Warehouse Processes Improvement using Lean Six Sigma and RFID technology

Miss Pakkaporn Rungruengkultorn

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Computer Science and Information Technology
Department of Mathematics and Computer Science
FACULTY OF SCIENCE
Chulalongkorn University
Academic Year 2021

การปรับปรุงกระบวนการคลังสินค้าโดยใช้ลีนซิกซ์ซิกมาและเทคโนโลยีอาร์เอฟไอดี

น.ส.ภัคภร รุ่งเรืองกุลธร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาวิทยาการคอมพิวเตอร์และเทคโนโลยีสารสนเทศ ภาควิชาคณิตศาสตร์และวิทยาการคอมพิวเตอร์
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2564

Thesis Title	Warehouse Processes Improvement using Lean Six Sigma and RFID technology
By	Miss Pakkaporn Rungruengkultorn
Field of Study	Computer Science and Information Technology
Thesis Advisor	Assistant Professor SOMJAI BOONSIRI, Ph.D.

Accepted by the FACULTY OF SCIENCE, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

.... Dean of the FACULTY OF SCIENCE
(Professor POLKIT SANGVANICH, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Assistant Professor ARTHORN LUANGSODSAI, Ph.D.)

.... Thesis Advisor
(Assistant Professor SOMJAI BOONSIRI, Ph.D.)

.... External Examiner
(Associate Professor PERAPHON SOPHATSATHIT, Ph.D.)

ภัคภร รุ่งเรืองกุลธร : การปรับปรุงกระบวนการคลังสินค้าโดยใช้ลีนซิกซ์ซิกมาและเทคโนโลยีอาร์เอฟไอดี. (Warehouse Processes Improvement using Lean Six Sigma and RFID technology) อ.ที่ปรึกษาหลัก : ผศ. ดร.สมใจ บุญศิริ

กระบวนการคลังสินค้ามีความสำคัญต่อความสำเร็จของทุกองค์กร ดังนั้นการมีกระบวนการคลังสินค้าที่ดีจะส่งผลต่อการมีประสิทธิภาพขององค์กร ซึ่งวิทยานิพนธ์นี้มีวัตถุประสงค์เพื่อปรับปรุงกระบวนการของคลังสินค้าในโรงงานผลิตเสื้อผ้าแห่งหนึ่งโดยการใช้วิธีการของลีนซิกซ์ซิกมาและเทคโนโลยีอาร์เอฟไอดีเพื่อช่วยในการลดเวลาและขั้นตอนที่ไม่จำเป็น ลีนซิกซ์ซิกมาเป็นหนึ่งในวิธีการของแนวคิดการพัฒนากระบวนทางธุรกิจโดยเป็นการรวมกันของเครื่องมือและหลักการระหว่างลีนและซิกซ์ซิกมา ในวิทยานิพนธ์นี้ใช้ขั้นตอนพัฒนาตามวิธีดีเอ็มเอไอซี (DMAIC) ซึ่งประกอบไปด้วยการกำหนด การวัด การวิเคราะห์ การปรับปรุงและการควบคุม นอกจากนั้นยังมีการวิเคราะห์ผังกระบวนการ แผนภูมิสายธารแห่งคุณค่า (Value Stream Mapping) กระบวนการเอสไอพีโอซี (SIPOC) และแผนภูมิการวิเคราะห์เหตุและผลในการวิเคราะห์และระบุถึงปัญหา ในวิทยานิพนธ์นี้ได้ออกแบบกระบวนการใหม่และจำลองโดยใช้โปรแกรมเฟล็กซ์ซิม (Flexsim) ซึ่งผลปรากฏว่าสามารถลดเวลาในกระบวนการ 91.5 เปอร์เซนต์และลดเวลาทั้งหมด 13 เปอร์เซนต์

สาขาวิชา	วิทยาการคอมพิวเตอร์และเทคโนโลยีสารสนเทศ	ลายมือชื่อนิสิต ....
ปีการศึกษา	2564	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

6278012423 : MAJOR COMPUTER SCIENCE AND INFORMATION TECHNOLOGY
KEYWORD: Business Process Improvement (BPI), Lean Six Sigma (LSS), RFID technology, Value stream mapping (VSM), Warehouse processes

Pakkaporn Rungruengkultorn : Warehouse Processes Improvement using Lean Six Sigma and RFID technology. Advisor: Asst. Prof. SOMJAI BOONSIRI, Ph.D.

The warehouse processes are critical to the success of every organization. Thus, a well-managed warehousing process increases an organization's efficiency. The objective of this thesis is to improve warehouse processes in garment manufacturing using Lean Six Sigma and RFID Technology to reduce waste time and non value-added activities of the current processes. Lean Six Sigma is business process improvement technique that combines the tools and principles of Lean and Six Sigma. The DMAIC methodology was employed in this research, which stands for Define, Measure, Analyze, Improve, and Control. Additionally, Model analysis, Value Stream Mapping (VSM), SIPOC charts, and Cause and Effect diagrams are the tools that utilized in warehouse processes to identify and analyze issues. Also, this research replicates warehouse processes by simulating warehouse modeling and cycle time using the Flexsim software. The simulation findings reveal that the new process reduce cycle time by 91.5 percent and reduce lead time by 13 percent.

Field of Study:	Computer Science and Information Technology	Student's Signature ....
Academic Year:	2021	Advisor's Signature ....

ACKNOWLEDGEMENTS

Following accomplishment of this thesis, I would like to acknowledge the following great individuals, without whom this thesis would be hard to complete.

I would like to thank you my thesis advisor, Assistant Prof. Dr. Somjai Boonsiri for her guidance and advice while I worked to complete my research. I would also like to thank my committee members, Assistant Prof. Dr. Arthorn Luangsodsai and Associate Prof. Dr. Peraphon Sophatsathit for their assistance in taking time for my defense and for their insightful comments and recommendations.

Secondly, I want to express my gratitude to Hua Thai Manufacturing for providing data and information on the warehouse processes.

Finally, I would like to thank you my family as a whole for their consistent understanding and encouragement while I conducted research and completed my thesis.

Pakkaporn Rungruengkultorn

TABLE OF CONTENTS

Page

.... iii

ABSTRACT (THAI) iii

.... iv

ABSTRACT (ENGLISH) iv

ACKNOWLEDGEMENTS v

TABLE OF CONTENTS vi

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER 1 1

INTRODUCTION 1

1.1 Background of research 1

1.2 Background of the company 3

1.3 Problem statements 4

1.4 Objective of the research 4

1.5 Scope of the research 4

1.6 Expected benefits 5

Document organization 5

CHAPTER 2 6

LITERATURE REVIEWS 6

2.1 Lean manufacturing 6

2.2 Six Sigma 8

2.3 Lean Six Sigma 14
2.4 RFID Technology 16
CHAPTER 3 20
PROPOSED METHOD 20
3.1 Define phase 20
3.2 Measure phase 21
3.3 Analysis phase 22
3.4 Improve phase 23
3.5 Control phase 25
CHAPTER 4 27
RESULTS AND DISCUSSION 27
4.1 Define 27
4.2 Measure 32
4.3 Analysis 33
4.4 Improve 35
4.5 Control 40
CHAPTER 5 41
Conclusion and Future Works 41
5.1 Conclusion 41
5.2 Future Works 43
REFERENCES 45
VITA 48

LIST OF TABLES

Page

Table 1. Six Sigma tools use in DMAIC methodology 13

Table 2. Simulation model object 24

Table 3. Comparison warehouse process before and after implement Lean Six Sigma and RFID technology 38

Table 4. Average Stay Time of Lean Six Sigma and RFID Implementation, Before and After 39

Table 5. Factors of Lean Six Sigma and RFID Implementation, Before and After 39

LIST OF FIGURES

	Page
Figure 1. Value Stream Mapping of a concept warehouse [3]	7
Figure 2. Six Sigma methodology	9
Figure 3. DMAIC improvement process	11
Figure 4. Improvement objective of Lean Six Sigma	15
Figure 5. RFID system	17
Figure 6. SIPOC chart definition	21
Figure 7. Value stream symbols	22
Figure 8. Fishbone diagram template	23
Figure 9. Warehouse process model (process mapping)	28
Figure 10. Fabric rolls and Inventory tags	30
Figure 11. SIPOC chart in warehouse	31
Figure 12. Current Value Stream Mapping	33
Figure 13. Fishbone diagram	34
Figure 14. Warehouse processes model	35
Figure 15. Average stay time in each process and Overall stay time	36
Figure 16. Future Value Stream Mapping	37

CHAPTER 1

INTRODUCTION

The introduction of the background of the research and the company's introduction are mentioned in this chapter. The problem statement, expected outcomes, and scope of the research are all indicated.

1.1 Background of research

A large number of big corporate organizations are confronted with a variety of internal issues from business processes, such as transportation process, production process, and warehouse process. A business process is a set of activities carried out by a group of people in order to fulfill a particular goal or objective. If business processes are efficient, they will be able to save money and shorten the amount of time needed for a process to complete. Business process improvement (BPI) is one strategy for assisting a business in becoming more efficient and redesigning those processes to accomplish the gains. Firms have used Business Process Improvement to identify methods to reduce the time required to complete procedures, reduce waste and friction, and increase the quality of their products. It functions by identifying areas where operations or personnel abilities can be enhanced to generate more efficient workflow and overall business success. The gradual improvement of business processes is the focus of business process improvement [1]. Entrepreneurs tasked with business process improvement typically use one of the several concepts or methodologies developed to aid in the management of such activities. Different methodologies can be used for business process improvement such as Six Sigma, Lean Management, Total Quality Management (TQM) and Kaizen are often used to support BPI operations inside an organization.

The warehouse process is one of the essential business processes in manufacturing that import, export, transport, manufacture products, and it is the process of storage products for subsequent distribution. A warehouse is any location that is used to store products, and keeping all products in a central area provides control over the products and helps you guarantee that consumers will get orders on schedule. The warehouse process varies according to the warehouse and storage facility, the corporate culture, and the number of products passing through the facility. The main activities that take place in the warehouse include receiving, putting away, storing, picking, packing, and shipping.

Time and process management are critical components of an effective company. One way to determine the process's quality is to analyze the model and simulate time. The simulation tool is used to assess the performance of processes by comparing the current and new processes, which can be measured in terms of lead time, cycle time, or activities accomplished.

1.2 Background of the company

In Thailand, the textile industry is a significant non-Western enterprise that includes more than 2,000 garment businesses and a nearly equal number of textile enterprises. The textile and clothing sector in the nation contributes significantly to the country's gross domestic product (GDP) and export income. However, the textile industry in Thailand primarily exports textiles and garments to the United Kingdom and the United States of America, and because the country faces a shortage of raw materials, therefore, has to import raw materials from other countries. In addition, with a rise in the number of orders, the manufacturing process must become faster and more efficient.

Hua Thai Manufacturing Public Co., Ltd. is an exporter manufacturer of textiles and apparel that provides garments for Coach and Burberry. The whole raw materials supply is comprised of imported goods, and all apparel is exported. In this companies produce men's and women's cloth for export to markets such as Europe, Canada, Japan, the United States, and the Russian Federation. The majority of raw materials are tax-free imports from Hong Kong, Japan, and China but all finished products must be exported.

1.3 Problem statements

This study aims to optimize the warehousing process at Hua Thai Manufacturing. The following are the issues:

1. The existing process has many stages.
2. Manual inventory counting, which is inefficient and waste time.
3. Manual inventory counting requires a large number of employees.

1.4 Objective of the research

The purpose of this study is to examine the implementation of a warehouse process in garment production with the goal of optimizing warehouse operations. In addition, it seeks to resolve warehouse issues and increase the effectiveness of warehouse management processes via the use of Lean Six Sigma and RFID technology.

1.5 Scope of the research

The following conditions will limit this study:

1. This model is intended for use in the garment manufacturing industry's warehousing process.
2. All data for process analysis is derived only from Hua Thai manufacturing.

1.6 Expected benefits

As a result of this research, the following outcomes are expected:

1. To improve the efficiency of the process and to accelerate it.
2. To minimize the amount of time with manually counting stocks.
3. To decrease workforce and more appropriate worker allocation.

Document organization

The following is the structure of this document. In Chapter 2, relevant literature reviews and associated theories are provided, and in Chapter 3, the proposed methodology is discussed in further detail. Chapter 4 presents and discusses the case study and experimental results, while Chapter 5 is conclusion.

CHAPTER 2

LITERATURE REVIEWS

In this chapter, the relevant literature as well as associated theories and concepts are examined, including Lean Manufacturing, Six Sigma, and Lean Six Sigma, which are all business process improvement methodologies. Additionally, this research uses RFID technology to help the warehouse increase efficiency and accuracy.

2.1 Lean manufacturing

Lean manufacturing is a systematic approach to reducing waste and non-value added activities in a production system in order to maintain productivity and enhance quality. It basically adapted to manufacturing processes [2]. The origins of Lean can be traced back to Toyota, a Japanese corporation, the Toyota Production System (TPS), Japanese engineers Taiichi Ohno and Shigeo Shingo pioneered this production strategy which is often referred to as Just In Time (JIT) Production in the middle of the 20th century. After World War II, when Japanese industry owners incorporated a variety of American manufacturing and quality control systems. Toyota's production process is based on Henry Ford's manufacturing techniques and Edwards Deming's Statistical Quality Control principles. The thought process of lean was thoroughly described from Massachusetts Institute of Technology by professors

James P. Womack, Daniel T. Jones, and Daniel Roos in their book “The Machine That Changed the World” in 1991 [3], wherein they contrasted Japanese and American businesses. Continuous improvement or kaizen events, and also redical improvement activities, are used to track aimed at reducing waste. In an effort to decrease task time variability, Lean Manufacturing sets up standardized work procedures. Lean is not just applicable to manufacturing processes; it can also be used to warehouse processes. A warehouse processes can be effectively improved using lean concepts and techniques. The Value Stream Mapping (VSM) is one of the most useful tools available. It defined as a collection of specific operations, both value added and non-value added, that are required to move a product through the production processes of a manufacturing facility. Figure 1. shows a Value Stream Mapping of a concept warehouse.

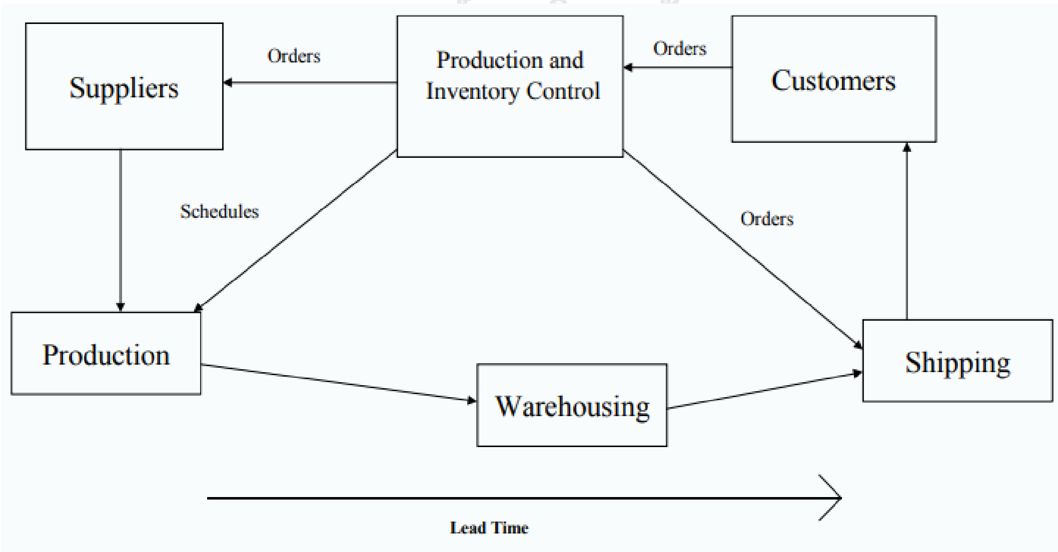


Figure 1. Value Stream Mapping of a concept warehouse [3]

Garcia [4] found that Lean concepts can be utilized effectively in a warehouse context and Value Stream Mapping is an advantageous tool for planning, developing and implementing lean warehouse processes that can effective implementation of lean methodologies results in a 25 percent reduction in lead time and a 50 percent reduction in order picking time, while improving inventory and order processing accuracy. Chen et al., [5] implement lean production and RFID technology to the warehouse and applied Value Stream Mapping to analyze the receiving, storing, picking, packaging, and shipping operations. The results of this case study demonstrated the value of RFID technology implementation in warehouse logistics operations. From the current stage to the future stage, the total time necessary to implement RFID technology into lean can be decreased by 87 percent.

2.2 Six Sigma

Six Sigma is a method used in business process improvement that has been around for a while. It was created for the first time in 1987 at Motorola by American engineer Bill Smith, who is widely regarded as the "Father of Six Sigma." Motorola was the first business to receive the Malcolm Baldridge National Quality Award in 1988, according to the Six Sigma concept implemented by the company. Six Sigma is a method for improving the efficiency of business processes. It refers to the strategies and techniques that are used to identify and discipline business processes in order to improve productivity and eliminate business process defects in an organization. Patel and Desai [6] mentioned that Six Sigma approach is divided into two components: process improvement and design improvement. DMAIC methodology is used in process improvement, whereas DMADV methodology is used in design improvement was shown in Figure 2.

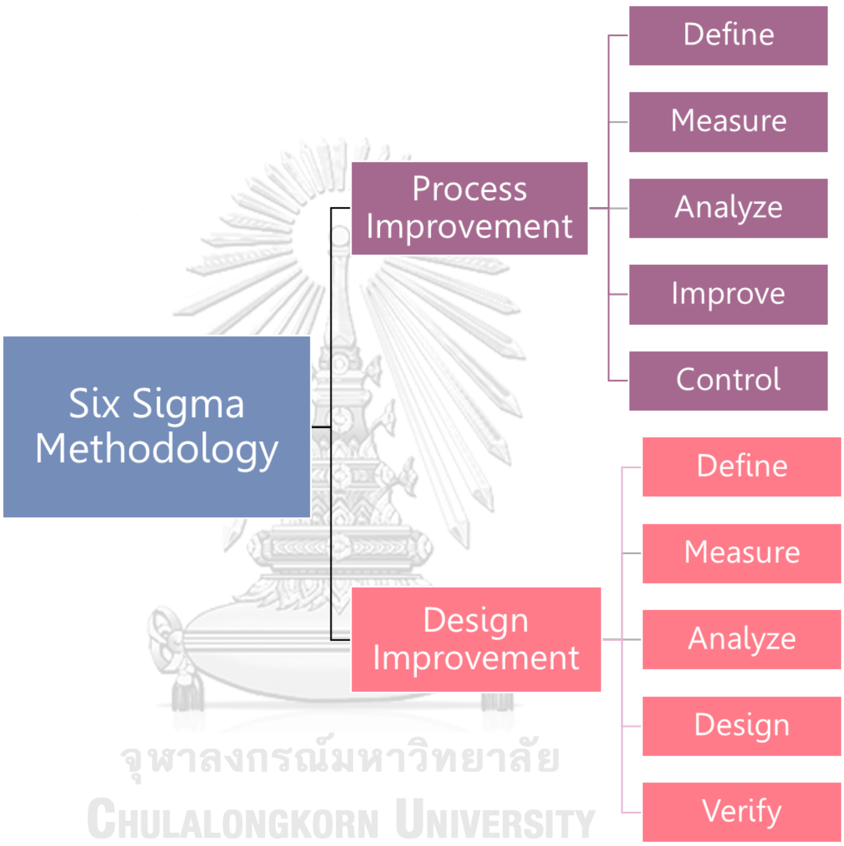


Figure 2. Six Sigma methodology

DMADV is primarily concerned with the process of design a new product. There are Define, Measure, Analyze, Design and Verify phase as follow:

- Define Phase - The project leader identifies the desires and needs that are deemed to be most significant to consumers by using historical data, customer comments, and other sources of information.

- Measure Phase – This phase is to gather data and document requirements in a manner that can be used to drive the remainder of the process using the specified metrics.
- Analyze Phase - This phase analyzes the proposed process or product to evaluate whether there are better methods to attain the intended goals and utilize data to find opportunities by the internal teams to create process improvement that will result in manufacturing process.
- Design Phase – Based on analyze phase, using the information to create the selected design and document the detailed process. Prior to the final product or service being publicly launched, the improved production process is evaluated and consumer test groups provide feedback.
- Verify Phase - The final phase is ongoing and involves adjustments after the product or service is out and client feedback is gathered.

DMAIC is another methodology for improving an existing process. There are the five steps of process improvement in Six Sigma as following phases: Define, Measure, Analyze, Improve, and Control. Figure 3 shows the DMAIC improvement process.

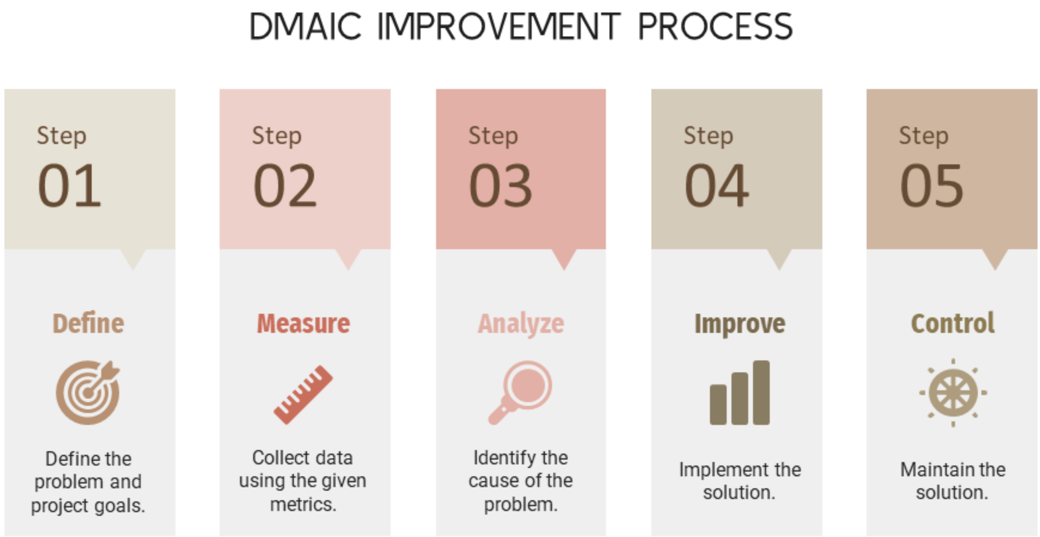


Figure 3. DMAIC improvement process

- Define Phase - In the first phase of the DMAIC methodology, the team leader is defining the definition of the problem and conducting interviews with both internal and external customers to ensure that the issue is really existing.
- Measure Phase – Measurement is crucial throughout the project's duration. The team begin concentrates at the data collection and assessing performance of the problem on current processes. The goals that should to focus are defining the process's starting point and searching for clues to determine the process's root cause.
- Analyze Phase – This phase is collects and analyzes data in order to substantiate theories about the root cause or leading cause of a waste and defect.

- Improve Phase – This phase is to move on to solution improvement that focuses on finding a permanent solution to the problem, implement the solution and then examines a suggested solution to see whether it is effective.
- Control Phase – The last phase of DMAIC. The teams must ensure that all improvements are regulated to sustain changes and outcomes. They begin by documenting precisely how they want to transfer that structure on to the individuals who will be working on the process.

Kumar et al., [7] mentioned that DMAIC methodology is problem-solving approach to identify the factors generating casting errors and regulate these factors. According to the DMAIC methodology, the outcomes of the study are based on several tools and methods, including Pareto analysis, Measurement System Analysis, and Design of Experiments. According to Pyzdek [8] DMAIC is a learning approach that emphasizes the gathering and analysis of historical data in order to carry out improvement actions that have many of tools to collect and analyte the data. Table 1 shows Six Sigma tools in case of DMAIC methodology that are frequently used throughout each phase.

Table 1. Six Sigma tools use in DMAIC methodology

Project Phase	Candidate Six Sigma Tools
Define	☐ Project charter ☐ VOC tools (surveys, focus groups, letters, comment cards) ☐ Process map ☐ QFD ☐ SIPOC ☐ Benchmarking ☐ Project planning and management tools ☐ Pareto analysis
Measure	☐ Measurement systems analysis ☐ Process behavior charts (SPC) ☐ Exploratory data analysis ☐ Descriptive statistics ☐ Data mining ☐ Run charts ☐ Pareto analysis
Analyze	☐ Cause-and-effect diagrams ☐ Tree diagrams ☐ Brainstorming ☐ Process behavior charts (SPC) ☐ Process maps ☐ Design of experiments ☐ Enumerative statistics (hypothesis tests) ☐ Inferential statistics (*X*s and *Y*s) ☐ Simulation
Improve	☐ Force field diagrams ☐ FMEA ☐ 7M tools ☐ Project planning and management tools ☐ Prototype and pilot studies ☐ Simulations
Control	☐ SPC ☐ FMEA ☐ ISO 900× ☐ Change budgets, bid models, cost estimating models ☐ Reporting system

DMAIC is characterized by the systematic approach that focuses on measuring data, eliminating needless operations and employing technology to achieve continuous improvement. Gupta and Kumar [9] presented that Six Sigma can implement in warehouse. This research examines the issue using the Six Sigma DMAIC method and performed to identify and analyze the root causes of the problem and can reduce financial loss in carbon black industry warehouse. It has a variety of tools for data analysis in this research, including the fishbone diagram for determining root causes, the analytical hierarchy method for determining the weighting of each root cause, and the Pareto chart for focusing attention on the most significant root causes. Additionally, it has a brainstorming tool of employee in warehouse that assists in the generation of ideas through the process map analysis.

2.3 Lean Six Sigma

Lean Six Sigma is a continuous improvement methodology and collaborative management technique that focuses on enhancing performance through the elimination of waste and faults. It combines Six Sigma method and lean manufacturing to eliminate waste, reduce cycle times, and ensure the quality of production and organizational processes. The concepts of Lean Six Sigma were first established by Michael George and Robert Lawrence Jr. in their 2002 book, Lean Six Sigma: Combining Six Sigma with Lean Speed as a combination and refinement of lean enterprise and Six Sigma tenets. Lean concepts assist in reducing or eliminating process wastes, whereas Six Sigma focuses on process variation reduction. The combination of Lean and Six Sigma is the best strategy to speed up quality, reduce costs, and reduce complexity. As a result of this, Lean Six sigma emphasizes process improvement and quality control. It provides the most improvement since it fully embraces them at all levels of operation by using DMAIC methodology for obtaining incremental successes that ultimately result in improved quality and waste reduction. Snee [10] mentioned that businesses encounter a range of improvement issues that need the use of the lean and Six Sigma methodology' goals and approaches. While business goals can create Six Sigma projects directly, in a holistic approach, goals can also serve as inputs for Value Stream Mapping (VSM), a lean method that can also be used to produce Six Sigma projects. Figure 4 shows the improvement objectives of Lean Six Sigma.

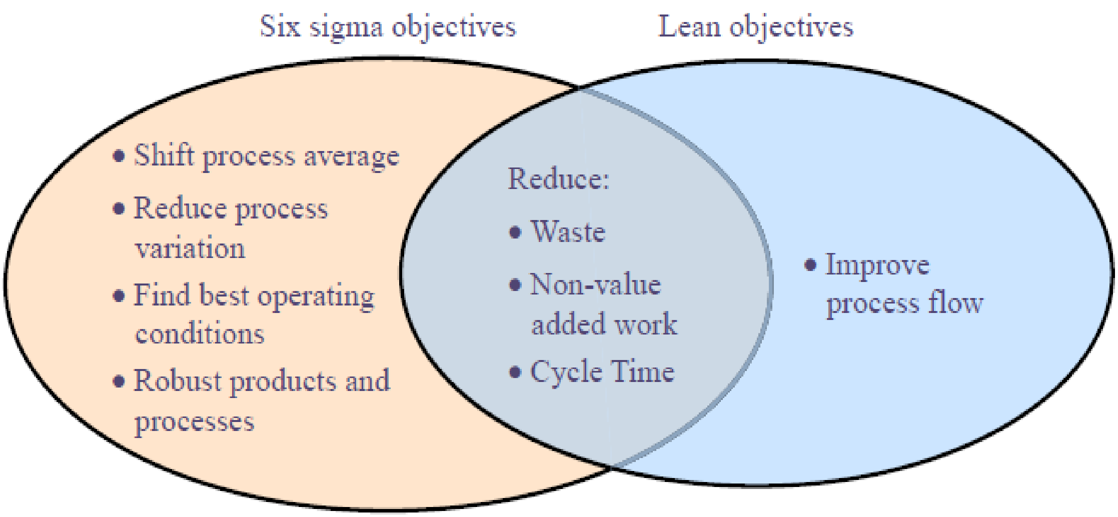


Figure 4. Improvement objective of Lean Six Sigma

When reducing or eliminating process variance is the best solution for the issue at hand, Six Sigma will prevail. Conversely, when reducing process complexity, lean tools will succeed. As a result, Lean Six Sigma is an effective strategy for streamlining process flow in order to reduce complexity, decrease downtime, reduce cycle time, and reduce waste. Pepper and Spedding [11] discovered that Lean Six Sigma should be seen as a prelude to developing more responsive supply chains via efficient communication, which results in strategic collaborations. For example, inventory reductions cannot be enforced in volatile circumstances, resulting in increased variability. As a result, a systematic strategy must be taken to optimize the whole system and concentrate the appropriate techniques in the proper locations.

2.4 RFID Technology

RFID technology or Radiofrequency identification technology is a wireless communication technology that enables computers to read the identification of cheap electronic tags and collect data that involves automatically identifying objects through low-power radio waves. Ernst F.W. Alexanderson demonstrated the first continuous wave (CW) radio transmission and generation in 1906. This accomplishment heralds the beginning of contemporary radio communication, in which all facets of radio waves are controlled. The early 20th century was considered the birth of radar. During World War II, radar used radio waves to detect and locate objects. The radio waves' reflection can establish an object's position and speed. Given that one type of RFID is a marriage of radio broadcast technology and radar, that results in the confluence of these two radio disciplines, and the concept of RFID came in the subsequent of radar development.

RFID is a type of passive wireless technology that allows for searching, identifying, tracking, and communicating items and people. It has emerged as a critical technology for improving production efficiency and effectiveness. RFID is composes of two main parts: tags and readers. A reader is a device equipped with one or more antennas capable of transmitting and receiving electromagnetic signals from RFID tags. These tags, which include a serial number of data, communicate with nearby readers through radio waves. Roberts [12] explained that in most cases, an RFID system will consist of an RFID device (tag), a tag reader equipped with an antenna and transceiver, and a host system or connectivity to an enterprise system, which shown in Figure 5.

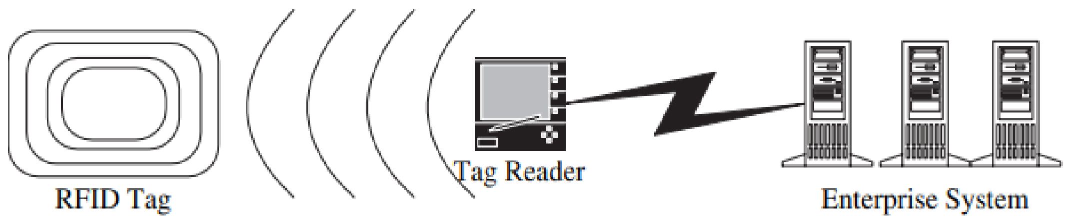


Figure 5. RFID system

RFID system has three components that make them work: an antenna, a transceiver, and a tag. When an antenna and a transceiver are combined, an RFID reader is created. There are two types of readers: Fixed and Mobile readers. Fixed readers are stationary that collect data from an antenna but Mobile readers are handheld readers with antennas built-in. Fixed readers are used in a wide variety of industries and applications because they can be used to identify objects as they pass through a defined area, such as a loading dock, and antennas provide communication, enabling businesses to transport and manage essential information between and within points of business activity. Ahuja and Potti [13] mentioned that there are several varieties of RFID tags, but there are generally categorized as active and passive. An active tag needs a power source and is often limited by the lifespan of its source. It can be attached to a powered device or a battery and limited by the dependency on a powered source. As a result, active tag is unsuitable for regular use because of their cost, size, and lifespan. However, passive tag is appealing because of its independence from a power source and low maintenance required. For a reason, a passive tag is often used due to the inexpensive cost and long lifespan. It is composed mostly of three components: an antenna, a semiconductor chip connected to the antenna, and some kind of encapsulation to protect the tag from the environment. The RFID reader activates and communicates with the tag then the passive RFID tag antenna collects energy from the reader and transmits data between the tag and reader. Wamba et al., [14] presented that the influence of RFID technology on one RFID-enabled warehouse's picking and shipping procedures. RFID implementation can act as an enabler of business process redesign and it demonstrates that the commercial value of RFID technology increases when the tagging process occurs inside the suppliers' facilities, enabling real-time data collection and synchronization, improved data quality, and improved information system integration within and across enterprises in real time. Wang et al., [15] focused on RFID technology that can to track the object movement for a flexible manufacturing assembly line and increase the accuracy of product tracking and lead time, hence improving production operations.

CHAPTER 3

PROPOSED METHOD

This research improves the business process improvement of Lean Six Sigma technique and combines it with RFID technology in the warehouse process of garment manufacturing. Cycle time, model process and lead time were adjusted to improve the process performance. The methodology consisted of 5 phases of DMAIC methodology there are Define phase, Measure phase, Analysis phase, Improve phase and Control phase. Each phase is described in detail below.

3.1 Define phase

Define phase of the DMAIC technique is the first stage in which the primary issue, process activities, and goals of the project are defined. In this phase is focus on the working process and action in the warehouse. The tools that are used for this phase are process mapping and the SIPOC chart. Process mapping is the flow chart that identifies the current process and understanding the conditions that exist during work activities. Describing a process from beginning to end will get a better knowledge of how the process works and find inefficiencies or opportunities for improvement. In this research, swim lane is used to describe the process work in warehouse process. On the other hand, the SIPOC chart is a technique for identifying all of the critical components of a process improvement project prior to beginning work. It is an acronym that stands for Suppliers, Inputs, Process, Outputs, and Customers. This chart was used to quickly review the whole process, including suppliers, outputs, and inputs, in order to identify any potential factors affecting the processes and outputs.

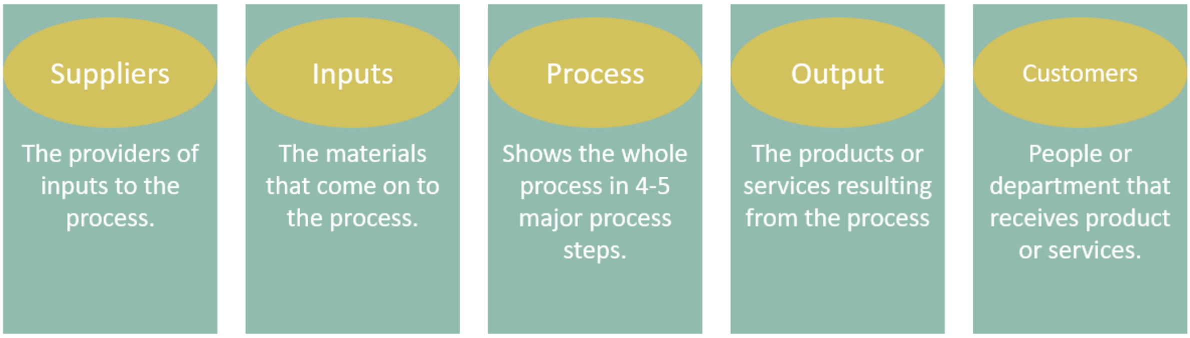


Figure 6. SIPOC chart definition

3.2 Measure phase

Measure phase defines the current state of the process for relevant data to be measured and collected. This phase determines and performs a measurement of the cycle time, lead time, and activity in the warehouse by creating the current Value Stream Mapping (VSM). This tool captures all critical flows such as work, information, or materials in a process and important process metrics. After creating the SIPOC chart and swim lane as required to define the scope and fundamental process phases in the previous phase, that will be able to create current Value Stream Mapping (as-is) in the measure phase. Figure 7 shows value stream symbols of Value Stream Mapping.

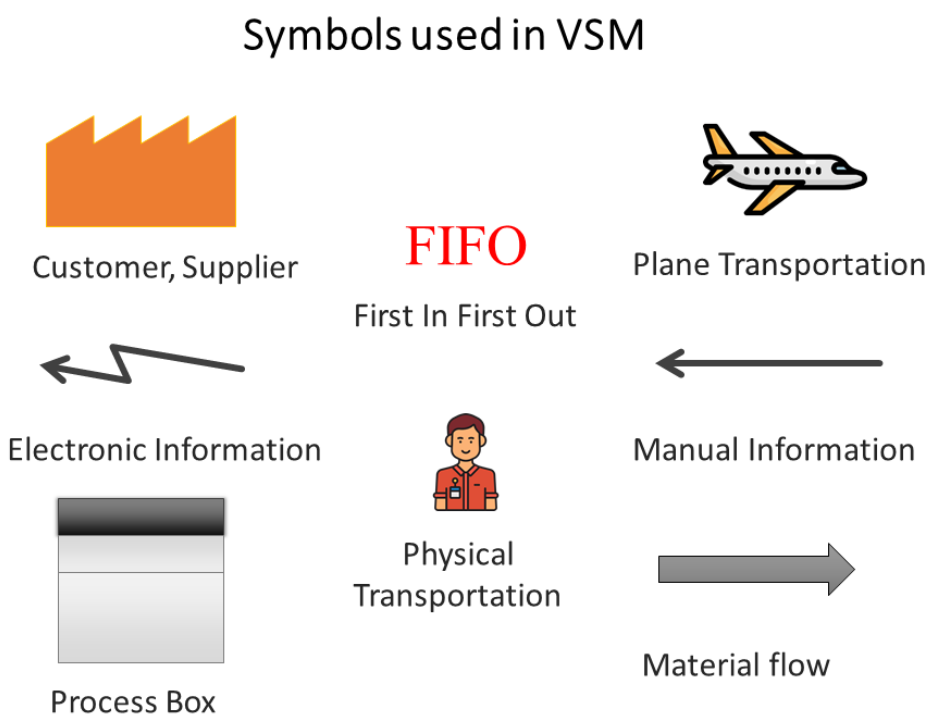


Figure 7. Value stream symbols

To construct a Value Stream Mapping, it should start at the end of the process with the final product supplied to the customer (in this case, the sewing department) and work upstream. Then identify the main activities and shows the movement of all materials. After that, collect process data in the warehouse, connect it to the boxes on the chart, and add lead time data.

3.3 Analysis phase

In the analysis phase, the collected data and information are analyzed. This phase identifies the root causes of the issue, conducts data analysis, and identifies the most significant reasons using a fishbone diagram (also known as the Cause-and-Effect Diagram). The issue should be written at the top of a fishbone skeleton to generate a fishbone diagram. Then, before brainstorming for more detailed causes and creating the design, the key reasons should be determined. The template of the fishbone diagram is shown in Figure 8. Moreover, simulation tool: Flexsim software is used to replicate the results and warehouse processes model that will be employed in the next phase.

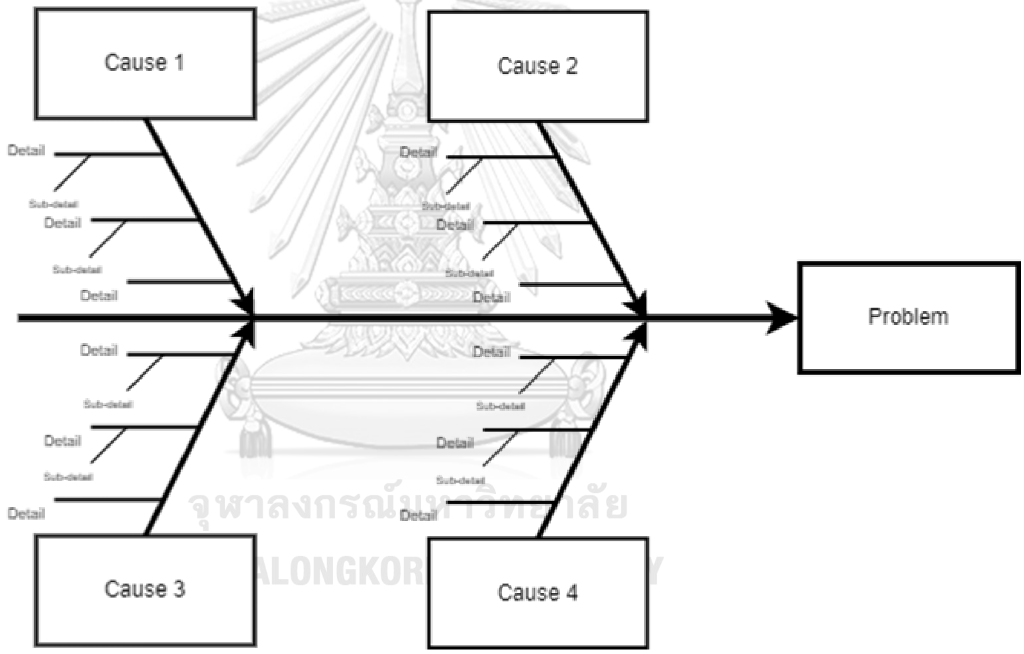
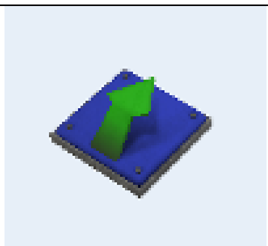
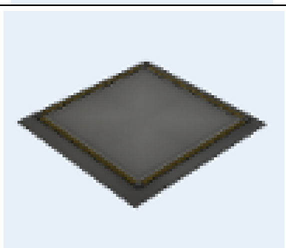


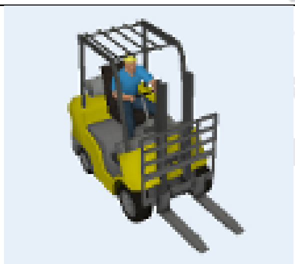
Figure 8. Fishbone diagram template

3.4 Improve phase

This is the stage at which solutions are developed, tested and implemented to improve the process. Once the analysis phase identifies the root causes of the issue, it is possible to implement strategies to eliminate the root cause and begins process changes. In this step, create a future state Value Stream Mapping (to-be) to update the present VSM to reflect the revised approach, including time savings estimates and a streamlined method. On the other hand, this study used Flexsim software to simulate warehouse processes after the application of Lean Six Sigma and RFID technologies to a future state in order to replicate time. This research has two types of object models in Flexsim software: Fixed resources and Task executer. Fixed resources are objects that stay fixed throughout the model and can represent different phases or processes in the model. Task executer is the top-level class for several objects in the library, such as operator that objects can travel, load flow items, and unload flow items. Table 2 describes the simulation model object and the critical concept of Flexsim simulation.

Table 2. Simulation model object

Objects	Type in Flexsim	Description
	Fixed resource	The source is what generates the flow items that transit the model.
	Fixed resource	The queue is used to store flow items that a downstream object has not yet accepted. By default,

		the queue operates on a first-in-first-out principle.
	Fixed resource	The processor is used in a model to simulate the processing of flow objects.
	Fixed resource	The sink is used to stop flow items that are finished in the model.
	Task executer	Operators can be invoked by objects for setup or processing purposes. They will remain attached to the object that called them until released.
	Task executer	The transporter is mostly used to move objects in a flow from one object to the another.

3.5 Control phase

Control phase is the last phase in DMAIC methodology. The improvement can only be sustained by controlling the project. It establishes a technique for controlling and validating the process by devising a strategy that anticipates the problem if performance begins to deteriorate. This phase should create supporting procedures and documentation to ensure that full-scale implementation can be sustained.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter discusses using research methodology belonging to DMAIC techniques utilizing a case study of warehouse garment manufacturing. This research applied lean Six Sigma of business process improvement and RFID technology in this warehouse to improve efficiency and reduce cycle time in the warehouse process. In addition, simulation tool is used to determine the warehouse process and simulate time.

4.1 Define

The warehouse process involves store materials or arrange and prepare materials for shipment at the specified time, actual quantity, and good quality. Thus, the warehouse's major logistical activities include receiving raw materials, checking and managing goods, storing materials in the warehouse, picking, and shipping. This warehouse process in the case study garment manufacturing was identified in process mapping (as-is process) as shown in Figure 9.

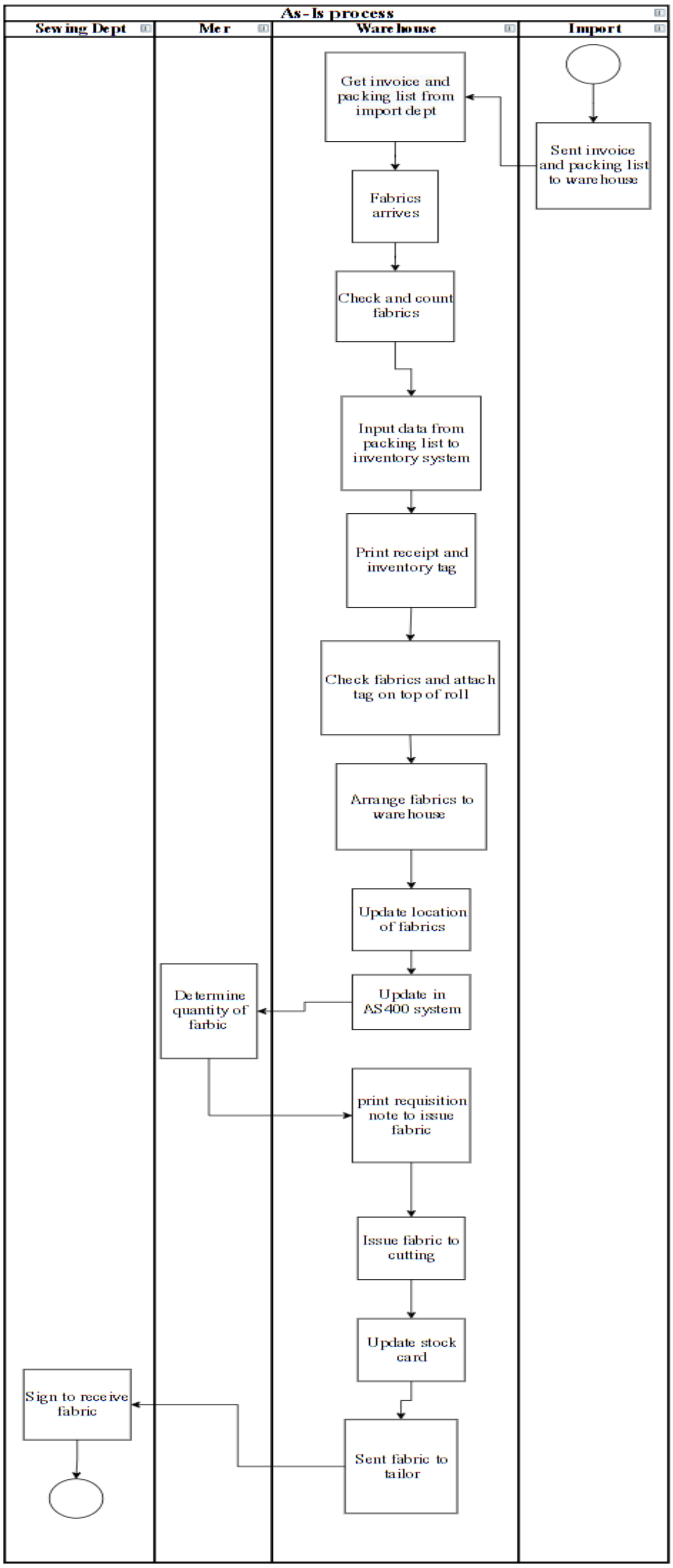


Figure 9. Warehouse process model (process mapping)

The warehouse process in this research needs to store raw materials that are fabrics into the warehouse and deliver them to the sewing department for the next production in garment manufacturing. The invoice and packing list ordered from a supplier in another country, such as Japan or Hong Kong, will be sent to the warehouse department by the import department. When raw materials arrive at the warehouse front door, staff must manually verify that the quantities of raw materials match to the packing list. The packing list is occasionally delivered by the provider; in this instance, the staff must create the packing list themselves. Following that, the personnel will unload raw materials into a temporary storage area, and the quality department will check the quality of the fabric to see if there are any flaws. Employees will enter data from the packing list into inventory management and print inventory tags, if the quality check is passed. Workers will next clip inventory tags to fabrics roll’s top and carry raw materials from the temporary storage area to the warehouse racks. Make sure to update the location in the inventory system as well as the Goods Receive Note (GRN) in the AS400 system after shifting materials to a warehouse so that the merchandiser can determine how much textile is needed for the sewing department. Figure 10. shows the example of inventory tags and fabric rolls in the warehouse.

Figure 10. Fabric rolls and Inventory tags

If a corporate employee is required to pick up material, he or she will create requisition notes and issue fabric before selecting the material from warehouse racks and transporting it to an automated fabric cutter machine. He or she will make a note on the stock card after cutting the cloth to update the new length of fabric that has been cut. The fabric will then be transferred to the sewing department, where staff must sign the request notes before it can be supplied to the production line.

During the define phase, SIPOC charts are another tool that is employed. This tool is being used in this research to capture the warehousing process in order to gather more information and scope for the analysis. Figure 11. shows the SIPOC chart in this warehouse garment manufacturing.

S	I	P	O	C
• Fabrics for Burberry clothes. • Fabrics for Coach clothes.	• Raw materials. - Fabric.	• Check raw materials. • Arrange fabrics to warehouse. • Update fabric location. • Create requisition note. • Cutting fabrics.	• Fabrics for tailor.	• Sewing Department

Figure 11. SIPOC chart in warehouse

According to the SIPOC chart, this warehouse has 2 primary suppliers, implying that textiles for Burberry and Coach clothing. The warehouse's input is focused on fabric, as is the warehouse's output, which is also focused on fabric. Additionally, the warehouse processes have 5 main steps:

1. Check the quantity and quality of raw materials.
2. Store raw materials in the warehouse rack.
3. Update the fabric's location.
4. Create a requisition note.
5. Cutting fabrics.

After obtaining output, the product is sent to the customer, which in this instance is the sewing department. The SIPOC chart demonstrates that caution must be used while storing materials due to the fact that there are several varieties of fabric that must be handled according to the brand utilized.

The last section of the define phase is the problem definition section. This warehouse counts items manually, which takes too much time and introduces human error, based on employee comments and warehouse operational procedures. Another issue is that manually counting products takes a huge number of personnel.

4.2 Measure

The warehouse processes are defined by process mapping and SIPOC chart but those tools show only basic processes without details and time. The measure phase needs to collect data in the warehouse processes using Value Stream Mapping to create the current process (as-is process) to identify production lead time, activity in the warehouse, and processing time before improvement. Figure 12. shows the current Value Stream Mapping in this warehouse.

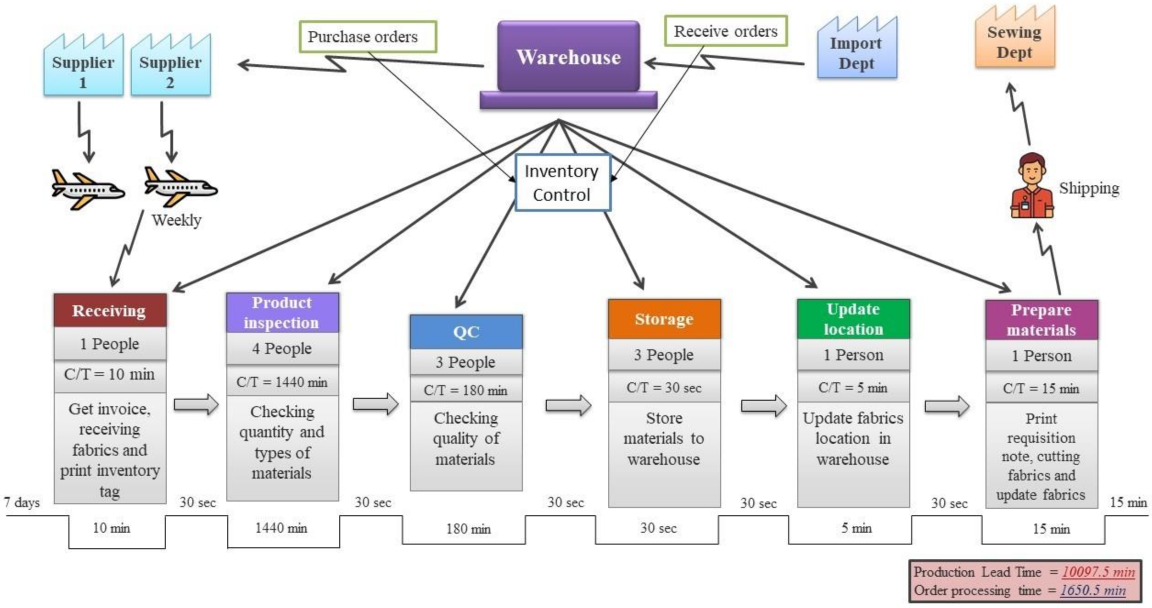


Figure 12. Current Value Stream Mapping

The existing Value Stream Mapping clearly depicts the warehouse process start from the beginning. The total lead time in the process is 11,748 minutes and production lead time is 10,097.5 minutes. The operation is divided into 6 parts: receiving, production inspection, quality control, storage, update location, and preparation materials. The average cycle time in each operation is in order as follows: 10, 1440, 180, 0.5, 5, and 15 minutes. So, the total cycle time in the current process is 1,650.5 minutes.

4.3 Analysis

This stage focuses on identifying the root causes of the primary source of the issues in order to improve the warehouse processes' accuracy and efficiency.

Fishbone diagram (Cause-and-effect diagram) is used to define the actual source of these problems. Figure 13 shows the fishbone diagram in the warehouse processes.

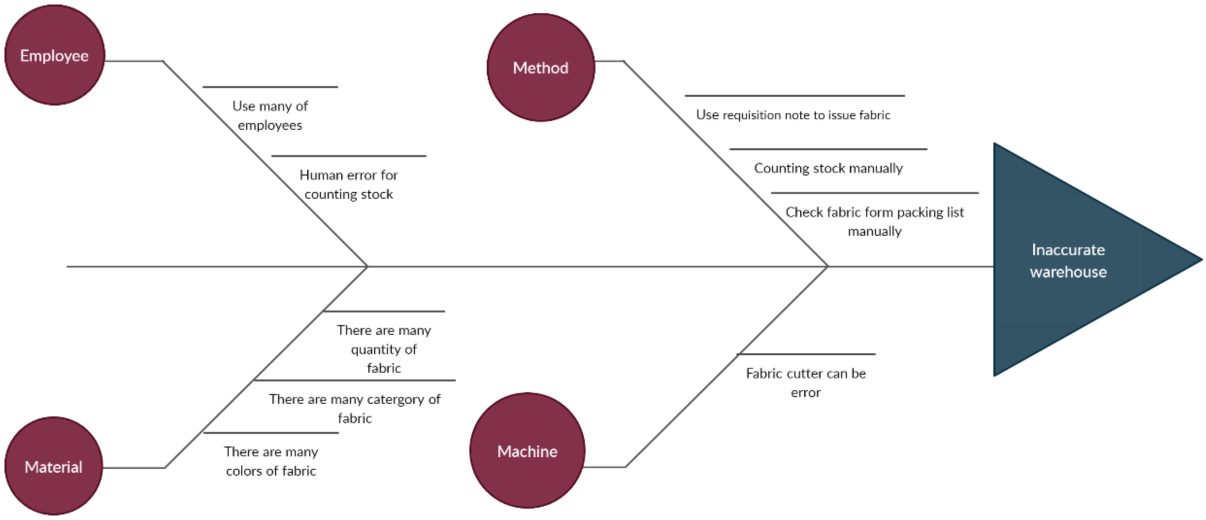


Figure 13. Fishbone diagram

There are several reasons for warehouse inaccuracy. First, the personnel make human errors when counting goods and employ a large number of people. Second, raw materials are split into several categories and amounts, making storage and retrieval problematic. The third cause is personally inspecting and counting textiles. Finally, there is a problem with the cutter machine. According to the investigation, this procedure appears to include a big number of personnel, some of whom may be shifted to other production departments to boost their worth to the company.

4.4 Improve

Following the analysis of root causes in the previous phases, it is time to optimize the current process in order to decrease waste and cycle time by identifying the optimum solution. Therefore, this research simulates the time and warehouse processes that combine with RFID technology by Flexsim software. Figure 14 shows the warehouse processes model to simulate processing time.

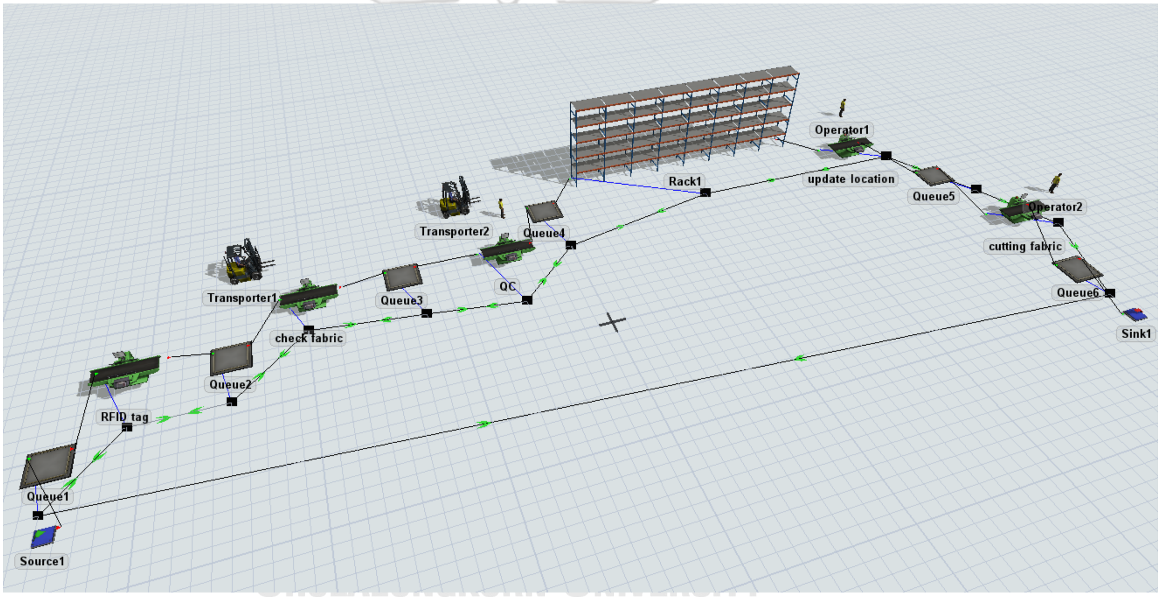


Figure 14. Warehouse processes model

The source, operator, processor, queues, transporters, rack, and sink must all be created to establish a simulation model. The term "source" refers to the supplier who supplies raw materials, "sink" refers to the stoppage of flow in warehouse processes, "processors" refers to each operation in the warehouse, "operators" refers to warehouse employees, and "transporters" refers to the car transport used to transport fabrics. Following constructing an object simulation, connect each object using the entities function. After combining RFID technology with a simulation model, Flexsim software can simulate the duration of each process and the overall processing time. Figure 15 shows the average stay time in each process and overall stay time.

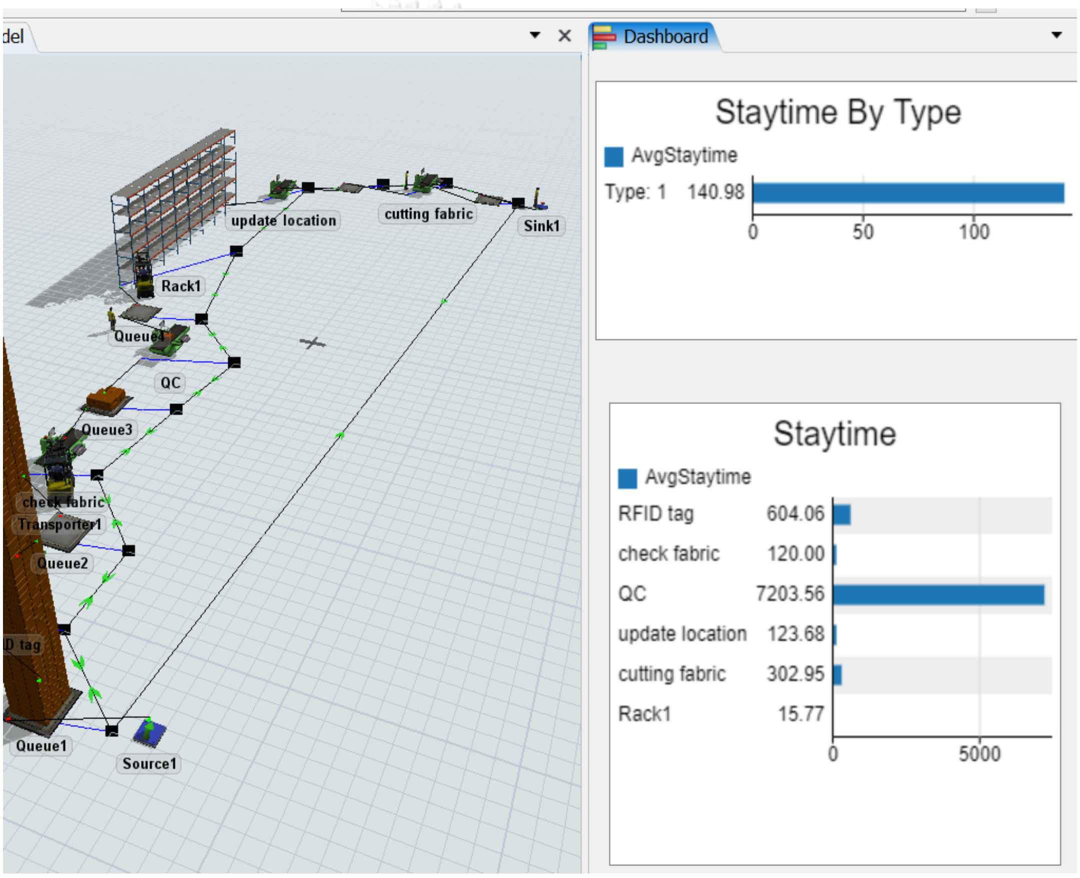


Figure 15. Average stay time in each process and Overall stay time

After a period of simulation, an improvement in future Value Stream Mapping was demonstrated, which reduced waste time and non value-added activities, resulting in process delays. Figure 16 shows a future Value Stream Mapping warehouse combined with RFID technology.

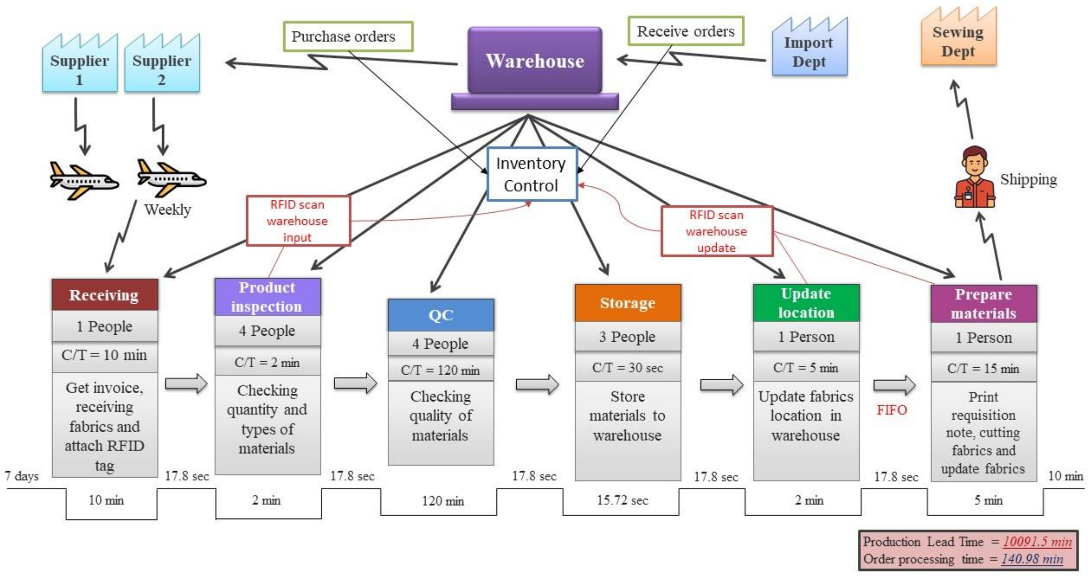


Figure 16. Future Value Stream Mapping

In this warehouse, several stages can be time-consuming. Table 3 compares the warehouse process before and after implementing Lean Six Sigma and RFID technology. After future process enhancements, it will be able to minimize unnecessary activities in each primary process, as well as decrease waste time and increase the quality of the garment warehouse. Another benefit of the trend of applying technology is that it can replace human labor in warehouses, hence reducing human error.

Table 3. Comparison warehouse process before and after implement Lean Six Sigma and RFID technology

Main Process	Current Task	Future Task
Receiving	Print inventory tags	Use RFID tags
Checking raw materials	Unpack and counting manually	Open application and checking by RFID
Raw materials storage	Quantify arriving materials	RFID scanning of arriving materials
Finding raw materials	Select raw materials	RFID scanning
Update location	Update manually	Real-time update

Implementing Lean Six Sigma and RFID technology solve the problem of inefficient warehouse processes and reduced processing time according to future Value Stream Mapping (to-be process). Additionally, in order to implement a FIFO warehousing system, kind and amount of fabrics would decide the allocation of textiles to storage. Different categories of objects would be sorted and stored by different places. As a result, the warehouse processing time is just 140.98 minutes and the production lead time is only 10,091.5 minutes. Following the execution of the simulation model, the simulation duration and results are examined, as shown in Table 4. It shows a comparison before and after Lean Six Sigma, and RFID implementation average stays time of each process. In addition, the various results obtained from the improvement warehouse processes are shown in Table 5.

Table 4. Average Stay Time of Lean Six Sigma and RFID Implementation, Before and After

Process	**Average stay time before Lean Six Sigma and RFID implementation (sec)**	**Average stay time after Lean Six Sigma and RFID implementation (sec)**
Receiving	610.00	604.07
Product inspection	86,400.00	120.00
Quality Control	10,800.00	7,204.08
Storage	30.00	15.77
Update location	300.00	123.68
Prepare materials	900.00	305.28

Table 5. Factors of Lean Six Sigma and RFID Implementation, Before and After

Factors	**Before Lean Six Sigma and RFID implementation**	**After Lean Six Sigma and RFID implementation**
Overall lead time for the warehouse processes	11,748.00 Min	10,232.48 Min
Number of employees	15 people	11 people
Storage location information	Manually	Automatically and real time

As a consequence, the cycle time for each process, including receiving, production inspection, quality control, storage, location updates, and material preparation, is reduced, resulting in a reduction in total lead time. Time is reduced by 604.7, 120, 7204.08, 15.77, 123.68, and 305.28 seconds in each process, correspondingly. After implementation, the overall lead time is reduced to 10,232.48 minutes, a reduction of 13 percent. The average time required to complete all activities was reduced by 91.5 percent. Furthermore, analyzing warehouse processes allows the reduction of work force, more appropriate worker allocation, and process acceleration. Additionally, the location of materials is updated in real time and with increased accuracy, which simplifies the process of counting, locating materials and decreasing lost fabrics.

4.5 Control

The final phase, known as the Control phase, is to ensure that the benefits gained through improved processes are sustained by control and monitoring of operations. Thus, warehouse processes need to include a control phase to guarantee that the proposed improvement strategies are implemented consistently. This phase involves the expansion of control and monitoring methods throughout manufacturing, and also process mapping updates and personnel training.

CHAPTER 5

Conclusion and Future Works

In this chapter discusses the research's findings and makes comparisons between existing processes and simulation results. Additionally, it discusses future work.

5.1 Conclusion

The textile and garment industry in the country makes a significant contribution to the country's gross domestic product and export revenue, since clothing is a need in daily life, increasing the quantity of orders and necessitating a speedier production process. However, with the emergence of numerous manufacturing industries in Thailand and overseas, the market has become more competitive. If the production process is too sluggish, the client base will dwindle. As a result, manufacturing requires a thorough understanding of business processes. Due to growing market competition, manufacturers are seeking for methods to improve current business and management processes in order to remain competitive.

This research examined at how to improve warehouse processes using a business process improvement methodology based on Lean Six Sigma methodologies and RFID technology. The case study is Hua Thai garment manufacturing warehouse processes that import textiles from another nation and store just raw materials prior to shipping to the production line for sewing clothes. This warehouse begins implementing Lean Six Sigma using 5 phases of the DMAIC methodology. The define phase analyzes current warehouse processes using process mapping and a SIPOC chart based on employees' comments and process practices. The existing warehouse has a problem statement in that items are counted manually, and a large number of staffs are required. All information will be used in the subsequent phase. The measure phase use Value Stream Mapping to organize existing processes in order to create current metrics and identify waste throughout the distribution process by recording warehouse processes cycle time to determine the waiting time, transporting time, and processing time using current Value Stream Mapping. The analysis phase employs a cause-and-effect diagram to determine the root causes of these defects. There are 4 primary causes of error: the worker, the materials, the method, and the machine. The improve phase aims to optimize and improve warehouse processes in order to reduce process waste and cycle time that show in future Value Stream Mapping. Control is the last phase. This phase control and monitoring approach is spread throughout operations, including process mapping updates and employee training.

Flexsim software is used as simulation tool for mimic warehouse processes including modeling and simulating the duration of each activity. As a consequence of using Lean Six Sigma with RFID technology in the warehouse, RFID is capable of collecting, transferring, verifying, and updating data. The FIFO warehouse system is encouraged by categorizing textiles for storage and ensuring that the first material or unit load to enter the warehouse is the first one out. This results in a high rate of stock turnover, increased warehouse space, and simple access to materials. After running the simulation and creating the future Value Stream Mapping, it is determined that the average time needed to accomplish all activities is 140.98 minutes, implying a 91.5 percent reduction in cycle time and the average production lead time is only 10091.5 minutes that give average total lead time provide only 10232.48, representing a 13 percent reduction in total lead time. Additionally, the workforce in the warehouse is decreasing as a result of process improvements and the use of technology to promote efficiency. Also, analyzing warehouse processes provides more precise personnel allocation and accelerates the process. Moreover, the location of items is updated in real time and with greater accuracy, which simplifies the process of counting and locating materials.

5.2 Future Works

The future works are listed as follows:

Firstly, although this research is limited to data gathered from warehouse garment manufacturing, the model could be adapted to other warehouses within the same business or to other manufacturing that requires comparable management or production processes within the enterprise.

Secondly, due to the fact that this study utilizes warehouses that keep solely raw materials use only in the manufacturing, no customer feedback is accessible. As a result, this model can be used to construct warehouses in conjunction with customer requirements.

Thirdly, this research employs Lean Six Sigma techniques in conjunction with RFID technology. It can enhance warehouse productivity by combining Lean Six Sigma with other technologies in the future.

REFERENCES

1. Zellner, G., *A structured evaluation of business process improvement approaches.* Business process management journal, 2011.
2. Wahab, A.N.A., M. Mukhtar, and R. Sulaiman, *A conceptual model of lean manufacturing dimensions.* Procedia Technology, 2013. **11**: p. 1292-1298.
3. Dekier, Ł., *The origins and evolution of Lean Management system.* Journal of International Studies, 2012. **5**(1): p. 46-51.
4. Garcia, F.C. *Applying lean concepts in a warehouse operation*. in *IIE Annual Conference and Exhibition*. 2004.
5. Chen, J.C., et al., *Warehouse management with lean and RFID application: a case study.* The International Journal of Advanced Manufacturing Technology, 2013. **69**(1): p. 531-542.
6. Patel, M. and D.A. Desai, *Critical review and analysis of measuring the success of Six Sigma implementation in manufacturing sector.* International Journal of Quality & Reliability Management, 2018.
7. Kumar, M., et al., *Winning customer loyalty in an automotive company through Six Sigma: a case study.* Quality and Reliability Engineering International, 2007. **23**(7): p. 849-866.
8. Pyzdek, T. and P.A. Keller, *A complete guide for green belts, black belts, and managers at all levels*. 2003, New York: McGraw-Hill.
9. Gupta, K. and G. Kumar. *Six Sigma application in warehouse for damaged bags: a case study*. in *Proceedings of 3rd International Conference on Reliability, Infocom Technologies and Optimization*. 2014. IEEE.
10. Snee, R.D., *Lean Six Sigma–getting better all the time.* International Journal of Lean Six Sigma, 2010.
11. Pepper, M.P. and T.A. Spedding, *The evolution of lean Six Sigma.* International Journal of Quality & Reliability Management, 2010.
12. Roberts, C.M., *Radio frequency identification (RFID).* Computers & security, 2006. **25**(1): p. 18-26.

13. Ahuja, S. and P. Potti, *An introduction to RFID technology.* Commun. Netw., 2010. **2**(3): p. 183-186.
14. Wamba, S., T. Coltman, and K. Michael, *RFID-enabled warehouse optimization: lessons from early adopters in the 3PL industry.* 2008.
15. Wang, J., Z. Luo, and E.C. Wong, *RFID-enabled tracking in flexible assembly line.* The International Journal of Advanced Manufacturing Technology, 2010. **46**(1): p. 351-360.

VITA

NAME	Pakkaporn Rungruengkultorn
DATE OF BIRTH	28 September 1996
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Bachelor of Science (B.S.in Chemistry) Mahidol University
HOME ADDRESS	431/4 Lalin greenvill onnuch road, Prawet Bangkok 10250