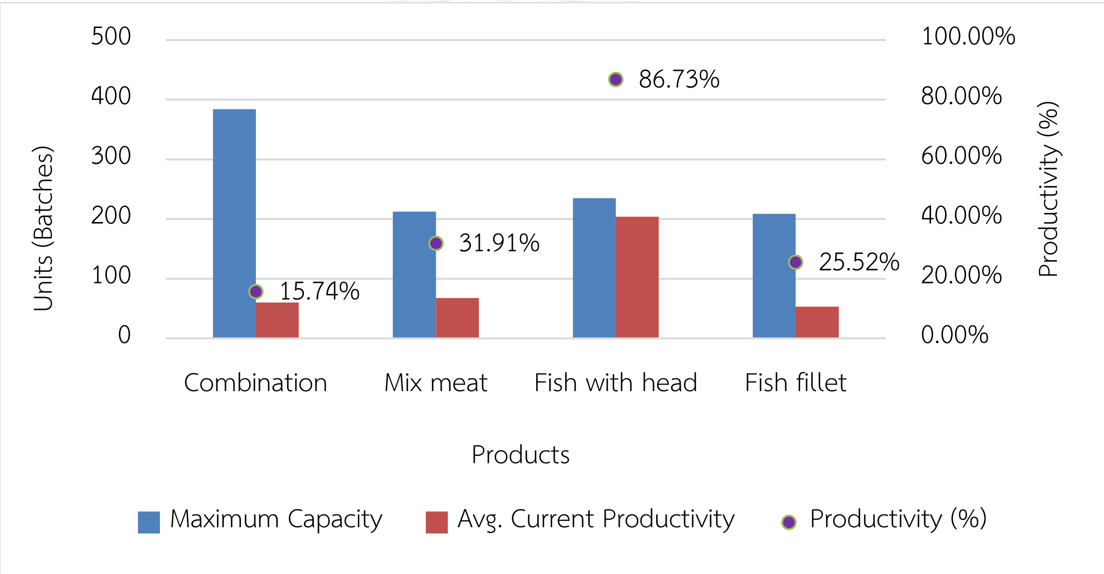


Figure 1-15: Productivity of Each Product

However, the problem of low productivity may cause from the machine and/or the efficiency of previous processes so the overall equipment effectiveness (OEE) needed to be considered to find the real root causes of the problem.

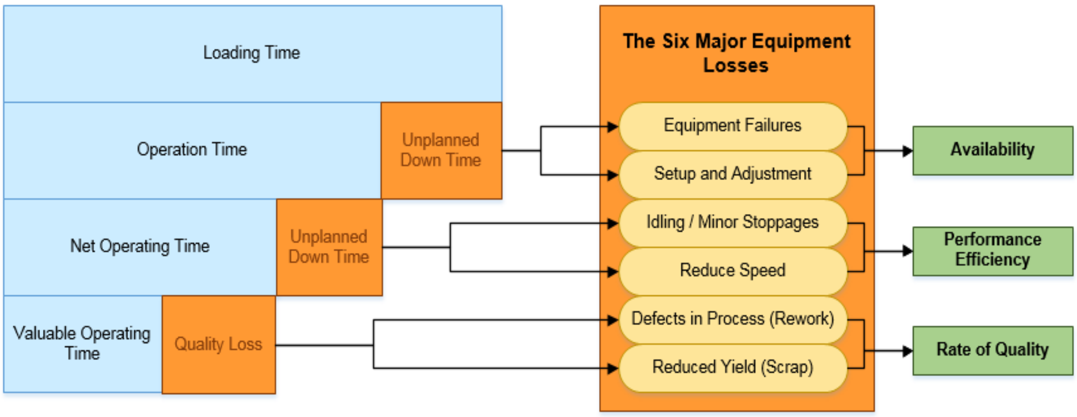


Figure 1-16: Overall Equipment Effectiveness (OEE)

Adapted from Godfrey (2002) and Pomorski (1997)

Table 1-2: Overall Equipment Effectiveness (OEE) Calculation

No.	Collected Data	Calculation	IQF2
1	Loading Time	1	540
2	Set-up Time	2	60
3	Operating Time	3 = 1 - 2	480
4	**Availability (A)**	4 = (3/1) x 100%	**88.89%**
5	Idle Time	5	90
6	Net Operating Time	6 = 3 - 5	390
7	**Performance (P)**	7 = (6/3) x 100%	**81.25%**
8	Actual Output	8	2417
9	Rework	9	45
10	Wasted Time	10 = (9 x 6)/8	7.63
11	Valuable Time	11 = 6 - 10	382.74
12	**Quality (Q)**	11 = (10/8) x 100%	**98.14%**
13	**OEE (A x P x Q)**	13 = 4 x 7 x 12	**70.88%**

OEE calculation in Table 1-2 shows that the IQF2 machine had OEE value of approximately 71%. The Availability (A) and Performance (P) indicators had the low value of about 89% and 81% respectively. However, from the six major losses in Figure 1-16, the high set-up time leaded to the low value of A indicator so it could be improved by starting the machine one hour before working time which is around 7 am. For the P indicator, the main problem seemed to be high idle time because of the product shortage. Although, the products were loaded into the machine, every single product loading was not full of loading area. In fact, approximately 28 bags were loaded at the input belt instead of 70 bags which is the fully loading capacity of the machine. Therefore, the research aims to improve productivity of the processes before entering IQF machine using Lean principle and practice.

1.4. Objective of Thesis

The objective of this research is to increase productivity of frozen cooked snow crab production by using Lean concept to analyze and improve the current processes.

1.5. Scope of Study

This research focuses on the productivity improvement of Combination (200g) product which consists of minced shoulder and small leg meat. (Figure 6b)

1.6. Proposed Methodology

1. Literature review of Lean concept including involved tools and techniques for analysis and implementation.
2. Gathering necessary and specific information of current processes such as cycle time, waiting time, inventory, etc.
3. Root cause analysis of current processes by using appropriate academic tools
4. Develop the feasible solutions and action plan for productivity improvement
5. Implement the solutions into the processes

6. Measure the new productivity to see the effectiveness of implemented solutions
7. Summary and Suggestions
8. Thesis Completion

1.7. Expected Benefits

1. To reduce non-value adding activities from production line
2. To increase productivity of Combination (200g) product
3. To decrease production lead time of Combination (200g) product
4. To be a guideline of other productions productivity improvement

CHAPTER 2: LITERATURE REVIEW

Literature review is important to the research because it brought the wide and vairety knowledge from various sources such as textbook, journal, and case study. Moreover, many tools and techniques are studied and adapted in order to create the most appropriate framework for the research. Lean principle is studies in this research in order to help the frozen food manufacturing solve the problem of low productivity by using suitable Lean tools and techniques. Furthermore, some methodologies are adapted to be an guildline for the problems analysis and effective solutions implementation.

According to MarketLine (2014), the growth of global frozen food market in the past few years was gradual, however, it forecasted that this market will grow significantly during 2013-2018. The figure 2-1 shows that in 2013, the percentage frozen ready meals value was the highest, 23.9% while the value of frozen fish/seafood was the second, 16.9%.

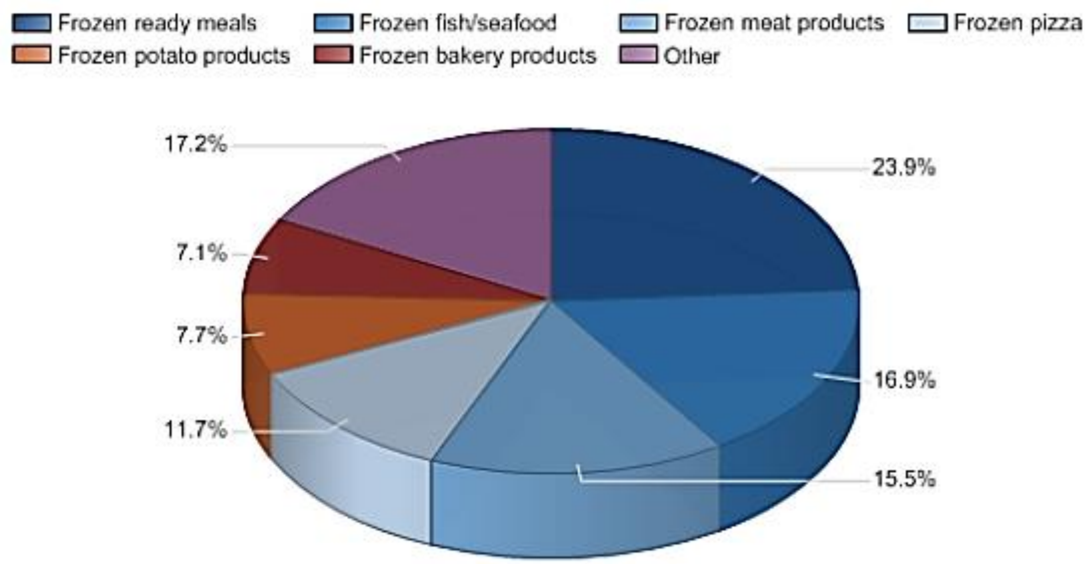


Figure 2-1: Global frozen food market category segmentation: % share, by value, 2013 (MarketLine, 2014)

In the intense competitive environment, the regularly SMEs would find the difficulty of adaptation because of low innovative capability. Matt and Rauch (2013) suggested that the implementation of lean methods could help the organization to improve the business operations and complete the competitors.

According to Goriwondo and Maunga (2012), lean manufacturing and six sigma priciples could help the improvement of competitiveness and performance of the organization. The Value Stream Mapping tool (VSM) and the Sig Sigma’s Define, Measure, Analyze, Improve and Control (DMAIC) were suggested to be used to map processes and achieve the improvement respectively. Moreover, they indicated the 3 steps of analysis method and tools. Firstly, Current State Map (CSM) will be used to separated value-adding (VA), non-value adding (NVA), and necessary but non-value adding (NNVA) activities by doing time record of each process and type of value. Next, the NVA activities will be analyzed by using perato analysis. This tool will identify the critical process which significant impact the production and productivity. After the critical problem is defined, the real root cause sould be investigated by using Cause-and-Effect diagram.

Hemanand et al. (2012) mentioned that the use of lean manufacturing approach could help to identify and eliminate wastes from the production and transfer the customer’s values through the product. The final goal of this research is to speed up production process by utilizing man and machine however, productivity need to be increased as well. The productivity of manufacturing is defined by layout and material flow in shop floor. They demonstrated the methodology of productivity improvement into 3 main steps. Firstly, all necessary information and data need to be collected including current layout, time study, takt time, and cycle time. Then, the problems could be identified. This case study was redesigned the current layout by reducing material handling and simulation the performance current layout by using WITNESS software. Finally, the analyzed results will be implement by proposing the new layout.

Hines and Rich (1997) argued that the value-adding processes of both intercompany and intracompany need to be identified in order to transfer the valuable product or service to the end customer. Hence, they proposed the seven value stream mapping tools which combined the traditional value stream mapping and seven wastes from lean principle together to identify wastes and find the suitable solution for wastes reduction. Figure 2-2. The waste and quality problems will be exposed from production process analysis. It is necessary to categorize the types of operation activity by doing value analysis. Moreover, the seven wastes from lean principle have to be analyzed to know the significant wastes that affect the production.

	Mapping tool						
Wastes/structure	Process activity mapping	Supply chain response matrix	Production variety funnel	Quality filter mapping	Demand amplification mapping	Decision point analysis	Physical structure (a) volume (b) value
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H

Notes: H =High correlation and usefulness
M = Medium correlation and usefulness
L = Low correlation and usefulness

Figure 2-2: The Seven Stream Mapping Tools (Hines & Rich, 1997)

History of Lean

According to Eaton (2013), the first time of using the word of Lean was in 1988 in 'Triumph of the Lean Production System' article but it is not notable. The book called 'The Machine that Change the World' and 'Lean Thinking' made the wide usage of Lean. The starting point of Lean was in 16th century when the continuous flow process and standardized term were developed by the Venetian Arsenal. As a result, the whole ship was produced in less than an hour. After that, during the Napoleonic Wars, the enable of changeover and standardized process techniques lead to the fast deliver broadside to against the competitors. In the 19th century, the Pareto rule was established. It was found that 20% of people owns 80% of Italy land. Henry Ford and others company used the continuous flow for their factory as a basic of Lean. In the meantime, the concept of takt time was created by the German aircraft. The production of fuselage was control by this concept which means the production of each process had to be lower than takt time. In the mid-1940s, Taiichi Ohno brought these concepts together in order to adapt with the production of Toyota, called Toyota Production System (TPS) which was developed to be Lean later.

What is Lean?

Lean is the concept of organization improvement bases on customers' requirement. Everything that does not add value to the customer is determined as waste so the target of Lean is the waste elimination in order to deliver the values to the customers (Eaton, 2013). He stated that the root of Lean concept is TPS which is focusing on waste elimination. Moreover, the ability to deliver the required output is also focused in TPS concept because if the wastes are eliminated and right values are delivered, it could guarantee that the resources are utilized and production is smooth and flexible. The roof of TPS house in Figure 2.3 shows that both internal and external values, which are quality, cost, delivery, safety, and morale, are provided to the customers. Just-In-Time and Jidoka concept support the value in the roof. The concept of Just-In-Time is to produce the required quantity of product when it is needed while

Jidoka concept focuses on the production and product quality. Another four steps create the strong house.

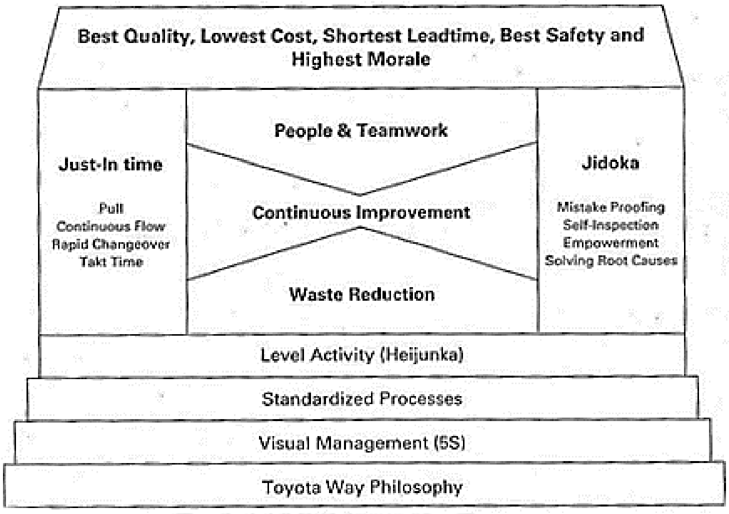


Figure 2-3: The Toyota Production System (TPS) House (Eaton, 2013)

The essential principle of Toyota Way are revealed by Liker and Meier (2006). It can be divided into four main groups with fourteen principles.

- *Philosophy* – It is the foundation.
    1. The short-term decision should support the long-term strategy.
- *Process* – The creation of right results by right process.
    2. Try to create the continuous flow because people and processes will be linked together and the problems will be appeared.
    3. Pull system with Kanban system help the organization avoid the overproduction and has ability to deliver the right product and quantity when the customer want.
    4. Heijinka or making the stable workload.
    5. Try to create the quality production because the problems could be avoided. However, when the problem occurs, it is necessary to fix it immediately although the productivity will be affected. This could enhance the performance of production line in the long-term.

6. Standardized tasks and processes based on the best practices establish the continuous improvement and employee empowerment.
7. The visual control is used to reveal all problems.
8. The suitable technology could help the people and process work efficiency.

- *People and Partners* – The development of people and partners could add value to the organization.

9. The leaders should understand the working process clearly in order to transfer and teach others in the organization.
10. It is necessary to establish the team to work along with the principles in order to track the results to achieve the organization’s goals.
11. Help the partners and suppliers improve their process to enhance the efficient and effective system throughout the supply chain.

- *Problem Solving* – The root causes of problem have to be solved continuously to make the learning of the organization.

12. Try to understand the situation clearly or put yourself in other’s shoes.
13. The decisions should be made from considering various circumstances and options.
14. Make the continuous improvement by learning from the past.

Since the wastes or non-value added activities elimination is the concept of Lean. Toyota categorized the wastes in to seven different types as table 2-1. However, they could be adapted for both manufacturing and non-manufacturing field.

Table 2-1: Seven Wastes of Lean Principle (Eaton, 2013)

Waste	Manufacturing	Non-Manufacturing
Overproduction	Waiting for parts to arrive at a process.	Waiting for information, people, materials or anything else to arrive.
Waiting	Processing more parts than can be sold or have already been requested by customers.	Doing more work than is absolutely required. In the non-manufacturing contexts it is often better to refer to this waste as 'overprocessing' rather than overproduction.
Transportation	The movement of materials and equipment.	The movement of information, materials and equipment.
Overprocessing	Under taking any work that is not explicitly required by a customer.	Under taking any activity that is explicitly not required.
Excess inventory	The costs of holding, managing, storing, and (often) disposing of stock.	Any unnecessary queuing of activity. For example, a stack of people brought in for an appointment, a stack of letters waiting to be typed, excess stock stored in operational areas, etc.
Unnecessary movement	The movement of human beings.	The movement of human beings.
Defects	Having to undertake a task more than once because it was done incorrectly the first time.	Having to undertake remedial work of any kind because not everything was done correctly the first time.

Eaton (2013) developed five principle of Lean from the combination of fourteen principle of TPS and the seven wastes. Figure 2-4. At the beginning, it is necessary to define the customer's values because Lean is to eliminate wastes or non-value added activity so this principle help the organization understand what should to be eliminated. When the value is determined, it need to be delivered into the process by using value stream. Establishing the flow without bottlenecks, delays, waiting and rework is the next step. Moreover, the pull system should be adopted. The production will be started when there is the demand from customer. The final principle is the perfection which means the process need to be improved continuously.

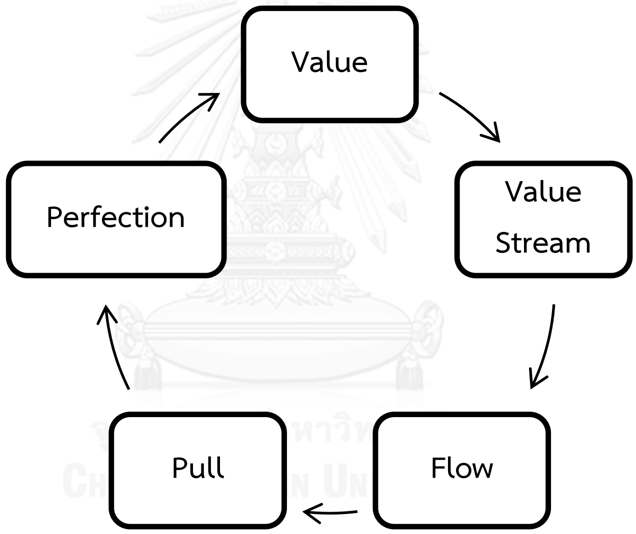


Figure 2-4: The Five Principle of Lean (Eaton, 2013)

Value Analysis

John et al. (2008) implied the more process optimization, the more proportion of value-adding activies. Thus, each single process that involved in providing product and service have to categorize the type of value. There are three main type of value in the production process as follows. (Hines & Rich 1997)

- Non-value adding (NVA) – The activity in this type should be immediately eliminated or reduced because it is unnecessary actions which are considered as a pure waste.
- Necessary but non-value adding (NNVA) – If the company would like to change the activities in this type, it involved major change because it could be operation procedure such as the layout.
- Value-adding (VA) – As the company has to produce value-adding product or service to the customer, the activity in this type is necessary for the product or service providing.

Value Stream mapping

Value stream mapping (VSM) is one of the lean tools that used to visualize material and information flow through the production process. Rother and Shook (1999) mentioned that material flow is focused in the regular production but the lean manufacturing focuses both material and information flow equally because the information flow helps operators know what part/product should they make including quantity and next tasks/processes. Moreover, the purposes of VSM development are to establish flow, eliminate waste, and adding value. Singh and Sharma (2009) emphasized that the more wastes production has, the more resources are consumed without adding value for the customer. The wastes are not only found in the production but also could be found in every activities including policies and procedures. The whole processes are drawn in a piece of paper in order to picture the production flow in each step. It contains all necessary data such as cycle time, work in process (WIP), quality, and performance of equipment. The reduction of lead time, inventory, quality improving and on-time deliveries, and resource utilization are the outcome of using VSM. (Goriwondo et al., 2011). They pointed out that there are five essential steps of VSM to improve the production line becomes lean as follows.

1. Defining the Value – The customer's values have to be identified in this step.
2. Identifying the Value Stream – All value added and non-value added actions are identified in this step. Moreover, it shows the step-by-step operation with the details of each process. It can be divided into two sub steps as follows.
    - Current state map (CSM) – shows the current information and material flow throughout the manufacturing process. It help the manufacturer see and understand the need of change. Figure 2-5 examines the current state map.
    - Future state map (FSM) – the purpose of FSM chart is to be the lean flow suggestion in order to close the gap between CSM and ideal flow. Figure 2-6 examines the future state map.
3. Flow the Product – The goal of VSM is the flow so the non-valued activities have to be eliminated or minimized while value activities have to be maximized.
4. Pull – The product need to be pulled by customer's demands because it is the concept of produce the right product to serve to the customer as quick as possible.
5. Strive for Perfection – The first four steps have to be reviewed because the production will have ability to produce the product that customer want with the appropriate cost. Moreover, the internal economy could be saved because of the reduction of mistake, scrap, and production cost.

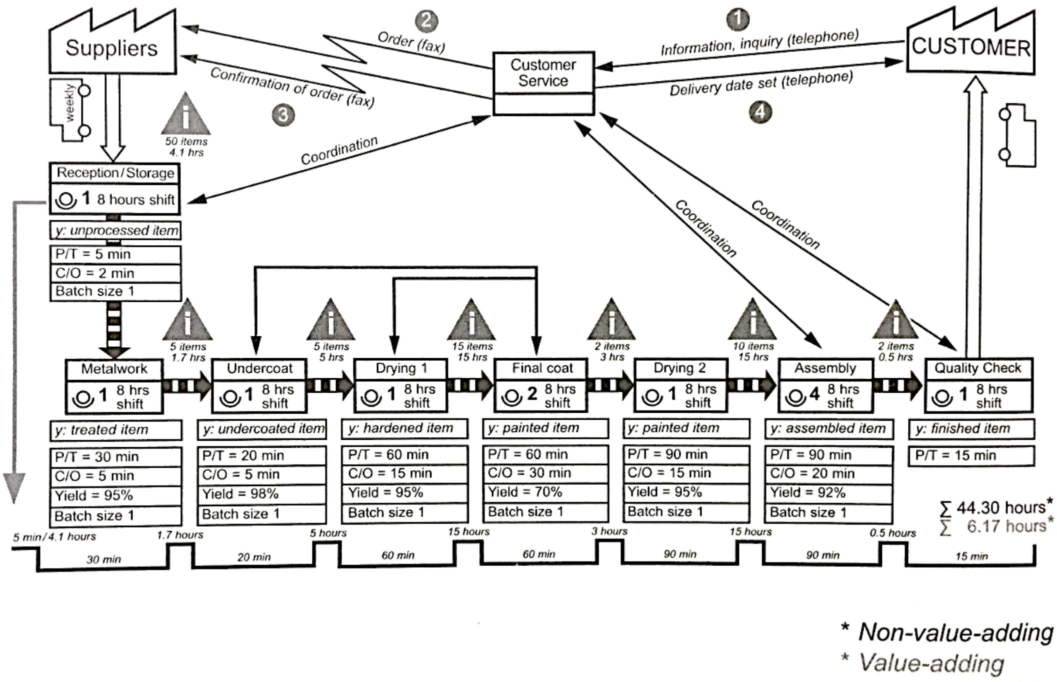


Figure 2-5: Example of Current State Map (John et al., 2008)

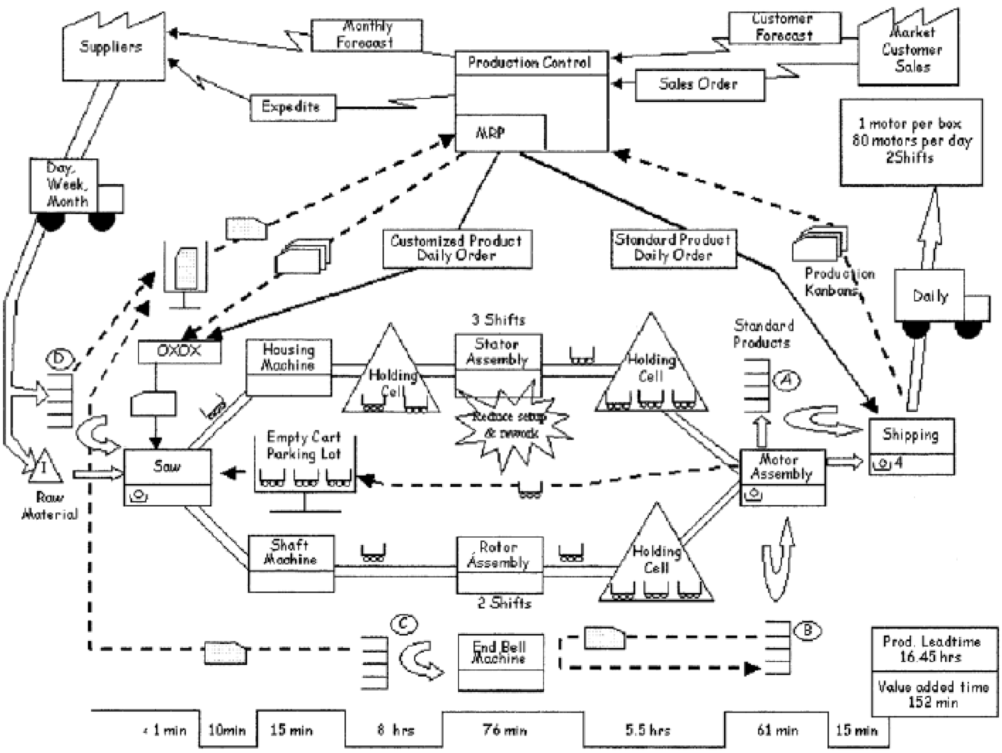


Figure 2-6: Example of Future State Map (McDonald et al., 2002)

Liker and Meier (2006) recommended the tips of creating value stream mapping. Firstly, the current state map is the foundation of future state map. Although the wastes and non-value added activities are revealed, they argued that these problems must not be fixed because Lean aims to create the future state map so the effective improvement will be done in the future. The concept of achievement will be presented future state map however, it is just a concept. The actual implementation is vary. Moreover, the expertise of lean should be assigned to develop future state map in order to make the efficiency of concept. In addition, the improvement plan has to be implemented in the actual production line to make sure the suitability. They noted that the action of improvement should be implemented in each product family more than the whole organization. Furthermore, the management person should be a leader because of the power and passionate of improvement. Finally, to make the effective and efficiency of improvement, it is necessary to keep developing another future state map in order to reach the perfection.

Brunt (2000) developed the effective methodology of value streams mapping. The methodology had been proved by Lean Processing Programme (LEAP) which was succeeded in the competitive advantage of UK automotive industry. It aims to help people who would like to improve the production line to be lean understand value stream clearly in order to remove wastes and add value to the product effectively. He proposed that the product family selection has to be chosen at the beginning. Then, drawing the current state map and developing the future state map will be done. Finally, the improvement plan which contains the necessary activities has to establish in order to move the current production line to the designed future production line. The VSM symbols are showed in Figure 2-7.

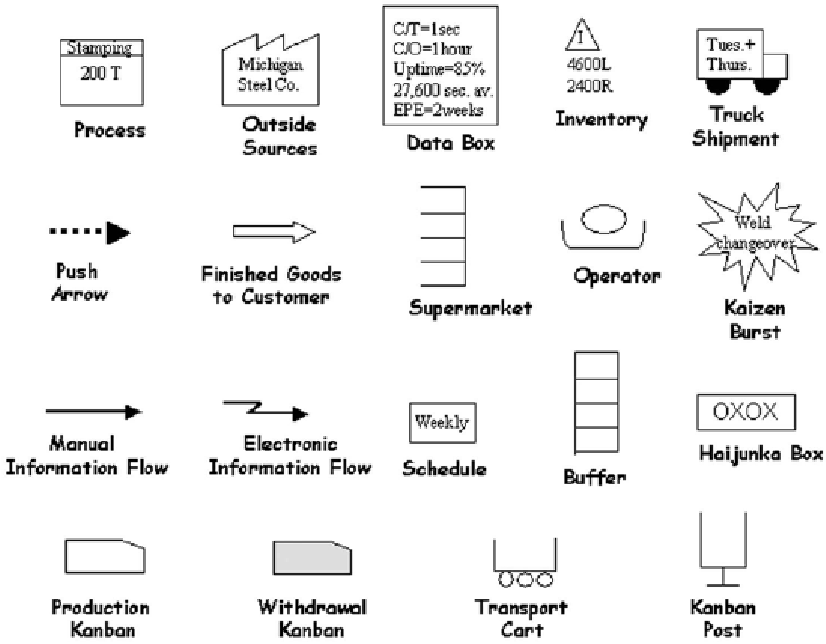


Figure 2-7: Value Stream Mapping Symbols (Rother and Shook, 1999)

For developing future state map, Brunt (2000) and McDonald et al. (2002) used the set of questions which can be divided into four aspects; demand, material flow, information flow, and supporting improvement. Table 2-2.

Takt time is the essential step of developing future state map. The calculation bases on the customer's requirement so available work time per shift will be divided by customer demand rate per shift. This number is the pace of production for instance, the production line is operated 8 hours per shift and customer requests 80 motors a day so takt time is 12 minute/motor. This means each motor should be produced 12 minutes in order to have ability to serve the demand.

Table 2-2: Questions Guideline for Developing Future State Map (Brunt, 2000)

Areas	Questions
Demand	a. What is the TAKT time?
	b. Should the company build to a "finished goods supermarket" or directly to shipping?
Material flow	c. Where can the company use continuous flow processing?
	d. Where do we need to use supermarket-based pull systems?
Information flow	e. At what single point in the production chain will the company schedule production?
	f. How will the company level the production mix at the pacemaker process?
	g. What increment of work will the company consistently release and take away at the pacemaker process?
Supporting improvements	h. What supporting process improvements are necessary (key improvement initiatives and critical success factors for implementation of the "future state" map)?

<u>Overall Equipment Effectiveness (OEE)</u>

Since the productivity losses may causes from the machine in the production line, Overall Equipment Effectiveness (OEE) needs to be calculated in order to know the real problem of productivity losses. Pomorski (1997) described OEE as a method that measures the entire manufacturing environment. He emphasised that the equipment availability together with production efficiency and effectiveness are considered in OEE. It can be applied for the analysis of various aspects such as the effectiveness of machine, manufacturing cells, and assembly lines. Moreover, it can be used to measure key performance indicator (KPI) of production efficiency in Total Productive Maintenance (TPM) and Lean manufacturing programs. The components of OEE are shown as follows.

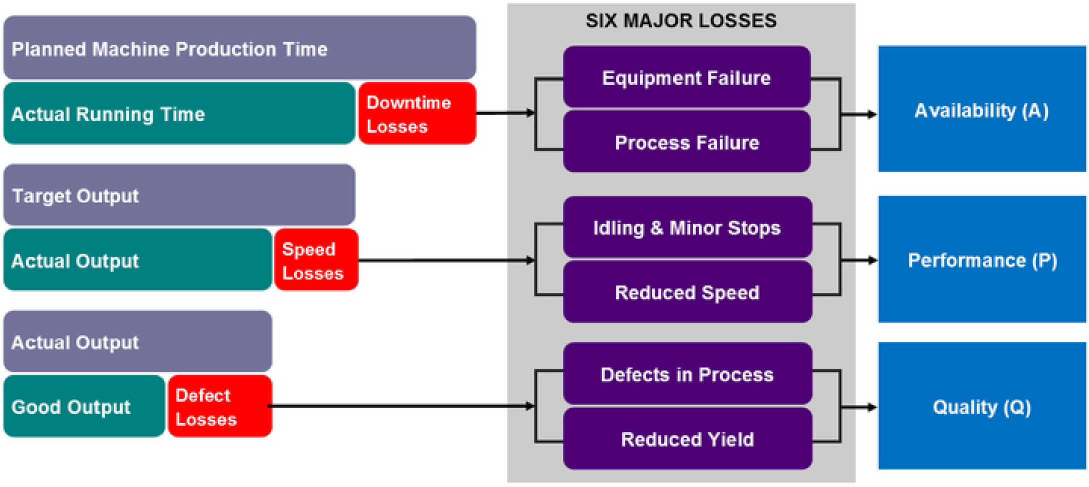
OEE % = Availability (A) % x Performance Rate (P) % x Quality Rate

Availability (A) – effectiveness of maintaining tools in a condition capable of running product measurement

Performance (P) – measure the equipment effectiveness and utilization while running production

Quality (Q) – manufacturing process measurement about the effectiveness of scrap, rework, and yield loss elimination

Dal et al. (2000) stated that both occasional and usual activities could affect the effectiveness of manufacturing process since they do not add value to the product. These activities are grouped in Figure 2-8 called six major losses. As can be seen that each loss contributes the low value of each component so the real problems of productivity loss are revealed by this method.



SIX MAJOR LOSSES	
Equipment Failure	Breakdown losses due to sudden and unexpected equipment failure.
Process Failure	Also called 'Setup and Adjustment losses', occur when production is changing over or adjustments made for correct positioning.
Idling and Minor Stops	Losses occur when production is interrupted by small problems such as parts that block sensors or get caught in chutes.
Reduced Speed	Losses occur when actual operating speed falls below the equipment's designed speed.
Defects in Process	Losses occur when products do not meet quality specifications which need to be reworked.
Reduced Yield	Yield losses occur when equipment start up is not immediately stable, so the first products do not meet specifications.

Figure 2-8: Six Major Equipment Losses
(http://www.rnaautomation.com/blog/measure-effectiveness-production-line/, downloaded 18 September 2014)

Spaghetti Diagram

After non-value adding activities are identified, they need to be minimized from the process. The spaghetti diagram indicates the actual flow of transportation and motion in the current process. It will be done by drawing the line of transportation and motion of product, paper, and people in shop floor layout. However, John et al. (2008) suggested that the different color should be used for each flow to make an ease of analysis. Figure 2-8 illustrates the spaghetti diagram of before and after process improvement.

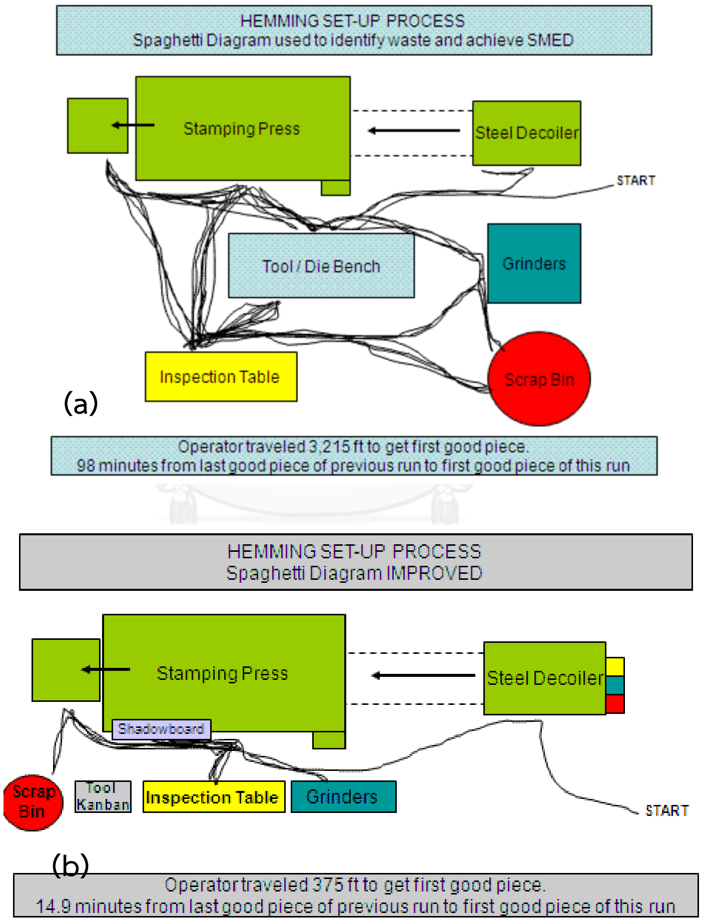


Figure 2-9: Illustration of Spaghetti Diagram

(a) The flow of current process, (b) The flow after process improvement

(http://www.six-sigma-material.com/Spaghetti-Diagram.html, downloaded 18 September 2014)

Cause-and-Effect Diagram (Ishikawa Diagram)

Cause-and-Effect Diagram is a useful tool as it make an ease of understand the relationship between the results (characteristics) and the causes that affect the process. (Ishikawa, 1990) The considered characteristic will be at the right hand site (fish head). The cause will be identified by grouping in categories. Then, the brainstorming is very important in this analysis because the various possible root cause will be identified by breaking each category into sub-category. Figure 10 examined the cause-and-effect diagram by using 6Ms which are Method, Man, Machine, Material, Measure, and Mother Nature. John at al. (2008) suggested that all causes has to be prioritized as follows.

(C) = Constant (the constant, invariable causes)
(N) = Noise (the cause which cannot be influenced directly and occur so to speak as "noise", e.g. lack of time
(X) = Variable (the decision variables which the project can influence)

Figure 2-10: Causes Priority (John et al., 2008)

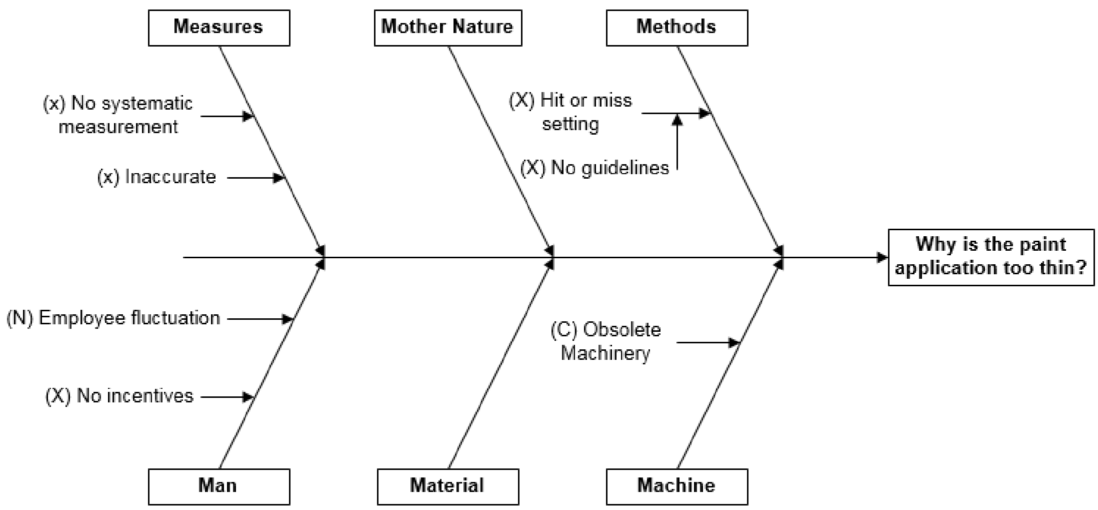


Figure 2-11 Cause-and-Effect Diagram (Example of Car Dealer, Spray-Painting) (John et al., 2008)

Line Balancing

The production is flow in assembly line that is implemented Lean principle since the purpose of Lean is to eliminate wasted and non-value added activities from the production line. Although wastes are reduced, the cycle time and workload of each workstation may be different and inappropriate which is the obstacle of the flow. For instance, there will be the high idle time if the cycle time of connected process is significant difference. Kumar and Suresh (2009) mentioned that line balancing technique balances all workstations in the production in order to increase the flow. Thus, the balanced workload leads to idle time reduction.

The production line consists of many workstations to produce an amount of product and each workstation contains many tasks to finish the process. There are a number of steps for calculation and implementation line balancing as follows.

1. The production sequence of each product is different so it is necessary to specify the relationship of process sequence by using precedence diagram
2. Workstation cycle time or takt time has to be calculated by dividing overall production time with required output. To do line balancing, the cycle time of all workstation has to be lower than this number because it can be guaranteed that the company has ability to produce product to meet customer demand.
3. The minimum number of workstations is calculated by dividing the total task time with takt time. However, in practice, the number of workstations may be higher than this number depends on circumstance such as policy, layout, and number of responsible operators.
4. Select a primary rule by which tasks are to be assigned to workstations, and a secondary rule to break ties.
5. The tasks will be assigned to each workstation. When the total task time at first workstation reaches takt time and no feasible tasks can be assigned, the tasks will be assigned to the next workstations. This step will be repeat until all tasks are assigned.

6. The balance efficiency can be calculated by dividing total tsk time with actual number of workstations multiply by takt time.

Kumar and Suresh (2009) recommended that many options need to be calculated and analyzed in order to compare the balance efficiency to find the suitable line balancing for the production line. However, re-layout need to be considered if it could increase the efficiency and balance of the production line.

5S

Eaton (2013) noted that the implementation of 5S activities can enhance the productivity of the company because workplace is visualized. This reduce the time of unnecessary activities such as finding the working equipment. 5S is the guideline about what employees have to do. It consists of five steps as flows.

Sort (Seiri)	– The unneeded, unwanted, and unused items are removed.
Straighten (Seiton)	– The used items such as machine and equipment are located and arranged in the working area in order to make the convenience and quickness of use. In addition, using guideline could be established as it is advantage for operation.
Sweep (Seiso)	– Working area has to be clean all the time.
Standardize (Seiketsu)	– Make sure that everyone understand and know what is needed to do. For instance the different color is used for the different purposes such as the white line area is the inventory location.
Sustain (Shitsuke)	– This step aims to maintain the standard since all activities have to be audited, review, and improve continuously.

Standardization

According to Liker and Meier (2006), standardized work was established by Toyota since the work should be performed efficiently without or the least wastes. Standardized work contains all necessary information of production line such as working method, number of operators, and locations however, this it has be supported by other types of standard. As can be seen from Figure 2-12, the quality, safety, and environmental standard are essential standard because it defines by social and customer which are outside organization. Moreover, procedures and specification standard, which define by internal requirements bases on Lean principle, support the working methods definition. They pointed out that employees' knowledge and skill have to be developed in order to increase the standard to the highest level.

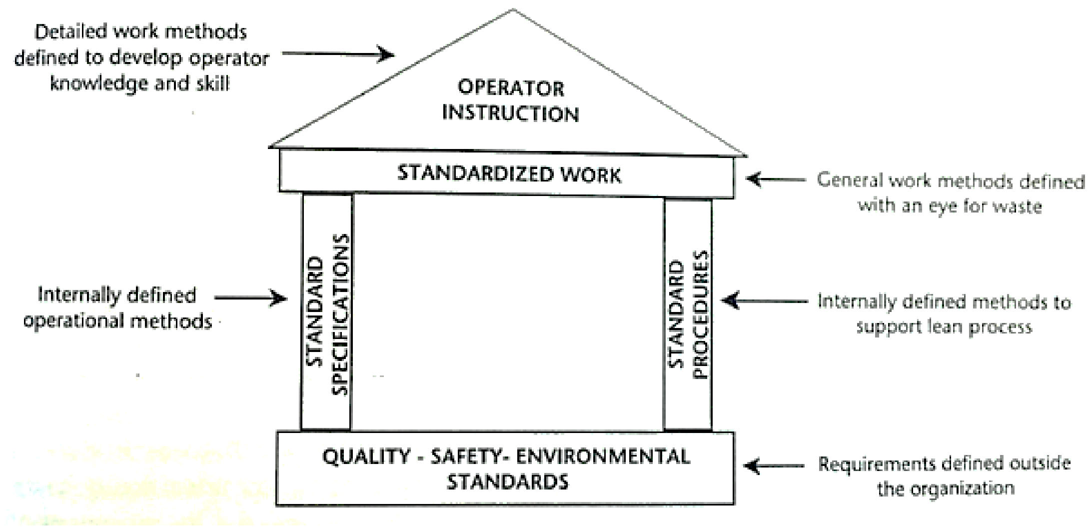


Figure 2-12: Relationship and Purpose of Standards

CHAPTER 3: Research Methodology

Since the company would like to improve productivity, the improvement team was set which consists of managing director, production manager, supervisor, and author as a consultant. As can be seen from table 3-1, the average current productivity, which was 60 batches a day, was much less than the maximum productivity of IQF machine because of high idle time as mentioned. Moreover, the factory faced a problem of low operator efficiency. Operators walk around and pretend that they are working so the work was slower than it should be. It could say that the factory may have ability to improve its productivity. Team had expected 10% of productivity improvement since it is the company goal. This goal based on the historical data since the minimum order of Combination (200g) product was 1,320 batches a month. Hence, the company could has ability to receive the new order from the increase frozen food demand if it can increase the productivity by 120 batches which means the daily average productivity has to be improved to 66 batches or 2,640 bags. Furthermore, the historical data shows that the maximum output of 83 batches a day can be produced. However, the operators seem to be exhausted if they have to produce 83 batches a day.

Table 3-1: Current and Expected Productivity

	Combination (200g)			Cooked snow crab R/M (box/day)
	Batches/month	Batches/day	Bags/day	
Maximum capacity of IQF machine	7,680	384	15,360	812
Average current productivity	1,200	60	2,400	128
Maximum current productivity	1,660	83	3,320	177
10% increase	1,320	66	2,640	141

Brunt (2000) argued that value stream mapping is a very useful tool as it help to communicate the overall material and information flow of the company. This could help the organization seeing and understanding the direction of values and wastes in the whole processes. He noted that the following four steps will help the company to map the value stream of material and information flow. Figure 3-1.

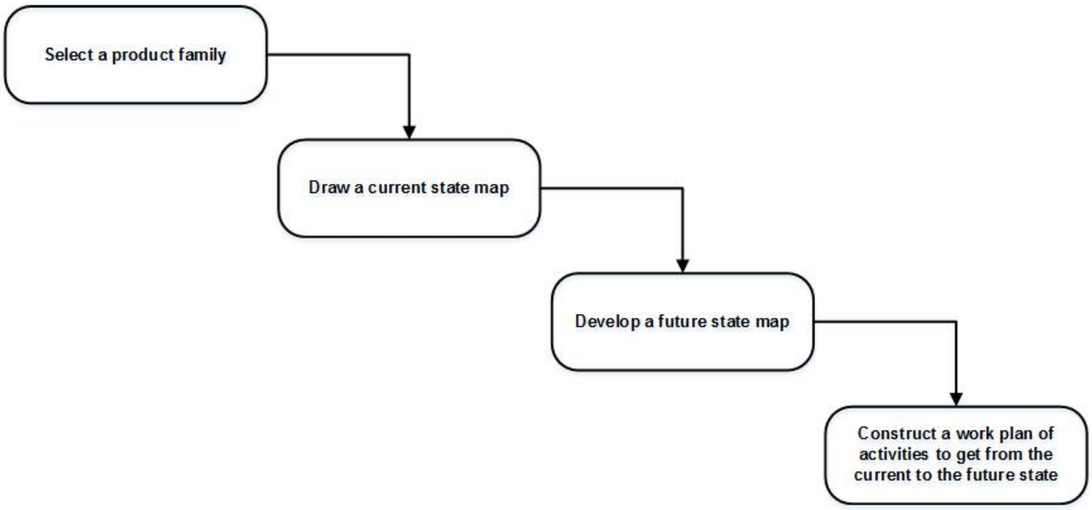


Figure 3-1: Essential Steps of Material and Information Flow Value Stream Mapping (Brunt, 2000)

3.1. Select a product family

This is the first step of mapping value stream of material and information flow. Product that plays the significant role to the company was selected. As a result from chapter 1, the productivity of Combination (200g) product was the least in the factory because of its complexity. In this section, the product characteristic, customer's values, and production process of this product were described in order to understand the both production and customer aspect.

3.1.1. Product Characteristic

The choosen product was Combination (200g) product shown in Figure 3-2 a (size 16cm x 18cm). It is the combination of 70.83% of shoulder meat, 12.50% of Nanban meat, and 16.67% of water.

(a)

(b)

Figure 3-2: Combination (200g) Product

(a) Combination (200g) Bag (b) Combination (200g) Product Components

In actual production, unit of input and output of each process is vary and different so the unit of batch from customer's perspective was used in this research. The conversion to be batch was done in order to make an ease of cycle time and inventory calculation. Table 3-2 shows the weight of meat and Separated part with shell for both a Combination (200g) bag and a batch of Combination (200g) product (40 bags). The input and output of each process were referred to these number to be the same unit as mentioned. Moreover, minimum acceptable percentage of separated part with shell and meat has been set, 45% and 22% respectively, in order to control the production quality. Table 3-3. For example, if there is the production of one cooked snow crab box which weigh 14.969 kilograms, shoulder and Nanban portion from part separation process should be weigh 4.89 and 1.90 kilograms respectively. The total percentage of these two portions is 45.34% which is acceptable. Nevertheless, the weight could be slightly lower but not lower than 45% otherwise there should be some quality issue.

Table 3-2: Batch Size Conversion

Unit	Portion	Meat (g)	Meat (kg)	Separated part with shell (kg)
A Combination (200g) bag	shoulder	141.67	0.14	
	Nanban	25.00	0.03	
	Total	166.67	0.17	
A batch of Combination (200g) product (40 bags)	shoulder	5666.67	5.67	10.36
	Nanban	1000.00	1.00	2.38
	Total	6666.67	6.67	12.74

Table 3-3: Cooked Snow Crab Portion Percentage

Cooked snow crab portions	Percentage of each portion with shell	Percentage of meat
Shoulder	32.68%	17.88%
Leg	26.92%	18.41%
Small leg (Nanban)	12.66%	5.32%
Arm	11.50%	7.21%
Ball	2.72%	0.94%
Claw	13.52%	11.81%
Total	100.00%	61.57%
Total percentage of Combination (200g) product	**45.34%**	**23.20%**
Minimum	**45.00%**	**22.00%**

3.1.2. Customer’s values

The values from customer’s point of view could be divided into two main aspects. Firstly, on time delivery, customer expects to receive the exact quantity of product on the committed date. If the delivery is delayed, customer could lose the opportunity to sell the product in the market and competitive advantage could be reduced.

Next, quality, this aspect is very important. The quality of Combination (200g) product could be separated into three types. The first type is cleanness which is significant for food production. Customer expects to receive the combination of cooked snow crab meat without shell and bone. The cleanness does not focus only the finished product but the clean production line also considered. GMP and HACCP standard could be the primary guarantee for the factory’s cleanness. The second type is the freezing quality. The product has to be frozen properly and completely. The final type of quality is raw material utilization. Since the customer is responsible for raw material ordering and cost, he would expect the highest utilization of the raw material. That means the production should produce the quantity of cooked snow crab meat as most as possible so the minimum production percentage has been set as mentioned in the previous section.

3.1.3. Production process

In this section, the process of Combination (200g) production was described by interviewing supervisor and observation production line. Wilson (2010) suggested that the time study method should be used to get the cycle time of each process. The actual cycle time was obtained by using stopwatch to record cycle time of each task five times and then average. Appendix A. Since cycle time was recorded several times, the problems of each task could be shown.

The operators in the production of Combination (200g) product are grouped into two team by working location. Each team has one team leader who is responsible to arrange the work to each operator. The first team works at production room 1 and 2 which consists of operators who work at part separation, IQF, meat combination, packing (200g), freezing QC, and packing (finished product) station. The second team works at production room 2 which consists of operators who work at shelling peeling and bone checking (blacklight and x-ray) station. Figure 3-3, 3-4, and 3-5 show the process flow of Combination (200g) Product.

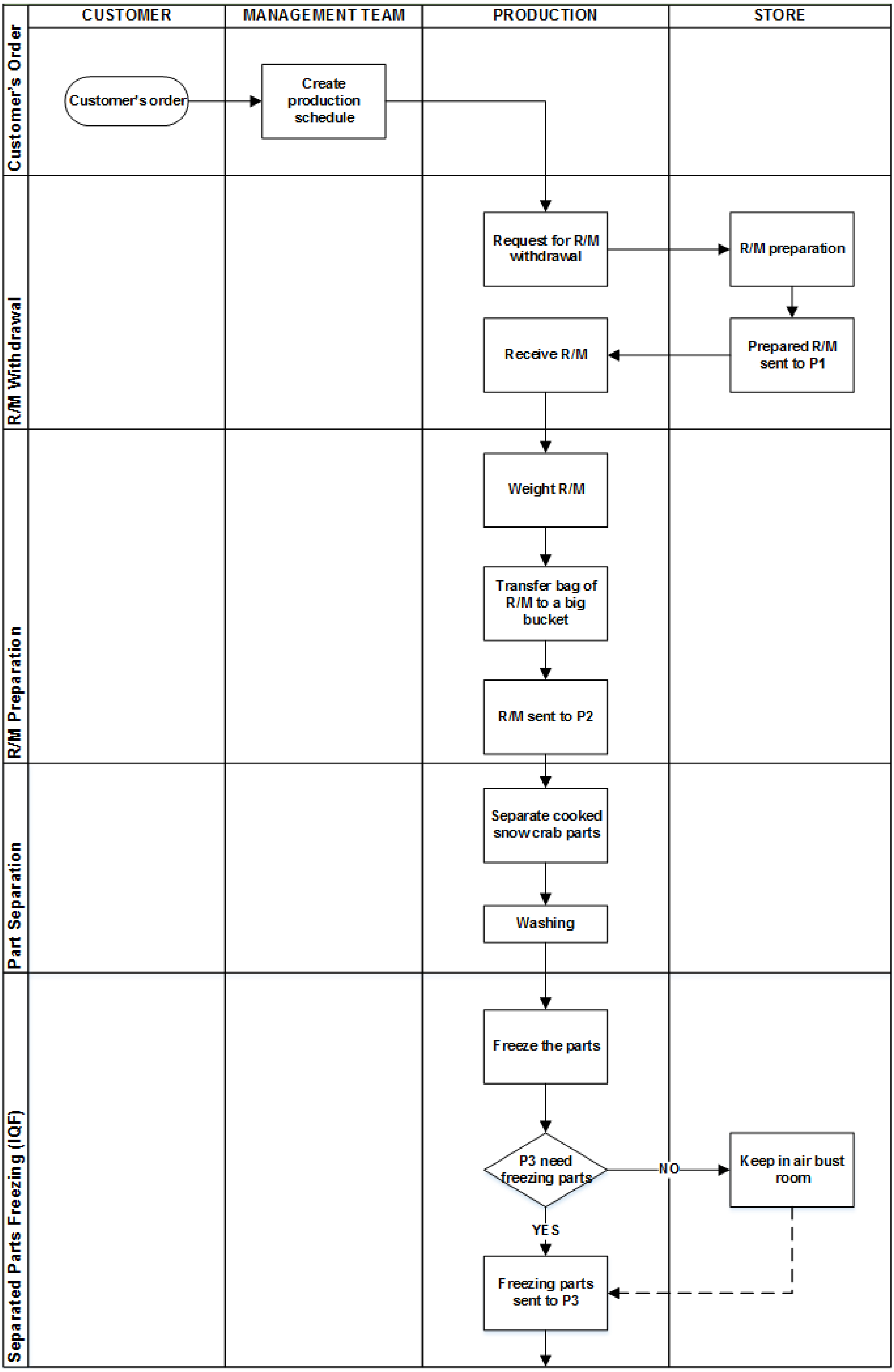


Figure 3-3: Process Flow of Combination (200g) Product

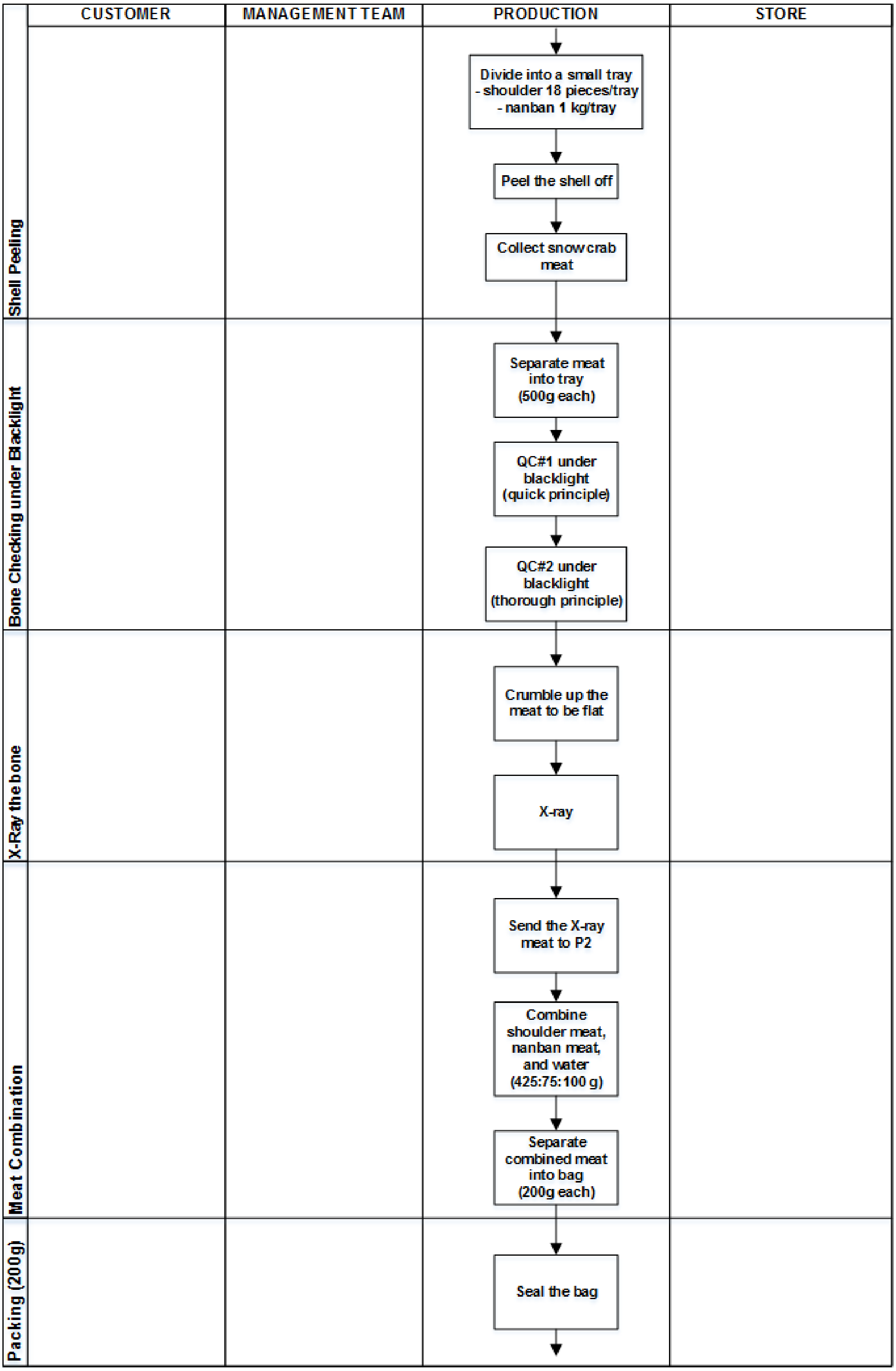


Figure 3-4: Process Flow of Combination (200g) Product (Cont'd)

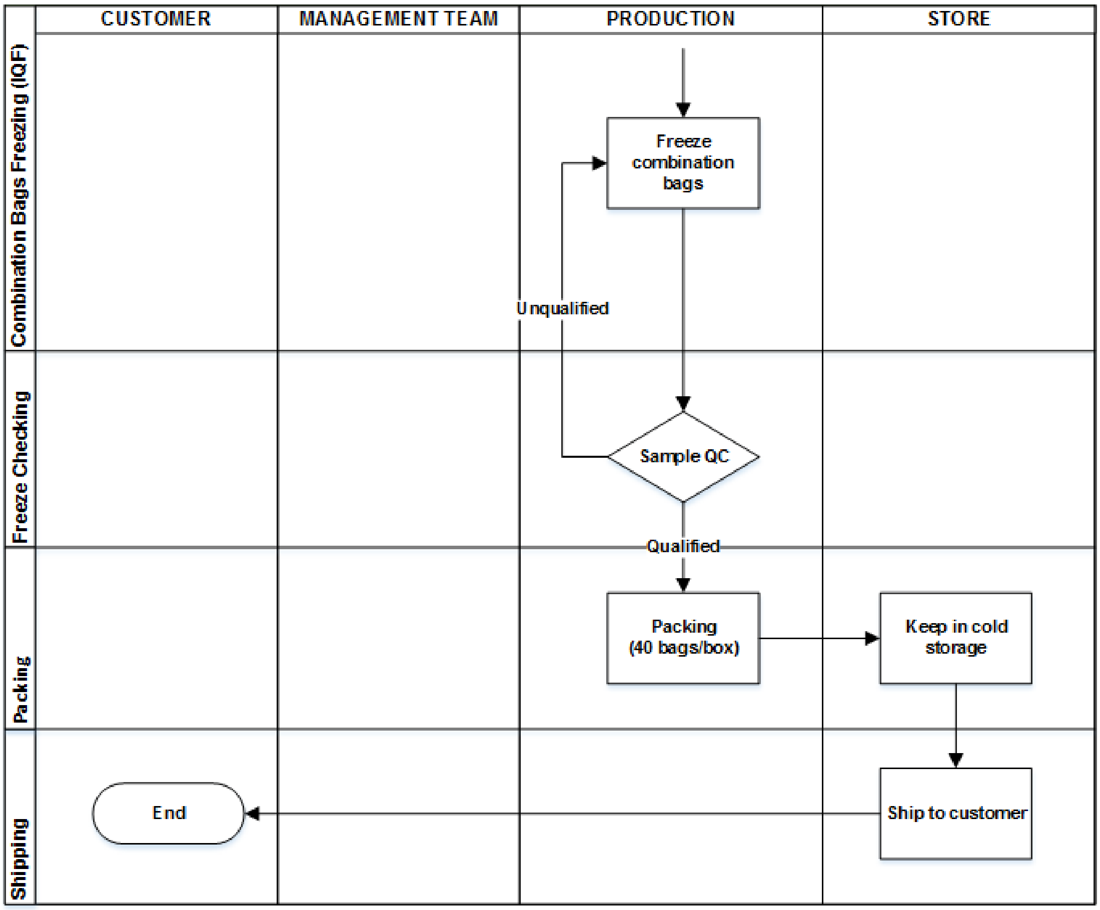


Figure 3-5: Process Flow of Combination (200g) Product (Cont'd)

1) Part separation

Part separation is the first process after R/M is entered to the production line. There are two operation tables located in production room 2. Each table consists of six operators. Cooked snow crab R/M was distributed at one side of each table so two operators of each table who were at that side are responsible to cut the shoulder off and pass the rest to another side of the table. Each portion of cooked snow crab was separated in different baskets. Figure 3-6 a. Each basket was weighted and recorded. If the percentage of output weight was lower than the acceptable percentage (45%), there should be some quality issue which has to investigate as soon as possible. Then, the full basket was washed in the chlorine water and fresh water in order to make sure the cleanness before processing next step. Figure 3-6 b. The cycle time of each batch was approximately 48.26 seconds. See table 3-4.

(a) (b)

Figure 3-6 Part Separation Process

(a) Separate Cooked Snow Crab Portions (b) Washing Separated Portions

Table 3-4: Cycle Time of Part Separation Process

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
Part separation	1	*Separate cooked snow crab portions*			48.26
		- Shoulder	4	36.26	
		- Nanban	8	6.55	
	2	Washing separated portions	12	5.45	

2) Separated part freezing (IQF #1)

The clean portions were transferred to the IQF machine to freeze them in order to make an ease of peeling. Figure 3-7 a. IQF speed was set at 1.073 m/min. After the parts are frozen, 10 kilograms of each type of parts were divided into diffent bucket. Figure 3-7 b. The weight of each freezing parts from this process was recoded in order to monitor the quality and performance of part separation process. If the weight of freezing parts was less than the standard, there should be some problems occurred in the part separation process. Since the separated parts were poured and spread continuously on the conveyor, time was not sinigficant so loading time was excluded. Thus, each batch of separated parts consumed 40.5 seconds.

(a) **(b)**

Figure 3-7: Separated Part Freezing Process (IQF #1)

(a) Clean Separated Parts (b) Freezing parts

3) Shell peeling

The buckets of freezing parts brought to production room 3 in order to prepare for shell peeling. As can be seen from Figure 3-8 a and c, around 18 pieces of shoulder and a kilogram of Nanban were divided into small trays separately. However, the end leg of Nanban portion needed to be cut before distribution. The shell peeling area consists of a distribution table, 4 shell peeling table, and washing area. Figure 3-9. Each operator took a tray of freezing part to peeling table. The scissors is used to peel the shell of both portions. Figure 3-8 b and d. When all parts in the tray were peeled, operator had to wash and exchange the empty tray for the tray of full freezing parts. In the meanwhile, the freezing parts, which were not brought to production room 3, were kept in the air blast room near IQF machine. When the freezing parts at shell peeling area ran out, the responsible operator would withdraw them from the air blast room.

The cycle time of peeling the shell of shoulder and Nanban was 165.75 and 21.16 seconds respectively. Table 3-5 indicates cycle time of each task in shell peeling process.

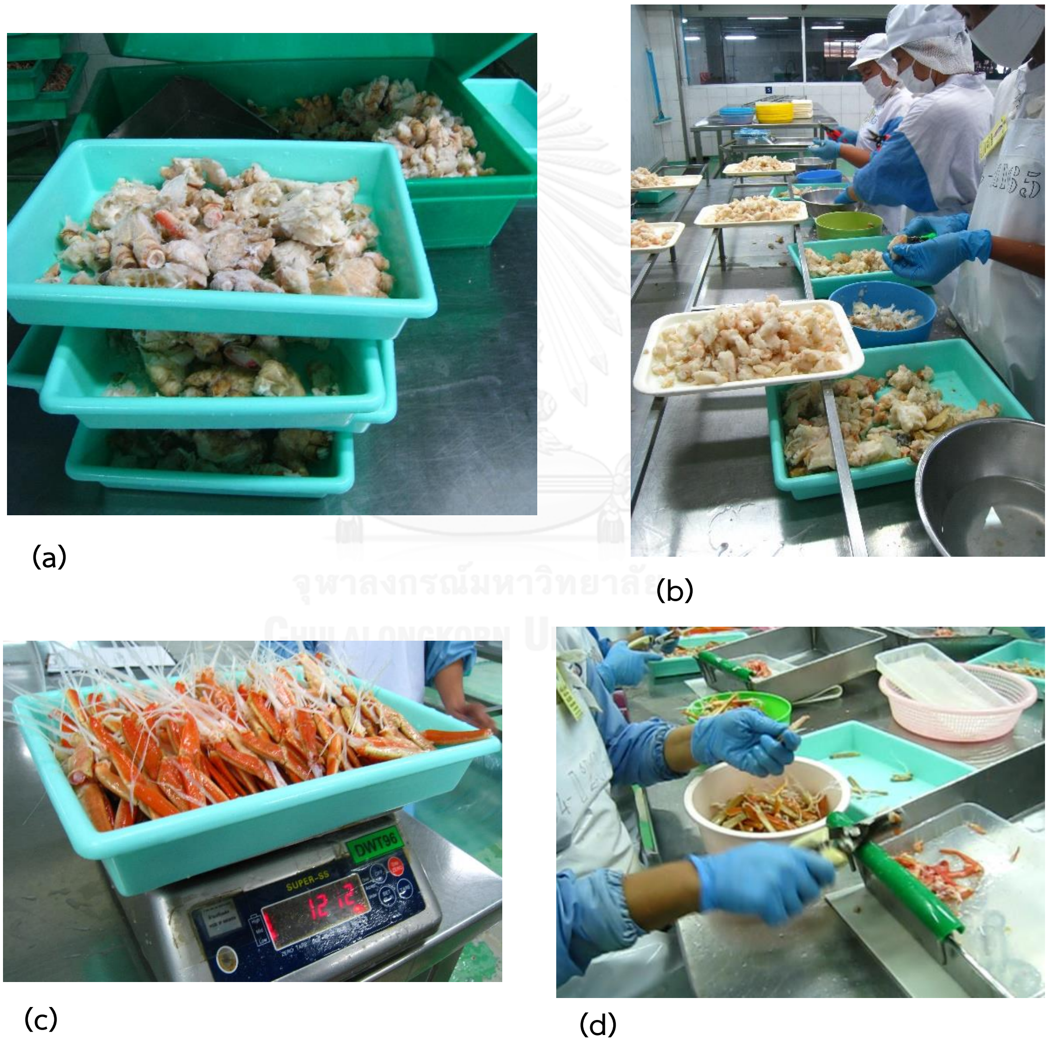


Figure 3-8: Shell Peeling Process

(a,c) Divide the Freezing Parts into a Small Tray (b,d) Peel the Shell off

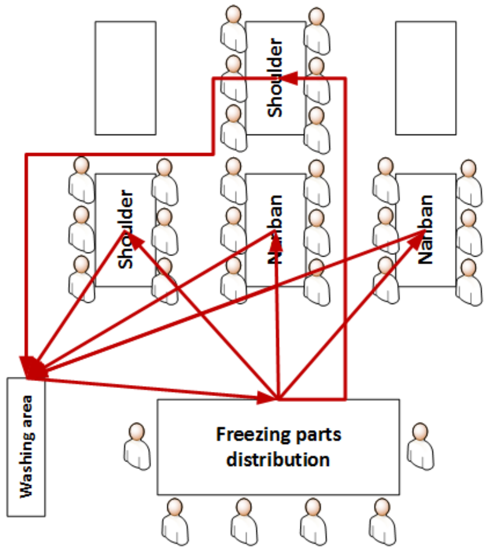


Figure 3-9: Shell Peeling Layout

Table 3-5: Cycle Time of Shell Peeling Process

Process	Step	Details	No. of operator	Cycle time (s)		Total cycle time (s)
Shell peeling	1	The buckets are brought to production room 3	1	79.01	79.01	479.06
	2	Divide the freezing parts into a small tray			84.49	
		- Shoulder (18 pieces/tray)	1	26.99		
		- Nanban (1 kg/tray)--> ***need to cut the ended leg before***	4	57.50		
	3	Each operator take a tray of freezing part to workstation		57.37	315.56	
	4	Peel the shell off				
		- Shoulder	12	165.75		
		- Nanban	12	21.16		
	5	Each operator return and wash an empty tray and take the new one		71.28		

4) Bone checking under blacklight

Shoulder and Nanban meat was collected on the table closes to blacklight station. It was prepared for the bone checking by dividing 500 g each small tray. Checking the bone under blacklight was done for two times. Figure 3-10 and 3-11. The quick and thorough principle were implemented at the first and second checking respectively. Quick checking reduces the thorough checking time because the big bone is pre-screened and removed. Figure 3-11. Total cycle time of a batch bone checking was 416.67 seconds. Table 3-6

Figure 3-10: Bone Checking Under Blacklight Process

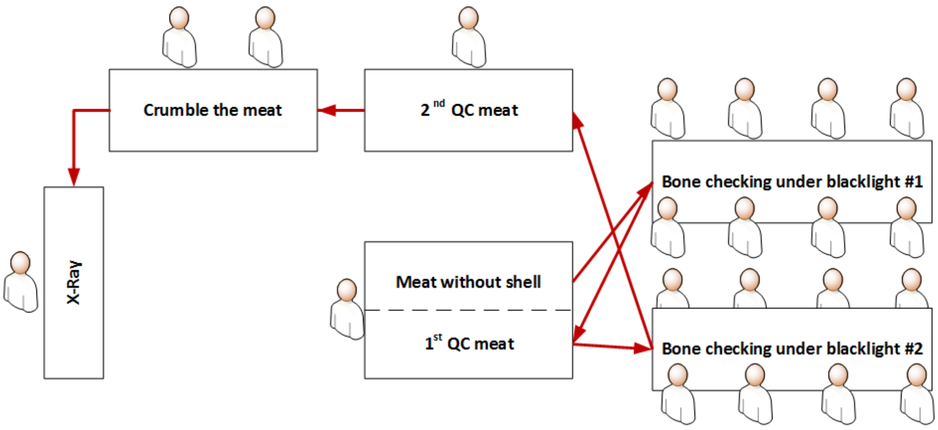


Figure 3-11: Bone Checking Under Blacklight and X-Ray Layout

Table 3-6: Cycle Time of Bone Checking Under Blacklight Process

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
Bone checking under blacklight	1	Prepare meat into small tray	1	66.67	416.67
	2	Black light 1st checking	8	100	
	3	Black light 2nd checking	8	250	

5) X-Ray

The meat that was done form bone checking under blacklight had to be x-ray in order to eliminate the left and invisible bone before combination process. Figure 3-12 b. However, it was necessary to crumble up the meat before entering the x-ray machine because the flat surface could increase the efficiency of x-ray. Figure 3-12 a. The cycle time of x-ray depends on the amount of bone in the meat. As can be seen from time study in appendix A, the fastest cycle time of x-ray process was 260.17 seconds while the longest cycle time was 638.15 seconds. However, the average cycle time is indicated in table 3-7.

(a) (b)

Figure 3-12: X-Ray Process

(a) Crumble the Meat (b) X-Ray

Table 3-7: Cycle Time of X-Ray Process

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
X-Ray	1	Crumble up the meat	3	43.22	505.53
	2	X-Ray	1	462.31	

6) Meat combination

Meat without bone from each portion was sent to production room 2 to be combined and packed. To make an ease of combination, the operator combined 500 g of meat with 20% of water so the amount of three Combination bags is produces from each combination. The ratio of shoulder meat and Nanban meat is 85:15. Thus, the operators has to prepare 425 g, 75g, and 100 g of shoulder meat, Nanban meat, and water respectively. Then, each 200g of combination meat was weighted and put in the prepared bag. Figure 3-13. The cycle time of this process is shown in table 3-8.

(a)

(b)

Figure 3-13: Meat Combination Process

(a) Weight the Combined Meat (b) Divide Combination Meat into Bag (200g/bag)

Table 3-8: Cycle Time of Meat Combination Process

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
	1	Operator walk from P2 to x-ray (P3) to collect qualified meat	1	30	
Meat combination	2	Combine shoulder meat, Nanban meat, and water (425:75:100)	1	282.72	510
	3	Divide combination meat into bag (200g/bag)	1	197.28	

7) Packing (200g/bag)

The pedal impulse sealer is used to seal the Combination (200g) bag. There is only one machine which has ability to seal one bag each time in the production line. Moreover, the resposible operator had remove some air before sealing because the air could reduce the freezing efficiency in the next step. Figure 3-14 The average cycle time of this process was 491.05 seconds.

Figure 3-14: Packing (200g/bag) Process

8) Combination bag freezing (IQF #2)

Combination (200g) bags were sent to IQF machine in production room 1. There were four operators in this station. Two operators were responsible to load the bags into IQF machine. Figure 3-15 a. Another were responsible to remove the freezing bags and put each batch in the specific bucket. Figure 3-15 b. However, for loading Combination (200g) bags into IQF machine, bags had to be arranged to be flat on the conveyor belt in order to make an efficiency of freezing. The loading surface contains 70 bags of Combination (200g) product for the maximum. To freeze the Combination (200g) bags, the same IQF speed as freezing separated parts can be used. The average cycle time of a batch freezing was 603 seconds because the product was not continuous loading into the IQF machine.

(a) (b)

Figure 3-15: Combination Bag Freezing (IQF #2) Process

(a) Loading Combination (200g) bags (b) Removing the Freezing Bags

9) Visual QC

This process aims to check the freezing quality since it is one of customer's values. It was a sample checking. Two freezing bags of each batch are random. If the sample bags are not frozen properly, the whole batch has to be frozen again. However, this was an operator's judgment which comes from the experience. The sample checking took 6.21 seconds.

10) Packing

This process is the final process of the production of Combination (200g) product. It produced the finished goods which were ready to ship when the customer requires. The freezing bags that passed the quality control were packed into the commercial box (40 bags/box) and kept in the cold storage. Figure 3-16. The cycle time of packing was 47.33 seconds.

Figure 3-16: Packing Process

3.2. Current state map analysis

In this section, the current production was analyzed. The current state mapping is the essential technique to show the problems in the production line because all steps and information were revealed. However, other techniques were used since some aspects or problems might not show in the current state map. Firstly, non-value added activities had to be revealed since the customer's values were analyzed. Secondly, spaghetti diagram technique was used to see the flow of material and information. Next, the questionnaire and interview needed to be done in order to understand the real problem in the production line in the operators' view. Finally, cause and effect of productivity problem was analyzed by using the gathering information.

3.2.1. Current state mapping

Since the customer's demands are forecasted yearly, cooked snow crab R/M is sent to keep in the company cold storage. The daily production schedule pushed cooked snow crab R/M through the production line. As can be seen from Figure 3-17, the production processes of Combination (200g) product are linear. It means that the product is produced in sequence which each process has to wait the parts that have been done from the previous process. It can be assumed that daily customer demand is the daily factory's expected output which is 66 batches. As mentioned in the product characteristics section, Combination (200g) product made from shoulder and Nanban portion of cooked snow crab so raw material has to be separated at the beginning of production. Then, they were passed to each process consecutively to do each particular work before mixture at meat combination process. The combined meat of two portions is packed 200g per bag and frozen before shipping to the customer.

The diagram shows that about the half of production processes produced inventories which affect the total lead time. The more inventory was produced, the more lead time that customer had to wait. Womack and Withers (2006) stated that the factory had to prepare more space of shop floor and containers to handle the increase inventory which considered as non-value added activities since it is not the customer's value. The total lead time (non-value added time) of Combination (200g) product was approximately 2.5 days whereas the total cycle time (value added time) was only 3,147.60 seconds or 52.46 minutes. Hence, the process cycle efficiency (PCE), which calculated by diving value added time by lead time, was only 4.09%. To improved PCE, the lead time need to be reduced which was done in the next section (future state mapping).

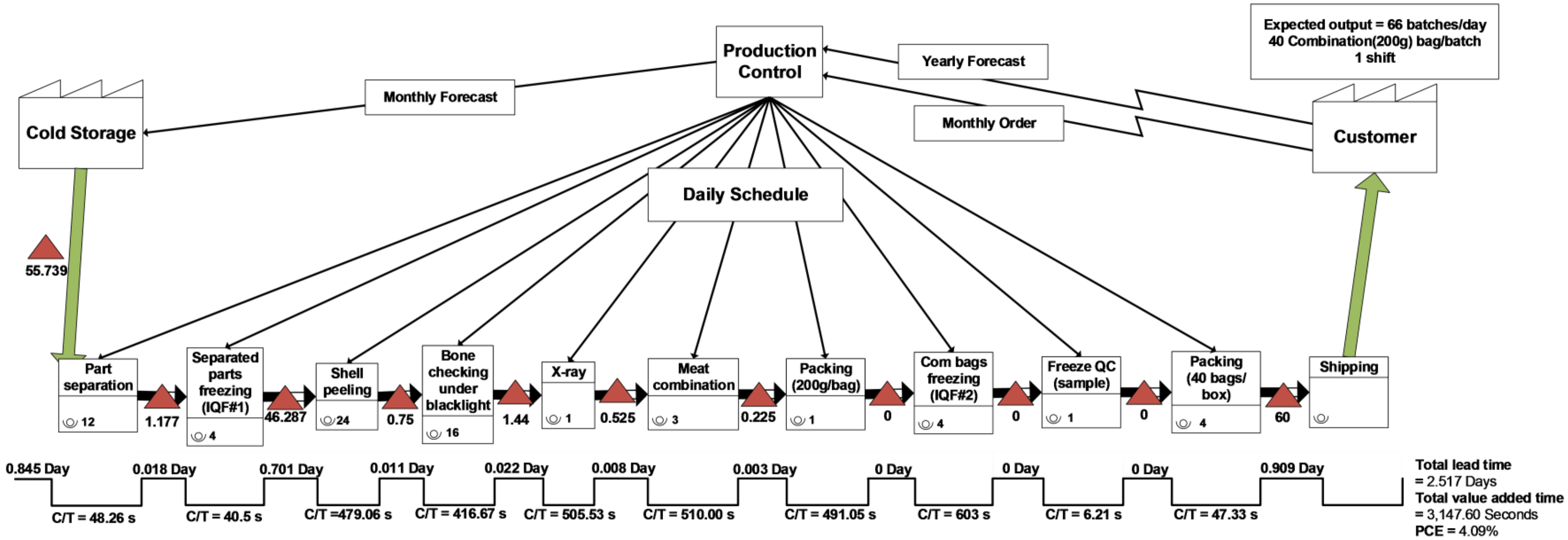


Figure 3-17: Current State Mapping

3.2.2. Observation

The purpose of observation was to reveal non-value added activities in the production line of Combination (200g) product. According to Liker and Meier (2006), seven major types of wastes usually used to identify non-value added activities in the manufacturing process. Every team members were assigned to walk through each process in the production line and note the wastes of each process by using seven type of wastes as a reference. The results of observation were concluded as follows and table 3-9.

1) Overproduction

There is no overproduction waste because the make-to-order principle is applied to the factory production.

2) Waiting

This type of waste occurred in the shell peeling and Combination bag freezing (IQF #2) process. These processes had to wait the individual parts and product from previous process. As can be seen from table 3-4, the freezing parts had to be separated into the small tray before peeling the shell. The freezing parts, which were stored in the air blast room, would be transferred to production room 3 when it was needed so sometimes operators had to stand around waiting for the supply.

As same as Combination bags freezing (IQF #2) process, the Combination bags were not transferred to IQF machine continuously. This caused the high idle time. According to the observation data the idle time took about 90 minutes a day.

3) Transportation

According to Liker and Meier (2006), the movement of raw materials, parts, work in process (WIP), and finished goods even it is a short or long distance causes the transportation waste.

This type of waste could be mainly found at R/M withdrawal, shell peeling, and meat combination process since the movement between processes was not quite flow and unnecessary. For instance, the transportation of R/M between cold storage and production room 1 was a long distance and operator has to walk many round to transport the required R/M. Moreover, the shell peeling and meat combination process, the responsible operators had to walk to air blast room and X-ray station respectively in order to get the parts when they were running out. This caused the waste of time and non-value added for the customer.

4) Overprocessing

As can be seen that bone checking process was done for three times in the current production, two times under blacklight and one time under x-ray. Although crab meat without bone is one of the values that customer is willing to pay for, this process should to be redesigned to increase productivity and maintain the quality.

5) Excess inventory

High WIP could be found at two areas. Firstly, R/M preparation area in the production room 1, the whole requested R/M was withdrawn from cold storage but the separation table and operators are limited. Furthermore, IQF #1 also produced high WIP because of unsmooth flow and different cycle time. It took large amount of time to peel the shell while freezing process is very quick.

6) Unnecessary movement

There was some unnecessary movement occurred in the part separation process. Since R/M was distributed only one side of the table, operators who stand at that side were responsible to cut the body off and then pushed other parts to other operators in the table in order to separate each part.

In addition, the unnecessary walking could be found at shell peeling process because when the entirely freezing parts in the small tray were peeled, operators had to walk to the distribution table to return the empty tray and get the new one instead. These movements did not add value to the product.

7) Defects

The IQF #2 was an only process that found a few defects since the Combination bag was not be frozen properly. There was 7 bags which are frozen incompletely out of

11,600 bags. The defect rate was only 0.034%. This is because the arrangement of these Combination bags was incorrect. They was not flatted on the IQF conveyor.

Table 3-9: Seven Wastes Analysis

Process	Overproduction	Waiting	Transportation	Overprocessing	Excess Inventory	Unnecessary Movement	Defect
Raw material withdrawal	NO OVERPRODUCTION ISSUE		/		/		
Part separation						/	
IQF #1					/		
Shell peeling		/	/			/	
Bone checking under blacklight				/			
X-ray				/			
Meat combination			/				
Packing (200g/bag)							
IQF #2		/					/
Freeze QC							
Packing							

3.2.3. Spaghetti diagram

Spaghetti diagram in Figure 3-18 indicates that the transportation of parts and products and the movement of operators in Combination (200g) production were confused especially in production room 3 which is the area of shell peeling process. The operators had to walk between distribution and operation table many times a day in order to receive and return freezing parts.

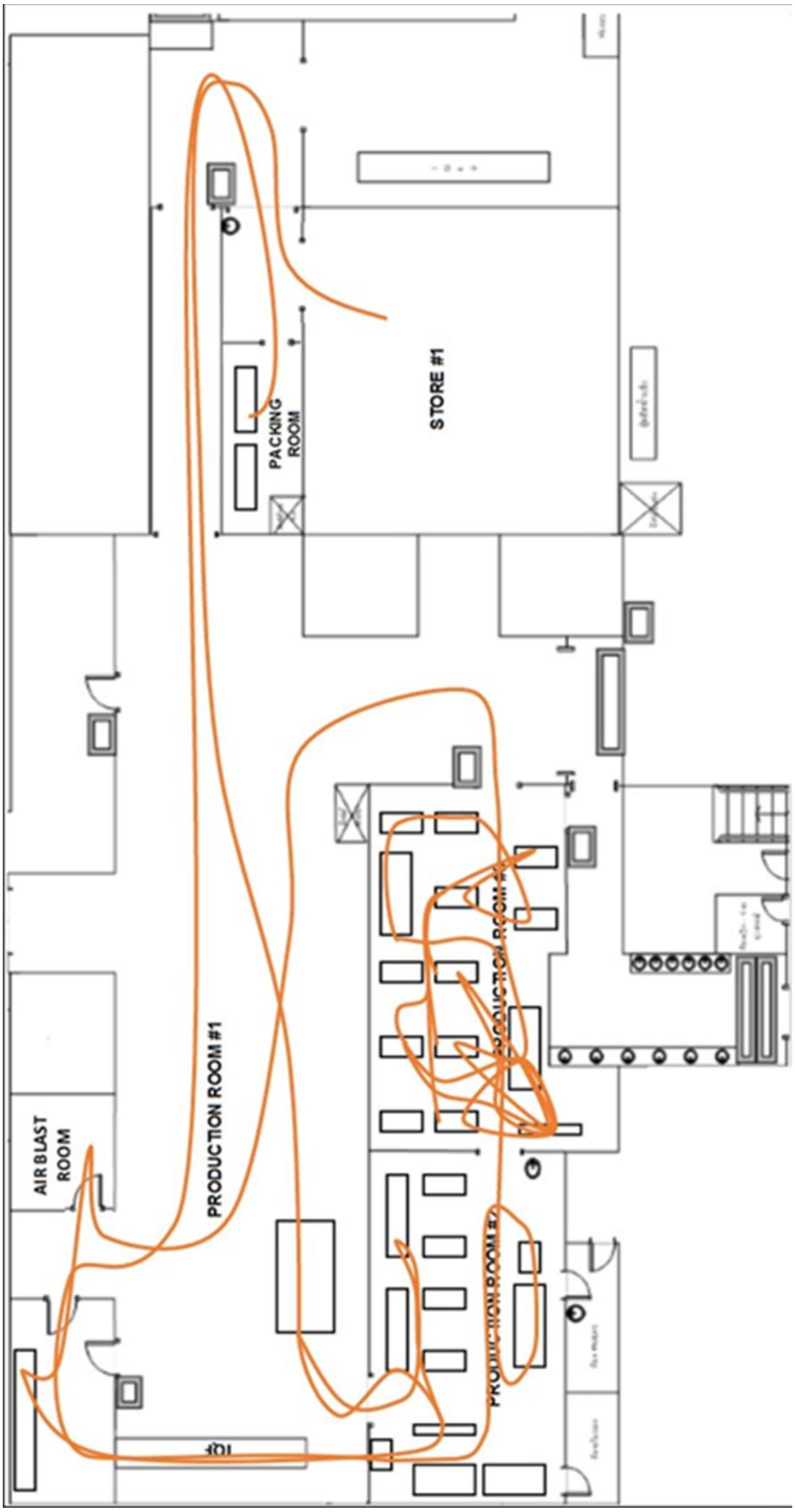


Figure 3-18: Spaghetti Diagram

3.2.4. Questionnaire

Questionnaires were distributed to supervisor, team leaders, and five operators who had ever worked in every process. They had been asked to select the difficulty level of each process. This questionnaire aimed to know the level of difficulty of each process from the workers' point of views in order to find the root cause of difficulty and solutions. As can be seen from table 3-10, Shell peeling, bone checking under blacklight, and packing (200g/bag) were the top three difficult processes.

From the analysis, shell peeling was the most difficult process in the production of Combination (200g) product since it is the manual operation which require high quality of work. As can be seen from the current state mapping analysis, operators' opinion conformed to the analyzed data. This process consumed high amount of time in the production although many operators were assigned to do the work.

As same as the packing (200g/bag) process, the analyzed data matched with the opinion from sample operators. Even though the process seemed to be simple, the method of sealing and the limited number of sealing machine could produce the difficulty of work.

For the bone checking under blacklight process, the carefulness is required and the bone is very small which is quite hard to find and make sure all the bones are eliminated. According to observation and analyzed data, the efficiency of this process affects the cycle time of the next process (x-ray). Although the cycle time of bone checking under blacklight process was not too high, the cycle time of x-ray process was quite high and fluctuate. This means this process was not quite efficient because there was a number of left bone in x-ray process.

Table 3-10: The Difficulty Level of Each Process

Process	Difficulty Levels				
	1	2	3	4	5
Part separation			/		
Separated parts freezing (IQF #1)		/			
Shell peeling					/
Bone checking under blacklight				/	
X-ray the bone			/		
Meat combination		/			
Packing (200g/bag)				/	
Combination bag freezing (IQF #2)		/			
Freeze checking (sample)	/				
Packing	/				
Difficulty Levels 1 = very easy, 2 = easy, 3 = fairly, 4 = hard, 5 = very hard					

3.2.5. Interview

The purpose of this interview was to understand the real problems that happen in the production line of Combination (200g) product so operators who work in each station, supervisor, and team leaders were interviewed. Three question about productivity improvement were asked to the interviewees. Appendix B. The analysis of the interview is shown as follows.

<u>The acknowledgement of daily targeted number of finished goods</u>

Since this research aims to improve productivity, it is necessary to make sure that this number was informed to all involved operators. As a result, supervisor and team leaders knew the daily targeted number of finished goods as they had to plan for R/M withdrawal while the majority of operators did not know about this number. This is because there was no production meeting before starting daily production. However, operators, who were in the process that need to request for packaging withdrawal, were notified this number.

<u>The obstacles which relate to low production speed and/or productivity, root cause, and suggestions</u>

Packing (200g/bag) process seemed to have a significant problem since it brought about high idle time in the next process, Combination bags freezing. The supervisor noted that there w only one sealing machine which a Combination bag (200g) can be sealed each time. Moreover, the responsible operator added that each bag took times since she had to remove some air before sealing in order to make an efficient freezing and reduce the packing space. Thus, they suggested that the vacuum packaging machine which is able to seal and remove some air simultaneously should be implemented. Moreover, multiple bags can be sealed at the same time which could reduce the production time and idle time in the next process.

For the part separation process, there are two tables in this process. The distribution of R/M for the secondary table was more difficult than the first table because of the narrow walk way and limited space. Moreover, the R/M distribution was done at one side of the table. That means operators who were at this side has to cut the body off and transfer the remained cooked snow crab portions to another side of the table in order to be separated. The operator, who was responsible for body separation, pointed out that his work had been interrupted by the transference of other parts.

In addition, team leaders mentioned that the direction and distance of some process might be inappropriate and consumed high amount of time. For instance, the distance between x-ray and meat combination process was quite far. To collect the x-ray meat, operator who works at meat combination process had to walk around 30 seconds per round and she had to walk many round per day to collect all the x-ray meat. Therefore, they suggested that the factory layout need to be adjusted to make an ease of working and reduce the wasted time.

The physical problems could produce the obstacle in many processes such as the heavy separated part basket leaded to the backache, the tiredness from all day standing for shell peeling, and exhausted eyes from looking for the bone under blacklight. These physical problems could be the causes of the slower production speed which could affect the overall factory productivity. The operators suggested that there should be some stools and magnifying glass to make them more comfortable.

Lean knowledge

As a result, interviewee operators including team leaders did not know the meaning of Lean principle and they never heard this word before because of the education level. The factory requires people who graduated at least secondary school to be an operator in production line. However, the bachelor's degree is required for supervisor and he has some experience in the manufacturing field so he has some basic knowledge about Lean principle.

3.2.6. Cause and effect analysis

Cause and effect diagram is an effective tool that widely used to identify the root cause of problem. (Eaton, 2013). Liker and Meier (2006) emphasized that all potential root causes have to be listed and understood. Then, they have to be narrowed in order to focus only the significant root causes.

As the results from observation, questionnaires, and interview, low productivity could be caused by several reasons. Figure 3-19 indicates all potential root causes of low productivity problem. The root causes could be grouped into four main aspects which are management, people, process, and environment. As can be seen that many issues came from management problem such as high processing time, high idle time and inventory, and lack of internal communication between demand and supply. These issues affected productivity of the factory significantly. Moreover, since the factory mainly depends on workforce, it is necessary to consider both physical and mental issue of the operators. Therefore, low productivity could arise from lack of experience, low motivation, and physical problems. Furthermore, the difficulty of process and inappropriate environment also were the reason of low productivity.

Since it is impossible and wastes time to solve all potential root causes, cause and effect matrix (C&E matrix) in table 3-11 was adapted to vote the priority of each root cause. The root causes that significantly affect to the productivity problem were scored 5 which was necessary to find the suitable solutions to solve these problem as soon as possible. On the other hand, the root causes, that were scored 1, were not important in the factory's perspective because of many reasons such as customer's values and no investment policy. Team decided that these problems did not play the significant role and could be fixed later. For the problems that had an equal score, they were arranged depending on the effect.

According to Pareto principle, 80% of problems cause by 20% of root causes. As can be seen form the Figure 3-20, the first nine bar charts represent 80% of root causes in the production line. However, the factory had no ability to fix the last two problems at the moment because of no investment police. They were planned to improve next year after the budgets and resources are arranged. For the top first seven problems, the majority causes from managements. Team believed that if these problems are fixed, the productivity can be increased.

The significate root causes of low productivity.

1. The difference of cycle time between the connected processes
2. Unnecessary tasks
3. Unbalance workload
4. No working standard/best practice
5. No performance evaluation policy
6. Poor information flow
7. Inappropriate layout

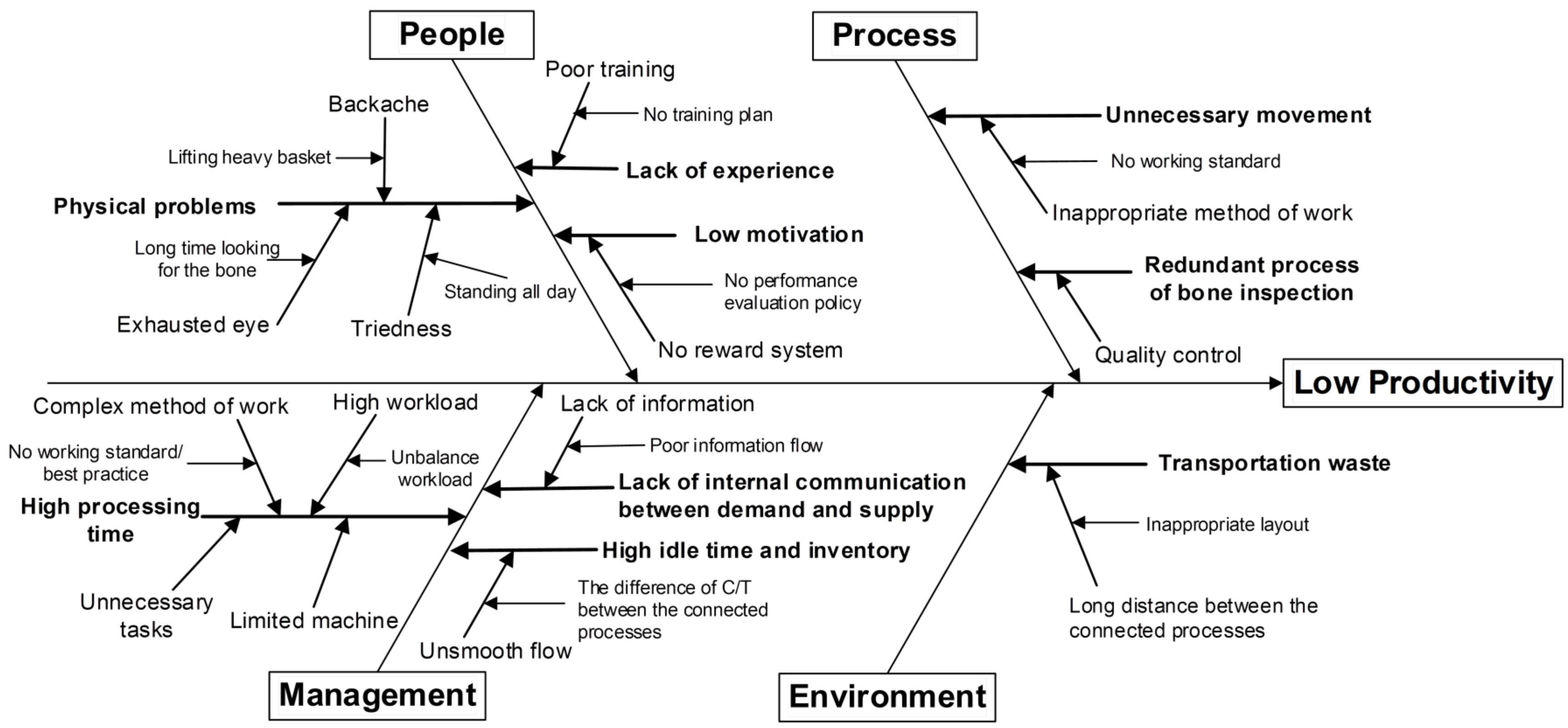


Figure 3-19: Cause and Effect Diagram

Table 3-11: Cause and Effect Matrix

Root causes of low productivity	Priority					Comments
	1	2	3	4	5	
People						
- No training plan		/				On job training
- No performance evaluation policy			/			
- Lifting heavy basket leads to backache			/			
- Long time looking for the bone leads to exhausted eye		/				No investment policy
- Standing all day leads to triedness		/				No investment policy
Process						
- No working standard				/		
- Quality control	/					Customer's value
Management						
- Poor information flow		/				
- The difference of C/T between the connected processes					/	
- Limited machine	/					No investment policy
- Unnecessary tasks					/	
- No working standard/best practice				/		
- Unbalance workload					/	
Environment						
- Inappropriate layout		/				

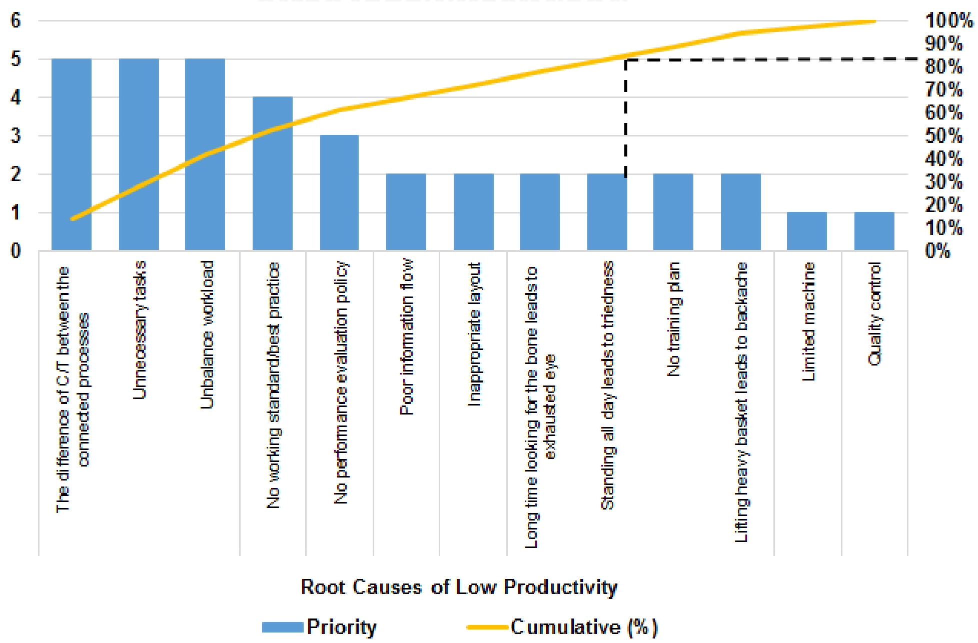


Figure 3-20: Pareto Chart for Prioritizing Problem-Solving of Low Productivity

3.3. Develop Future state map

Brunt (2000) emphasized that the current state map has to be analyzed before develop future state map. He suggested that the questions which are in the following four aspects should be answered in order to develop the suitable direction for the factory.

1) *Demand*

a. *What is the TAKT time?*

Takt time of the machine and manual have to be calculated separately because the net available time is different. IQF machine is opened 8 a.m. to 5 p.m. without breaking while operators have to work 10 hours with 60 minutes for launch breaking and 30 minutes for cleaning working areas. Hence, the net available time of IQF machine is 32,400 seconds while the net available time of operators is 30,600 second. The customer demand was calculated from the expected productivity improvement rate, 10% or 66 batches a day. Takt time calculation of IQF machine and manual are presented in Figure 3-21 and 3-22 respectively. As a results, the factory has to produce a batch of Combination (200g) product in every 491 seconds for IQF machine and 464 seconds for manual processes in order to response to the daily demand.

Net Available Time			Customer Demand		
Working shifts / day	1	shifts	Customer demand / day	66	batches
Hours / shift	9	hours			
Available time / shift	540	minutes			
Break time / shift	0	minutes			
Lunch time / shift	0	minutes	Net available time / day	32400	seconds / day
Planned downtime / shift	0	minutes	Customer demand / day	66	pieces / day
Net working time / shift	540	minutes			
Net working time / shift	32400	seconds			
Net available time / day	32400	seconds	**Takt time =**	**491**	seconds / batch

Figure 3-21: Takt Time Calculation of IQF Machine

Net Available Time			Customer Demand		
Working shifts / day	1	shifts	Customer demand / day	66	batches
Hours / shift	10	hours			
Available time / shift	600	minutes			
Break time / shift	0	minutes			
Lunch time / shift	60	minutes	Net available time / day	30600	seconds / day
Planned downtime / shift	30	minutes	Customer demand / day	66	pieces / day
Net working time / shift	510	minutes			
Net working time / shift	30600	seconds			
Net available time / day	30600	seconds	**Takt time =**	464	seconds / batch

Figure 3-22: Takt Time Calculation of Manual Work

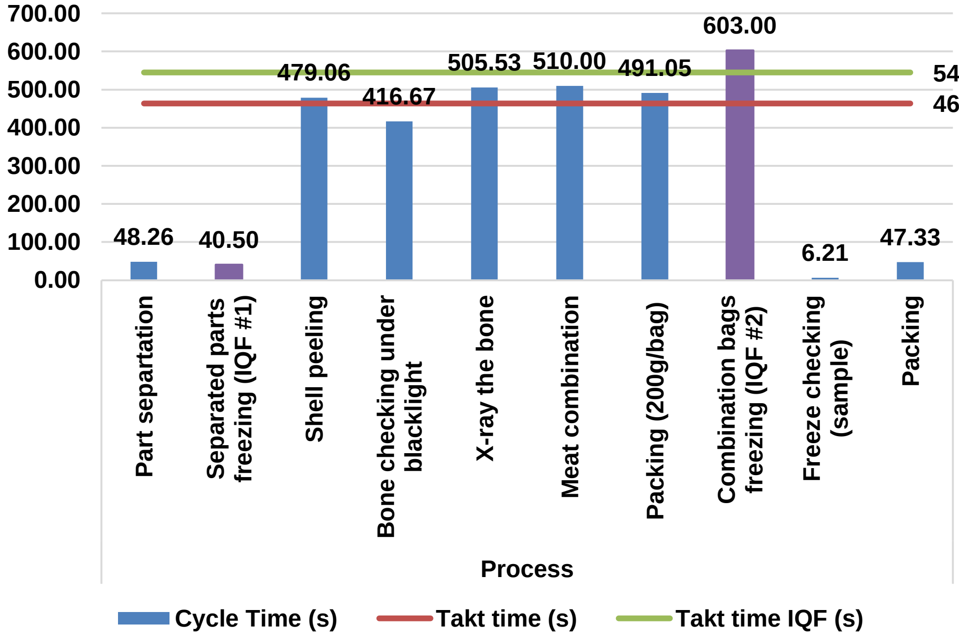


Figure 3-23: Cycle Time VS Takt Time

As can be seen from Figure 3-23, the cycle time of shell peeling, x-ray, meat combination, and packing (200g/bag) process was higher than takt time. Meat combination was the bottleneck process since it consumed the highest amount of production time which was 510 seconds. For IQF machine, the freezing of Combination (200g) bags also excessed the IQF takt time because the product shortage leaded to high idle time. Therefore, it can guarantee that the freezing time will be decreased, if the cycle time of previous processes is improved.

b. *Should the company build to a "finished goods supermarket" or directly to shipping?*

Since the company makes products from customers' requirements and orders, the shipping quantity and date are arranged a year in advance although they could be adapted or changed depending on market situation.

Production schedule is planned in order to separate the total required quantity to daily production quantity. The daily finished product is kept in the cold storage for shipping to the customer on the committed date. Therefore, the finished goods supermarket is proper with the production of Combination (200g) product because it help to create the pull system. McDonald et al. (2002) suggested that a Kanban system should be used to trigger the upstream process to produce and replenish the withdrawal quantity. The Kanban size should be 40 bags since the product is shipped in a batch of 40 Combination (200g) bags. The finished goods can be withdrawn from the supermarket for the delivery when the customer want. Then Kanban will be sent back to the upstream process in order to tell that another 40 bags are needed. Figure 3-24.

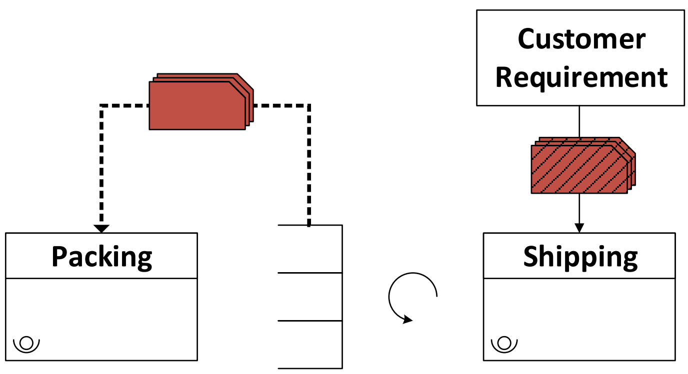


Figure 3-24: Finished Goods Supermarket

2) Material flow

d. Where can the company use continuous flow processing?

Rother and Shook (1999) stated that the production of a piece of product which will be passed to the next process without interruption or wastes called “continuous flow” It is seem to be impossible to implement continuous in the production line of Combination (200g) product because output and input unit between some process is not the same.

However, the continuous flow could be implemented at two process areas. Firstly, bone checking under blacklight process through x-ray process, this is because the layout is suitable for implementation of continuous flow since each sub-process is close together. Moreover, the output and input unit of these process is the same (500g of peeled meat in a tray) so this unit could be transfer from step to step with no WIP. Although the output of x-ray process is same as the input of the next process (meat combination) the continuous flow is impossible because the cycle time of x-ray process is vary depending on the amount of left bone. Figure 3-25.

Freeze QC and packing process also could be introduced the continuous flow since output and input unit is the same and one piece flow is possible. Figure 3-25. Although these two processes are located quite far, the re-layout may need to done.

Figure 3-25: Continuous Flow

e. Where do we need to use supermarket-based pull systems?

Although the finished goods supermarket is implemented in the production of Combination (200g) product, two additional supermarket has to be implemented before shell peeling and meat combination process because cycle time between previous process and these process are very different. The supermarket introduces the pull system which the production in the flow is controlled.

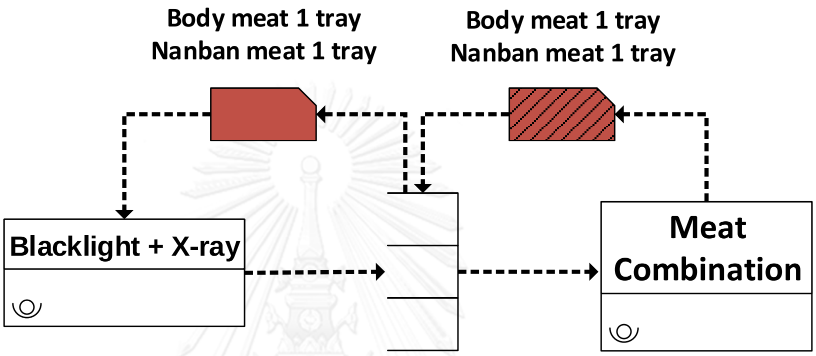


Figure 3-26: Supermarket (Meat Combiantion Process)

The first supermarket will be located at meat combination process which shoulder and Nanban meat are mixed. Figure 3-26. The containers will be used as supermarket to stock the required shoulder and Nanban meat. When the meat is withdrawn (the container is empty), the signal will be sent back to produce and refill the meat until the required quantity is met. Since the required quantity of shoulder and Nanban meat are 475g and 75g respectively for each time of meat combination, a tray of shoulder and Nanban meat, 500g, is attached in both production and withdrawal Kanban. Thus, if the meat in container is withdrawn, the signal will be sent to previous process (X-ray) to replace the withdrawal quantity.

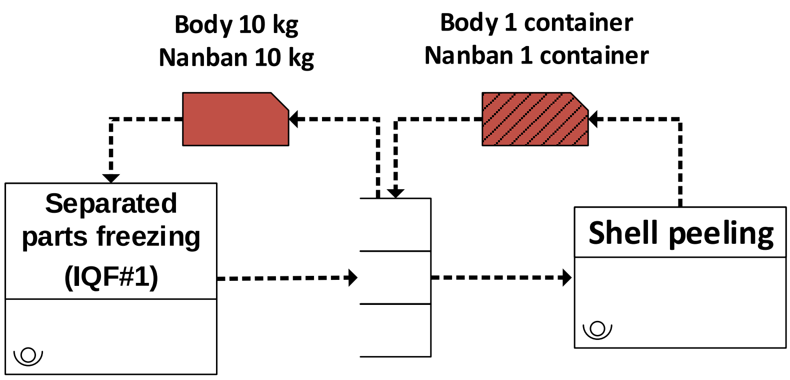


Figure 3-27: Supermarket (Shell Peeling Process)

Operator who is responsible to prepare freezing parts for shell peeling has to wait for the transportation of the freezing parts from air blast room, therefore, the next supermarket will be implemented at part separation process. When a container of each freezing part is withdrawn from the supermarket, the production Kanban will trigger the IQF#1 to refill 10 kg of withdrawal part. Figure 3-27.

In addition, the flow between packing (200g) process and freeze QC & packing should be maintained, however, the supermarket-based pull systems is not practical to keep the inventory between these process. Thus, FIFO ("first in, first out") principle is implemented with a maximum certain amount of work. FIFO lane size is 2,640 Combination bags per day or 66 batches per day. When the lane is full, the production of upstream process is stopped so the factory could avoid overproduction. Figure 3-28ใ

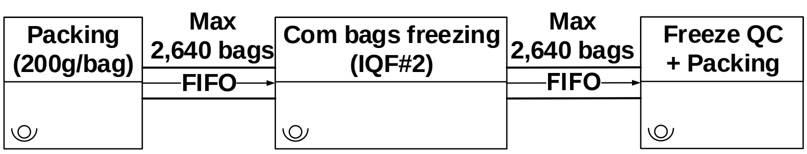


Figure 3-28: FIFO (First in, First out)

3) *Information flow*

   e. *At what single point in the production chain will the company schedule production?*

“The pacemaker process is the process to which production is scheduled; everything before it is pulled from the pacemaker process and everything after is continuous flow.” McDonald et al. (2002, p.222) In the Combination (200g) production, the pacemaker process should be meat combination process. Since the pull system has been implemented between meat combination and blacklight/x-ray process, the pacemaker cannot be schedule upstream. Therefore, this single point will control the overall production of Combination (200g) product.

   f. *How will the company level the production mix at the pacemaker process?*

There is no different types of product in the Combnation (200g) product. Moreover, meat combination is a unique process for the company production so the company cannot level the production mix at the pacemaker process.

However, if the company would like to introduce lean production to all productions, pacemaker process need to be reconsidered and production mix could be levelled. For instance, the production line of cooked snow crab can be produced two types of finished goods, Mix meat and Combination (200g) product. The production of both finished goods is separated that means there is no production of mix meat product on the day that produce Combination (200g) product. Rother and Shook (1999) suggested that levelling the production mix at the pacemaker process could reduce the finished goods inventory because the different customer requirements can be served with a short lead time. Therefore, the factory should produce both product in the same production day since some process can be shared and they use the same R/M and freezing speed.

g. *What increment of work will the company consistently release and take away at the pacemaker process?*

Rother and Shook (1999) emphasized that if large batches of works are released to the production, many problems will be occurs such as the difficulty of tracking and monitoring, the complexity of information, and complication of response to the change of customer's requirement. Hence, they suggested that the consistent increments of work or pitch should be calculated in order to know when and how often the production should be checked. The monitor of pitch leads to the ability to maintain takt time and quickly respond to the problems. Since each batch of Combination (200g) product should be produced 464 seconds (takt time), the pitch of this production is about 8 minutes. Thus, the Kanban will be introduced to the production line in every 8 minutes in order to signal and check if a batch (40 bags of Combination (200g)) is done. The pitch could help production to track their performance. If the production pace is synchronize with the pitch, it could be guarantee that the customer demand is met.

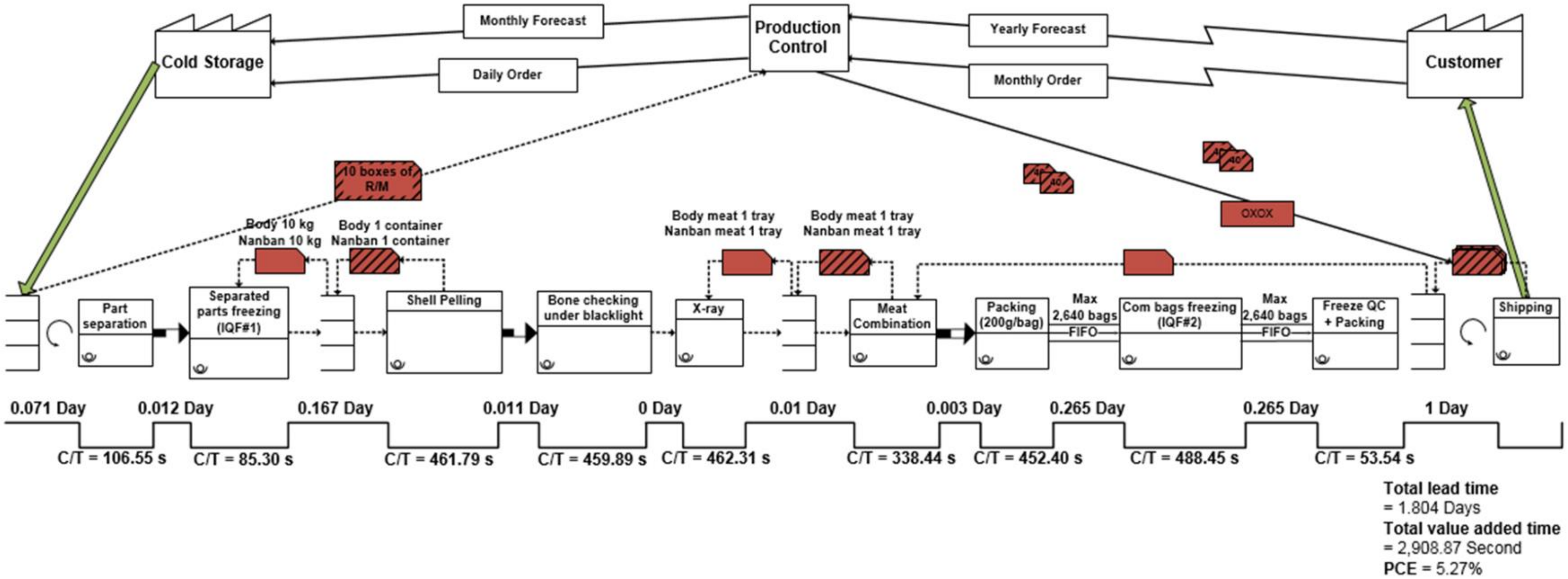


Figure 3-29: Future State Mapping

4) *Supporting improvements*

h. *What supporting process improvements are necessary (key improvement initiatives and critical success factors for implementation of the "future state" map)?*

According to cause and effect analysis, there are seven significant root causes which are need to be solved. The possible solutions have been concluded in the table 3-12.

Table 3-12: Root Causes and Solutions

Root Causes	Possible Solutions
Very different cycle time between the connected processes	- Add more workstations to separate the tasks in the process - Calculate the most suitable workstations and number of operators
Unnecessary tasks	- Consider all tasks in the current process and remove the task that is unnecessary for the process
Unbalance workload	- Increase the number of operators to operate faster response to downstream - Decrease the task in the process while the number of operators is the same
No standard of work/Best practice	- Study the best practice method of work and document as a factory's standard
No performance evaluation policy	- Correct the output performed by each operator or group of operator of specific process - Conclude and visualize the daily output of each process - Set up weekly meeting to share the results and problems - Introduce the reward system
Poor information flow	- Introduce the pull system in the production for instance continuous flow and supermarket
Inappropriate layout	- Re-layout the possible area that could be implemented continuous flow

The future state map in Figure 3-29 shows that the hybrid system, push and pull system, was implemented in the production of Combination (200g) product. Various techniques were applied such as Kanban, supermarket, and FIFO. When the company receives the order from customer, production control will send the required quantity to the shipping department in order to withdraw finished goods from supermarket. Then, production Kanban will be sent back to the meat combination process to produce the withdrawal quantity and push the work to packing (200g/bag) process. The production Kanban size is 40 bags or a batch because it is the size of commercial product. The Combination (200g) bag is flow through the IQF machine to the quality control and packing process using FIFO principle. When the FIFO lane is full, 2,640 Combination (200g) bags a day, the upstream production will be stopped. Therefore, it could say that meat combination process is an only one process that receive production schedule because it is a pacemaker process.

Since the production is scheduled at meat combination process, parts will be removed from supermarket and production Kanban will be trigger x-ray process to refill the removed quantity. The withdrawal and production Kanban size is a tray of shoulder and Nanban meat. A tray of meat (500g) is pulled from the bone checking under blacklight #1 since the continuous flow is implemented between these processes. The separation of workstations is discussed in the next section.

Freezing parts are withdrawn from the supermarket and pushed through the shell peeling process to bone checking under blacklight process. The withdrawal size is one container of frozen shoulder and Nanban. Once they are removed from the supermarket, IQF machine has to produce 10 kilograms of each part to refill the empty supermarket space (1 container = 10 kilograms).

The daily requirement of cooked snow crab R/M is sent to cold storage. An amount of R/M will be prepared in the supermarket. When they are withdrawn to use in the production line, the withdrawal Kanban is sent back to the system in order to trigger cold storage to refill the withdrawal quantity until it reaches the daily required quantity.

3.4. Implementation

To improve the current production, the designed future improvement concept need to be implemented to the entire production flow, however, it is impossible to implement it at once. Rother and Shook (1999) suggested that value stream loops need to be used in order to break the implementation into steps. As can be seen from Figure 3-30, the future state concept of Combination (200g) product could be divided into six implementation loops which were grouped by the flow of information and material. The significant root causes that were analyzed would be fixed by tools and techniques in different loop as follows.

Root Causes	Loop
Very different cycle time between the connected processes	3,5
Unnecessary tasks	All
Unbalance workload	6
No standard of work/Best practice	All
No performance evaluation policy	3
Poor information flow	1,2,4,5
Inappropriate layout	4

The implementation plan in table 3-13 indicates the necessary improvements of each loop. Leaders are responsible to track the progress and drive the improvement to succeed.

Table 3-13: Implementation Plan

Loop	Description	Start date	End date	Leader	Comments
All	Introduce the basic of Lean and 5S principle throughout the company	15-Dec-14	26-Dec-14	Sasitorn	Lean and 5S knowledge
	Create standardized process and procedures of Combination (200g) production	15-Dec-14	26-Dec-14	Suthum	Standardized work document
	Eliminate unnecessary tasks	15-Dec-14	26-Dec-14	Siripong	Reduce cycle time
1,2,5	Set up supermarket pull system	5-Jan-15	9-Jan-15	Parnjai	Establish pull system
		5-Jan-15	9-Jan-15	Wattsana	
3	Line balancing	5-Jan-15	9-Jan-15	Sornnarai	Balance cycle time
5	Balance workload	5-Jan-15	9-Jan-15	Parnjai, Wattsana	Resources utilization
4,6	Establish continuous flow	5-Jan-15	9-Jan-15	Sornnarai	One piece flow
4	Re-layout	5-Jan-15	9-Jan-15	Siripong	Reduce transportation waste and establish continuous flow
3	Performance Evaluation	5-Jan-15	9-Jan-15	Siripong	Set up equipment and system

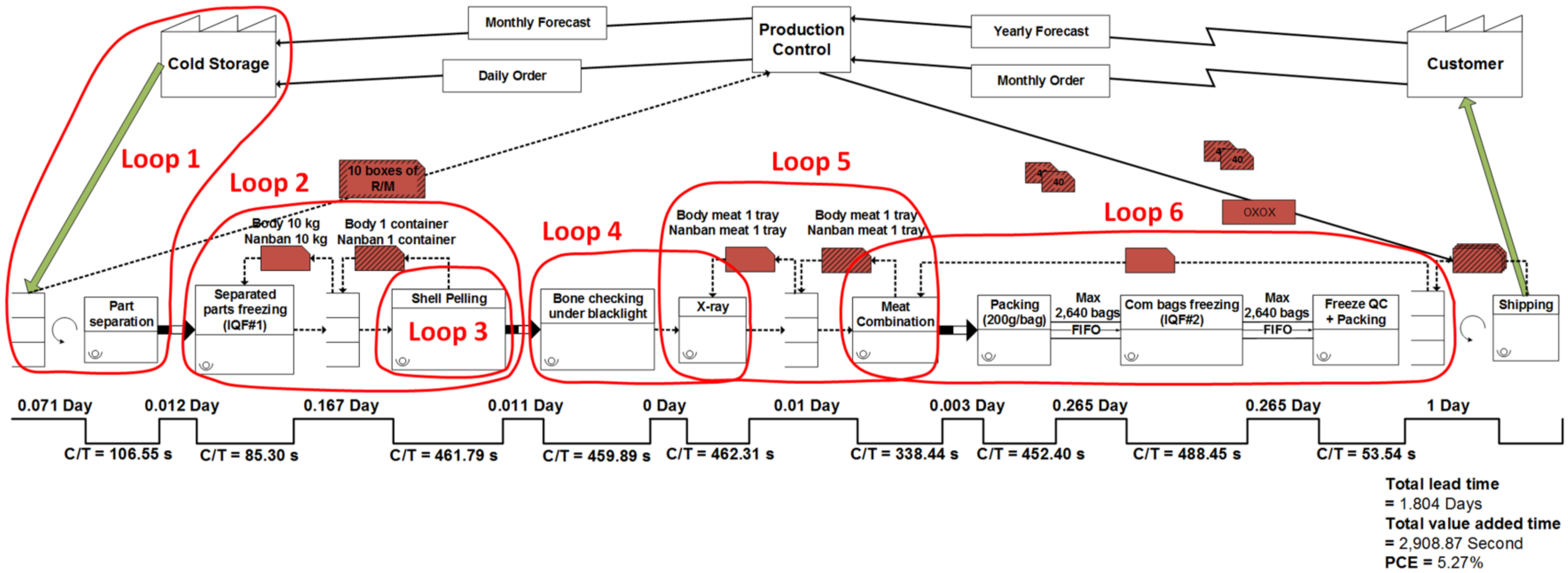


Figure 3-30: Implementation Loops

3.4.1. 5S and lean principle introduction

The basic of 5S and principle has been taught to the supervisor and team leaders since they are close to operators in the production line. They are responsible to inform that there is some changes in the production line because some tools from lean have been implemented. Moreover, the involved operators have to be explained the basic of lean principle such as the definition and purposes including seven wastes.

5S has already been implemented for many years for example there is daily cleaning after work, and the necessary equipment are arranged in the working areas, however, team has found that operators do not know the purpose of doing 5S. Therefore, the meaning of 5S from Alley (2010) has been adapted and attached at the visible area (Figure 3-31). Figure 3-32 shows the production areas that implemented 5S activities. Furthermore, it is necessary to make sure that team leaders including supervisor involves in 5S activities since other operators will realize that these activities are important.

Figure 3-31: 5S (Adapted from Allen, 2010)

Figure 3-32: Production Areas after 5S Implementation

3.4.2. Supermarket implementation

Supermarket is implemented at four loops of production line as follows.

Loop 1: The cart with big bucket is the supermarket in this loop. The bucket has ability to contain maximum 10 boxes of cooked snow crab R/M.

Loop 2: In this loop, two carts are implemented as the supermarket. Each cart has ability to contain 10 containers of freezing parts. Both carts is prepared with full load after IQF machine. When there is a demand from next process, one of the carts will be pulled out to supply the freezing parts. Then, the empty part is returned to exchange another full loaded cart. In a meantime, the return empty cart authorizes the production of freezing part to refill the used amounts.

Loop 5: Two supermarket carts are implemented at this loops. Each cart can contain six trays of shoulder meat and a tray of Nanban meat. Figure 3-33 shows the tray for x-ray meat. The method of using supermarket is same as loop 2. It will be pulled and produced when it is needed.

Figure 3-33: Trays for X-Ray Meat

Loop6: The supermarket of this loop is the rack at cold storage which the finished goods of Combination (200g) product are kept. A committed amounts of finished goods will be withdrawn in order to prepare for shipping on the committed date.

3.4.3. Establish standardized processes and procedures

Liker and Meier (2006) mentioned that standardized work document is a primary tool of establishing standardized processes and procedures. Various standard types have to be created because they serve different functions. They stated that the steps of work in the document could help the company achieves all standards.

The essential standards of the case study company could be divided into three types which are quality standard, process standard, and standard procedures. Quality standard comes from the customer's value which are cleanness, freezing quality, and raw material utilization. Although this standard has been documented, it has to be visualized at the involved areas as a KPI (Key Performance Indicator). Therefore, the expected yield has been set and visualized at part separation and shell peeling process because raw material is transform at these processes. Figure 3-34. The current output is updated hourly on the visual board in the production line so operators know that how much they have produced and how much they have to produce at this point in time.

Daily Targeted Output

Cooked Snow Crab Raw Material 141 boxes

Process	Portion	Weight (kg)
Part Separation	Shoulder	689.75
	Nanban	267.21
Shell Peeling	Shoulder Meat	377.38
	Nanban Meat	112.29

Figure 3-34: Expected Yield

Process standard is a working instruction for operators in the production line. Appendix C. It consists of processing method and steps, number of operators, and cycle time. This information bases on the best practice performance in the past. For instance, the best practice of loading Combination (200g) bags to IQF machine is hitting the bag to the conveyor before making it flat. This is faster than only flat the bag without hitting by 1.37 second per bag.

Standard procedures is a production rules. In the production of Combination (200g) product, Kanban system is implemented in order to increase the efficiency of pull system from supermarket and limit the amount of inventory. Liker and Meier (2006) suggested that this standard should be visualized at the particular work areas and do not need to be documented in the standard work because it is self-explanatory. In this case, withdrawal and production Kanban is implement in the production line. It can be said that Kanban produces a communication system because the information between demand and supply is shared. As the carts are implemented as the supermarket in production line, Kanban cards will be attached at each card in order to show the information and be an authorization of withdrawal and production. Figure 3-35 shows the example of implemented Kanban card. As can be see that all necessary information is in the card such as part description, quantity, R/M container no., production date, and location. It is attached at the cart between IQF #1 and dividing and distribution freezing parts. The full cart with Kanban card is withdrawn from IQF #1 workstation and transferred to production room 3 to prepare for shell peeling process. Then, the empty cart is return with the same Kanban card in order to triggers the upstream process to replenish the withdrawal quantity.

Part Description			**R/M Container No.**	
Freezing Shoulder and Nanban			AKSN 002/15	
			Production Date	14-Jan-15
Qty.	Shoulder	8	**Cart No.**	1
	Nanban	2	**Location**	IQF Machine

Figure 3-35: Kanban Card

3.4.4. Establish continuous flow and pull system

Since the continuous flow is implemented bone checking under blacklight and x-ray process, however, the cycle time of x-ray process was over takt time. Hence, line balancing technique has been used by following the steps in balancing an assembly line from Kumar and Suresh (2009).

Table 3-14: Bone Checking Under Blacklight and X-Ray Tasks and Cycle Time

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
Bone checking under blacklight	1	Prepare meat into small tray	1	66.67	416.67
	2	Black light 1st checking	8	100	
	3	Black light 2nd checking	8	250	
X-Ray	1	Crumble up the meat	3	43.22	505.53
	2	X-Ray	1	462.31	

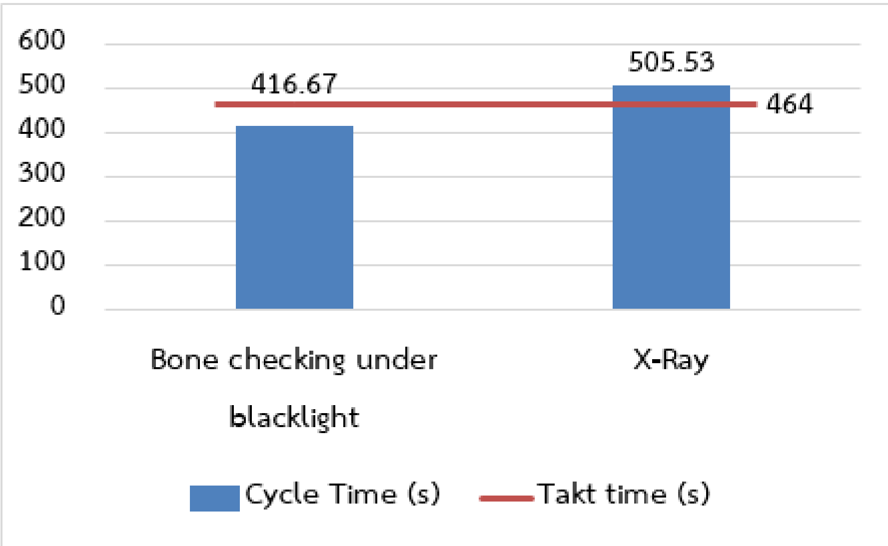


Figure 3-36 Workstations Cycle Time

1) Specify the sequential relationships among tasks using a precedence diagram.

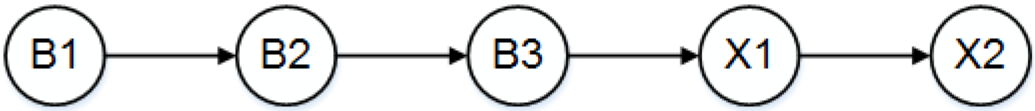


Figure 3-37: Precedence Diagram

2) Determine the required workstation cycle time or takt time that has been calculated previously. Takt time is 464 seconds per unit

3) Determine the theoretical minimum number of workstations (N_t) required to satisfy the workstation cycle time constraint using the formula

$$N_t = \text{Sum of task times (T) / Takt time}$$

$$= (416.67+505.53)/464$$

$$= 1.9875 = 2 \text{ workstations (round up)}$$

4) As can be seen from Figure 3-37, the tasks among these processes have to be performed as a linear sequence.

5) Make task assignments to form workstation 1, workstation 2, and so third until all tasks are assigned. It is important to meet precedence and cycle time requirements.

Two options was purposed. The same number of operators was calculated in the first option. The number of operators in the second option was reduced. Table 3-15 and 3-16.

Option 1

Table 3-15: Task Assignment for Bone Checking Under Blacklight and X-Ray Process (Option 1)

Workstation	Task	Task time (s)	Remaining unassigned time (s)	Feasible remaining tasks	No. of operator
1	B1	66.67	397.33	B2	1
	B2	100	297.33	B3	8
	B3	250	47.33	X1	8
	X1	43.22	4.11	Idle	3
2	X2	462.31	1.69	None	1

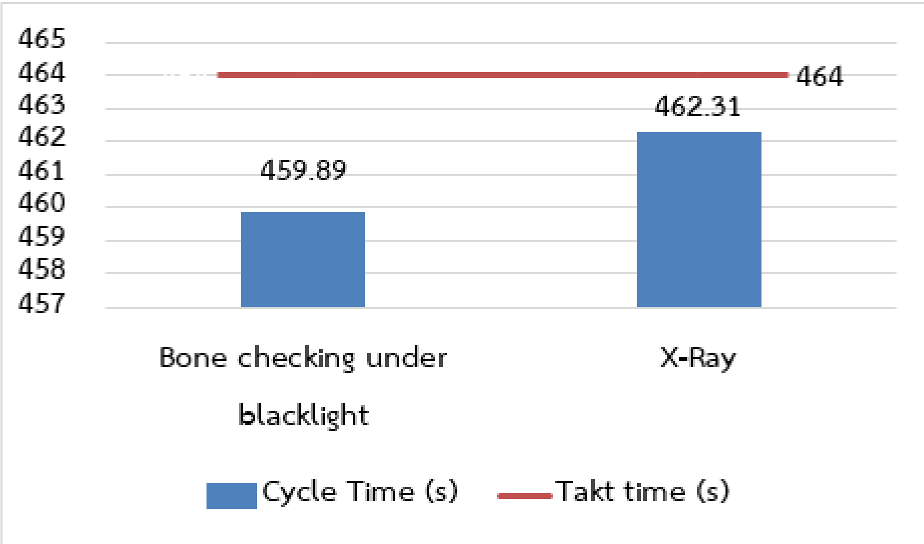


Figure 3-38: Workstations Cycle Time (Option 1)

<u>Option 2</u>

Table 3-16: Task Assignment for Bone Checking Under Blacklight and X-Ray Process (Option 2)

Workstation	Task	Task time (s)	Remaining unassigned time (s)	Feasible remaining tasks	No. of operator
1	B1+B2	216.67	247.33	B3	4
	B3	200	47.33	B3	10
	X1	43.22	4.11	X1	3
2	X2	462.31	1.69	None	1

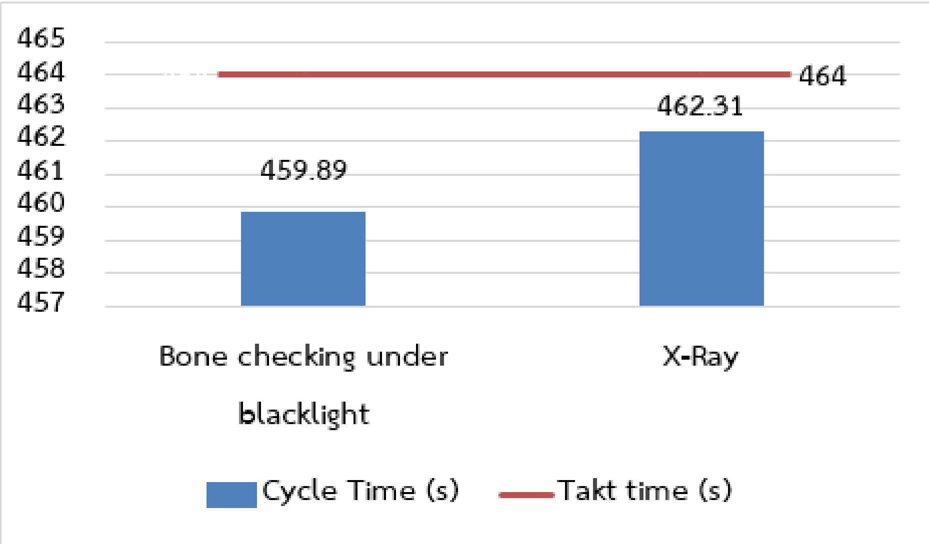


Figure 3-39: Workstations Cycle Time (Option 2)

6) Calculate the efficiency

Efficiency = Sum of task time / (Actual number of workstations x Takt time)

Option 1: Efficiency = 922.20 / (2*464) = 99.38%

Option 2: Efficiency = 922.20 / (2*464) = 99.38%

As a result in Figure 3-38 and 3-39, the total cycle time and efficiency of both options were equal however, the second option seemed to be more suitable because of lower number of operators. However, operators who work at workstation 1 need to be trained because the more bone removed from blacklight station, the less cycle time of x-ray process. This could help the factory achieves the best practice cycle time which was 260.17 seconds. Moreover, it was necessary to re-layout these workstations in order to enhance the effective continuous flow. Figure 3-40.

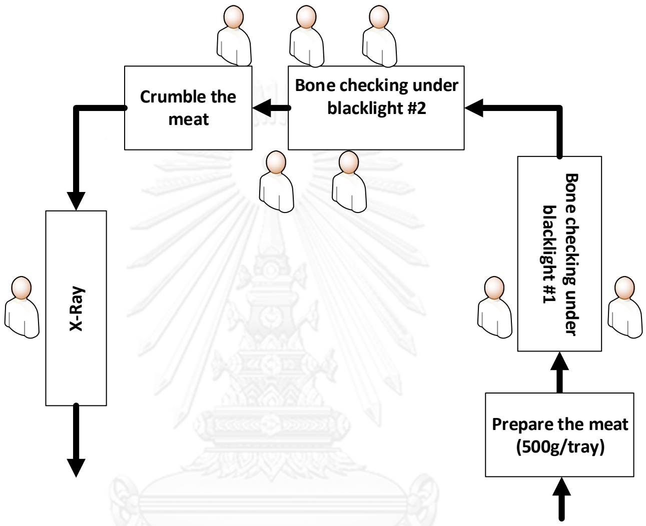


Figure 3-40: Re-layout Bone Checking under Blacklight and X-Ray Stations

As the supermarket was implemented at shell peeling station in order to establish the pull system, operator does not need to walk to air burst room to bring the buckets of freezing parts so its cycle time of 79.01 seconds could be deleted. Table 3-17. Moreover, for the Nanban part, operators had to cut the ended leg before dividing into small tray. This task can be moved to be done at the part separation process since the cycle time was very low. Therefore, the total cycle time of current process is 400.05 seconds which was lower than takt time, however, line balancing technique could be used to enhance process efficiency. Team found that every operators should not walk to take and return the tray by themselves since it wastes time. Hence, an operator was assigned to distribute the trays to each shell peeling table.

Two options are purposed. The same number of operators was used to calculate for option 1. Table 3-18. For option 2, the number of operators who are responsible to divided freezing Nanban part was reduced by two operators because of the removal of cutting end leg process. Moreover, the number of operators who are responsible to peel Nanban was decreased to 10 operators because the operation time of this process was low comparing to peeling shoulder part.

Table 3-17: Shell Peeling Tasks and Cycle Time

Process	Step	Details	No. of operator	Cycle time (s)		Total cycle time (s)
Shell peeling	1	The buckets are brought to production room 3	1	79.01	79.01	479.06
	2	Divide the freezing parts into a small tray			84.49	
	2.1	- Shoulder (18 pieces/tray)	1	26.99		
	2.2	- Nanban (1 kg/tray)--> ***need to cut the ended leg before***	4	57.50		
	3	Each operator take a tray of freezing part to workstation		57.37	315.56	
	4	Peel the shell off				
	4.1	- Shoulder	12	165.75		
	4.2	- Nanban	12	21.16		
	5	Each operator return and wash an empty tray and take the new one		71.28		

Option 1

Table 3-18: Task Assignment for Shell Peeling Process (Option 1)

Workstation	Task	Task time (s)	Remaining unassigned time (s)	Feasible remaining tasks	No. of operator
1	2.1	26.99	437.01	2.2	1
	2.2	57.50	379.51	3	4
	3+5	128.65	250.86	4.1	1
	4.1	165.75	85.11	4.2	12
	4.2	21.16	63.95	idle	12

Option 2

Table 3-19: Task Assignment for Shell Peeling Process (Option 2)

Workstation	Task	Task time (s)	Remaining unassigned time (s)	Feasible remaining tasks	No. of operator
1	2.1	26.99	437.01	2.2	1
	2.2	115.00	322.01	3	2
	3+5	128.65	193.36	4.1	1
	4.1	165.75	27.61	4.2	12
	4.2	25.39	2.21	idle	10

As a result, the efficiency of the first and second option was 86.22% and 99.52% respectively so the second option is more appropriate because of higher efficiency. Moreover, this process could reduce the number of operators which is a cost advantage for the factory.

3.4.5. Balance workload

The cycle time of meat combination process was high. When tasks details were revealed, team found that inappropriate number of operators causes overloaded work. Table 3-20. However, the first task could be deleted because the supermarket was implemented. Therefore, the number of operators should be added in order to balance workload. Table 3-21.

Table 3-20: Meat Combination Tasks and Cycle Time

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
Meat combination	1	Operator walk from P2 to x-ray (P3) to collect qualified meat	1	30	510
	2	Combine shoulder meat, Nanban meat, and water (425:75:100)	1	282.72	
	3	Divide combination meat into bag (200g/bag)	1	197.28	

Table 3-21: Balance Workload of Meat Combination Process

Process	Task	Details	No. of operator	Cycle time (s)	Total cycle time (s)
Meat combination	1	Combine shoulder meat, Nanban meat, and water (425:75:100)	2	141.36	338.64
	2	Divide combination meat into bag (200g/bag)	1	197.28	

3.4.6. Performance evaluation

As low motivation is a cause of low productivity, team has decided to establish performance evaluation policy in order to record the output of individual operator at specific process. Shell peeling process has been chosen in the beginning phase because it is the most difficult process with consumes high cycle time as observation and questionnaire. The cart with digital scale is moved along the shell peeling line to collect the meat from each table. The output of each operator is weighted and recorded. At the end of the week, the record will be evaluated and shared in the meeting. The best performance operators of shoulder and Nanban portion are rewarded separately. Figure 3-41.

Figure 3-41: Performance Evaluation

CHAPTER 4: Results and analysis

After the manufacture line of Combination (200g) product was implemented the designed future state and solutions, the data was kept for two weeks. Appendix D. The output meets the expected target which is 66 batches a day.

Table 4-1 shows the comparison of cycle time, number of operators, and inventory between the traditional and implemented production. The overall trend is improved. The total cycle time is reduced to 2908.87 seconds which is 7.58% improvement. Moreover, the cycle time of all processes is lower than takt time which means that the designed future state and implementation plan enhance the factory productivity and performance to serve the daily expected productivity.

Moreover, the total number of operators is reduced from 82 to 73 since the significant problem of the factory is low operator efficiency. The resources are utilized in the improved production line. At the beginning of implementation, some operators whose responsible tasks are changed may not familiar with the improved production line, as a result of which the cycle time is quite high but it is still lower than takt time. For instance, the average cycle time of bone checking under blacklight almost reaches the takt time, however, the cycle time tends to be lower when they have found the suitable and effective way to finish the job.

Finally, since the pull system and continuous flow were implemented in the production line, the inventory is improved 28.33%. The supermarket is used in the pull system. It helps increase the efficiency of communication between supply and demand processes. In the improved production line, the waste of waiting is eliminated because parts and products are positioned and refilled at the designed supermarket. There is no inventory for the processes that are implemented continuous flow because of one piece flow production.

Table 4-1: Results of Implementation

<table>
<tr><th rowspan="2">Process</th><th colspan="2">Cycle Time (s)</th><th colspan="2">No. of Operators</th><th colspan="2">Inventory (day)</th></tr>
<tr><th>Before</th><th>After</th><th>Before</th><th>After</th><th>Before</th><th>After</th></tr>
<tr><td>Raw material withdrawal and preparation</td><td></td><td></td><td>1</td><td>1</td><td>0.845</td><td>0.071</td></tr>
<tr><td>Part separation</td><td>48.26</td><td>106.55</td><td>12</td><td>12</td><td>0.018</td><td>0.012</td></tr>
<tr><td>Separated parts freezing (IQF #1)</td><td>40.50</td><td>85.30</td><td>4</td><td>4</td><td>0.701</td><td>0.167</td></tr>
<tr><td>Shell peeling</td><td>479.06</td><td>461.79</td><td>31</td><td>27</td><td>0.011</td><td>0.011</td></tr>
<tr><td>Bone checking under blacklight</td><td>416.67</td><td>459.89</td><td>17</td><td>17</td><td>0.022</td><td>0</td></tr>
<tr><td>X-ray the bone</td><td>505.53</td><td>462.31</td><td>4</td><td>1</td><td>0.008</td><td>0.01</td></tr>
<tr><td>Meat combination</td><td>510.00</td><td>338.64</td><td>3</td><td>4</td><td>0.003</td><td>0.003</td></tr>
<tr><td>Packing (200g/bag)</td><td>491.05</td><td>452.40</td><td>1</td><td>1</td><td>0</td><td>0.265</td></tr>
<tr><td>Combination bags freezing (IQF #2)</td><td>603.00</td><td>488.45</td><td>4</td><td>4</td><td>0</td><td>0.265</td></tr>
<tr><td>Freeze checking (sample)</td><td>6.21</td><td rowspan="2">53.54</td><td>1</td><td rowspan="2">2</td><td>0</td><td rowspan="2">1</td></tr>
<tr><td>Packing</td><td>47.33</td><td>4</td><td>0.909</td></tr>
<tr><td>Total</td><td>3147.60</td><td>2908.87</td><td>82</td><td>73</td><td>2.517</td><td>1.804</td></tr>
<tr><td>Improvement rate (%)</td><td colspan="2">7.58%</td><td colspan="2">10.98%</td><td colspan="2">28.33%</td></tr>
</table>

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This research applied lean concept to enhance the productivity in frozen food manufacturing as the company would like to prepare its capacity for the increased demand. The maximum capacity of factory was calculated by focusing at freezing (IQF) and dehydration machine in that these processes consumed the highest amount of production time. The productivity of each product was compared to the calculated maximum capacity in order to know the potential and ability of productivity increment. As a result, the current productivity was much lower than the maximum capacity of factory which means the company could be able to improve its productivity.

The production of Combination (200g) product was chosen to be improved because its productivity was the lowest in the factory. However, IQF machine might cause the problem of low productivity so the overall equipment effectiveness (OEE) had to be calculated. OEE considers various aspects such as Availability (A), Performance (P), and Quality (Q) thus, it could help the company to find the real root cause of low productivity. As a consequence, the IQF machine of Combination (200g) production had OEE value of 70.88% which was no Quality issue. The Performance and Availability value were slightly low which was 81.25% and 88.89% respectively. The low value of Availability because of high set-up time so the company decided to run the machine one hour in advance. The Performance problem caused by high idle time because of product shortage. Therefore, lean tools and techniques were used to improve the performance of production line in order to solve the problem of low productivity.

Managing director, production manager, supervisor, and author as a consultant were grouped as a team in order to fix the low productivity problem. 10% productivity improvement or 66 batches a day was aimed to be a target in accordance with the company goal. Customer's values were revealed which are on time delivery and quality. Value stream mapping technique was used to identify the problems in the current production and match the appropriate solutions for the productivity improvement.

At the beginning, current production needed to be analyzed so the current state mapping was done to show the flow of material and information in the current production line. For this reason, the total cycle time referred to value added time was only 3,147.60 seconds while the total lead time referred to non-value added time was 2.517 days. Meat combination process was the bottleneck process because it spent the highest amount of production time which was 510 seconds. Nevertheless, the current state mapping did not show the whole problems and root causes of low productivity so team observed the current production line to categorize value added and non-value added activities by using seven wastes concept. Since the Combination (200g) product is made to order, the overproduction issue could be cut, however, the remaining wastes were found in the production line. Moreover, spaghetti diagram was sketched to visualize the actual flow of transportation and motion of material and operators in the current process. It shows that the transportation and motion of some process was confuse which need to be improved. In addition, understanding the operators' perspective was done in the questionnaire and interview process. They claimed that shell peeling process was the most difficult process in the Combination (200g) production line. This might be the reason of high cycle time, 478.06 seconds. The interview shows that some tasks, factory layout, and limitation of machine were the working obstacles in the operators' point of view. For example, x-ray machine and meat combination station were located in the different production room hence the parts transportation between these stations took time. The information from current state mapping, observation, spaghetti diagram, questionnaire, and interview was concluded in cause and effect diagram. The problem of low productivity could cause by process, people, environment, and management. All possible root causes were listed in this diagram. Nonetheless, the company was unable to solve all root causes because of the limitation of budgets and resources so cause and effect matrix (C&E matrix) and Pareto chart were used to rate and rank the major root causes. As a result, low productivity problem caused by seven significant root causes which are the difference of cycle time between the connected processes, unnecessary tasks, unbalance workload, no working standard/best practice, no performance evaluation policy, poor information flow, and inappropriate layout. These would be solved by the suitable solution.

After finishing current stage analysis, future state mapping created the visualized improvement. Material and product flow is a key for production line improvement so the continuous flow and pull system were operated at some possible areas by using one piece flow, supermarket and FIFO techniques. Hence, it said that this improved production line is the hybrid system which is the combination between push and pull system. Moreover, Kanban cards are used at each supermarket for withdrawal and production purpose. The withdrawal and production quantity is defined by Kanban size. Meat combination process controls the production of Combination (200g) product since it is a pacemaker process which pull material from upstream process and push the product to FIFO lane. When FIFO lane is full, the production line will be stopped. FIFO lane size has been set at 2,540 Combination (200g) bags a day as it is a daily demand.

Eventually, the suitable solutions were analyzed and implemented in order to fix the significant root causes that were ranked at the beginning. Notwithstanding, 5S is an essential tool of lean principle since it brought about the clean and well organized production line which could enhance production efficiency. Although it has been implemented for many years, the concept and meaning have to be explained and emphasized. In addition, the basic and purpose of lean principle also has to be described to all employees due to the factory improvement concept. For the poor information flow problem, the supermarket was used to establish pull system in order to create the communication between demand and supply in the improved production line. For instance, when material is removed from the supermarket by using withdrawal Kanban card, the production Kanban card will be sent back to upstream process for ordering the replacement. Furthermore, the factory's standards and best practices including working steps were documented. There are three types of standard that are essential to the company. Firstly, quality standard was created since cleanness, freezing quality, and raw material utilization are the customer's values in the quality term. Next, the method and steps of production were developed as a process standard. The best practices were studied and added in this standard. Finally, standard procedures were made to be a production rules.

Since some processes in the production line were established continuous flow and pull system, the tasks in these processes had to be revised. Therefore, line balancing technique was used in the bone checking under blacklight and x-ray process, and shell peeling process. As a result, the tasks in these process were balanced and cycle time was improved. This also solved the problem of different cycle time between the connected processes which leads to high idle time and inventory. Nevertheless, meat combination process which was the bottleneck process could be solved by using line balance technique since the workload was high so more operators were assigned to balance the workload.

The more motivation operators has, the more efficiency and effectiveness production line is. Thus, the policy of performance evaluation was established in order to create the reward system.

As a result in table 5-1, the productivity of Combination (200g) production line has been increased by 10% as a company target. The overall cycle time has been reduced to 2,908.87 seconds which is almost 8% improvement. Consequently, the process cycle efficiency (PCE) is improved to 5.27%. The total lead time has been decreased to 1.804 days. The number of operators has been deleted by 9 operators since there was low operator efficiency. As can be seen from Figure 5-1, after lean tools and techniques were implemented in the production line, the production of each process performs under takt time which can guarantee the ability to serve daily demand and productivity improvement.

Table 5-1: The Improvement Results

	Before	After
Output (batches)	60	66
Cycle Time (s)	3,147.60	2,908.87
Lead time (day)	2.517	1.804
No. of operators	83	74
Process cycle efficiency (PCE)	4.09%	5.27%

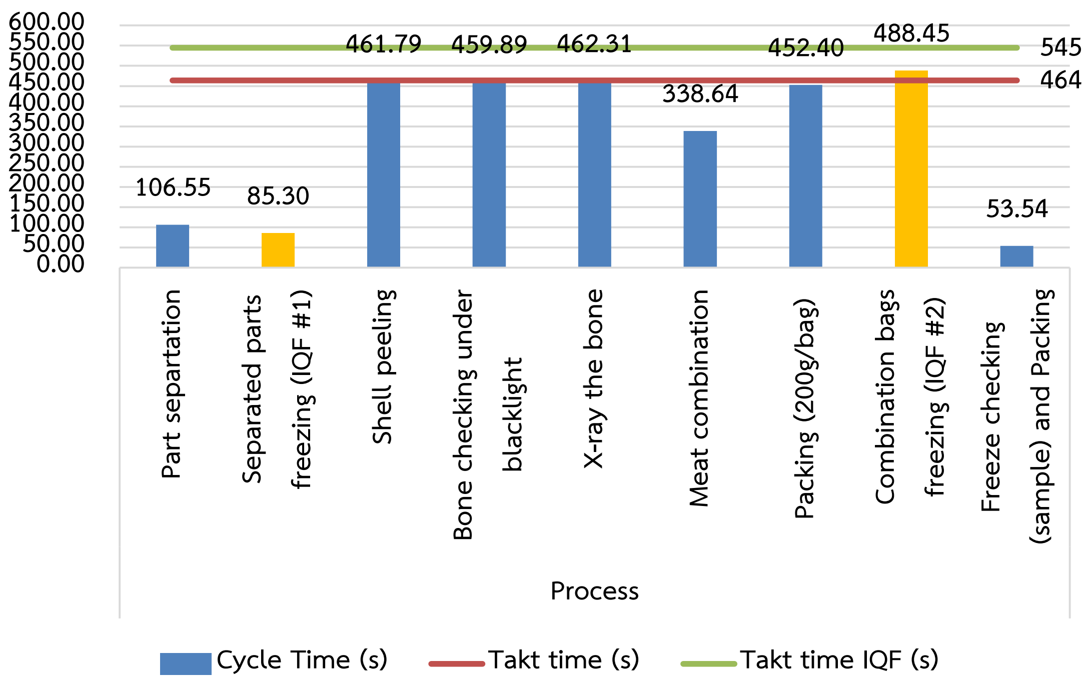


Figure 5-1: Process Improvement Cycle Time

5.2. Recommendations

The productivity improvement in this research focused only on Combination (200g) product so it would be necessary to analyze other product family in order to improve the overall productivity of the company. Other lean tools and techniques need to be researched to adopt the appropriate tools and techniques for each product family. Moreover, since Combination (200g) and Mix meat product use the same raw material, IQF machine, and production line, these production can utilize in parallel. The deleted 9 operators can be assigned to work in Mix meat production. However, the mix quantity has to be calculated by considering the capacity analysis. (McDonald et al., 2002) Furthermore, the remaining root causes of low productivity that were analyzed have to be considered in the future research. The solutions and investment need to be analyzed in order to plan and arrange budget and resources for the future improvement. As can be seen that the production line has been changed for the improvement. It is sure that the change affects the operators who work in this production line so culture change should be studied in order to manage people for adapting the change with the least conflicts. Finally, the resources in the improved production line are utilized so cost benefits should be analyzed in order to evaluate the effective of implemented solutions.

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APPENDIX

Appendix A: Time Study – Before Improvement

No.	Process	Part or Sub-process	Cycle time 1	Cycle time 2	Cycle time 3	Cycle time 4	Cycle time 5	Average cycle time (s)	Total cycle time (s)
1	Part separation	Shoulder	38.58	38.77	39.54	38.68	38.31	38.78	48.26
		Nanban	9.50	9.46	9.61	9.48	9.35	9.48	
2	Separated parts freezing (IQF #1)	Shoulder	32.04	31.25	31.33	30.42	31.14	31.24	40.50
		Nanban	9.23	9.24	9.34	9.20	9.29	9.26	
3	Shell peeling	Shoulder	281.41	264.68	270.29	267.27	272.53	271.24	479.06
		Nanban	205.32	210.82	210.02	207.81	205.14	207.82	
4	Bone checking under blacklight	QC #1	119.05	117.55	121.05	119.05	118.55	119.05	416.67
		QC #2	293.86	297.52	301.54	299.46	295.74	297.62	
5	X-ray the bone	Crumble	43.04	43.33	43.57	42.96	43.20	43.22	505.53
		x-ray	464.18	260.17	382.01	567.04	638.15	462.31	
6	Meat combination		509.40	510.34	509.48	507.15	513.64	510.00	510.00
7	Packing (200g/bag)		491.47	509.19	504.17	498.03	452.40	491.05	491.05
8	Combination bags freezing (IQF #2)	Com. bags	577.05	625.10	557.28	640.03	615.56	603.00	603.00
9	Freeze checking (sample)		6.18	6.22	6.20	6.21	6.24	6.210	6.21
10	Packing		47.28	47.46	48.13	47.24	46.54	47.330	47.33

Appendix B: Interview

Interviewees – Supervisor, team leaders, and operators who have at least one year experience from each process

P.1	Part separation
P.2	Separated parts freezing (IQF #1)
P.3	Shell peeling
P.4	Bone checking under blacklight
P.5	X-ray the bone
P.6	Meat combination and packing (200g)
P.7	Combination bags freezing (IQF #2)
P.8	Freeze checking (sample)
P.9	Packing

Interview Questions

1) As the production schedule is created, do you know how many finished products which are required in each particular day?

   Supervisor: Yes, I know the daily targeted finished goods since I got the production schedule from the management team. The production schedule is set one month in advance and it could be change depends on the change customer requirements or unexpected situation.

   Team Leader 1 and 2: Yes, I know how many finished goods are required each day. I have got a production plan and I have to request for raw material withdrawal a day before the production day.

   P.1: No, I do not know the number of the finished products which are required in each particular day.

   P.2: No, I do not know the number of the finished products which are required in each particular day.

P.3: No, I do not know the number of the finished products which are required in each particular day.

P.4: No, I do not know the number of the finished products which are required in each particular day.

P.5: No, I do not know the number of the finished products which are required in each particular day.

P.6: Yes, I have to know the targeted number of finished goods because I have to withdraw Combination Bags.

P.7: No, I do not know the number of the finished products which are required in each particular day.

P.8: No, I do not know the number of the finished products which are required in each particular day.

P.9: Yes, I know the daily number of finished goods because I have to request for packaging withdrawal.

2) What are the obstacles in your responsible process that lead to low production speed and/or productivity? What do you think is the root cause of the problem? And any suggestions?

   Supervisor: I think there is a high idle time in the IQF#2 process since the previous process has only one sealing machine which a Combination bag (200g) can be sealed each time. I suggest to purchase automatic sealing machine which can seal multiple bags of Combination product at the same time.

   Team Leader 1 and 2: The direction and distance between some processes is quite chaos and far. For instance, to combined and pack cooked snow crab meat, operator who works in production room 2 has to walk to production room 3 many times in order to correct the x-ray meat. Therefore, I think the factory layout need to be adjusted to make an ease of working.

P.1: Since R/W is poured just one side of the table, I have to separate the body and legs. Then push the legs to other members in the table in order to do other process. This leads to the lower production speed because my responsible job is interrupted.

P.2: The separated part basket is very heavy.

P.3: I get tired because I have to stand all day. It would be good if there is the installation of some stool in my responsible station.

P.4: My eyes are exhausted because I have to stare the meat under blacklight for a long time in order to separate the bone from the meat. I suggest to install a magnifying glass in this station.

P.5: If the bone is shown in the monitor of x-ray machine, it takes times to eliminate the bone from cooked snow crab meat.

P.6: I think the sealing process produces a problem of speed reduction. Each Combination bag takes time of sealing since I have to remove some air out of the bag before sealing.

P.7: I have to wait for the Combination bags from previous production for a long time.

P.8: I do not have any problem in my responsible job.

P.9: I do not have any problem in my responsible job.

3) Have you heard about Lean principle?

Supervisor: I know that Lean principle is the method of wastes elimination from production.

Team Leader 1 and 2: I have heard the word of Lean but I do not know what it is.

P.1: No, I have never heard about Lean principle before.

P.2: No, I have never heard about Lean principle before.

P.3: No, I have never heard about Lean principle before.

P.4: No, I have never heard about Lean principle before.

P.5: No, I have never heard about Lean principle before.

P.6: No, I have never heard about Lean principle before.

P.7: No, I have never heard about Lean principle before.

P.8: No, I have never heard about Lean principle before.

P.9: No, I have never heard about Lean principle before

Appendix C: Standardization

Process	Workstation	Step	Work Elements	Number of Operators	Total Number of Operators	Throughput Time (s)	Total Cycle Time (s)	Notes
Part separation	1		R/M transportation	1	13		106.55	- The same pattern is used - Kanban size 10 boxes of cooked snow crab R/M
		1	*Separate cooked snow crab parts*					
			- Shoulder	4		36.26		
			- Nanban	8		6.55		
		2	Cut the end leg of Nanban part			58.29		
		3	Washing			5.45		
Separated part freezing (IQF#1)	1	1	Load the separated parts into IQF machine	2	4	12	85.30	IQF speed = 1.073 m/min Temperature = -45 C
		2	Freeze the parts			916.8		
		3	Remove the freezing parts from IQF machine and divide them into the bucket,10 kg each	2				
			- Shoulder			69.37473594		
			- Nanban			15.92526406		
Shell peeling	1		Freezing parts transportation	1	27		461.79	- Two supermarket carts - Kanban size Shoulder = 8 containers/cart Nanban = 2 containers/cart
		1	Divide the freezing parts into a small tray					
			- Shoulder (18 pieces/tray)	1		26.99		
			- Nanban (1 kg/tray)	2		115.0046		
		2	Distribute to shell peeling table	1		128.64713		
		3	Peel the shell off					
			- Shoulder	12		165.75		
			- Nanban	10		25.39		
Bone checking under blacklight and x-ray	1	1	Prepare meat into tray	4	18	216.67	459.89	
			Black light 1st checking					
		2	Black light 2nd checking	10		200		
		3	Crumble up the meat	3		43.22		
	2	1	X-Ray	1		462.31	462.31	
Meat combination	1		Meat transportation	1	4		338.64	- Two supermarket carts with small trays of x-ray meat - Kanban size Shoulder meat = 6 trays/cart Nanban meat = 1 tray/cart
		1	Combine shoulder meat, Nanban meat, and water (425:75:100)	2		141.36		
		2	Divide combination meat into bag (200g/bag)	1		197.28		
Packing (200g/bag)	1	1	Packing (200g/bag)	1	1	452.40	452.40	
Combination bags freezing (IQF #2)	1	1	Load combination bags into IQF machine	2	4	103.2	488.45	- FIFO lane 2,640 bags per day - For step 1, hitting the bag to the conveyor then, flat it again (best practice C/T = 5.16s/bag)
		2	Freezing			916.8		
		3	Remove the freezing parts from IQF machine and divide them into the bucket,10 kg each	2		385.25		
Freeze QC and packing	1	1	Checking freezing quality (sample)	1	2	6.21	53.54	
		2	Packing (40 bags/box)	1		47.33		

Appendix D: Time Study – After Improvement

No.	Process	Cycle time 1	Cycle time 2	Cycle time 3	Cycle time 4	Cycle time 5	Cycle time 6	Cycle time 7	Cycle time 8	Cycle time 9	Cycle time 10	Average cycle time (s)
1	Part separtation	105.18	106.53	110.21	102.39	111.55	108.66	104.98	106.36	102.08	107.58	106.55
2	Separated parts freezing (IQF #1)	83.36	86.08	85.15	85.30	85.68	86.10	87.02	84.28	86.23	83.81	85.30
3	Shell peeling	464.82	467.05	461.51	468.97	463.26	455.36	455.80	459.82	461.75	459.52	461.79
4	Bone checking under blacklight	465.94	461.77	460.11	463.57	456.60	459.82	458.25	459.35	457.45	456.04	459.89
5	X-ray the bone	480.42	466.40	451.45	457.09	434.85	472.93	482.73	470.97	445.99	460.28	462.31
6	Meat combination	335.64	339.21	339.09	340.70	337.80	340.32	338.18	339.28	337.09	339.08	338.64
7	Packing (200g/bag)	446.72	452.37	455.28	450.53	450.25	452.14	453.80	457.39	459.22	446.30	452.40
8	Combination bags freezing (IQF #2)	494.50	487.80	482.56	482.95	488.16	484.49	489.88	489.49	496.96	487.72	488.45
9	Freeze checking (sample) and Packing	52.78	53.51	54.33	53.68	52.83	53.45	52.98	53.46	53.73	54.65	53.54

VITA

Miss Sasitorn Kamonsuwan was born on 3th October, 1987 in Chonburi, Thailand. In 2010, she received the bachelor’s degree in Information Engineering from King Mongkut's Institute of Technology Ladkrabang (KMITL). After a few years working as a customer quality engineer at Celestica Thailand, she enrolled the dual master’s degree program of Engineering Management and Engineering Business Management offered by Chulalongkorn University, Thailand and University of Warwick, United Kingdom respectively.