THE IMPLEMENTATION OF PLAN-DO-CHECK-ACT CYCLE TO IMPROVE THE PRODUCTION LINE PRODUCTIVITY IN SURFACE MOUNTED TECHNOLOGY AREA OF INDUSTRY

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently in candidature for any degree.

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ABSTRAK

Lean mempunyai koleksi alat dan konsep yang sangat luas. Satu cara untuk memulakan organisasi dengan operasi pengeluaran yang bagus adalah menggunakan alat Lean. Pertubuhan yang berbeza boleh menggunakan teknik yang berbeza untuk meningkatkan proses pembuatan atau pengurusan mereka. Projek ini membincangkan penambahbaikan produktiviti di Kawasan Surface-Mounted-Technology (SMT) dengan menggunakan Alat Lean iaitu Plan-Do-Check-Act (PDCA) adalah metodologi berulang yang menggunakan pendekatan saintifik untuk membangunkan hipotesis, jalankan percubaan, menilai hasil dan memperbaiki eksperimen. Matlamat projek ini adalah untuk meningkatkan produktiviti pengeluaran SMT line No-6 oleh pelaksanaan PDCA dan Simulasi. Ia melibatkan pengenalan masalah di barisan pengeluaran SMT yang mempunyai keluaran produktiviti yang rendah disebabkan oleh masa proses yang tinggi dan tidak konsisten. Tindakan untuk menyelesai masalah untuk meningkatkan kecekapan proses akan dilaksanakan. Terdapat kesesakan pada proses tertentu dan keadaan ini memperlahankan kelajuan pengeluaran dan mempengaruhi aliran keseluruhan proses. Oleh itu, metodologi PDCA digunakan sebagai panduan untuk mengenalpasti punca masalah yang dipilih, membangunkan dan menapis tindak balas dan melaksanakan tindakan untuk menyelesai punca-punca masalah. Dari kajian ini, sebanyak lima penambahbaikan telah dicadangkan untuk mengurangkan masa proses, supaya unit pengeluaran per jam (UPH) sebenarnya dapat ditingkatkan. Dengan pelaksanaan PDCA sebagai penyelesaian, produktiviti garis meningkat dan UPH pengeluaran yang dihasilkan di SMT No-6 meningkat sebanyak 39% (73 unit menjadi 102 unit) dan ini membantu syarikat untuk memenuhi permintaan pelanggan.

ABSTRACT

Lean has a very extensive collection of tools and concepts. In order to improve the manufacturing operations, one way for an organisation to start, is to use a lean tool that captures their interest and resonates with them in some way. Different organisations may use different techniques to improve their manufacturing process or management. The current project addresses the line productivity improvement of a Surface-Mounted-Technology (SMT) by making use of the Lean Tool which is Plan-Do-Check-Act (PDCA) is an iterative methodology that applies a scientific approach to develop a hypothesis, run experiment, evaluate results and refine the experiment. The aim of this project is to improve the production productivity performance of the SMT production line No-6 by the implementation of PDCA and Witness Simulation. It involves problem identification at the SMT production line that has low productivity output due to the problem of high and inconsistent cycle time and provide solution to improve the efficiency of the current situation. There are bottlenecks on certain processes and this situation decelerates the production speed and affects the overall process flow. Therefore, the PDCA methodology is used to serve as a guideline for identifying the root cause of the selected problem, developing and refining countermeasures and implementing finalise solutions. From this research, total of five improvement have been suggested to decrease the cycle time of production processes, so that the actual production unit-per-hour (UPH) can be increased. With the implementation of the PDCA approach as a solution, the line productivity increased and the actual production UPH produced in the SMT production line No-6 increased by 39% (73 units to 102 units) and this helped the company to meet the customer demand.

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LIST OF ABBREVIATION

AOI	Automated Optical Inspection
CP	Capability Index
FA	Final Assembly
ILO	International Labour Organisation
LMS	Lean Manufacturing System
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
PDCA	Plan Do Check Act
SMD	Surface Mounted Device
SME	Small and Medium Enterprise
SMT	Surface Mounted Technology
THT	Through Hole Technology
TOC	Theory of Constraint
UPH	Unit-Per-Hour
UTH	Ultra-high temperature

CHAPTER ONE

INTRODUCTION

1.1 PROJECT BACKGROUND

Global changes, both political and social, have impacted the demand for manufactured goods. Output is expected to increase just 3.4 percent in 2017, and rising costs are resulting in lower margins. In order to reduce costs and improve margins, productivity gains and worker efficiencies are essential [1].

Operating equipment more efficiently, better utilizing labour, higher productivity and reducing waste are examples of incremental improvements that yield results. But many companies do not realize that actually having visibility into manufacturing inefficiencies means businesses can be more agile in production and continue to meet production demands and growth targets in a structured, manageable way [1]. Before doing any improvements, we should clearly notify the difference between productivity and efficiency. Efficiency is about *doing the same with less*. Productivity is about *doing more with the same.* Growth in labour productivity is measured by the change in output per labour hour over a defined period of time [2].

For most of the last three decades, many companies have been encouraged to take an efficiency mindset to their business, especially for the manufacturing sector to gain more profits, improved financial status, productivity and customer satisfaction [3]. But the most basic problem is whether the right improvement action has been taken by the company at the right time and the right place? In order to bring more benefits to the company, most to make sure all the strategic planning is being done correctly and effectively. One of the effective solutions is to improve productivity of production is by reducing the cycle time to complete one unit of product in order to achieve takt time and hit the customer demand.

The Plan-Do-Check-Act (PDCA) cycle is a four-step problem-solving iterative technique used to improve business processes [4]. The PDCA can help differentiate a

company from its competition, especially in today's corporate world, where anything that can help them streamline their processes to reduce costs, increase profits and improve customer satisfaction can give them an advantage. Companies are looking to enhance their internal and external processes often deploy PDCA methodology to minimize errors and maximize outcomes. Once put into effect, companies can repeat the PDCA cycle and make it a constant in their organization as something of a standard operating procedure for continuous improvement purpose [5].

The processes and statistical data based on the following ideas action occurs in a system of interconnected processes. Variation exists in all processes are used in statistical thinking and it is necessary to understand clearly. In order to improve productivity, various techniques have been used to deal with the problems from different areas such as time study, method improvement, quality improvement tools, line balancing technique through PDCA approach and simulation using Witness 14 Software.

Used of stopwatch and video recording in time study are the most common of time measurement techniques that record the times and the rate of working for a particular task or job which was carried out under specified condition. Since the project background is related to Surface-Mounted-Technology (SMT) area, special and specific measurement technique to undergo the time study is required. Time study actually is a very easy and useful scientific approach to measure, record and analyse the time it takes to perform actions, in order to evaluate performance and set baselines for process improvement.

1.2 BACKGROUND OF THE STUDY

The observed company is a sound system designer and manufacturer located in West Malaysia. This company is a contract manufacturer which generates products or goods under the brand name of a different company and it is opposed to Original-Equipment-Manufacturer (OEM). Production departments in this company include SMT, Through-Hole-Technology (THT) and Final-Assembly (FA).

A huge majority of today's electronics are manufactured with SMT. Devices and products that use SMT have a large number of advantages over traditionally routed circuits; these devices are known as surface mount devices (SMD). These advantages have ensured that SMT dominated the Printed-circuit-board (PCB) world since its conception. PCB is the most basic component required to make a sound system device. This company use SMT to mount electronic components onto the surface of the PCB and many components are very small in size.

Virtually, SMT process is used commercially in today's industry because it offered significant advantages during manufacture, and in view of the size, the use of SMT components enabled far more electronic components to be packed into a much smaller space. In addition to the size, SMT allowed automated production and soldering to be used, and this brought significant improvements in reliability. Why SMT was selected as the background of study? This is due to the PCBs produced in SMT is the very first step in manufacturing of a sound system device. If the actual total units of PCBs produced per hour in SMT line is not high enough to supply to the next station which is THT, then the customer demand is not able to be met. This problem occurred because the productivity of the production line of this company is not high due to inconsistent cycle time of every processes.

Basically, there are total of six production lines in the SMT area in the company. Each production line will run production of PCBs in batches. They will process the top side of the PCBs first then only turn over to process the bottom side in different batches, as shown in Figure 1.2.1 and Figure 1.2.2.

Figure 1.2.1: Top Side of PCB

Figure 1.2.2: Bottom Side of PCB

The whole SMT processes for making the PCBs are studied in this research. This case study project is conducted to solve the issue of the SMT line production which has the low UPH of PCBs produced. Each production line has 5 operators to handle all the machines. Besides the low production rate, which is inadequate to meet the customer needs, it also results in higher production costs. This case study has been fixed to analysis the SMT production line No-6 and this line is specified to produce the PCBs for one of the latest soundbar model in this company. This current actual production UPH of that specified model is only 73 units. In order to meet the customer demand, the targeted actual production UPH must achieved 90 units for the entire production line.

Therefore, every machine in SMT production line played a crucial role to ensure smooth production so that the right units with highest quality of PCBs can be delivered on time. The major concerns are to solve all the problems occurred in the line so that no one process becomes a bottleneck.

1.3 PROBLEM STATEMENT

SMT for producing PCB has increased extensive utilization of hardware. But for this research company, their performance such as productivity of production line in SMT area is not good since they are not able to achieve targeted daily demand. This will lead to a huge loss to this company in terms of overpay to speed up their production. A contract manufacturer like this company should strengthen their performance and make sure they can achieve the customer demand. In order to strengthen their competitiveness, the productivity of production line in SMT area must be the most important thing to always being observed. For this research project, method to improve productivity in SMT area will be carried out. This aspect helps in achieving customer demand and increase the revenue of the company.

1.4 OBJECTIVES

The research examines the various way to reduce the cycle time of every stations in a SMT line in order to improve the line productivity of the production line. All of the standard work and specifications of the SMT process were taken into consideration so that the problem that occur can be resolved. The objectives of this research are:

1. To improve the productivity i.e. actual production UPH for the specific SMT line by using PDCA cycle in order to meet the customer demand.
2. To compare and analyse the impact of two-line configurations through simulation model in Witness Simulation 14 Software.
3. To propose the productivity improvement techniques in order to improve the company production.

1.5 SCOPE OF WORK

The case study needs the whole understanding of the process flow of SMT. For example, the function of each machines in the line and also the specific time study method used for SMT. It will concentrate on how to increase the line productivity i.e. actual production UPH by using PDCA cycle which use four-stage approach for continually improving processes, products or services, and for resolving problems. It involves systematically testing possible solutions, assessing the results, and implementing the ones that are shown to work. The work study techniques will be used to examine the processes. The cycle time for every process in the entire production line will be measured and recorded by using stopwatch time study technique. Some productivity improvement tools such as process flow chart, 5 why analysis method, Yokoten approach will be presented into the project.

1.6 SIGNIFICANT OF THE STUDY

The study is conducted by using real manufacturing processes data. The research defines the necessity of doing improvements in line productivity. Based on the research objectives, the final result will solve the problem of ineffective of SMT production line and help the company to produce required or targeted units of product in order to meet customer demand. The project will provide the company with knowledge on how to apply the productivity improvement techniques to improve the cycle time of each processes under the guideline of PDCA lean tool. The project will focus primarily on the improvement of the productivity performance in term of cycle time of the SMT production line of the company.

1.7 RESEARCH METHODOLOGY

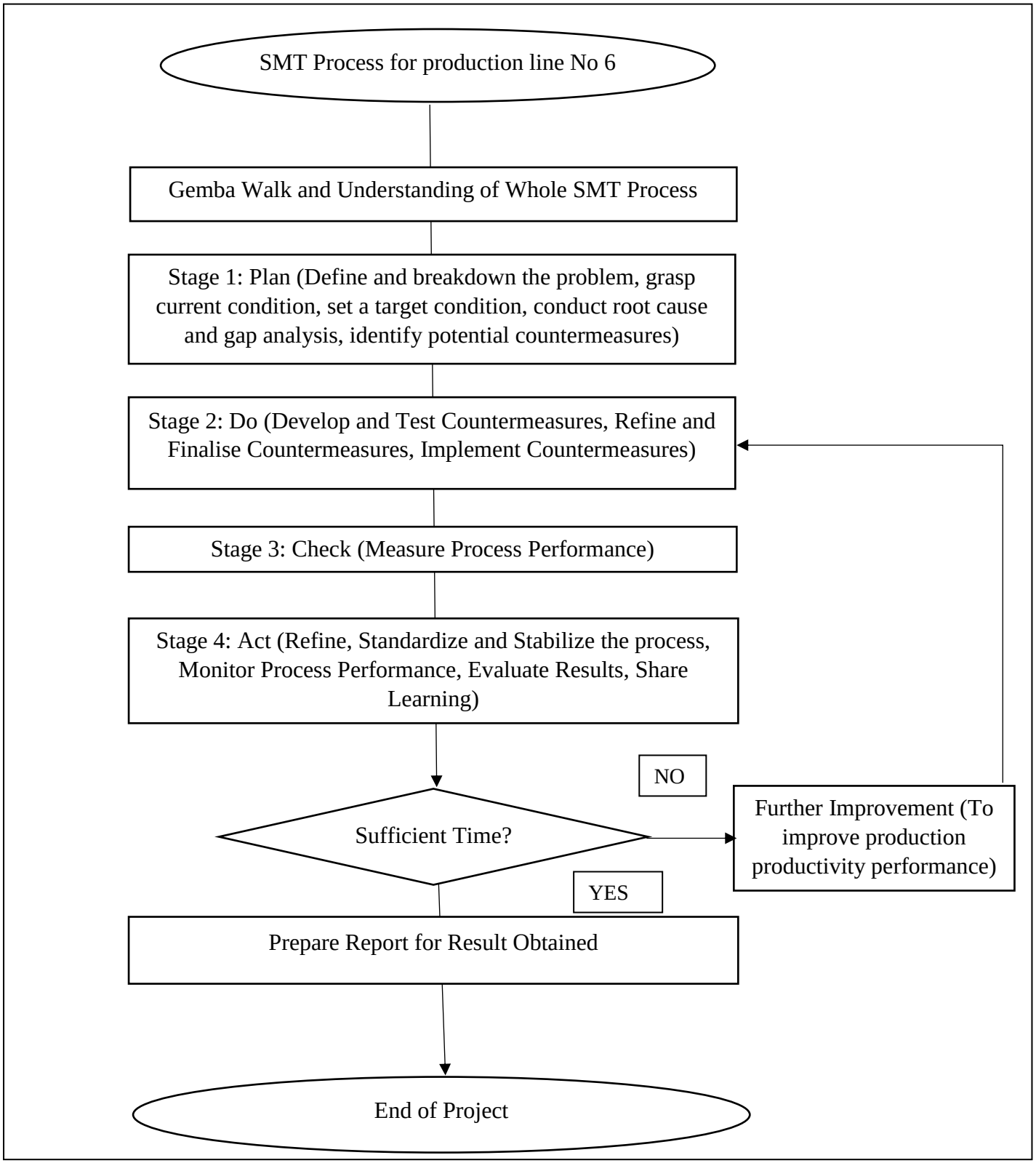

Figure 1.7: Research Methodology Flow Chart

Every process involved in the SMT production line must be studied and how the operators in the line are performing their task must be observed and learned in order to truly understand the operation. Next, a process flow chart should be drawn to illustrate the manufacturing process of PCB, what are the machines and steps required for the production line.

Throughout the improvement project, the first step consists of defining and breaking down the problem that existed at the production line. Then, Gemba Walk technique is used to grasp current condition then only followed by setting a target condition. A pattern of operating that the project wants to reach in the future. Next, use of any tools such as 5 why analysis or cause and effect diagram to conduct root cause and gap analysis. This will identify the reasons behind the problems and emphasize the problem that need to be tackled first in the production line. A brainstorming of appropriate solution or potential countermeasures will be carried out based on all the root causes. Next step is to identify, test, refine, finalise and implement countermeasures. Once the implementation of the solution has been started, the performance of the production line before and after improvements done is tracked and analysed. The simulation model has to be constructed to analysis the differences between the original production line and improved production line condition. Lastly, the performance must be standardised and monitored and shared learning action will be carried out at the end in order to list down any improvements which can be shared or leveraged to other departments or sections.

1.8 THESIS OUTLINE

The thesis is divided into five chapters. Chapter One (Introduction) will be briefly discussed about the project background, background of the case study, problem statement, objectives, scope of work and research methodology for the project. Chapter Two (Literature Review) will be explained more details about the Lean Manufacturing, Lean Tool PDCA cycle, bottleneck processes, line balancing and Witness Simulation. Chapter Three (Methodology) will emphasize on the PDCA 12 steps as well as simulation model construction by using Witness 14 simulation software, Results and discussions will be describe in Chapter Four (Results and Discussion) and Chapter Five (Conclusion) will summarize this research.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter will discuss and provide literature review information about Lean Manufacturing, PDCA, Bottleneck Process and Line Balancing. Furthermore, this chapter will also discuss time parameters in a production system such as cycle time and takt time. Research via journals and books was conducted to synthesis all the high qualities research evidence that relevant to this project.

2.1 LEAN MANUFACTURING

Lean-Manufacturing-System (LMS) is an important approach that could maximize customer value and reduce the amount of waste. The use of LMS in Malaysia is still lacking especially among Small-and-Medium-Enterprise (SME) in rural areas. In accordance with the growth of manufacturing industries in Malaysia, the practice of LMS is very important to assist the firms achieving high production efficiency. Basically, there are 7 types of wastes in lean manufacturing as illustrated in Figure 2.1.

	Type of Waste	Description
1	Overproduction	Producing too much or too soon, resulting in poor flow of information or goods and excess inventory.
2	Defects	Frequent errors in paperwork, product quality problems, or poor delivery performance.
3	Unnecessary inventory	Excessive storage and delay of information or products, resulting in excessive cost and poor customer service.
4	Inappropriate processing	Going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach may be more effective
5	Excessive transportation	Excessive movement of people, information or goods resulting in wasted time, effort and cost
6	Waiting	Long periods of inactivity for people, information or goods, resulting in poor flow and long lead times.
7	Unnecessary motion	Poor workplace organisation, resulting in poor ergonomics, eg excessive bending or stretching and frequently lost items.

Figure 2.1: Description of LMS 7 wastes [6]

2.2 PLAN-DO-CHECK-ACT (PDCA) CYCLE

PDCA is a well-known and respected approach to help a team plan or implement a solution to a problem. The basic philosophy of PDCA is to continually identify and eliminate sources of waste and variation that reduce value provided to customers [7]. There are total of four phase which consist of 12 steps approach in the full PDCA cycle and illustrated as in Figure 2.2.1.

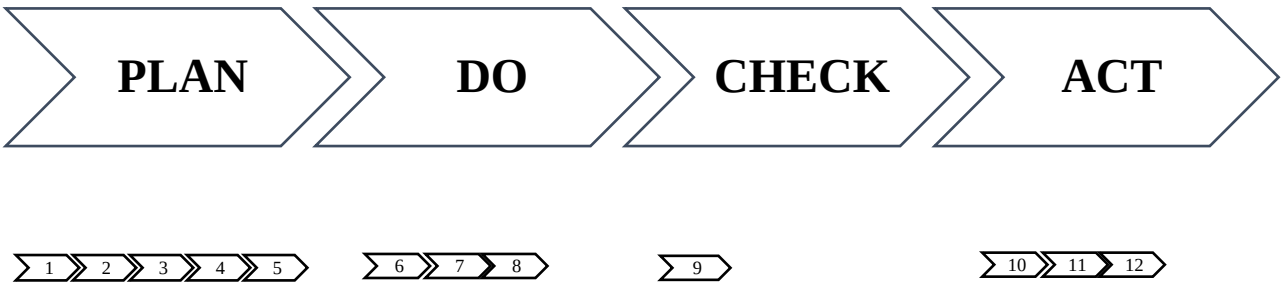

Figure 2.2.1: PDCA 12 steps approach [8]

1. Define and break down the problem.
2. Grasp current condition.
3. Set a target condition.

4. Conduct root cause and gap analysis.
5. Identify potential countermeasures.
6. Develop and test the countermeasures.
7. Refine and finalise countermeasures.
8. Implemented countermeasure.
9. Measure process performance.
10. Refine, standardize and stabilize the process
11. Monitor process performance
12. Evaluate results and share learning.

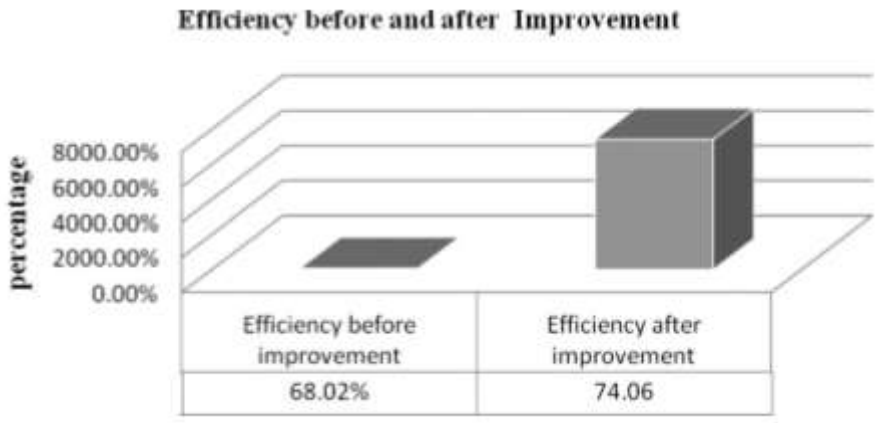

Figure 2.2.2: Comparison between efficiency before and after improvement

Figure 2.2.2 is the result from a study that implemented PDCA cycle as a method for the continuous quality improvement in the dairy laboratories [9]. This method was used to identify and analyse the critical problems that occur in the preanalytical stage of ultra-high-temperature (UHT) milk samples, to find the root causes of their occurrence and proffer solutions. Results showed a reduction in the number of the contaminated UHT milk samples from initial 368 to 85. Moreover, the capability index (CP) increased from 0.52 to 1.07. These reductions in the number of contaminated milk samples and increase in CP increased the efficiency from 68.02% to 74.06% and the effectiveness from 88.95% to 96.85%. Thus, PDCA methodology can be successfully applied in the dairy laboratory to reduce the occurrence of errors and increase the processes capability to enhance the efficiency and effectiveness of dairy laboratory [9].

2.3 SURFACE MOUNT ELECTRONICS

SMT, electronics assembly is the predominant form of electronic circuit construction worldwide today [10]. A completed surface mount electronics assembly has three main ingredients: the printed circuit board or PCB, solder paste, and the functional electrical components which must be connected. The PCB is a complex rigid assembly of many layers. The top and bottom of the PCB are covered in metal contacts. All of the functional electronic components will be attached to these pads.

2.3.1 SURFACE MOUNTED TECHNOLOGY PRODUCTION LINE

A simplified version of the SMT manufacturing process is illustrated in Figure 2.3.1. First, all the PCB will be loaded into the laser marking machine to do the laser marking on the PCB. Then, a layer of solder pastes will be applied on the PCB. Due to the majority of SMT defects originating in the printing process, before placing one single component on a PCB, a Solder-Paste-Inspection (SPI) machine will check the solder coating, thickness, aperture, as well as the printing press and speed [11]. Data recorded on SPI machines is linked directly to Automated Optical Inspection (AOI) which is allowing us to quickly investigate and analyse any concerns or failures. If there is any failure, the PCB has to send it back to touch up process. In order to solder components to a PCB, it is necessary to “print” solder paste bricks over the metallic contact pads on the board. Once this is successfully achieved and verified by optical or laser inspection, the components are placed on top of the solder bricks and their leads are pushed into the solder paste. When the components have been attached, the solder paste is melted using either reflow soldering or vapor-phase soldering to create the electro-mechanical junctures [12]. To finalize the product, the entire assembly is carried through a reflow oven [13]. This oven raises the solder paste above its melting temperature and secures the components to the board. Finally, the manufactured PCBs are inspected by using AOI machine in order to verify solder quality, part markings, pad placement and solder joints so that a high quality of PCB can be produced. Each AOI shares software and offline programming capabilities, giving us ultimate flexibility to examine the product at every step of the manufacturing process.