Production line process improvement with process reengineering - A case study in garment factory

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กระบวนการผลิตบริษัทเอบีซี มีจุดบกพร่องที่ควรได้รับการแก้ไข ซึ่งจุดบกพร่องเหล่านี้สามารถนำไปสู่ผลผลิตที่ต่ำกว่าเกณฑ์ และความล้มเหลวในการผลิตที่ไม่เป็นไปตามเป้าหมายที่ตั้งไว้ได้ ด้วยเหตุนี้จึงเสนอแนวทางการแก้ไขปัญหาโดยการรื้อปรับกระบวนการทางธุรกิจ และออกแบบกระบวนการใหม่โดยใช้เทคนิคฮิวริสติก เพื่อปรับปรุงกระบวนการผลิตในปัจจุบันให้มีประสิทธิภาพมากยิ่งขึ้น รวมไปถึงการใช้วิธีการประเมินและการวิเคราะห์ช่องว่างระหว่างกระบวนการ ในงานวิจัยนี้จะออกแบบกระกวนการใหม่ และจำลองกระบวนการผลิตในสายการผลิตใหม่หลังจากนำเสนอแนวคิดของการพัฒนากระบวนการที่มีอยู่โดยใช้วิธีออกแบบกระบวนการใหม่ และดำเนินการจำลองกระบวนการใหม่แล้ว พบว่า ผลผลิตและระดับการบริการของบริษัทเพิ่มขึ้นประมาณ 45 เปอร์เซ็นต์ และทางบริษัทควรให้ความสำคัญกับการใช้กำลังการผลิตและระยะเวลารอคอยสินค้าเป็นตัวชี้วัดในการได้ผลลัพธ์จากการจำลองที่คาดหวังไว้ โดยสรุปแล้ว งานวิจัยนี้แสดงให้เห็นถึงขั้นตอนการออกแบบสายการผลิตใหม่ที่แนะนำให้ทางบริษัทปฏิบัติตามอย่างเคร่งครัดเพื่อที่จะสามารถแก้ปัญหาที่กล่าวมาในข้างต้นได้ในระยะยาว

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The production process concerns in ABC manufacturing are failing to meet daily production targets and having low productivities. Business Process Reengineering (BPR) is a method of employing process redesign heuristics to improve an existing production line process using an evaluation approach and fit-gap analysis. A simulation tool is used to model the production process redesign. After adopting the provided approach and conducting the simulation, the company's production productivity and service level increases by about 45 percent. To get the required simulation results, critical measurements such as manufacturing capacity and lead time are used. This research demonstrates the redesign production process that must be followed in order to overcome the critical issues.

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

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Yanin Palasri

TABLE OF CONTENTS

List of tables

List of figures

Page

CHAPTER 1

INTRODUCTION

This research identifies the core cause of ABC Garment Manufacturing Company's production process problem and proposes a business process reengineering (BPR) solution to fix the root cause. The introduction of ABC Garment Manufacturing Company is simply given in this chapter. The statement of the problem, the predicted outcomes, the scope of the investigation, and the contribution of this work are all included.

Nowadays, the garment and textile industries are one of the important business sectors that drives Thailand's GDP and export revenue growth every year (Investment, 2016). The large number of Computer Integrated Manufacturing Systems widely distributed in manufacturing industry. It aids in the standardization of the production line process and increases efficiency to a certain extent. The existing management information systems face difficulties in keeping up with the fast-changing pace of the complex business models and the diversified customer needs (Xu et al., 2012). With the emerging of new technologies such as Enterprise Resource Planning (ERP) software, it is a popular software that widely used among medium to large business's scale. The various benefits have provided to the organization for the post implementation, for instance, reduce the production cost, increase service quality, and raise process efficiency in long-run (Costello, 2018).

In this research, the case of ABC garment manufacturing company is brought up to study about production line process. The existing production line process and business operations of Thailand’s manufacturing are overly reliant on reports and redundant procedures, resulting in daily output target being missed. It is expected that Enterprise Resource Planning (ERP) software can facilitate the production process complexity and be able to eliminate the redundant tasks. The assessment approach and fit-gap analysis have been applied in this research. However, with the analysis result, the ERP software implementation consumes longer time than expected. Plus, the standard functions of ERP software do not support the business requirements and customized program is required. Therefore, the approach has been changed to apply the Business Process Reengineering (BPR) as the proposed methodology based on the new analysis which will be described in chapter 3 and 4.

1.1) The Company Profiles

ABC Garment Manufacturing Company is a garment manufacturer that provide Made-To-Order service to customers. Its subsidiaries manufacture men’s and women’s clothing for export to Europe, Canada, Japan, USA, and Russia. Most of raw materials are imported products with non-tax charge, in other words called “Bonded Goods”. Once the production process is completed from raw materials to finish goods and according to the Thai customs law, all finish goods must be 100% re-exported. To follow the rigorous procedures, ABC Garment Manufacturing Company has a strong tracking system to track all materials, inventory and any transaction movement that occurred in the ABC Garment Manufacturing Company's production line process.

1.2) Problem Analysis

It is a company that dedicated to manufacture original equipment manufacturer or OEM for the top world brand name. In addition, the garment manufacturing is a huge process. All operations are done in different departments in garment factory. Also, the production line process is a sequential process starting from the designing, sampling, laying, marking, cutting, stitching, checking, finishing, pressing, and packaging (Textileblog, 2020). Therefore, the garment industry required an adaptable and flexibility technology to track and control the entire production line process. The QR code has been used for the tracking every production step and the in-house program is developed as the core back-end system connected to the Oracle Database. On the other hand, this firm has suffered from low productivities which has resulted in the inability to meet the daily output target.

The problems of ABC garment's production process were analyzed using the cause-effect diagram as shown in Figure 1.

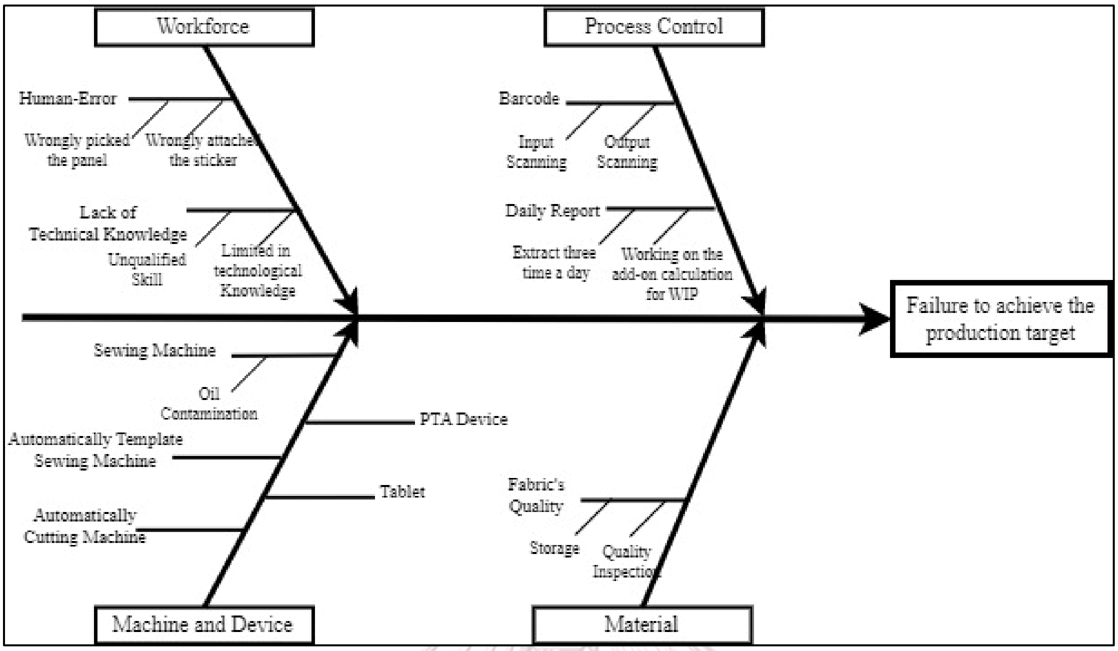

Figure 1. ABC garment's production process: Cause-Effect Diagram

From Figure 1, various production problems in ABC garment manufacturing have been identified. The problems are classified into 4 categories: workforce, process control, machine & device, and material. Daily report is considered as one of the problems that cause the failure to achieve production target. ABC's production manager extract report three time a day and manual calculate the number of work-in-process (WIP) for each garment workstation. As a result, it has slowdown the production line process since the worker rely too much on the report. In this research, daily report is selected and analyzed using fit-gap analysis and the proposed solution is provided to resolve this daily report problem.

1.3) Problems Statement

- An increase in production lead time of production process
- The failure to achieve the production capacity target each day
- Too much daily manual work for the officers

1.4) Expected Results

- Once the Business Process Reengineering (BPR) is implemented to current production process, it is expected that BPR can improve the current production process by decreasing the production lead time and increasing the production capacity to achieve the daily target.

1.5) Scope and Limitations

The focus of this research will be on garment production process only. The original propose solution is to implement the ERP software to improve the garment production process. However, the ERP software project implementation / enhancement is time-consuming and required skilled consultant. Therefore, an alternative solution has been proposed to implement the business process reengineering (BPR) by using the simulation tool BPsimulator (BPsimulator, 2021).

1.6) Contribution of this work

Design the new process of garment production line process and obtain the effective number of resources that optimize the production efficiency to meet the target production each day (Somphanpae & Boonsiri, 2016). Also, the benchmarking major findings of this study have been initiated and compare with other related standards work.

1.7) Outline of the thesis

This thesis is organized as follows. Literature reviews and related theories are presented in Chapter 2, followed by the proposed methodology in Chapter 3. The case study and experiment are presented in Chapter 4. Meanwhile, Chapter 5 is results and discussion. Lastly, Chapter 6 is given by the conclusion and future work.

CHAPTER 2

LITERATURE REVIEW AND RELATED THEORIES

In this chapter, the related literature and theories were reviewed. The prominent points of each literature have been brought up and applied as the guidelines of this research. Particularly, the issue's identification in garment factory, the dependency tasks in garment production process, and fit-gap analysis & technology acceptance model are reviewed and used in this research. Business Process Reengineering (BPR), re-design heuristics and the BPsimulator-based simulation are reviewed as the related theories.

2.1) Literature Review

2.1.1) Identify the issues occurred in garment industry

The most important aspect of this literature study is the ability to construct a cause-effect diagram to identify prevalent difficulties in the garment business. The main factors that affect the garment industry are labor rigidity, instability, political changes, regulations, informality, low productivity and low competitiveness (Bautista-Calderon et al., 2019). The case study of small company that manufacture the prima cotton polo shirts has been brought up in this review. It is found that this company suffers from the product's delivery to customers, and the problem was analyzed using an Ishikawa diagram (Cause-Effect diagram) in Figure 2 (Bautista-Calderon et al., 2019).

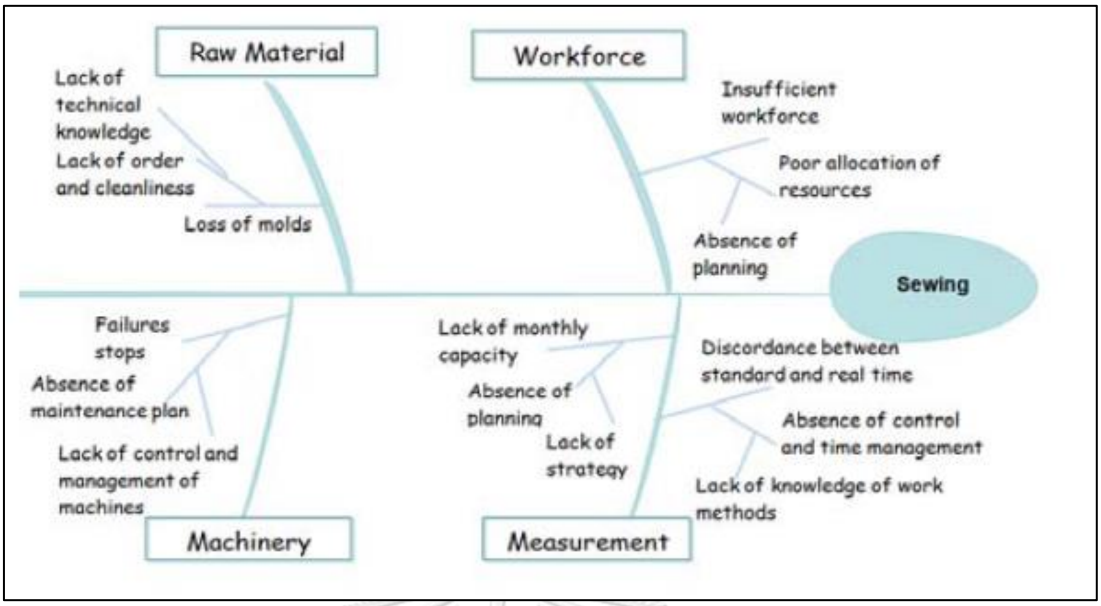

Figure 2. Ishikawa Diagram (Bautista-Calderon, Padilla-Reyes, Maradiegue-Tuesta, & Alvarez-Merino, 2019)

Figure 2 is retrieved from the literature review called "Improvement of shirt making production through lean manufacturing". The root causes of the problem came from lack of technical knowledge, the deficient allocation of resources, the lack of control and management of machines, the lack of control and management of time and the lack of strategy and planning of production capacity (Bautista-Calderon et al., 2019).

2.1.2) The dependency of department in garment industry

A supply chain is a system of departments, people, technology, activities, information, and resources involved in moving a product or service from suppliers to customers. It is an activity that transform natural resources, raw materials and components into a finished product that is delivered to the end customer (Nagurney, 2006). The researchers of this paper have decomposed the business processes of garment manufacturer and derive the dependencies among different departments. By completing the order, it must be coordinated with multiple departments as shown in Figure 3 (Xu et al., 2012).

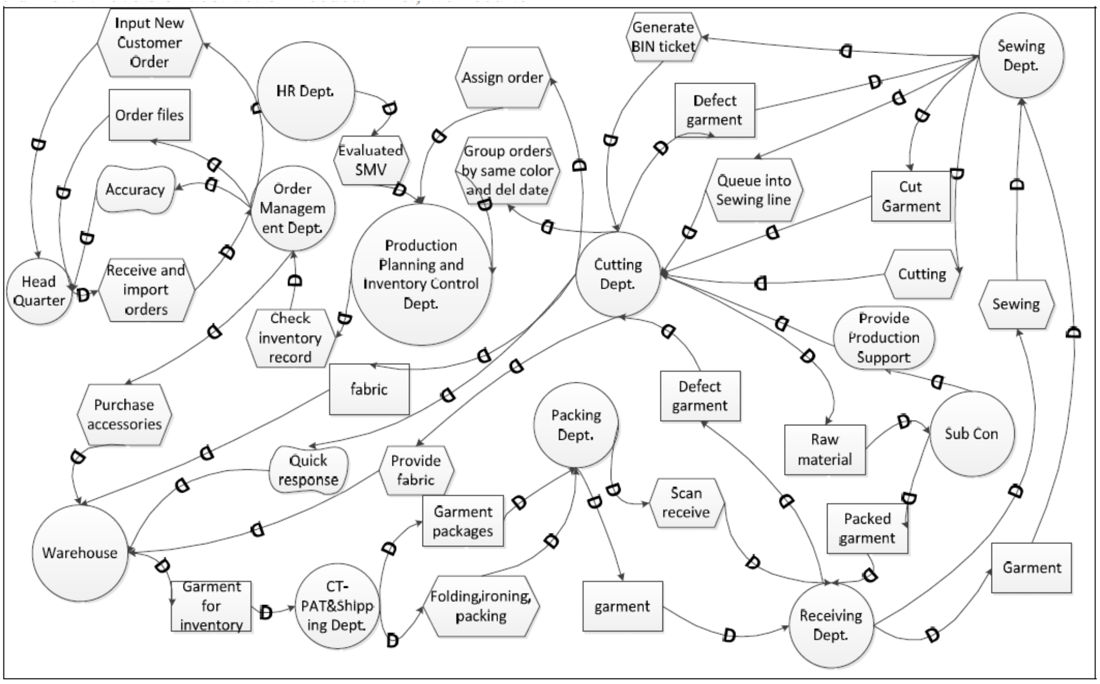

Figure 3. Dependency of departments in garment manufacturing company (Xu et al., 2012)

Figure 3 is retrieved from literature review called “Service-Driven Migrating of Enterprise Information Systems: A Case Study”. It represents 11 departments which are Head Quarter, Warehouse, Order Management Department, HR Department, CT-PAT & Shipping Department, Production Planning and Inventory Control Department, Packing Department, Cutting Department, Receiving Department, Sub con and Sewing Department. There are tasks and resources to construct connections between two departments. The symbol in the middle of the arrow represented the dependency between each workstation. Giving an example of Sewing Department depends on Cutting Department to provide garment cutting task, and Cutting Department relies on Warehouse to purchase and distribute the fabric materials (Xu et al., 2012). Due to the complexity dependencies of the process, the researcher has tried to extract services required for each department by enumerated the candidate services by decomposition of the business process and the dependency relationship shown in Figure 4 (Xu et al., 2012). .

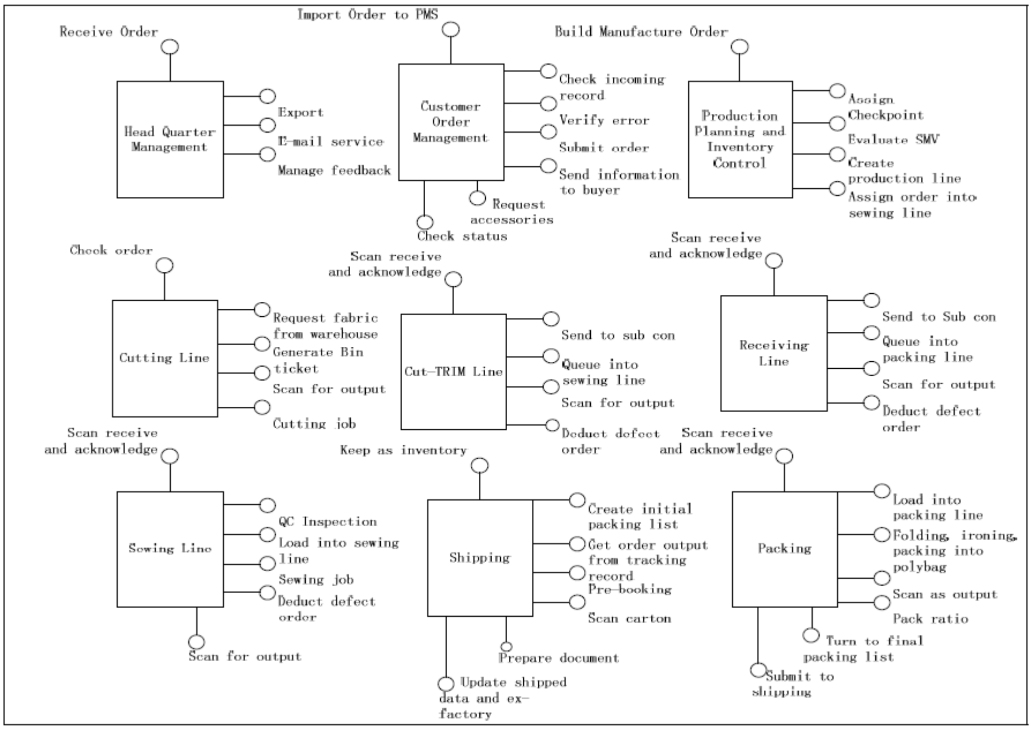

Figure 4. Candidate services extracted from the business process (Xu, Zhao, Tan, & Liu, 2012)

Figure 4 is retrieved from literature review called “Service-Driven Migrating of Enterprise Information Systems: A Case Study”. The candidate services are categorized by different departments. There are several candidate services in one department and each service performs a unique task. From Figure 4, there are many services exist in each department, and they also have duplicated function. For example, shipping department consists of 7 services/activities starting from keep an inventory, create initial packing list, get order output from tracking, record pre-booking, scan carton, prepare document and update shipped data and ex-factory. These functional units are independent in each department, which may bring extra overhead to the system (Xu et al., 2012).

The problems become more obvious when the researcher models the strategic dependencies between departments, the services they offer, and the constraints they impose on each other (Xu et al., 2012). In such the case, the researcher has decomposed the business processes of garment manufacturers and derive the dependencies among different department by applying the i* modeling framework (Xu et al., 2012) and a service oriented through the process.

The i* model (Xu et al., 2012) has been specially developed based on the early requirements in this literature. There are two basic models in the i*framework: the strategic dependency (SD) model and the strategic rationale (SR) model. The strategic dependence illustrates connection between different actors in terms of achieving goals, performing tasks, and providing resources. Through understanding the dependencies between actors, the enhancements and weaknesses of goals and tasks could be analyzed. As a result of this literature research, i* model (Xu et al., 2012) is used to deconstruct the production line process and capture the diagram displayed in chapter 4, Figure 9: Dependency of departments in ABC garment manufacturing company.

2.1.3) Fit-Gap Analysis

This literature carried out the Fit gap analysis method to understand and compare installed systems of Transportation Reservation Management (TRM) module with existing requirements. Then, Technology Acceptance Methodology (TAM) model has been applied. It is expected that TAM be able to identify the factors that can influence user behavior in the acceptance and the use of the system TRM at PT.XYZ (Jingga, Cornelius, & Limantara, 2019).

Fit Gap analysis has been conducted after receiving the input data from PT.XYZ company. Five columns have been identified: Business requirement, describe existing solution, priority, degree to fit, gap description and new capabilities. After that, risk analysis has been designed based on the fit gap analysis. After performing Fit Gap Analysis, the TAM has been used to find out the acceptance of the user towards the system TRM. The results of the TAM calculation will be compared with the hypothesis that the authors have previously determined (Jingga et al., 2019).

In short, the fit gap analysis and TAM model have carrier revealed that the features of TRM system are still not in accordance with the requirement or the system design request and many features needed to be developed. Therefore, the authors have foreseen the practical use and advantage of the two methodologies; therefore, fit gap analysis is selected to be applied as one of the research methodologies. In the sense of TAM model and from the authors' perspective, the tool is more involved in people behavior not the process flow itself.

2.2) Related Theories

2.2.1) Business Process Reengineering

Business process reengineering is an approach to improve the effectiveness and efficiency of a business process. With the business process reengineering (BPR) implementation, it is expected that there will be radical change and significant improvement of the company performance (Mochyidin, Hartanto, Devara, & Rantetana, 2011). Organizations nowadays are under increasing pressure to adapt their business processes to relentless technological, political, organizational and other changes. Under such conditions, being able to rapidly generate good new ideas about how to meet these challenges becomes a critical skill. A body of process innovation techniques known collectively as Business Process Reengineering has emerged to address this challenge (Mark & Petti, 2006).

Petrozzo and Stepper (1994) said that there are several reasons why a company needs to do business process reengineering (Petrozzo & Stepper, 1994):

(i) A fixed or significant increase in the number of employees required to carry out activity within the company,

(ii) The process is very sensitive to the changes of input, it will be problematic if it affects production (decrease)

(iii) To produce products that involves large numbers of people

(iv) Customers are disappointed to the product (or service) and it may lead to a poor customer experience or image

(v) Employee's morale decreases and communication with customers is not as expected

(vi) Management allows for change

2.2.2) Re-design Heuristics

The main component of the design stage is the methodological evaluation of a set of redesign heuristics. Redesign heuristics can be seen as rules of thumb for deriving a different process from an existing one (Dumas, La Rosa, Mendling, & Reijers, 2013). There are 29 redesign heuristics listed in the literature review of fundamentals of business process management, it is the lists of best practices which is derived from the real-life experiences. The best practices also consider process improvements from the perspective of improving contact with customers (customers), how to implement processes (process operation), when the process is executed (behavior), allocation and number of resources involved (organization), data (information), enabling technology (technology), and finally, collaboration and communication with third parties (external environment). The best practices are, to the best of knowledge, and the most comprehensive list available. In the next chapter, selected best practices and the adaptation into redesign heuristics for garment's manufacturing-based business processes are presented.

2.2.3) The BP Simulation

Business Process Simulator or BPsimulation is a web application of simulation software class for the analysis of business process. It is used to access the dynamic behavior of the process over time (Somphanpae & Boonsiri, 2016). The purpose of the service is to search for bottlenecks in the business process where lack of resources or of performers, evaluation of the resource utilization such as performers of the business process functions, estimation of cost of a process instance, and determination of the actual operation time from task statement until its completion.

The results allow decisions in the process design or resource provision that aim to improve factors such as process performance, process and product quality and resource utilization. By running the simulations, companies can predict how business process perform under specific conditions based on the redesign heuristics and therefore, help to predict optimal responses to future changes. Process simulation can identify the most effective process flow and help to prevent problems from cropping up during the process execution (Somphanpae & Boonsiri, 2016).

2.2.4) Plan-Do-Check-Act Cycle (PDCA)

PDCA or Plan-Do-Check-Act cycle is a four-step problem-solving iterative technique used to improve business process. The cycle consists of Plan – Identify an opportunity for change, Do – Implement the change on a small scale to test, Check - Review results by analysis data to determine if the changes was successful ("What is Continuous Process Improvement," 2020). Lastly, Act – The final step is to take corrective action once past mistakes have been identified and resolved. The PDCA Cycle is repeated and can be redefined perhaps to better results under new guidelines. The cycle draws its inspiration from the continuous evaluation of management practices (Hargrave, 2021). It is planned to use as the tools for continuous process improvement.

CHAPTER 3

RESEARCH METHODOLOGY

The research methodology has been developed based on the concept of the business process management (BPM). The BPM is the discipline of improving a business process from end-to-end by analyzing it, modelling how it works in different scenarios, executing improvements, monitoring the improved process and continually optimizing it (Lutkevich, 2021). Refer from the textbook of business process management (Weske, 2007), a simple diagram of business process management lifecycle has been created to describe the BPM life cycle in Figure 5.

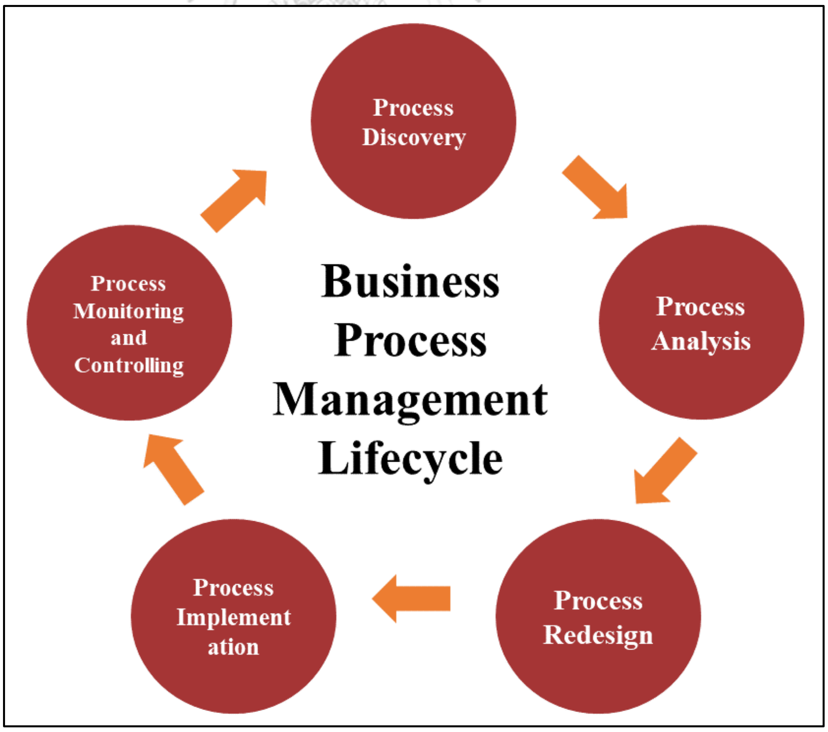

Figure 5. Business Process Management Lifecycle management (Weske, 2007)

Business Process Management (BPM) life cycle is models that systematize the steps and activities that should be followed for conducting business process management (BPM) project (de Morais, Kazan, de Pádua, & Costa, 2014). It begins with the process discovery where the current process of end-to-end steps is identified. Process analysis step adds activities aimed at aligning business objectives with their processes, whether to establish them or update them. The redesign of business processes involves the creation of new specifications, activities and tasks, rules, and definitions for exchanging information among functional groups, physical design, and IT infrastructure. Management during implementation involves training, metric policies and performance evaluation, strategic alignment evaluation and risk analysis and monitoring. The monitoring and control of processes deal with adjustments of resources to ensure process objectives through performance measurements and evaluation. The refining step is associated with organizational change, continuous improvement and optimization activities in search of the efficiency and effectiveness of processes implemented in the organization (de Morais et al., 2014).

3.1) Process Discovery

The As-Is production line process in ABC garment manufacturing company is illustrated in Figure 6 and Figure 7. From Figure 6, the diagram consists of multiple parties who are involved in production line management starting from purchasing raw material, planning production, warehouse management, pattern maker and training department. The production line process will get start when the raw material flow in to “L0A” process until “L3S” process – the final process of 5LAS. Firstly, rectangular shape represents a “Process/Activity”, diamond shape represents a “Decision Node”, circle shape represents “Page Connector”, the arrow represents “Process/Activity Connector”, parallelogram shape represents “Input/Output”, a half cylinder shape represents “Stored Data in the system” and last symbol represents “Documentation”.

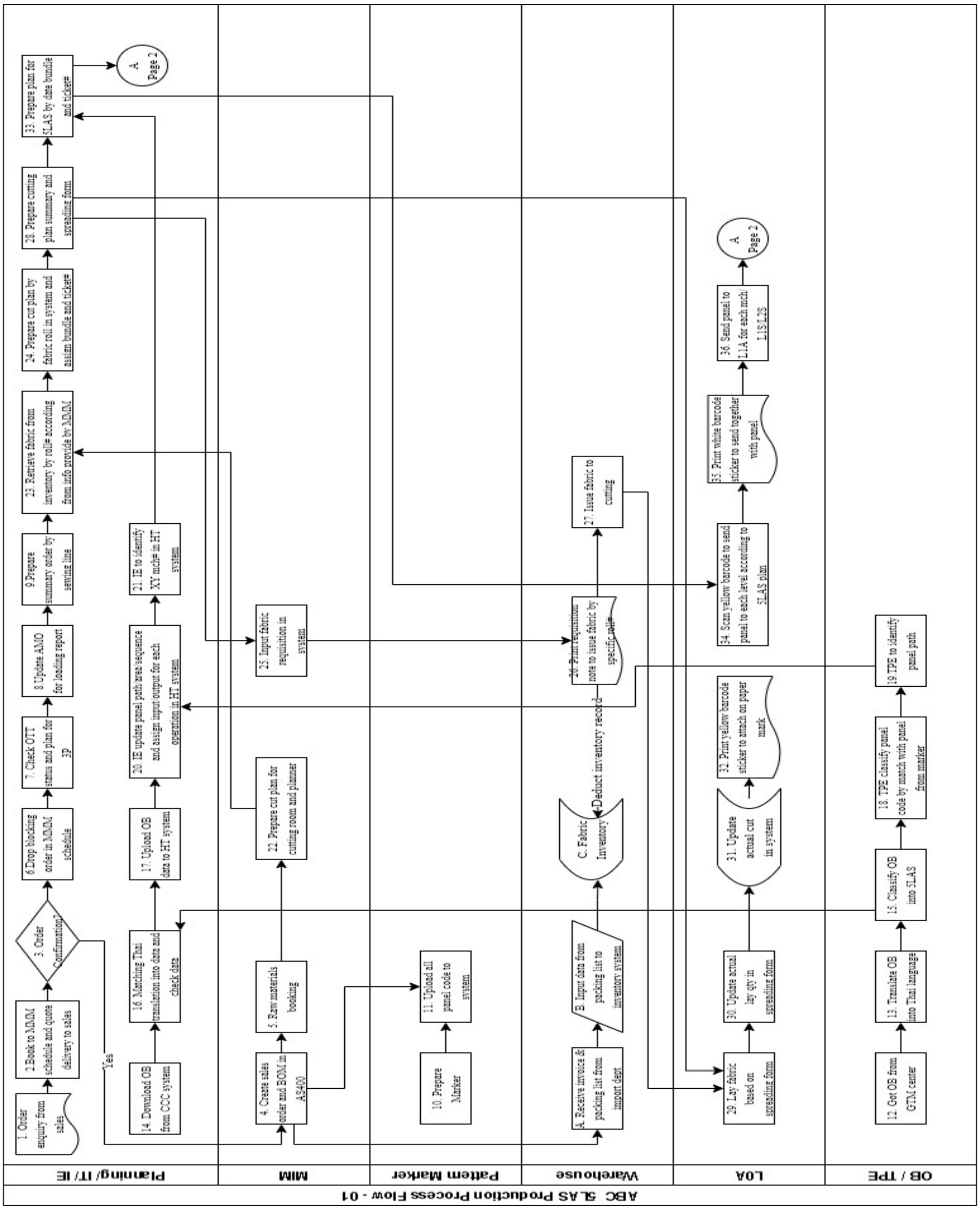

Figure 6. ABC Production Process Flow_01

After the planning process is done from Figure 6, the fabric will be issued out from the warehouse and directly sent to the starting process of L0A, one of 5LAS process, as displayed in Figure 7.

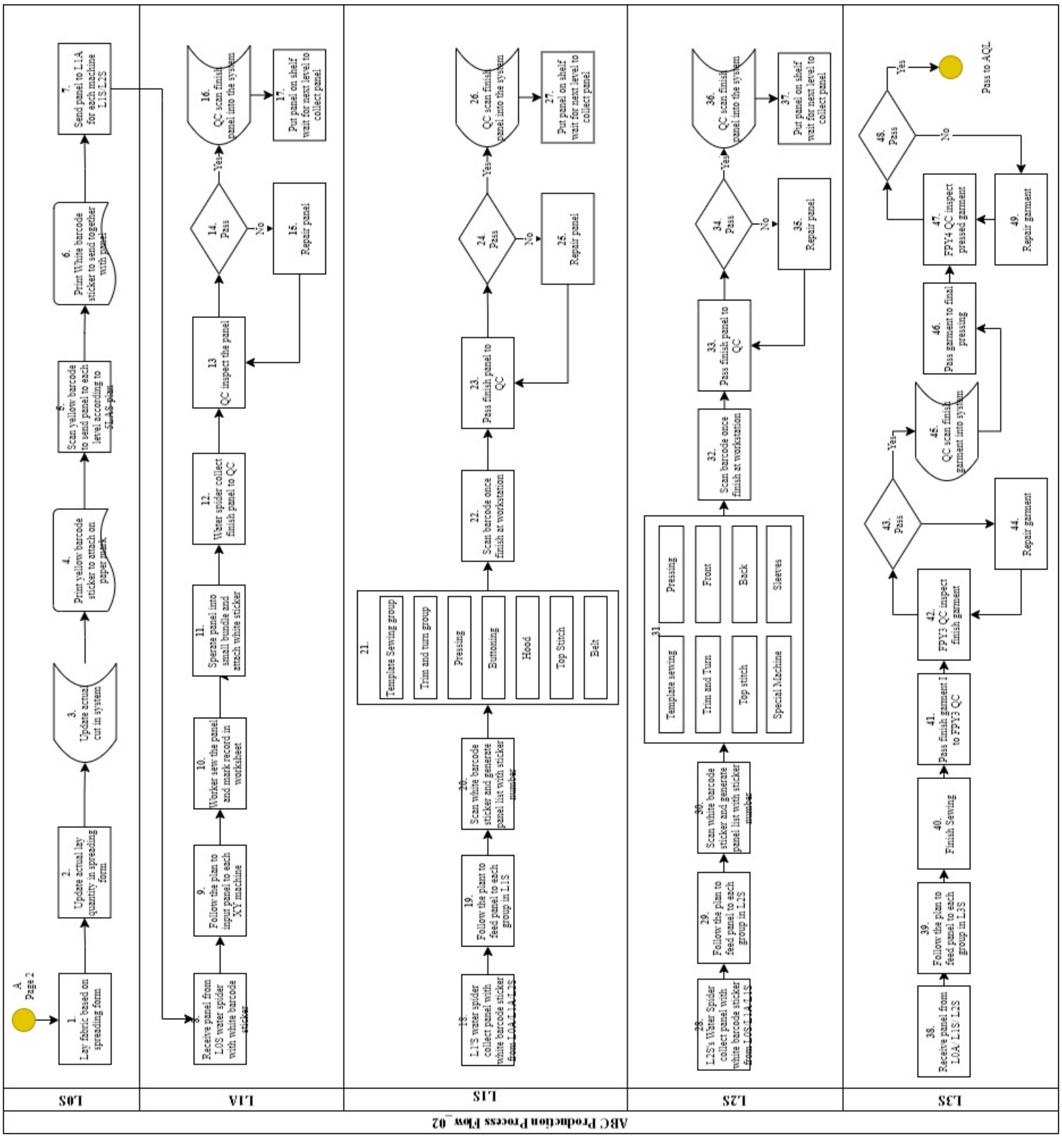

Figure 7. ABC Production Process Flow_02

3.2) Process Analysis

In the process analysis, two tools have been applied at this stage: cause-effect diagram and fit-gap analysis. For the cause-effect diagram, it is used to identify the root causes of the problem of the ABC garment manufacturing's existing production process as describe in Figure 1: ABC garment's production process: Cause-Effect diagram, chapter 1. After the critical issues of an increase in production process's lead time, the failure to achieve the production capacity target each day and too much daily manual work for the officers have been identified, the fit-gap analysis in chapter 3 will be conducted to address how well the system under consideration fits the proposed solution.

3.3) Process Redesign

Once the fit gap analysis of each problem area is identified in Table 1, we will know the gap between the As-Is and To-Be production line processes. Two solutions are proposed:

- Develop a customized program to auto generate the report including the manual calculation which is currently done by the officer
- Redesign the production process based on the Business Process Reengineering (BPR) – Redesign heuristics

Firstly, the core production process in ABC garment manufacturing company is 5LAS process in which the standard function of ERP software to automatically generate the report is not support the production process complexity. Therefore, the customized program has been proposed to develop on the ERP software being as the new capacity to reduce or eliminate these gaps. However, the customized program is required to develop on ERP software, the implementation take long time like a year based and the company's financial may not support during the Covid19 pandemic. Hence, we have shifted the plan of ERP software implementation to propose another solution.

Another proposed solution is to redesign the production process based on the Business Process Reengineering (BPR) – It is a process in which the enterprise can make a significant improvement in some key aspects of enterprise's performance, such as cost, quality, service, and speed (Miao, 2010). The production process has been redesigned based on the redesign heuristics – Task elimination, resequencing, parallelism, and resource optimization are a part of redesign heuristics which are selected to apply in the business process reengineering (BPR) in order to approve and adjusted some parameters refer from the enterprise's performance. The new production process is tested and simulated using the simulation tool (BPsimulator, 2021). OXCLOSE clothing style is one of the luxury branded raincoats. With the complexity of its production process, the OXCLOSE clothing style's production process is brought up to be a case study of the production process and redesign in this research.

3.4) Process Implementation

The last step is to simulate the redesign production process of clothing styles OXCLOSE which is a made to order from ABC's customer to ensure that the proposed solution improves the current production process. The input of simulation consists of process flow, resources, and initial value of decision parameters.

3.5) Process Monitoring and Controlling

After the simulation, the production capacity and the production lead time of each OXCLOSE's clothing part from As-Is/To-Be production process is compared. With the comparison, the researcher expected that the production capacity is increased, and the production lead time is decreased, respectively.

CHAPTER 4

Case Study and Experimental Details

In this chapter, all related theories from Chapter 2 have been applied to conduct the experiment. The ABC Garment Manufacturing Company's production process is brought up as a case study to perform the process analysis and fit gap analysis with the aim of process's gap discovery. The suggested solution will be provided after the process gap has been identified. Lastly, the experiment of new process is stimulated in this chapter.

4.1) Process Analysis and Fit Gap Analysis

Referring from the literature review of The Dependency of department in garment industry, the concept of Candidate Services extract from business process and the dependency of department in each garment company (Xu et al., 2012) has been applied to the production line process. The multiple services of each department have been broken down into the diagram called "Candidate Services extracted from the business process". The services are categorized by different departments as shown in Figure 8. The diagram represents activities that must be performed under each production's management (Planning/IT/IE, MIM, pattern maker and warehouse) department and 5LAS process. For example, "Receive invoice and packing list", "Input data into the system", "Issue fabric to cutting" and "Print requisition note to issue fabric" are activities that must be performed under warehouse department.

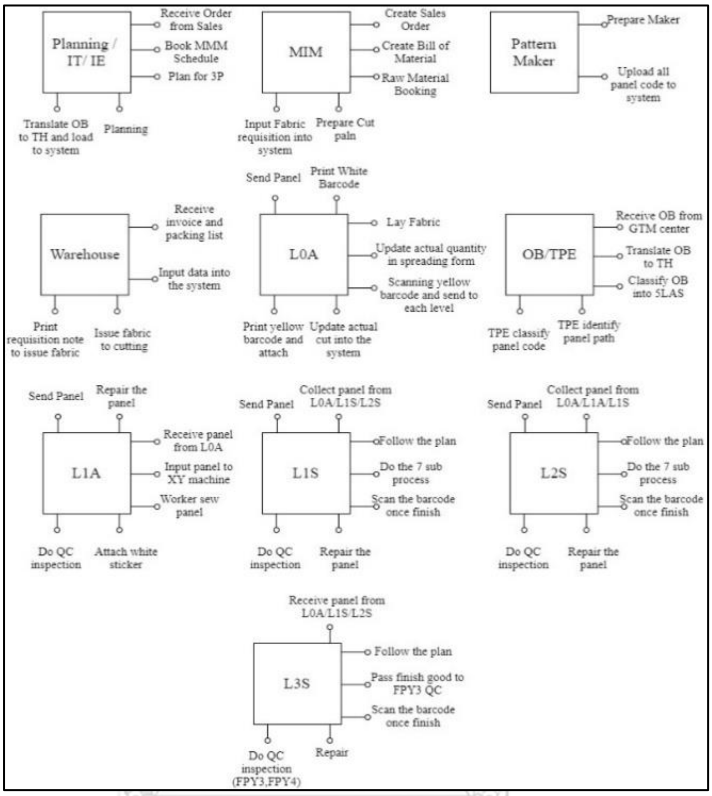

Figure 8. Candidate Services Extracted from 5LAS process

The 5LAS process is a core garment production process at ABC company. It consists of 5 process – L0A, L1A, L1S, L2S and L3S. Each of clothing style has different 5LAS production line process flow in which currently this process is managed and controlled by the officer. After applying the analysis model to 5LAS process covering with a different perspective of the production process flow, it can be seen that the 5LAS production line process in each clothing style is totally different considered by the dependency among the workstations, goals and dependency relationship modelling process. Therefore, the standardize template of

5LAS production line process can’t be modeled. Instead, a high-level of the overall production process has been constructed in Figure 9.

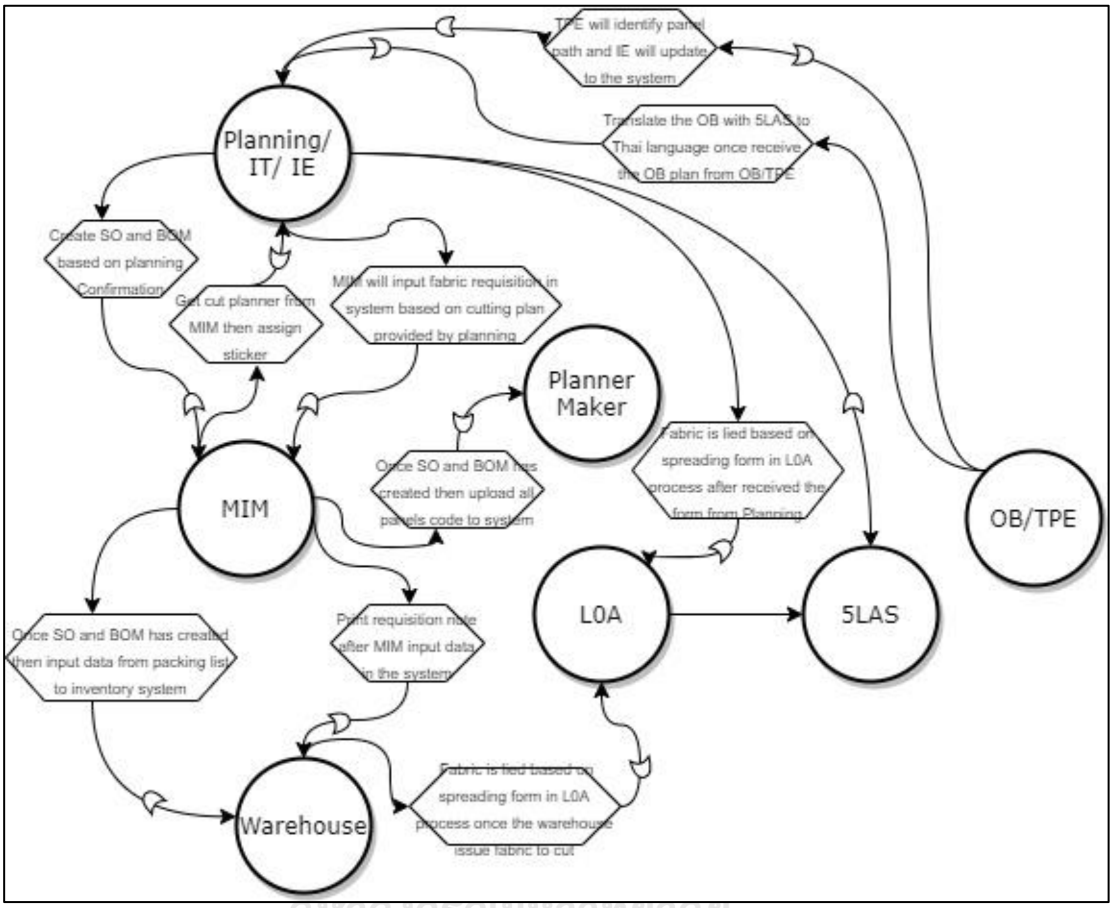

Figure 9. Dependency of departments in ABC garment manufacturing company

The dependency tasks of each department are represented in Figure 9. It consists of five departments: Planning/IT/IE (Industrial Engineering), MIM (Merchandising), planner maker, warehouse, and OB/TPE and two core processes: L0A and 5LAS. The diagram starts with the MIM department receives the order confirmation from planning department then MIM department will be able to create the SO (Sales order) and BOM (Bill of Materials) in the system. This indicates the dependency among two departments that MIM department must wait until it receives the order confirmation from the planning department. The dependency is well described by the symbol of the connector connected between two departments.

After getting essential data for analysis, the fit gap analysis template has been conducted as shown in below table:

Table 1. Fit Gap Analysis Comparison Between ERP Software Implementation and Business Process Reengineering.

		ERP Software Implementation		**Business Process Reenginerring**	
Problem Area	***Existing Solution***	***Gap between existing & new***	***New Capacity needed to reduce or eliminate gap***	***Gap between existing & new***	***New Capacity needed to reduce or eliminate gap***
Relied too heavily on the report. The operation can't start until the report is generated	Most of the officers and workers felt indifferent toward the number of current reports as they have continued doing the same operation.	The process of each clothing style is very complex to automate on the system, also the standard function of ERP software is not supporting such kind of process complexity.	The new customized program is required to develop on the ERP software to support the process variety and complexity.	To apply the automation - one of the re-design heuristics approach. Data sharing (Intranets, ERP) Similarly to the proposed solution of ERP implementation. The standard function of ERP may not support the clothing style complexity	The new customized program is required to develop on the ERP software to support the process variety and complexity.
Fail to achieve daily production target	The officer and foreman need to work closely to the workers. They have monitored and controlled the production process by QR code tracking and manually update the daily report to identify which process/ step is delayed which possibly causing the slowdown in entire production process	The external device such as QR code scanner and QR code reader needs to connect to ERP system. The cost of infrastructure's setting and maintenance may high. Also as mentioned in point no#1, the process of each clothing style is too complex to automatically generate from the system in which the manual calculation is the process after the report is generated.	The new customized program is required develop on the ERP software to support the process variety, process variety, complexity, and manual calculation.	Once the production process is re-designed based on the re-design heuristics approach. The new production process is required to test the effectiveness using the simulation model or tool.	Define the simulation approach (Simulation tool/model, expected result and result measurement) as it is required to prove the new production process efficiency
Low productivity	The management team has set up weekly meeting for the workers who work in the assembly process. The purposes are to brainstorm, share and gather the idea about the causes of the low productivity	N/A	N/A		

From Table 1, problem area is retrieved from Figure 1. ABC's garment production process: Cause-Effect diagram. The two solutions have been proposed: ERP software implementation and business process reengineering. In each solution, the gaps of the proposed solutions are identified in column "Gap between existing & new" and the new capacity has been suggested to eliminate the gap of the new solution.

It can be seen from Table 1 that ERP implementation solution is required a new customized program to support the process complexity. Moreover, the ERP implementation and customized program development take long time like a year-base and the company's financial may not support during the Covid19 pandemic. Hence, this proposed solution has been dropped and focused more on the business process reengineering solution.

4.2) Design the new process

The Business Process Reengineering (BPR) is selected as the new approach to solve the current problem in ABC Garment Manufacturing Company's production process. OXCLOSE clothing is one of the luxury branded raincoats that contains production process complexity. The OXCLOSE consists of many clothing parts and each part will be embodied at the end of the production process. As per process analysis, we detected some parameters that reduce the entire production process efficiency. The hat, one of the OXCLOSE's clothing parts, consists of many dependencies works and sub-processes. It is the relationship in which a task relies on one or more tasks to be performed in a certain order before it is marked complete.

There are 11 OXCLOSE's clothing parts produced under L1S process. Each has dependency workstation between L1S sub-process – B1X, B21, B31, B41, B51, B61 and B71 where B1X is Template Sewing, B21 is Trim and Turn, B31 is Pressing, B41 is buttoning, B51 is Hood, B61 is Top Stitch, and B71 is Belt.

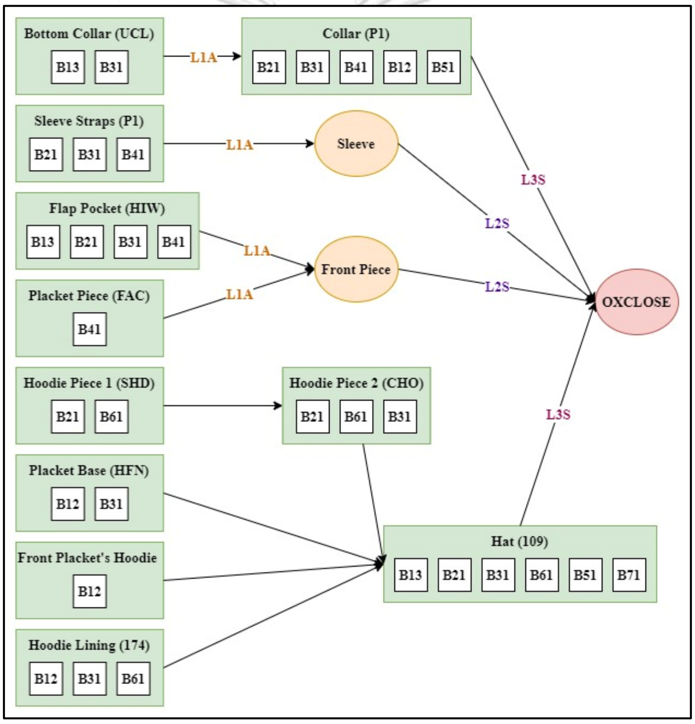

Figure 10. OXCLOSE's L1S production process critical path

Critical path method (CPM) is a technique where tasks have been identified the necessary for the project completion and determine scheduling flexibilities. Figure 10. is a OXCLOSE's clothing parts' critical path which captured only sub-process under L1S process. A rectangular with green color represents the OXCLOSE's clothing part. A small square under each clothing part represents the work sequencing of L1S sub-process. A circle with orange color represents the assembly of each clothing parts that perform under L1A process. A circle with red color represents the final assembly of clothing parts that perform under L3S process. Once the L1S sub-process tasks of each clothing part are done, the finished clothing parts will be sent to next workstation which will be performed under other processes such as L2S or L3S process.

The redesign heuristics (Mansar & Reijers, 2007) are applied with current L1S production process of OXCLOSE clothing style. Below is the fit gap analysis classified by redesign heuristics result table.

Table 2. Fit Gap Analysis of Redesign Heuristics

<table>
<tr><th>Clothing Part/ Redesign Heuristics</th><th>Task Elimination</th><th>Task Composition</th><th>Triage</th><th>Resequencing</th><th>Parallelism</th><th>Process Specialization/ Stardardization</th><th>Resource Optimization</th></tr>
<tr><td>Hoodie Piece 2 (CHO)</td><td rowspan="7">The production process of Hoodie Piece 2 (CHO), Hoodie Piece 1 (SHD), Hoodie Lining (174), Collar (P1), Buttom Collar (UCL, Flap Pocket (HIW) and sleeve straps (P10) consit of unique design (Based on customer's requirement). These processes are very important and they can't be eliminated</td><td rowspan="7">The production step can't be merged/ split into single step/ two steps due to each step has unique operation</td><td rowspan="7">The production step can't be divided/ grouped into two or more alternative tasks due to each step has unique operation</td><td>Hoodie Piece 2 (CHO) required a sequential production step. It can't be re-order since it starts from Templating Sewing, Top stitch, and Pressing</td><td rowspan="3">The Hoodie Piece 2 (CHO)'s production step can parallely run along with Hoodie Piece 1 (SHD)'s and Hoodie Lining (174) step since these three clothing parts are independent process</td><td rowspan="7">Each of clothing part's production is a process specialization since it is a made to order's product. The process itself can't be standardize.</td><td rowspan="3">The production process of Hoodie piece 1 (SHD), 2 (CHO) and Hoodie Lining (174) are quite similar. It is possible to centralization worker to avoid group of people overloaded and another group waiting for work.</td></tr>
<tr><td>Hoodie Piece 1 (SHD)</td><td>Hoodie Piece 1 (SHD) required a sequential production step. It can't be re-order since it starts from Templating Sewing and Top stitch</td></tr>
<tr><td>Hoodie Lining (174)</td><td>Hoodie Lining (174) required a sequential production step. It can't be re-order since it starts from Templating Sewing, Pressing and Top stitch.</td></tr>
<tr><td>Collar (P1)</td><td>The production steps (L1S) of Collar (P1) are dependency to other workstations (Process under L1A and Bottom Collar (UCL) clothing parth).Once all components from L1A process are ready at L1S workstation. L1S sub-process should have started the tasks immediately since it contains many sub-processes</td><td>The Collar (P1) can't run parelly since it contains dependency task which depended on L1A process</td><td>B12 is a common sub-process of L1S among other clothing parts, it is possible to re-allocate resources.</td></tr>
<tr><td>Bottom Collar (UCL)</td><td>Bottom Collar (UCL) required a sequential production step. It can't be re-order since it starts from Templating Sewing, and Pressing</td><td>Bottom Collar (UCL) is possible to parallely run with other processes except Collar (P1)</td><td rowspan="2">B31 is a common sub-process of L1S among other clothing parts, it is possible to re-allocate resources.</td></tr>
<tr><td>Flap Pocket (HIW)</td><td>Flap Pocket (HIW) required a sequential production step. It can't be re-order since it starts from Templating Sewing, Trim and Run, Pressing and Buttoning</td><td>Flap Pocket (HIW) 's production step can parallely run along with Hoodie Piece 1 ,2 and Hoodie lining step since these four clothing parts are independent process</td></tr>
<tr><td>Sleeve Straps (P10)</td><td>The production process of Sleeve Straps (P10) are dependency to other work stations (Process under L1A). It is required a sequential production step. It can't be re-order since it starts from Trim and Run, Pressing and Buttoning</td><td>Despite the fact that Sleeve traps (P10) is depended on L1A process, sub-process under L1S can parelly run with others</td><td>Regarding to the resource optimization, we intend to increase the production capacity of the sleeve straps because OXCLOSE clothing style require 2 pieces of sleeve straps per clothe.</td></tr>
<tr><td>Placket Piece (FAC)</td><td colspan="4" rowspan="2">Placket Piece (FAC) and Front Placket's Hoodie (HFF) contains only 1 sub process. Hence, it can't be eliminated, composition, triage, resequencing</td><td rowspan="2">Placket Piece (FAC) and Front Placket's Hoodie (HFF) can parellely run with other processes under L1S. After tasks under L1S process are done, then only placket piece (FAC) will be sent to L1A process</td><td rowspan="4">Each of clothing part's production is a process specialization since it is a made to order's product. The process itself can't be standardize.</td><td>Worker under B41 process can be re-allocated to other clothing parts which its process is B41</td></tr>
<tr><td>Front Placket's Hoodie (HFF)</td><td rowspan="2">Clothing part of front placket's hoodie and placket base, B12's sub-process is the first workstation of both clothing parts and they contain few processes. Hence, shared resources between these clothing parts are applied to B12 workstation.</td></tr>
<tr><td>Placket Base (HFN)</td><td rowspan="2">Placket Base (HFN) and Hat (109) are clothing parts that consists of unique design (Based on customer's requirement). The process can't be eliminated</td><td rowspan="2">The production step can't be merged/ split into single step/ two steps due to each step has unique operation</td><td rowspan="2">The production step can't be divided/ grouped into two or more alternative tasks due to each step has unique operation</td><td>Placket Base (HFN) required a sequential production step. It can't be re-order since it starts from Templating Sewing and Pressing</td><td>Placket Base (HFN) is possible to parallely run with other processes.</td></tr>
<tr><td>Hat (109)</td><td>Hat (109) clothing part is a assembly of Hoodie Piece 1,2, Hoodie Lining, and Front Placket's Hoodie. Once all clothing piece are ready, it is considered as the top priority to start the process</td><td>Hat (109) can't run parelly since it contains dependency task and required input from other process</td><td>It is difficult to share resources among other processes. Due to its dependency, and unqiue skill</td></tr>
</table>

Based on the Table 2, it can be concluded that:

- Task Elimination – Collar base activity in L1S process is eliminated. This activity is unnecessary for the process and has no additional value in increasing the speed of processing as it can be completed in earlier process.
- Resequencing – Resequencing the 7 sub processes in L1S process, the tasks with lots of dependency works would have started first. Because the dependency works take time than others. For example collar (P1), this clothing part contains many L1S sub-process – L21, L31, L41, L12, and L51 and it required input from other workstation. Once all components are ready, the L1S process of collar (P1) should have start immediately.
- Parallelism – The individual tasks that do not require a dependency process can be proceeded parallel with other workstations. Regarding to Table 2, hoodie piece 1 (SHD) and hoodie lining (174) be able to run parallelly due to these clothing parts have no dependency to other workstations. In addition, these two clothing parts are the component of hat.
- Resource Optimization – The number of resources is allocated based on the number of dependency tasks of the clothing parts. Resource sharing is applied for the clothing parts contained fewer processes. From Table 2, it is possible to apply resource optimization to most of clothing part's production

process since among all of clothing parts consist the same sub-process of B12 – Trim and Turn and B31 – Pressing.

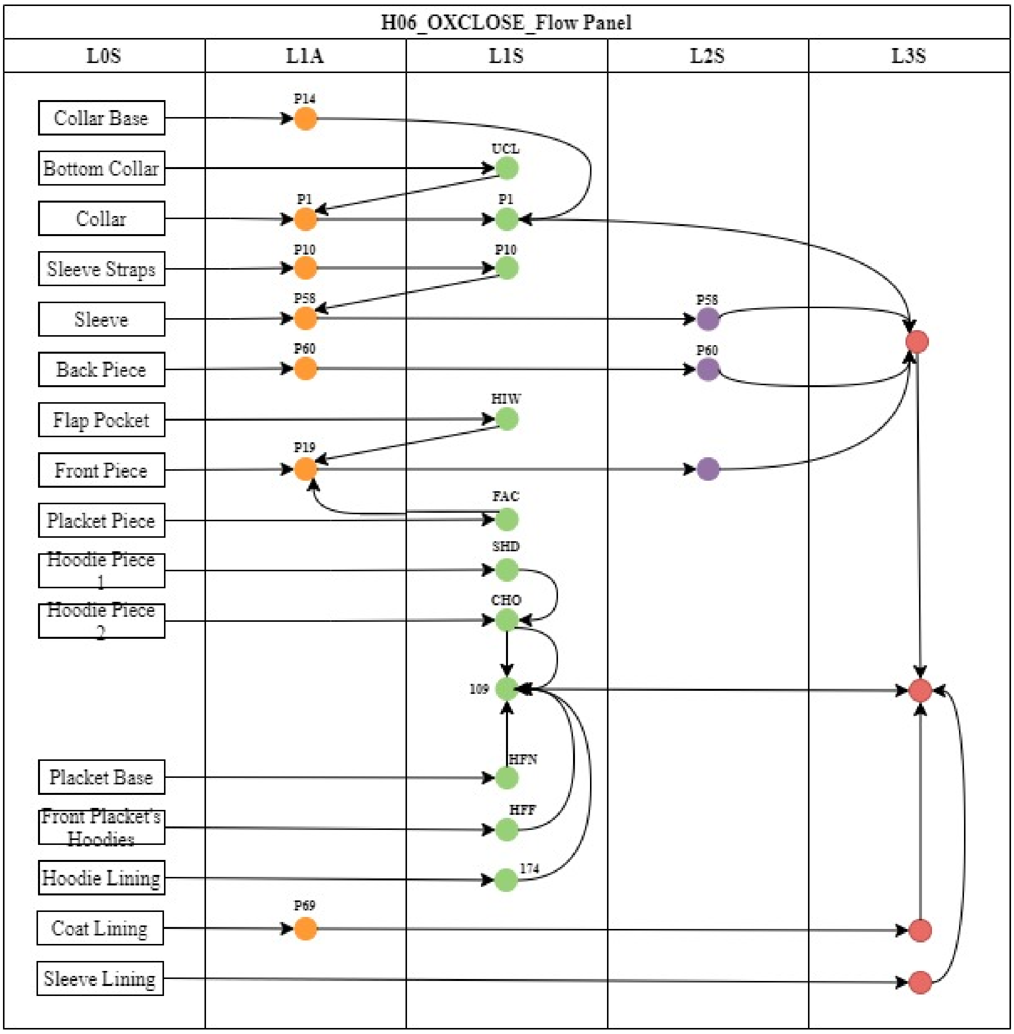

Figure 11. OXCLOSE_5LAS flow panel

Figure 11 and Table 3 show the redesign OXCLOSE clothing style's 5LAS process flow

The L1S process consists of 7 sub processes: B1X, B21, B31, B41, B51, B61, and B71 where B1X is Template Sewing, B21 is Trim and Turn, B31 is Pressing, B41 is buttoning, B51 is Hood, B61 is Top Stitch, and B71 is Belt in which Table 3 represents the redesign work sequence of OXCLOSE clothing style. The clothing parts highlighted in yellow can be proceeded in parallel. Also, the clothing part of collar (P1) and flap pocket (HIW) could have started first. Since both processes contain multiple dependency work in sub-process.

Table 3. OXCLOSE_7 Sub processes flow panel

	Step Sequences					
Clothing Part	1	2	3	4	5	6
Hoodie Piece 2 (CHO)	B12	B61	B31			
Hoodie Piece 1 (SHD)	B12	B61				
Hoodie Lining (174)	B12	B31	B61			
Collar (P1)	B21	B31	B41	B12	B51	
Bottom Collar (UCL)	B13	B31				
Flap Pocket (HIW)	B13	B21	B31	B41		
Sleeve Straps (P10)	B21	B31	B41			
Placket Piece (FAC)	B41					
Front Placket's Hoodie (HFF)	B12					
Placket Base (HFN)	B12	B31				
Hat (109)2	B13	B21	B31	B61	B51	B71

4.3) Test with new process

Two production line processes are mainly redesigned: 5LAS process and 7 sub processes in L1S process (One of the 5LAS process). We have firstly tested the redesign of 7 sub processes and then followed by the overview of 5LAS process. The assumption is if the redesign of sub process giving a good result, then the production lead time of the entire 5LAS product should be decreased.

CHAPTER 5

RESULTS AND DISCUSSION

In Chapter 5, experimental results from previous chapter are discussed and presented with reference to the aim of the study. Benchmarking and findings of this research are revealed. They explain the prominent points and the findings of this research which are led to the best practices at the end of this chapter.

Table 5 shows the new production capacity of each clothing part as well as the production lead time of each workstation in the redesign L1S process. Whereas Table 4 depicts the current standard time calculation and production capacity for OXCLOSE's L1S clothing part process. Data in table 4 is a real data that retrieved from ABC garment manufacturing company.

Table 4. Current production capacity of each clothing part and the standard time

Clothing Part	Standard Time (Min)	No. of Piece (1 Hr)
Hoodie Piece 2 (CHO)	3.97	15
Hoodie Piece 1 (SHD)	2.15	27
Hoodie Lining (174)	4.1	14
Collar (P1)	6.86	8
Bottom Collar (UCL)	0.68	87
Flap Pocket (HIW)	2.68	22
Sleeve Straps (P10)	2.67	22
Placket Piece (FAC)	2.53	23
Front Placket's Hoodie (HFF)	0.82	72
Placket Base (HFN)	0.79	75
Hat (109)	14.11	4
Total standard time and total pieces produced in 1 hr	**41.36** (Min)	**369**

Table 5. New production capacity of each clothing part and the standard time calculation

Clothing Part	Std. Time (Min)/Piece	No. of Piece /Hour
Hoodie Piece 2 (CHO)*	**3.58**	**29**
Hoodie Piece 1 (SHD)*	**2.09**	**33**
Hoodie Lining (174)*	**4.06**	**27**
Collar (P1)***	**6.51**	**17**
Bottom Collar (UCL)**	0.92	63
Flap Pocket (HIW)*	**2.39**	**24**
Sleeve Straps (P10)**	**2.02**	**47**
Placket Piece (FAC)	2.53	23
Front Placket's Hoodie (HFF)**	1.21	66
Placket Base (HFN)**	1.39	62
Hat (109)***	**14.05**	**8**
Total standard time and total pieces produced in 1 hr	**40.75** (Min)	**399**

The use of redesign heuristics (Mansar & Reijers, 2007) on clothing parts has led in increased production capacity and a shorter manufacturing lead time. From Table 4 and Table 5, the average production capacity of each clothing part is increased by 45%. The number of new outputs is subtracted by the current output to get the differentiated amount after applied the redesign process. Then, adding up the group of differentiated amounts together and divided by the count of each clothing part.

The asterisk (*) in each clothing part means this clothing part applied the redesign process where (*) is Parallel Tasks, (**) is Resource Optimization, (***) is Resequencing Task.

In parallel tasks (*), the researcher has set each L1S'sub processes in the simulation tool to parallelly run the clothing part. In other words, Hoodie lining, Hoodie piece 1, Hoodie piece 2 and Flap pocket are simultaneously run. The standard time of some clothing part has slightly decreased because the dependency among each sub-process is removed.

In resource optimization (**), the researcher has re-allocated the worker in each sub-process with the centralization to avoid one group of people overloaded and another group waiting for work. For example, clothing part of front placket's hoodie and placket base, B12's sub-process is the first workstation of both clothing parts, and they contain few processes. Hence, shared resources between these clothing parts are applied to B12 workstation. As a result, the production capacity is decreased, and the standard time is increased, respectively. However, it doesn't impact the entire production process much. It is reasonable to increase production lead time of bottom collar (UCL), front placket's hoodie (HFF) and placket base (HFN) as it will be offset with a decrease in production lead time of flap pocket (HIW) and sleeve straps (P10). Also, these clothing parts required a single piece per final assemblage unlike flap pocket (HIW) and sleeve straps (P10) which required double pieces.

For the case of bottom collar and sleeve straps, B31's sub-process is the second workstation of both clothing parts. Regarding to the resource optimization, we intend to increase the production capacity of the sleeve straps because OXCLOSE clothing style require 2 pieces of sleeve straps per clothe. Therefore, we have set the shared resources and the allocation rule in the B31's sub-process the simulation tools. As a result, the sleeve straps production capacity is doubled increased whereas the bottom car's is decreased.

Lastly resequencing task (***), since collar and hat contain many sub-processes than others and require the input from other processes such as L1A and within L1S itself, they should have started the tasks immediately once all components are ready at the workstation. Plus, these two clothing parts are considered as the top priority to start the process. The production capacity of both clothing parts is increased in accordance with the increase in other components such as hoodie piece 1, 2 and hoodie lining etc.

5.1) Benchmarking

To see the advantage of the new process, standard time and production capacity's comparison are made between the existing and new production process. These two variables are the important keys to disclose the new process efficiency. According to (Phiphopsuthipaiboon & Boonsiri, 2016), the business process reengineering (BPR) of unnecessary process elimination and process modification are applied to computer service center. Based on Soontorn's finding, the cycle time for service processes (day/working time) is reduced from 2.57 to 1.36 day/working time.

The new process reduces 6 unnecessary steps and this approach decreased cycle time and waiting time as per expectation. (Immawan, Asmarawati, & Cahyo, 2018) claims that key performance indicator (KPI) is one of the measurement tools to assist the comparison between the old and new business process. They also included production capacity as the main variable in KPI measurement. Meanwhile, standard time and production's capacity are two important key measurement in this thesis. With the redesign of production process, the average production capacity of each clothing part is increased by 45%. Comparing to other research, 45% is also a great achievement.

5.2) Findings

Process discovery and process analysis are the main principal of this research. Process discovery is an initial step which provides a baseline for process improvements and identifies key problem areas to be addressed by business process reengineering (BPR). The garment manufacturing process is very complex and lots of dependency tasks are required especially from the production process of fabric to finished product. It is crucial to break down the process into detail level. Besides, process analysis tool is also enabled you to understand the health of different operations within a business to improve process efficiency, identify the detrimental elements in an operation and how to overcome obstacles. Without a proper analysis, it will be a waste of time and effort solving the wrong problems or switching from one software to another. Hence, the researcher should consider and put these two processes as the highest priority at the beginning of the research.

5.3) Best Practices

To guide the process improvement action continuously, the new production process of OXCLOSE clothing style has been suggested to factory's manager since the new process provide the improvement of standard time and production capacity. It can substitute the current production process in long-run. In addition, we did some more studies about the continuous process improvement. Plan-Do-Check-Act (PDCA) cycle is one of the most popular tools, it is a four-step model of carry out change as the cycle should be repeated for continuous improvement. However, in a scope of this research, only the business process reengineering (BPR) has been focused as one of the methodologies to solve the core problems and it provided us the expected quantitative results. In the future work, the researcher will continue to study about how to improve the process continuously by using PDCA too.

CHAPTER 6

CONCLUSION

This chapter provides a short summary of the research. It describes the final conclusion of the method processes used to fulfil the research’s objectives. Future work and some limitations are also discussed.

This research focuses on the 5LAS process improvement by using the cause-effect diagram to identify the core problems in production process. After that, the fit-gap analysis is performed to discover the best fit solution. The redesign heuristics to the existing production line process is the final conclusion and the concept is applied.

The new process is being constructed using the simulation tool to model the new production process. The result of the simulation shows the increasing in production capacity and slightly decreased in production lead time of the clothing style OXCLOSE which is met the objective of this research paper.

In future work, the researcher has planned to study about the ERP software implementation to overcome the low productivity problems such as the behavior of relying too heavily on the report and manual work which is caused by the report. Due to the current circumstance of Covid19 pandemic, ABC Garment Manufacturing

Company has brought up a new protocol to create a hygienic workplace. All workers must be fully vaccinated and tested for Covid19 every week. With this protocol, it has been reported that no workers are infected to the disease for 3-4 months. However, the contingency plan is still required during this pandemic. Per suggestion, in order to compensate for infected workers during the pandemic, the manufacturing workers should be trained in multitasking to compensate for the lack of workers in some clothing's tasks activity.

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