# COMPARISON OF ACTIVITY-BASED COSTING AND TIME-DRIVEN ACTIVITY-BASED COSTING FOR PRINTED CIRCUIT BOARD ASSEMBLY IN INDUSTRY PRODUCTION

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NUR SYAFIKAH BINTI PINUEH

Thesis submitted in fulfillment of the requirements
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# ABSTRAK

Analisis pengekosan tradisional (TCA) ialah kaedah untuk menetapkan kos kepada produk berdasarkan jumlah sumber yang digunakan. Isu dengan TCA ialah overhed kilang hanya dianggap sebagai buruh langsung, jadi perubahan kecil dalam jumlah sumber mencetuskan perubahan besar dalam jumlah overhed yang digunakan. Setelah itu, pengekosan berasaskan aktiviti (ABC) telah dibangunkan untuk mengatasi masalah peruntukan kos yang berkaitan dengan TCA dengan menggunakan analisis yang lebih terperinci tentang hubungan antara kos overhed dan pemacu kos. Walau bagaimanapun, ABC secara teorinya kurang tepat kerana mengabaikan potensi kapasiti yang tidak digunakan yang mana bermanfaat untuk peramalan. Model ABC dan pengekosan berasaskan aktiviti dipacu masa (TDABC) pernah dikaji dalam garis proses induktor magnetik. ABC menonjolkan pemacu kos dalam struktur pengekosan manakala TDABC menilai peranan kadar kos kapasiti dan persamaan masa yang akhirnya membawa maklumat penggunaan kapasiti yang berguna untuk ramalan pada masa hadapan. Objektif utama kerja ini adalah untuk mencadangkan amalan terbaik kaedah pengekosan untuk pengeluaran industri elektronik. ABC dan TDABC dibangunkan untuk pengeluaran elektronik yang terletak di Pasir Gudang, Johor. Kedua-dua kaedah dibandingkan dari segi peruntukan kos, tindakan penentuan pemandu yang diambil untuk aktiviti tambahan, pertimbangan kos, bermaklumat, ketelusan, terlalu memudahkan aktiviti dan ramalan kapasiti. Hasilnya, ramalan kos seunit untuk PCBA tunggal menggunakan kaedah ABC diperoleh pada RM14.02 yang lebih tinggi sedikit kira-kira 5.27% daripada kaedah TDABC, iaitu hanya RM2.66. Seterusnya, TDABC juga menyediakan jumlah dan nilai tepat yang berkaitan dengan kapasiti syarikat yang tidak digunakan. Analisis kapasiti yang tidak digunakan memberikan dua maklumat iaitu masa yang tidak digunakan dan kos yang tidak digunakan. Masa yang tidak digunakan dan kos yang tidak digunakan untuk aktiviti penyediaan bahagian memuatkan ialah -1,787,800 minit dan MYR -10,499,733.60 masing-masing, yang boleh dikatakan bahawa kaedah pengekosan sebelumnya melebihi menentukan kos pengekosan. Sementara itu, masa tidak digunakan dan kos tidak digunakan untuk aktiviti pencetakan tampal pateri masing-masing ialah 776,200 minit dan MYR 1,711,402.40, yang boleh dikatakan kos pengekosan aktiviti ini ditakrifkan dengan baik kerana ia hanya berbeza sedikit dengan masa penggunaan sebenar dan kos terpakai. Dengan membandingkan kaedah ABC dan TDABC, salah satu ciri terpilih yang telah dibandingkan ialah bilangan pemacu yang ABC hanya menggunakan pemacu tunggal manakala TDABC menggunakan berbilang pemacu. Oleh kerana keterbatasan masa, kajian ini hanya mengambil kira satu pengeluaran syif, justeru untuk kajian akan datang boleh mempertimbangkan untuk menjalankan kajian bagi syif malam bagi melihat perbezaan tahap usaha (sumber manusia) antara syif siang dan syif malam.

# ABSTRACT

Traditional costing analysis (TCA) is a method used to assign costs to products based on the volume of resources used. The issue with TCA is that factory overhead only considered direct labor, so a small change in the volume of resources triggers a massive change in the amount of overhead applied. Subsequently, activity-based costing (ABC) was developed to overcome the cost allocation problems associated with TCA by using a more detailed analysis of the relationship between overhead costs and cost drivers. However, ABC is theoretically incorrect when it ignored the potential for unused capacity which will be beneficial for forecasting. Recently, the model of ABC and time-driven activity-based costing (TDABC) method was compared in the study of magnetic inductor's process line. ABC highlights the cost driver in the costing structure while TDABC appraises the role of capacity cost rate and time equation which eventually leads capacity utilization information that is useful for forecasting in the future. The main objective of this work is to compare the costing method for electronic production. ABC and TDABC is developed for the electronic production located at Pasir Gudang, Johor. Both methods are compared in term of cost allocation, driver determination action taken for an additional activity, cost consideration, informative, transparency, oversimplification of activities and capacity forecast. As a result, a forecasting of cost per unit for a single PCBA using ABC method was obtained at RM14.02 which slightly higher about 5.27% than TDABC method, which is only RM2.66. Next, TDABC also 0provided the exact amounts and values relating to a company's unused capacities. The unused capacity analysis gives two information which are unused time and unused cost. The unused time and unused cost for preparation loading part activity are -1,787,800 minutes and MYR -10,499,733.60 respectively, which can be said that the previous costing method over defined the costing cost. Meanwhile, the unused time and unused cost for solder paste printing activity are 776,200 minutes and MYR 1,711,402.40 respectively, which can be said that this activity costing cost is well defined as it is only slightly different with its actual used time and used cost. By comparing ABC and TDABC method, one of selected features that has been compared is number of drivers which ABC only used single driver while TDABC used multiple drivers. Due to limitations of time, this study only considers one shift production, thus for future study may consider to conduct the study for the night shift in order to observe the difference level of effort (human resources) between day shift and night shift.

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## LIST OF SYMBOLS

| | |
|---|---|
| \$ | Dollar currency |
| $\beta_1$ | Estimated time to perform the incremental activity |
| % | Percentage |
| $x_i$ | Quantity of the incremental activity |
| $\beta_0$ | Standard time to perform the basic activity |
| $T_t$ | Time needed to perform an activity |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ABC | Activity-based costing |
| APAC | Asia pacific |
| AOI | Automated optical inspection |
| CCR | Capacity cost rate |
| CCS | Capacity cost supplied |
| CAD | Computer-aided design |
| CAM | Computer-aided manufacturing |
| COVID-19 | Coronavirus disease 2019 |
| FCT | Functional test |
| ICT | In-circuit test |
| JIT | Just-in-time |
| JTAG | Joint test action group |
| MRP | Material requirements planning |
| PCRS | Practical capacity resources supplied |
| PCB | Printed circuit board |
| PCBA | Printed circuit board assembly |
| SMD | Surface-mounted device |
| THT | Through-hole technology |
| TDABC | Time-driven activity-based costing |
| TQM | Total quality management |
| VMI | Visual manual inspection |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Research background

Electrical or electronic circuits using a diagram is called a schematic, that consists of component symbols connected by lines. The symbols represent passive components such as resistors and capacitor, integrated circuits such as microcontrollers, and the lines represent conductive pathways that allow electrical current to flow from one point of the circuit to another. A schematic is, after all, just a drawing. To actually achieve the functionality of the circuit such as control fan speed, or blink a light emitting diode, the schematic drawing need to build up into its physical components and physical interconnections. Usually simple schematic used breadboard to show its physical version, whereas complex circuit designs used printed circuit board (PCB) to show its physical version (Keim, 2020).

The PCBs are mainly used to provide electrical connection and mechanical support to the electrical components of a circuit. They are frequent in electronic devices and can be easily identified as the green-coloured board. Based on the design specifications and requirements, many active such as operational amplifiers and batteries and passive components are mounted on the PCBs to match the form factor of the final design. Form factor is an aspect of any hardware design that describes the overall size, shape, and other pertinent physical characteristics of the PCB. PCB design form factor is decided by taking into account many factors, including board configurations, mounting systems, and chassis. Copper interconnects are used to connect the components on a PCB and serve as a route for electrical signals (Bhunia & Tehranipoor, 2019).

To develop a working PCB that operates according to the required functionality, three key steps must be successfully completed. First, develop a suitable design specification for the required circuit, then develop the circuit schematic to meet the initial design specification, and finally develop the PCB layout which is the actual representation of the design that will be manufactured. Secondly, manufacture process. The manufacture of the PCB itself must stick to the design details. The two main steps are manufacturing the PCB base which is insulating base with metal interconnect, and electrically and mechanically connecting the electronic components to the PCB base. Thirdly, testing process. The purpose of testing the design and manufactured PCB is to find out whether the design is working or not. Testing is undertaken at several points during the design and manufacture which are include both simulation and physical testing (Grout, 2008).

Next, by considering PCB production in the Asia Pacific (APAC) region, China leads the charge, accounting for 50% of the global production in 2018, followed by Taiwan with 12.6%, and South Korea with 11.6%. It is anticipated that the existence of significant electronics manufacturers in these nations, such as Sony, Panasonic, Samsung, and others, will keep the engine of expansion running. Another countries that are developing in the APAC area which manufacture PCBs include Vietnam, Thailand, and Singapore. In fact, around 91% of the global PCB and printed circuit board assembly (PCBA) production is concentrated in APAC. As continuous the generations, the PCB sector is constantly evolving with novel developments and trends in a variety of associated technologies occurring each year. These are the major advancements boosting the PCB sector ahead. First, there is the growing digitization. PCB and PCBA sales will continue to increase on the consumer and industrial fronts due to the rising need for digitalization in developing and underdeveloped nations. The second is the rise in the rate of recycling PCBs. Government regulations pertaining to sustainability and the environment will likely encourage the promotion of PCB recycling in 2021 as well as future years. Thirdly, advancements in PCB design. It is anticipated that improvements in PCB design, such as substituting conventional flame retardant type 4 with bismaleimide-triazine resin epoxy and polyamides, would boost competitiveness and expansion in the worldwide PCB industry (MKTPCB, 2021).

Besides, by considering Malaysia exports and imports, in 2020, Malaysia exported \$606M in PCB, making it the 11th largest exporter of PCB in the world. At the same year, PCB was the 63rd most exported product in Malaysia. The main destination of PCB exports from Malaysia are Singapore with \$192M, United States with \$72.2M, Thailand with \$55M, China with \$39.6M, and Hong Kong with \$29.1M. The fastest growing export markets for PCB of Malaysia between 2019 and 2020 were Ireland with \$9.94M, Netherlands with \$7.35M, and South Korea with \$3.79M. While for import scenario, also in 2020, Malaysia imported \$2.07B in PCB, becoming the 6th largest importer of PCB in the world. At the same year, PCB was the 13th most imported product in Malaysia. Malaysia imports PCB primarily from China with \$773M, Chinese Taipei with \$343M, South Korea with \$193M, United States with \$159M, and Singapore with \$155M. The fastest growing import markets in PCB for Malaysia between 2019 and 2020 were China with \$168M, Thailand with \$66.3M, and South Korea with \$57.9M (Observatory of Economic Complexity, 2021).

Furthermore, a production line refers to the organized path of assembly for a product. At each workstation in the production line, a factory worker or machine adds a piece to the finished product, performs a quality control check to the completion of the project. Thus, the original concept of the production line was used to turn raw products into usable goods by assigning workers individual roles in the process (Ray, 2023). While workstation refers to any point on the production line where operators execute a task on the manufactured piece. An ideal production rate is where each product is produced within the set time frame (Corning Data International, 2021).

The traditional approach for setting up a workstation is to start with a generic workbench and plunk down the equipment, materials, and tools needed to do the job. A workbench like this can be fine in some settings, like a maintenance shop where a variety of different tasks are performed on different types of items. However, when the work involves high-volume production, intricate tasks, or specialized operations, the traditional approach can create hindrances that waste time, lead to defects, and even create long-term disorders like back injuries or shoulder problems. It is normally better to design a specialized workstation in these circumstances. The workstations must then be set up to be integrated with material handling systems (Mac, 2015).

Additionally, mass-producing circuits with PCBs are cheaper and faster than with other wiring methods, as components are mounted and wired in one operation (Grigalunas, 2019). There are five types of production which are mass production, batch production, job production, service production and customized production. Through this study, I will focus on mass production. Mass production means there is continuous production, and all employees work continuously to produce the same items at the same time. In this kind of production, the forms and size of the products remain the same and every employee focuses on the same product. All resources are utilized to produce the same range. To make production more efficient and effective, multiple tasks may be carried out at once to get quick results (Study Smarter, 2020).

Moreover, there are several existing methods of accounting which are financial accounting, managerial accounting, and cost accounting. Financial accounting refers to the processes used to generate annual financial statements. The results of all financial transactions that occur during an accounting period are summarized in the balance sheet, income statement, and cash flow statement. The financial statements of most companies are audited annually by an external audit firm. Next, managerial accounting uses much of the same data as financial accounting, but it organizes and utilizes information in different ways. Namely, in managerial accounting, an accountant generates monthly or quarterly reports that a business's management team can use to make decisions about how the business operates. For cost accounting, its helps businesses make decisions about costing. Essentially, cost accounting considers all the costs related to producing a product. Analysts, managers, business owners, and accountants use this information to determine what their products should cost (Fernando, 2023).

On top of that, there are also another specific costing method which are activity-based costing (ABC) and time-driven activity-based costing (TDABC). As explanation, ABC is a system to find production costs. It breaks down overhead costs between production-related activities. The ABC system assigns costs to each activity that goes into production, such as workers testing a product. Because ABC gives specific production cost breakdowns, we can see which products are actually profitable (Blakely, 2021).

While TDABC is an advance of ABC method which the costing gives owners of small, medium, and large business alike a clear understanding of the actual cost of product production, delivery of service offerings and individual tasks performed inside their companies. To accomplish this, TDABC focuses on the relationship between time and cost measurement to determine costs of one unit of time for an activity in the business, whatever that unit is. This ability to understand unit economics enables management reporting (King, 2018).

## 1.2 Problem statement

Traditional costing analysis (TCA) is a method used to assign costs to products based on the volume of resources used, such as labor hours or machine hours (Srivastav, 2016). Under this method, factory overhead such as production supervisor salaries, factory utilities and rent, equipment setup costs and maintenance, is usually applied based on either the amount of direct labor hours consumed, or machine hours used. The trouble with TCA is that factory overhead much higher than the basis of allocation, so a small change in the volume of resources triggers a massive change in the amount of overhead applied. When total manufacturing costs MYR189,097.79 and total sales MYR1,181,861.14, the company's overhead costs will consume 16% of monthly revenue. This is a common issue in automated production environments, where factory overhead is quite large and direct labor is close to non-existent (AccountingTools, 2023).

ABC was developed to overcome the cost allocation problems associated with traditional costing, by using a more detailed analysis of the relationship between overhead costs and cost drivers. Many cost drivers may be used to determine the causes of overhead, which can be used to minimize overhead costs. Examples of cost drivers are direct labor hours worked, the number of customer contacts made, the number of engineering change orders issued, the number of machine hours used, and the number of product returns from customers (AccountingTools, 2023). However, ABC theoretically incorrect when it ignored the potential for unused capacity which will be beneficial for forecasting (Kaplan & Anderson, 2007). For example, in the wind wire using CNC machine of magnetic inductor, when practical capacity is 247,000 and used time is 1043.71 minutes, then the unused time is 246,156.29. While the other hand when capacity cost rate times practical capacity, then subtract the total cost, the unused cost is MYR622,775.41. Consequently, high unused time and cost can be minimize in the future.

Zamrud (2021) compared the model of ABC and TDABC in the study of magnetic inductor's process line. ABC highlights the cost driver in the costing structure while TDABC appraises the role of capacity cost rate and time equation which eventually leads capacity utilization information that is useful for forecasting in the future. Therefore, this research study was conducted to compare cost allocation, driver determination action taken for an additional activity, cost consideration, informative, transparency, oversimplification of activities and capacity forecast with different product and to decide either ABC or TDABC is suitable for the company.

### 1.3 Research objectives

1. To determine the cost driver rate of industry production by using ABC method.
2. To analyse the unused capacity of industry production through capacity cost rate and time equation in TDABC method.
3. To compare ABC and TDABC method in an industry production by comparing selected features in both methods.

### 1.4 Research question

1. How does ABC determine the cost driver rate?
2. Why unused capacity generated by TDABC makes TDABC better than ABC?
3. How does TDABC appeal its speciality in costing analysis better than ABC?

## 1.5 Research scope

1. The product under study is PCBA.
2. Data collection is taken from XX company in Pasir Gudang, Johor.
3. The XX company is a company that manufactures electronics products.
4. The data duration is 1 year which only consider 1 shift working hour.
5. Method analysis used are ABC and TDABC.

## 1.6 Thesis outlines

Chapter 1 describes the research background, problem statement, research objectives, research question, and research scope. Chapter 2 disclosures about circuit theory, overview of PCB from its design flow until testing process, relation of PCB with PCBA, information on PCB production statistics and overview different types of method which include TCA, ABC and TDABC. This chapter 2 also cover about research motivation that fill the gap between this research study with previous study. Chapter 3 describes in detail the research methodologies used in the study which can be categorized into four phases. Phase 1 is problem definition, phase 2 is on site observation, phase 3 is data analysis and phase 4 conclusion. Chapter 4 describes the implementation of ABC method and TDABC method into the production process. This chapter 4 also discuss the comparative study about these two methods in aspect of eight features which are cost allocation, driver determination, action taken for additional activity, cost consideration, informative, transparency, oversimplification, and capacity forecast. Chapter 5 summaries this research study in scope of fulfillment of research objectives and some recommendation for further study.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Chapter 2 discusses the studies about circuit theory, printed circuit board (PCB), traditional costing analysis (TCA), activity-based costing (ABC), time-driven activity-based costing (TDABC) and research motivation for both ABC and TDABC applications.

## 2.2 Circuit theory

A network constructed up of wires and circuit components is identified as a circuit. Particularly, on an electrical schematic, wires tend to be displayed as straight lines, while nodes are locations where wires connect. On a schematic diagram, each individual symbol represents a circuit element. This section presents an overview of the three most common passive linear circuit elements found in electronic circuits, which are resistors, capacitors, and inductors (Bhunia & Tehranipoor, 2019).



### 2.2.1 Resistors and resistance

Resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor. They are designed to have a specific resistance value, measured in ohms. There are many types of resistors, which can be divided into fixed resistors, variable resistors, high-power resistors, low-power resistors, and many more. Figure 2.1 shows different types of resistor representative (JAK Electronics, 2023).

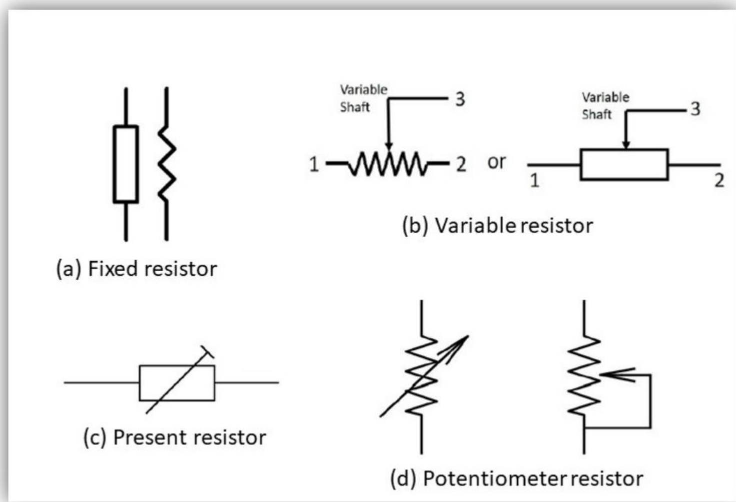


Figure 2.1 The difference types of resistor and its schematic drawing.
Source: JAK Electronnics (2023)

### 2.2.2 Capacitor and capacitance

Potential energy is stored in an electric field by passive two-terminal electrical components identified as capacitors. Their capacitance is what distinguishes them. They are used in electrical circuits to permit alternating current to flow through while restricting direct current. Other than that, they are employed in analog filter networks to control the power supply output. While in resonant circuits, capacitor and capacitance act in tuning radios to the required frequencies. The typical schematic diagram of three types of capacitors is shown in Figure 2.2 (Bhunia & Tehranipoor, 2019).



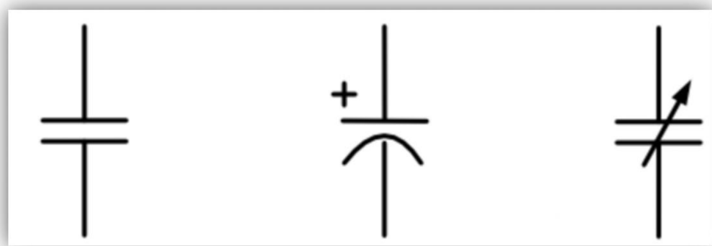


Figure 2.2 The different types of capacitors (fixed, polarized, and variable).
Source: Bhunia & Tehranipoor (2019)

### 2.2.3 Inductors and inductance

Inductor is totally different from a capacitor. In the case of a capacitor, it stores energy as electrical energy, but an inductor stores energy in the form of magnetic energy. One key feature of the inductor is that it also changes its polarity while discharging. In this way, polarity during discharging can be made opposite to the polarity during charging. The polarity of the induced voltage is well explained by Lenz’s law. The inductor is also called a choke, a reactor or just a coil. Figure 2.3 shows the example of inductor’s schematic diagram (BYJU’S, 2023).

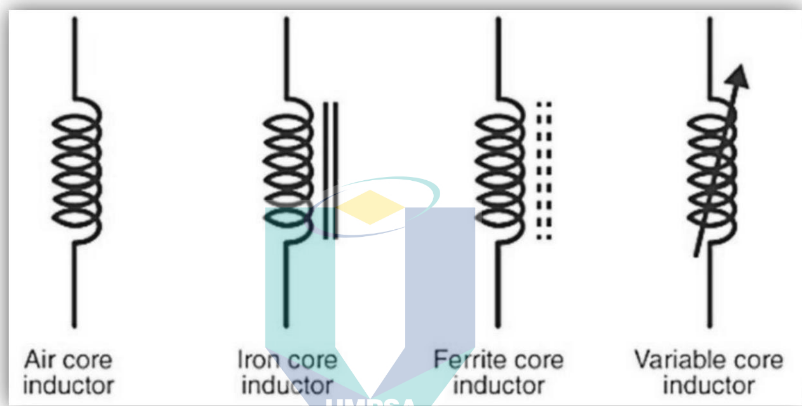


Figure 2.3 The difference types of inductor.
Source: BYJU’S (2023)



## 2.3 Overview of PCB

A PCB is a thin board composed of composite epoxy and fiberglass laminate. To electrically link a variety of components on a board, including as transistors, resistors, and integrated circuits, conductive routes are carved or printed on the board. Stated differently, a PCB is designed to electrically connect as well as support electronic components by using conductive tracks and pads. In order to connect both mechanically and electrically to the PCB, components are usually soldered onto it. A PCB with electrical components, vias, and conductive traces can be seen in Figure 2.4 (Khandpur, 2006).

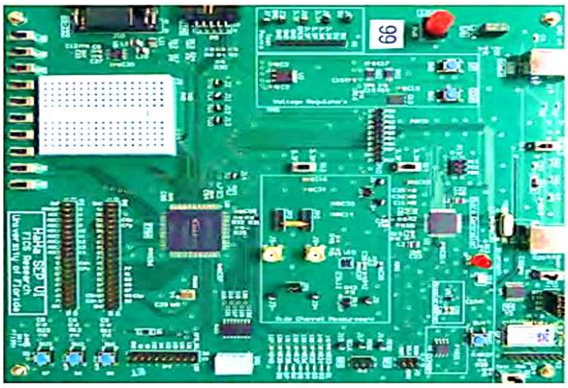

Figure 2.4 Example of PCB with their components.
Source: Khandpur (2006)

### 2.3.1 PCB design flow

The four phases of the PCB design flow are part selection, schematic capture and simulation, board layout, and board verification and validation. In Figure 2.5, the PCB design flow is displayed (National Instruments Corporation, 2023).

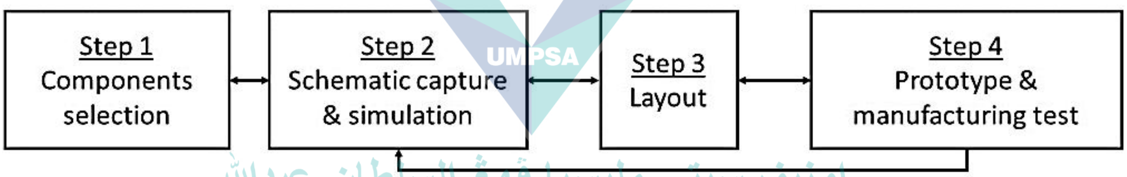


Figure 2.5 The PCB design flow.
Source: National Instruments Corporation (2023)

1. Part selection

   The part selection step assesses and examines the ways that various components function together in addition to being a part of the design as a whole.

2. Schematic capture and simulation

   Capture is a design interface where components are represented graphically and linked together to create the topology of the design. After a schematic is captured, a simulation program that focuses on integrated circuits is generally employed to analyze the impact of signals and components on the design, anticipate circuit behavior, and verify the accuracy of circuit designs.

3. Board layout

Layout is done through computer-aided design (CAD) software, in which the design's schematic symbols in the format of the actual component physical dimensions. The final design is then exported to a Gerber format.

4. Prototype test and manufacturing test

Prototypes test validates if the design satisfies the desired criteria.

### 2.3.2 Creating a PCB design

A PCB is a structure made up comprising several dielectric layers for insulation and multiple copper layers for electrical signal conductivity. The fundamental components of PCB are as follows.

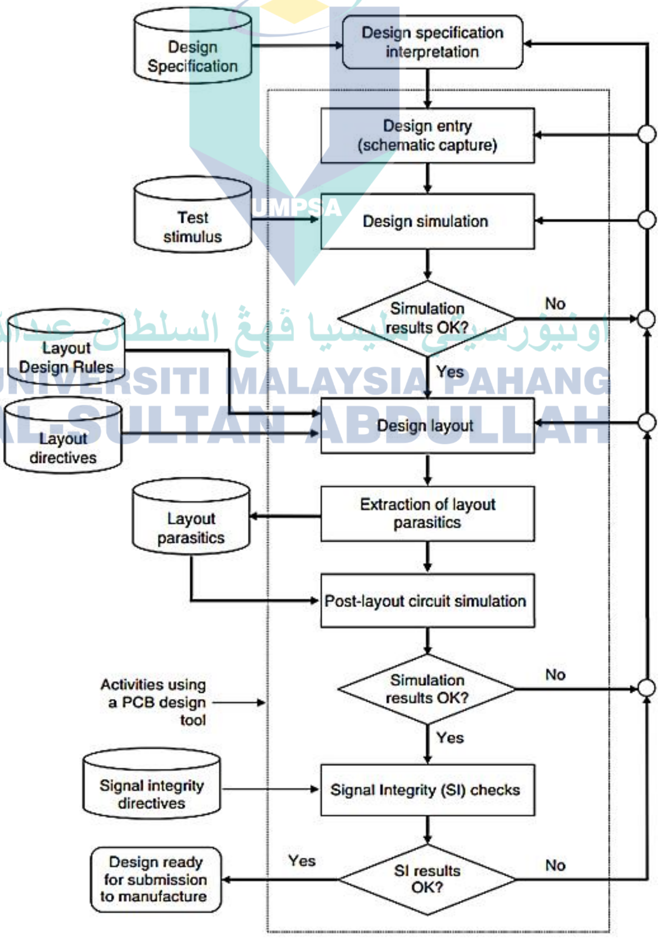


Figure 2.6 Another source for step to PCB design.

Source: Grout (2008)

1. Board outline

   A PCB's board outline is frequently cut into a certain shape. Thus, a variety of techniques were applied to specify the layout of the board outline including the importation of DXF files, which are utilized by mechanical CAD applications to establish a particular shape for the design.

2. Creating copper routes

   Electrical signals are sent across various components and connectors on a PCB board via copper routes. By stacking copper on the board surface and etching away leftovers copper, the copper pathways are formed. By covering areas of copper pathways with a mask and eliminating any excess copper, etchings are produced.

3. Drilling holes

   A PCB board must have holes drilled into it in order to provide spots for component attachment or signal paths to various layers. A via is a plated-through hole in a board that connects a copper route on one layer to another copper route on another layer electrically.

4. Components on a PCB

   Semiconductor devices which include surface-mount devices (SMD) and through-hole technology (THT) components are more commonly referred to as components on a PCB. THT components tend to be bigger and have longer pins that are soldered one by one onto a board after they are placed into drilled holes. Conversely, SMD components happen to be substantially smaller enabling the soldering of smaller leads to the board surface.

5. Gerber files

   The gerber file describes as a file format utilized in the production of PCBs. Fabrication machines require gerber files to set up electrical connections like pads and traces. In normal circumstances, the file comprises the information needed to drill and refine the circuit board.

### 2.3.3 PCB design verification

To verify that the circuit design is functionally correct, the design is tested both before and after manufacturing. Before manufacturing, the design is simulated using an appropriate simulation model of the circuit and a suitable test stimulus. Simulation is undertaken twice (Grout, 2008).

1. Before creating the PCB layout, to verify the correct electrical functionality of the circuit schematic diagram.

2. After the PCB layout, by extracting layout information.

After manufacturing, the PCB is physically tested for electrical and nonelectrical properties. Figure 2.7 shows the typically, PCB design verification which are involve two process, inspection and testing (Bhunia & Tehranipoor, 2019).

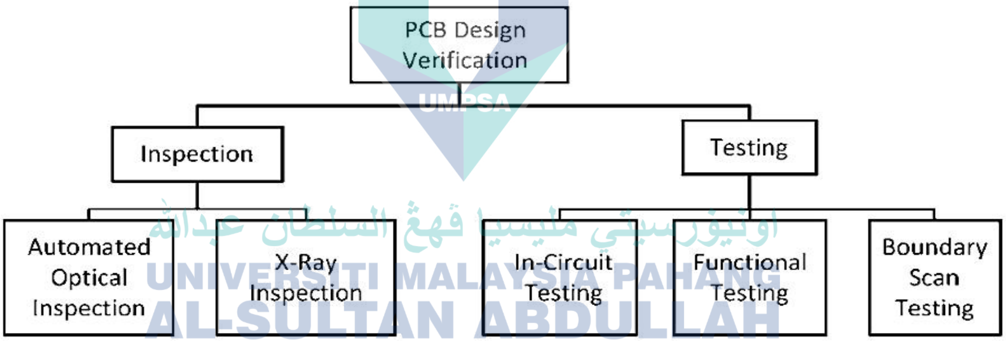


Figure 2.7 The taxonomy of PCB verification methodologies.
Source: Bhunia & Tehranipoor (2019)

#### *2.3.3.1 PCB inspection process*

PCB is composed of solder connections and a handful of components. Every issue that goes undetected during the manual inspection step might lead to major complications while the system is operating. The inspection procedure has been automated to minimize the mistakes brought about by human participation.

In order to identify and locate any flaws in a board, automated optical inspection (AOI) techniques are combined with either post-reflow, pre-reflow, or both. Pick-and-place machines with AOI capability are typically used to inspect components for defects and misalignment.

Solder joint analysis is challenging due to the higher PCB density. X-ray-based inspection techniques identify the problems brought on by the intricacy of viewing the layered contents of complex PCBs. The multi-layered PCBs are easier for PCB inspectors to examine with the help of automated x-ray inspection.

#### *2.3.3.2 PCB testing process*

The PCBs are tested after the inspection procedure. While inspection techniques such as AOI, examine for severe faults and overall PCB construction quality, high-level quality assurance requires extensive PCB testing. In-circuit tests (ICTs), functional tests (FCTs), and joint test action group (JTAG) boundary scan tests are the testing methodologies that are often adopted.

ICTs are useful in confirming if a board and all of its parts are operating in accordance with the specifications. On the contrary, FCTs play a role to determine if a PCB passes or fails. Test delivery system integration is made possible by JTAG.



## 2.4 The relation between PCB with PCBA

PCB and printed circuit board assembly (PCBA) are both important terms in the electronics industry. Some people use them interchangeably, but they are actually two distinct things.

The main difference between these two terms is that PCB refers to a blank circuitry board, while PCBA refers to a board that contains all of the necessary electronic components for the board to function as needed. A PCB is not yet functional because it does not have the required components in place, while a PCBA is a complete and functional board. PCBs and PCBAs are two different parts of the same process or can be said that a PCBA is built on top of an existing PCB (Electronics Manufacturing Services Group, 2022).

## 2.5 PCB's production information

### 2.5.1 International production statistics

According to the PCB industry expert, German-speaking countries may see growth between 6% and 7%. France, Span, and Italy could grow as much as 9–10% while Central Europe could see growth between 10–13%. However, in 2019, PCB industry affected by multiple factors, the output value fell slightly by 1.7% year-on-year to US$61.3 billion and the early part of 2022 had signs of continued growth on a lower level due to coronavirus disease 2019 (COVID-19) impacts. Even though global face critical issues, according to Michael Gasch, semiconductors are expected to remain strong with double-digit growth. Therefore, PCB growth should be around 5–8% (Jennifer, 2022). This is because in the worldwide electronic component business, the PCB sector has the highest output value. It is also the foundational industry for the production of electronic information products. Despite COVID-19's effects on the sector, the PCB industry has been able to expand as a result of 5G's swift growth. Global PCB output value is predicted to reach 79.2 billion US dollars by 2025 from 62.5 billion US dollars in 2020.



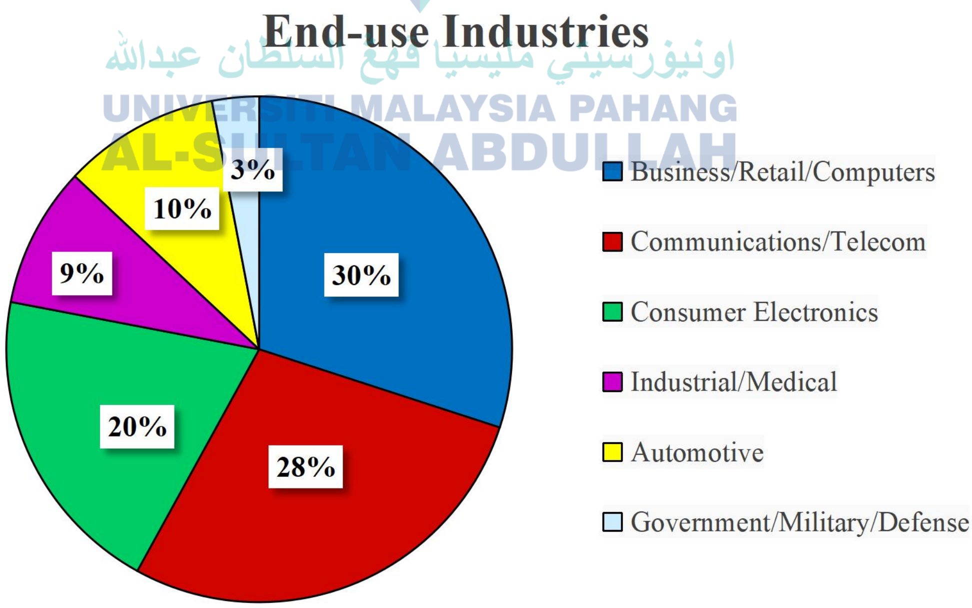


Figure 2.8 The top end-use industries that relying heavily on PCBs.
Source: Liu (2021)

Talking about major global PCB and PCBA demand in terms of applications, recently communications and automotive have been growing up. Roughly 60% of the worldwide PCB market is made up of communications related to business, computers, and telecom, and this trend is anticipated to sustain. Nevertheless, the utilization of PCBs in the automotive sector is projected to grow at a rapid pace in 2021 because modern automobiles demand a broader range of intricate and integrated elements (Liu, 2021).

### 2.5.2 Asian production statistics

The output value of PCBs was globally declined a bit in 2019. Trade frictions, a drop in terminal demand, and depreciating currency rates are all contributed to the worldwide PCB output value of US$61.3 billion, a 1.7% decrease from US$62.4 billion in 2018. Mobile phones are the major application outlet for PCBs. The growth of downstream industries is a major favourable condition for the development of PCB manufacturing companies. Considering the Taiwanese semiconductor and module manufacturers' significant presence in the personal computer and mobile phone industrial network, Taiwanese PCB companies such as Zhending, Xinxing and Huatong have successively entered the world's top ten PCB manufacturers rankings. Among them, Zhending, which is closely related to Apple's business, became the world's number one PCB manufacturer in 2019.

China is the world's top PCB producer, and broadly speaking, seven Chinese businesses are listed among the TOP 10 worldwide PCB producers in 2019. Regarding the general development trend for 2020, 5G continues to be the primary catalyst behind the expansion of the industrial economy. 2020 is predicted to have a 2% increase in the worldwide PCB production value, with an output value scale of around 62.5 billion US dollars. From 2020 to 2025, the global PCB output value is expected to grow at an average annual compound growth rate of approximately 5%. Global PCB output is anticipated to surpass around US$80 billion by 2025 (Rocket PCB, 2020).

### 2.5.3 Malaysia production statistics

January 2010 had a double digit annual gain of 28.8% in the sales value of manufacturing sector, amounting to MYR9.7 billion which bringing the total to MYR43.3 billion and it was a rise from MYR33.6 billion in January 2009. The year-on-year increase in the sales value during the present month was produced by the growth in the sales value of 76 industries which is 65.5% from the total 116 industries. The manufacturing of semi-conductor devices (54.4%), television and radio receivers (70.6%), sound or video recording, or reproducing apparatus (70.6%), other basic industrial chemicals except fertilizers and nitrogen compounds (60.5%), electronic valves and tubes, and PCBs (29.4%), and refined petroleum products (7.4%) were the five key sectors whose sales value elevated extensively (DOSM, 2023).

## 2.6 Traditional costing analysis (TCA)

TCA is an accounting method used to determine the cost of making products to make a profit, and it is based on allocating overhead manufacturing costs. This system relies on calculating predetermined overhead rates and applying the rates to a given metric. For some companies, the often less-complicated TCA does an excellent job of allocating overhead. However, for many products, the allocation of overhead is a more complex issue, and ABC system is more appropriate. Figure 2.9 shows musicality's products. ABC showed that the solo product creates a loss for the company. ABC is a more accurate method, because it assigns overhead based on the activities that drive the overhead costs. It can be concluded, then, that the cost and subsequent gross loss for each unit's sales provide a more accurate picture than the overall cost and gross profit under TCA method (Rice University, 2023)

| | Solo | Band | Orchestra |
|---|---|---|---|
| Cost per Unit via ABC | $22.50 | $16.90 | $17.70 |
| Cost per Unit via Traditional | 18.50 | 16.75 | 20.00 |
| Difference | $ 4.00 | $ 0.15 | $(2.30) |

Figure 2.9 The different two method apply on musicality's products.

Source: Rice University (2023)

### 2.6.1 Calculation of cost per unit by using TCA method

Company A budgeted production for 10,000 units with standard wage of $15 per hour, total direct labor hours of 5,000 and total manufacturing overhead of $250,000.

Table 2.1 The TCA calculation from Company A

| Cost pools | Total cost | Total activity |
|---|---|---|
| **Assembly** | $150,000 | 10,000 machine hours |
| **Material handling** | $75,000 | 4,500 orders |
| **Inspection** | $12,000 | 1,000 inspection hours |

Company A received an order for 500 units of one of its products. The info for the products are as follows:

1. Machine hours = 900
2. Material handling = 250
3. Inspection hours = 100
4. Direct material cost = $100
5. Direct labor hours = 300



Based on information above, calculation for the total product cost and unit cost under the TCA method for the new order can be calculated by using Equation 2.1 until 2.5. In TCA, the overhead cost is allocated as applied overhead based on the predetermined overhead rate.

**Step 1**: Determine the predetermined overhead rate by using Equation 2.1. Under the TCA, the activity base is normally the direct labor hours.

$$\begin{aligned}\text{Predetermined overhead rate} &= \frac{\text{total manufacturing overhead}}{\text{total direct labor hours}} \\ &= \frac{\text{direct material cost} \times \text{production unit}}{\text{total direct labor hours}} \\ &= \frac{\$50{,}000.00}{5{,}000} \\ &= \$10\end{aligned} \tag{2.1}$$

**Step 2**: Determine the applied overhead cost. The formula is as shown in Equation 2.2.

$$\begin{aligned}&\text{Applied overhead cost} \\ &\quad = \text{predetermined overhead rate} \times \text{actual direct labor} \\ &\quad = \$10 \times 300 \\ &\quad = \$3{,}000\end{aligned} \tag{2.2}$$

**Step 3:** Determine the direct labor cost by using Equation 2.3.

$$\begin{aligned}\text{Direct labor cost} &= \text{actual direct labor} \times \text{wage rate} \\ &= 300 \times \$15 \\ &= \$4{,}500\end{aligned} \tag{2.3}$$

**Step 4**: Determine the product cost under traditional allocation method. The total product cost can be computed by adding the direct material cost, the direct labor cost, and the applied overhead cost using the sum formula as shown in Equation 2.4.

$$\begin{aligned}\text{Total product cost} &= \text{direct material cost} + \text{direct labor cost} + \\ &\quad\ \text{applied overhead cost} \\ &= \$100 + \$4{,}500 + \$3{,}000 \\ &= \$7{,}600\end{aligned} \tag{2.4}$$

**Step 5**: Lastly, the unit cost can be determined by using formula as shown in Equation 2.5.

$$\text{Unit cost} = \frac{\text{total product cost}}{\text{total orders}} = \frac{\$7{,}600}{500} = \$15.20 \tag{2.5}$$

## 2.7 Activity-based costing (ABC)

### 2.7.1 Definition of ABC

ABC is a system that assigns costs to cost objects by first tracing costs to activities and then tracing costs to cost objects. Cost object is a technical term in cost management and is any item such as products, departments, projects, activities, and so on, for which costs are measured and assigned (Lee & Kao, 2001). ABC systems in manufacturing organizations typically recognize four levels of activities which are unit, batch, product-sustaining, and facility-sustaining.

At the unit level, resources are consumed in activities such as assembly and individual testing of each unit. At the batch level, activities include setups for production runs and sample testing of a predetermined number of units. Next, product sustaining level which includes activities such as product design and materials procurement. Each product requires design work, irrespective of the number of units which will be produced or the number of batches. The last level is the facility sustaining level. It encompasses the many products that may be produced in the same facility. Facility-sustaining activities include general maintenance and facility administration (Raz & Elnathan, 1999).

### 2.7.2 Concept of ABC

ABC was defined by Cooper and Kaplan as a strategy for resolving TCA management system issues. In many instances, these TCA systems lack the ability to precisely calculate the actual expenditures of manufacturing and associated services. As a result, managers were deciding options based on misleading data, particularly in situations when there are numerous products. To fairly assign expenses, ABC explores for cause and effect connections rather than use broad arbitrary percentages. Following the identification of the activity costs, the cost of every activity is allocated to each product that utilized that particular activity. By performing this, ABC is able to pinpoint areas with high overhead expenses per unit and focus on discovering strategies to either reduce costs or raise prices on more expensive products (Kaplan, 2007).

There are five aspects that need to be taken care in applying ABC as costing calculations which are cost allocation, fixed cost, variable cost, cost driver, and cost driver rate. It is simpler to relate direct labor and material costs to products than it is to precisely distribute indirect costs to products. In cases when products utilize common resources in disparate ways, the cost distribution process must incorporate some form of weighting. The cost driver is the measurement of how each product utilizes a common activity. For instance, by recording the duration of each product's transactions require at the counter and then quantifying the amount of every kind of transaction, bank tellers' costs can potentially be assigned to individual products (Kaplan & Bruns, 1987).



### 2.7.3 Calculation of cost per unit by using ABC

The Gadget Co produces three products, A, B and C, which all are made from the same material. Information of the three products for the last year are displayed in Table 2.2.

Table 2.2 The cost pools for all three products.

| Cost pools | A | B | C |
|---|---|---|---|
| **Products and sales volume (units)** | 15,000 | 12,000 | 18,000 |
| **Selling price per unit** | $7.50 | $12 | $13 |
| **Raw material usage (kg) per unit** | 2 | 3 | 4 |
| **Direct labor hours per unit** | 0.1 | 0.15 | 0.2 |
| **Machine hours per unit** | 0.5 | 0.7 | 0.9 |
| **Number of production runs per annum** | 16 | 12 | 8 |
| **Number of purchase order per annum** | 24 | 28 | 42 |
| **Number of deliveries to retailers per annum** | 48 | 30 | 62 |

The price for the raw material remained constant throughout the year at $1.20 per kg. Similarly, the direct labor cost for the whole workforce was $14.80 per hour. The annual overhead costs were as follows, as shown in Table 2.3.

Table 2.3 The annual overhead costs.

| Annual overhead cost | $ |
|---|---|
| **Machine set up costs** | 26,550 |
| **Machine running costs** | 66,400 |
| **Procurement costs** | 48,000 |
| **Delivery costs** | 54,320 |



**Step 1**: Determine the predetermined cost drivers. The details from Table 2.4 are used to calculate all costs as shown in Equation 2.6 until 2.9.

Table 2.4 The predetermined costs drivers.

| Cost pools | $ | Cost drivers |
|---|---|---|
| Machine set up | 26,550 | 36 production runs (16 +12 +8) |
| Machine running | 66,400 | 32,100 machine hours (7,500 + 8,400 + 16,200) |
| Procurement | 48,000 | 94 purchase order (24 +28 +42) |
| Delivery | 54,320 | 140 deliveries (48 +30 +62) |
| Totals | 195,270 | |

$$\text{Cost per machine set up} = \frac{\$26{,}550}{36} = \$737.50 \quad (2.6)$$

$$\text{Cost per machine hour} = \frac{\$66{,}400}{32{,}100} = \$2.0685 \quad (2.7)$$

$$\text{Cost per order} = \frac{\$48{,}000}{94} = \$510.6383 \quad (2.8)$$

$$\text{Cost per delivery} = \frac{\$54{,}320}{140} = \$388 \quad (2.9)$$

**Step 2**: Determine the allocation of overheads to each product.

Table 2.5 The allocation of overheads.

| **Products** | **A** | **B** | **C** | **Total** |
|---|---|---|---|---|
| Machine set up costs | 11,800 | 8,850 | 5,900 | 26,550 |
| Machine running costs | 15,514 | 17,375 | 33,510 | 66,400 |
| Procurement costs | 12,255 | 14,298 | 21,447 | 48,000 |
| Delivery costs | 18,624 | 11,640 | 24,056 | 54,320 |
| Total costs | 58,193 | 52,163 | 84,913 | 195,270 |

**Step 3**: Determine the overhead cost per unit to each product.



Table 2.6 The overhead cost per unit to each product.

| **Number of units produced** | **15,000** | **12,000** | **18,000** |
|---|---|---|---|
| Overhead cost per unit | 3.88 | 4.35 | 4.72 |

**Step 4**: Lastly, the unit cost can be determined as follow.

Table 2.7 The unit cost of each product.

| **Total cost per unit** | **A** | **B** | **C** |
|---|---|---|---|
| Materials | 2.40 | 3.60 | 4.80 |
| Labour | 1.48 | 2.22 | 2.96 |
| Overheads | 3.88 | 4.35 | 4.72 |
| Total | 7.76 | 10.17 | 12.48 |

### 2.7.4 Advantages and disadvantages of ABC

There are several advantages of ABC, which are as follows:

1. Accurate demand forecast. This is because ABC it helps to identify inefficient products, departments and activities which bring to the accurate demand forecast (Kaplan & Bruns, 1987).
2. Improves management system which means the research framework, implementation process of ABC system can provide useful reference and contribution to the enterprises or industries in terms of analysis (Lu et al., 2017).
3. Improve internal and user relationships. By users, is not simply a matter of getting support of top management, appropriate rewards/recognition, and strong team dynamics but it must address the needs of users such as ease of use and level of required training (Pike et al., 2011).
4. Strategic resource allocation. Developing ABC evaluation mainly allows the identification of entire process resources and activity traces and applies mathematical constraints. (Yang, 2018).

There are several disadvantages of ABC, which are as follows:



1. Time consuming. This is because the measures of development team inputs and system performance need to be obtained using a questionnaire to both developers and users of the systems (Pike et al., 2011).
2. Difficulty in assigning overhead costs to products and customers, such as the chief executive's salary. These costs are termed business sustaining and are not assigned to products and customers because there is no specific method. Even though it brings contributions to the products, it is not large overhead costs which we need to take into account (Kaplan & Bruns, 1987).

### 2.7.5 Comparison between ABC with TCA

Table 2.8 and Table 2.9 show the comparison aspects of ABC with TCA from two different articles.

Table 2.8 The first comparison aspects between ABC with TCA.

| No. | Aspects | TCA | ABC |
|---|---|---|---|
| 1. | Original purpose | Inventory valuation. | More accurate product cost for management decision. |
| 2. | Improve purpose | Management control in term of variance analysis. | Leads to activity-based management. |
| 3. | Main concept | Production and value added by production department. | Cost tracing by cost object. |
| 4. | Overhead cost allocation | Allocate using production volume-based drivers (use single cost driver). | Trace to activities, then to products using various drivers (use multiple cost drivers to give indirect cost to product). |
| 5. | Product cost accuracy | Non-accurate distorted due to assume that al products consume indirect costs similarly. | Fairly accurate view of cost by identifying and giving costs based on activities that generate them. |
| 6. | Capacity focus | Labor and machine utilization, production volume variance. | Measure unused capacity costs to manage capacity. |

Source: James (2023)

Table 2.9 The second comparison aspects between ABC with TCA.

| No. | Aspects | TCA | ABC |
|---|---|---|---|
| 1. | Complexity | Simple method of allocation that is easy to understand and implement. | More complex method that requires more time and effort to implement, but provide more detailed and accurate view of cost. |
| 2. | Cost effectiveness | Less expensive to implement. | More costly to implement due to its complexity. |
| 3. | Applicability | Suitable for business with simple production process. | Suits companies with complex operations. |
| 4. | Weightage | Direct cost such as direct labor and direct material. | Indirect cost such as overhead expenses and support cost. |

Source: Dheeraj (2013)

## 2.8 Time-driven activity-based costing (TDABC)

### 2.8.1 Definition of TDABC

TDABC is the possibility to measure the differences resulting from variations in activities under a process and to express them as time and cost. Such information helps to improve the efficiency of their execution (Kaplan & Anderson, 2007).

### 2.8.2 Concept of TDABC

TDABC simplifies the costing process by eliminating the need to interview and survey employees for allocating resource costs to activities before driving them down to cost objects. TDABC assigns resource costs directly to the cost objects using two sets of estimation. First, it calculates the cost of supplying resource capacity. In this first step, the TDABC model calculates the cost of all the resources personnel, supervision, occupancy, equipment, and technology supplied to this department or process. It divides this total cost by the capacity the time available from the employees performing the work of the department to obtain the capacity cost rate. Second, TDABC uses the capacity cost rate to drive departmental resource costs to cost objects by estimating the demand for resource capacity that each cost object requires (Kaplan & Anderson, 2007).

When compared to traditional ABC model, the TDABC model may identify significantly greater variation and complexity without driving up the requirement for data estimations, storage, or processing capabilities. An organization can recognize complexity by using TDABC instead of being compelled to depend on inaccurate, simplified ABC models of its intricate businesses (Kaplan & Anderson, 2007). TDABC also have the ability to analyse unused capacity of a production.

It is also important to note that unused capacity could be found, as stated by Cooper and Kaplan (1992), by subtracting the activity usage from the activity availability. Therefore, it provides the relationship between the costs of resources used and the costs of resources supplied. The researchers will also emphasize that practical capacity is more appropriate than theoretical capacity. Therefore, practical capacity should be used in the calculations of unused capacity (Tanis, 2012).

This unused capacity can indicate healthy growth of company, however too much unused capacity can hurt the company. This is because if the resources supplied cost not handle well, it will impact the practical capacity as well as impacts the time equation and capacity utilization which eventually cut the growth rate of the company.

### 2.8.3 Calculation of unit per cost by using TDABC

Customer Direct Inc. has its own call centre selling and supporting its warehouse inventory and distribution direct to the products' end user. All employees work a five-day week and are paid for eight hours each day. Additionally, they are given 30 minutes for lunch, two breaks totaling 30 minutes, and spend 30 minutes in training each day, resulting in six-and-a-half hours (390 minutes per day) available for assigned activities. Allowing for each employee receiving 10 days vacation and six paid holidays per year, each employee is available for work 244 days per year.

**Step 1**: Determine the departmental costs, the number of employees, practical capacities in minutes and the capacity cost rates per minute.

Table 2.10 The allocated resources for each departments.

| Department | Cost | Employees | Minutes | $/Minute |
|---|---|---|---|---|
| Purchasing | 525,000 | 5 | 475,800 | 1.10 |
| Warehouse | 520,000 | 10 | 951,600 | 0.55 |
| Shipping | 300,000 | 6 | 570,960 | 0.53 |
| Customer service | 1,800,000 | 25 | 2,379,000 | 0.76 |

**Step 2**: Determine the time equations and cost per minute for each activities using the following Equation 2.10 until 2.13.

$$\begin{aligned}\text{Purchase order processing time} = {} & 10\ (\text{prepare the basic PO}) + \\ & 15\ (\text{if contact vendor}) + \\ & 5 \text{ times the number of line items}\end{aligned} \qquad 2.10$$

$$\text{Order entry time} = \begin{array}{l} 5\ (\text{enter customer header indormation}) + \\ 2\ (\text{if a new customer}) + \\ 2\ \text{times the number of line items} + \\ 10\ (\text{if an international customer}) + \\ 2\ (\text{if special handling required}) \end{array} \tag{2.11}$$

$$\text{Pick/pack order time} = \begin{array}{l} 3\ (\text{prepare/print pick} - \text{pack}) + \\ 4\ \text{times the number of line times} + \\ 1\ \text{times the number of line items w/} \\ \text{special packing} + 3\ \text{times the number of cartons} \end{array} \tag{2.12}$$

$$\text{Order shipping time} = \begin{array}{l} 8\ (\text{prepare basic docs}) + \\ 5\ \text{times the number of cartons} + \\ 10\ (\text{if international shipment}) + 5\ (\text{if "rush" order}) \end{array} \tag{2.13}$$

With the capacity cost rates and formulas established, the model is ready for use. Operating results for the purchasing department for the first month reveals that they processed 400 purchase orders representing 5,600 line items and initiated 85 vendor contacts. Note that the use of practical capacity enables quantification of any excess capacity for the month, in this case 5,725 minutes and $6,297.50. Knowing which processes have excess or shortages of capacity enables management to choose whether to redeploy resource capacity to other processes or use excess capacity for other activities. Either way, the result is a more efficient use of resources.



Table 2.11 The time equations and cost per minute for each activities.

| | **Number of transcations** | **Minutes / Transaction** | **Total minutes** | **Cost @ $1.10/Minute** |
|---|---|---|---|---|
| Purchase orders | 400 | 10 | 4,000 | 4,400.00 |
| Line items | 5,600 | 5 | 28,000 | 30,800.00 |
| Vendor contacts | 85 | 15 | 1,275 | 1,402.50 |
| Capacity used | | | 33,275 | 36,602.50 |
| Capacity available | (475,800 / 244 × 20 days) | | 39,000 | 42,900.00 |
| Excess capacity | | | 5,725 | 6,297.50 |

**Step 3**: Determine transactional data for the month for two customers, A and B.

Table 2.12 The transactional data for two customers.

| **Quantity** | **Customer A** | **Customer B** |
|---|---|---|
| Orders placed | 2 | 12 |
| Line items | 200 | 200 |
| Orders requiring special handling | 0 | 4 |
| Warehouse contacts | 0 | 10 |
| Cartons | 6 | 12 |
| Items requiring special packaging | 0 | 20 |
| Orders requiring "rush" handling | 0 | 3 |

**Step 4**: Determine the estimated costs for these two customers, A and B.

Table 2.13 The estimated costs for two customers.

| **Variables** | **Customer A** | **Customer B** |
|---|---|---|
| Orders entry | | |
| Customer header | 2 × 5 min × \$0.76 = \$7.60 | 12 × 5 min × \$0.76 = \$45.60 |
| Line items | 200 × 2 min × \$0.76 = \$304.00 | 200 × 2 min × \$0.76 = \$304.00 |
| Special handling | - | 4 × 2 min × \$0.76 = \$6.08 |
| Warehouse contact | - | 10 × 5 min × \$0.76 = \$38.00 |
| Pick/pack | | |
| Prepare/print | 2 × 3 min × \$0.55 = \$3.30 | 12 × 3 min × \$0.55 = \$19.80 |
| Line items | 200 × 4 min × \$0.55 = \$440.00 | 200 × 4 min × \$0.55 = \$440.00 |
| Special packing | - | 20 × 1 min × \$0.55 = \$11.00 |
| Cartons | 6 × 3 min × \$0.55 = \$9.90 | 12 × 3 min × \$0.55 = \$19.80 |
| Order shipping | | |
| Basic docs | 2 × 8 min × \$0.53 = \$8.48 | 12 × 8 min × \$0.53 = \$50.88 |
| Cartons | 6 × 5 min × \$0.53= \$15.90 | 12 × 5 min × \$0.53= \$31.80 |
| Rush orders | - | 3 × 5 min × \$0.53= \$7.95 |
| Total cost | \$789.18 | \$974.91 |

**Step 5**: Lastly, the unit cost for both customers A and B can be determined using Equation 2.14 and 2.15, respectively.

$$\text{Unit cost for customer A} = \frac{\text{total product cost}}{\text{total orders}} = \frac{\$789.18}{2 \times 6} = \$65.765 \quad 2.14$$

$$\text{Unit cost for customer B} = \frac{\text{total product cost}}{\text{total orders}} = \frac{\$974.91}{12 \times 12} = \$6.77 \quad 2.15$$

Therefore, it can be seen that TDABC method involves the calculation of capacity cost rate and time equation. The calculation of capacity cost rate involves two aspects which are multiple drivers and productive capacity supplied resources. While for time equation formulation, it is determined by considering the time taken for each sub-activities involved. From the time taken, variable is added to it. Thus, the unused capacity can be conducted and give information of unused time and unused cost for each sub activities. TDABC also is selected as the best practice due to its appealing outcomes from comparison made in several aspects which are cost allocation, driver determination, action taken for an additional activity, cost consideration, informative, transparency, oversimplification of activities, and capacity forecast.

### 2.8.4 Advantages and disadvantages of TDABC

There are several advantages of TDABC, which are as follows:

1. It can be applied in any industry or company with very complex cost objects. This is because TDABC has the capacity to model complex activities (consisting of multiple sub-steps) by using cost rates that vary by resource (Defourny et al., 2022).
2. Provide the exact amounts and values relating to a company's unused capacities. Companies may enhance their cost management systems with the help of TDABC. This happens because managers possess the capacity to prioritize process enhancements, rationalize their product diversity and combination, price customer orders, and oversee interactions with consumers by having access to accurate cost and profitability statistics (Kaplan & Anderson, 2007).
3. Cost allocation more accurate. TDABC does not require interviews with employees of organizations because it directly assigns the costs of resources from cost objects through a simple formula which is hourly cost rate. The basic principle of this methodology is that it converts cost drivers into time equations, which represent time required to perform a given activity (Alves et al., 2018).

There are several disadvantages of TDABC, which are as follows:

1. It lacks the ability to identify activities in the first implementation step, such as practical capacity costs rate (Gervais et al., 2010).
2. Lack of visibility of non-productive time. Since the cost associated with departmental non-productive time is integrated into the cost of capacity supplied and the resulting cost per minute, the total cost of such events is not computed individually so visibility to such costs is hidden (Pereira et al., 2022).

### 2.8.5 Comparison between TDABC with ABC

Table 2.14 shows several aspects of difference between TDABC with ABC which are as follows.

Table 2.14 The difference between TDABC with ABC

| No. | Aspects | TDABC | ABC |
|---|---|---|---|
| 1. | Character of factors for assign of costs | Time driver. The method works with time of operating period, which resulting from incidence of factors. | Cost driver. The method works with number of occurrence of factors. |
| 2. | The number of factors for assign of costs | By every activity the numbers of factors are unbounded. | By every activity, only use one factor. |
| 3. | The accuracy of method | The method captures the assign of costs to activities in suitable way. The accuracy is better than by the method of ABC. | The method does not capture the specification of activity, which influenced the costs. |
| 4. | Extensiveness of system for assign of costs | For every activity we needed only one-time equation, which captured all the specifications and variation of activity. | Every different in the fulfillment of the activity needed implementation of new separated activity. |
| 5. | The ability to captured unused capacity | Yes | No |

Source: Fakolade and Atanda (2019)

## 2.9 Research motivation

### 2.9.1 ABC's research motivation

Gunasekaran and colleagues (1999) stated that the justification criteria for the implementation of ABC in small and medium enterprise are divided into five dimensions, as shown in Table 2.15.

Table 2.15 The justification criteria for the implementation of ABC.

| No. | Dimension | Characteristics | Justification |
|---|---|---|---|
| 1. | Market forces | Quality, flexibility | Focus should be placed more on non-financial and intangible metrics rather than costs. |
| 2. | Strategies | TQM, JIT, MRP | Eliminate non-value adding operations, cost drivers, numerous performance indicator, and financial and non-financial measurements. |
| 3. | Technology | CAD/CAM, internet, multimedia | Minimize the amount of direct labor required, acquire data from every activities, raise overheads, boost the knowledge worker's efficiency, remove congestion delays, and record activity data online. |
| 4. | People | Multi-functional workforce, knowledge workers, smaller team, employee involvement | Direct labour cost becomes an overhead, continuous skill development, re-engineering, empowered self-directed teams for product and process developments, increasing the productivity of support staff, collective accountability and reward programs, and overhead removal. |
| 5. | Characteristics | Leadership, matrix organisation, teamwork, employee empowerment | Prioritize long-term strategic choices based on high-quality flexibility and responsiveness, improved teamwork and communication, reduction in time and effort needed to complete tasks, the removal of functional barriers and hand-offs, an incentive system based on team productivity instead of individual productivity, the reduction of conflicts caused by knowledge workers and the collective incentive system, re-engineering suggestions from employees to cut down on non-value adding activities, and motivation-based communication. |

Source: Gunasekaran et al. (1999)

A number of applications are employed in the ABC technique, as shown in Figure 2.10. There are five types of applications area such as medical, production, agricultural, social science, and technology. The pie chart is constructed based on findings of 30 published papers from 2010 to 2022 which can be refer in Table 1, Appendix A. The other 20 published papers are not included in the pie chart as it considers as long-time range to be discussed in research motivation.

Production sector has the highest percentage of 37% with 11 out of 30 research articles. For social science and medical, the amount are 27% with 8 papers and 23% with 7 papers, respectively. Whereas, both technology and agricultural sectors have similar rate of 7%, representing 2 research articles, separately.

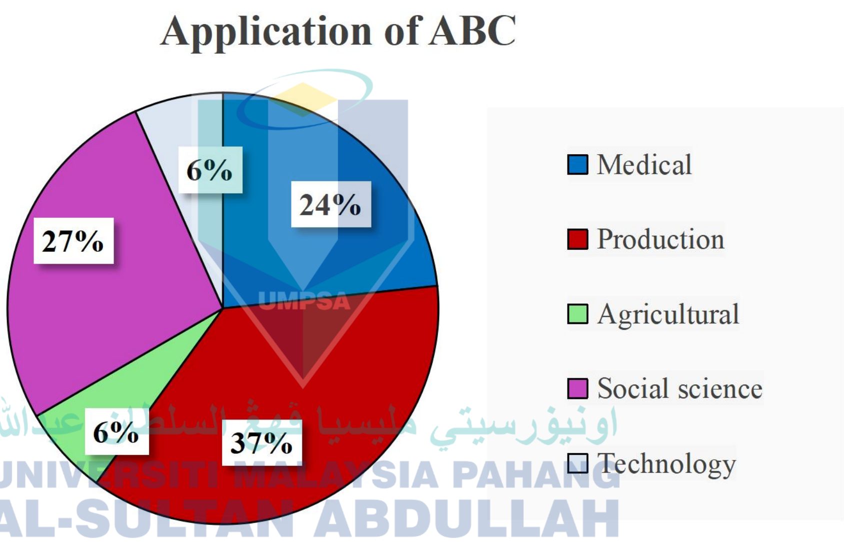




Figure 2.10 The application of ABC.

From the findings of the published work, production sector that has the highest rate of 37% has been chosen as the keyword to analyse and expand the implementation of ABC in the area of electronics manufacturing process. It is the most suitable to be implemented as it focuses on level of worker's effort and involves continuous production line. Based on Table 2.16, three published works that discussed the application of manufacturing process in their literature studies have been summarize according to the issues and other methods they applied along with ABC.

Table 2.16 The application of ABC method.

| Author (Year) | Issues | Method |
|---|---|---|
| Saeed et al. (2023) | The competition in manufacturing industries increase along with years. Several companies left because they could not keep their rising overhead costs in check. | Literature review on ABC (10 years) |
| Alami (2020) | Manufacturing firms strive to lower their manufacturing costs compared to their competitors in order to survive escalated cost challenges. | ABC, TCA, mixed integer linear programming (MILP) |
| Almeida and Cunha (2017) | Given the fierce competition of today, there has been a lot of demand to boost productivity and reduce manufacturing costs. | ABC |

As more companies enter manufacturing, they face more competition, which means they have to offer good customer service at a fair price. Several businesses have left because they could not keep their rising overhead costs in check. From the research finding, ABC is a good system because it was adopted by many businesses in the manufacturing sector to achieve several advantages, including cost ascertainment which inevitably assisted them in making wise price decisions, cost reduction advantage which assisted them in increasing profitability, increased productivity, time and resource savings, and, most importantly, improved production quality (Saeed et al., 2023).



The direct labor and direct material costs are the main costs in the TCA. Conversely, in the modern manufacturing period, with numerous products offered and automated processes, the distribution of overhead makes up a significant amount of the product cost and consequently, overhead expenses are regarded as the main cost. Therefore, research on a feasible approach for dispersing the overhead expenses is required. Thus, Alami introduced a MILP model for ABC. She presents an approach for calculating hourly rates based on the total number of hours allocated to the department and explains how taking on additional work will decrease hourly rates and provide the company a competitive advantage. Because of this, this model gives managers at production sites an essential tool for making decisions concerning which orders to accept each period with the goal to minimize labor costs (Alami, 2020).

One essential requirement for businesses and organizations to be relevant is satisfaction with consumers. Meeting consumer demands is necessary to ensure customer satisfaction, but the product's selling price must always exceed its cost of manufacturing. According to a study from Almeida and Cunha, the ABC methodology was implemented to analyze the different tasks involved in a Portuguese company's coffee production process. This enabled the collection, analysis, and reflection of a number of highly significant pieces of information for the organization, including the definition of product costs and sales prices, the identification of processes that requires additional effort to enhance or adjust to new realities and needs, and the reorganization of certain areas of the industrial unit (Almeida & Cunha, 2017).

### 2.9.2 TDABC's research motivation

There are four issues that remain as questions in TDABC method at a practical level (Gervais et al., 2010).

1. There seems to be some hesitation between use of standard costs and use of actual costs to determine the unit cost of resource groups.
2. Evaluating the cost of under-activity is not so simple.
3. The need to observe the principle of homogeneity remains with this method.
4. It is not necessarily easy to measure times.

According to Figure 2.11, there are several applications area used in the TDABC method such as medical, production, social science, and technology. The pie chart is constructed based on findings of 50 published works from 2016 to 2023 which can be refer in Table 2, Appendix A. The area of medical has the highest percentage of 74% with 37 out of 50 research articles. Meanwhile, the area of technology has the lowest rate, with only 2 research articles. Other than that, the percentages for production and social science sectors are 14% with 7 papers and 8% with 4 papers, respectively.

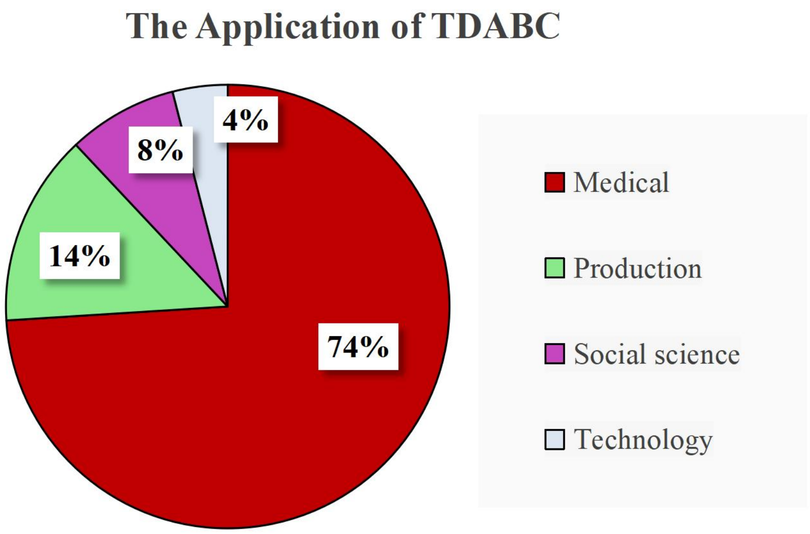


Figure 2.11 The application of TDABC.

Then, the production sector which only has 14% rate from overall studied articles, has been chosen as the explore key to study and analyse the implementation of TDABC in the area of electronics manufacturing process. It is the most suitable to be implemented as it eliminates unproductive system and strengthen the status of TDABC advantages into production environment. Based on Table 2.17, two published works that discussed the application of manufacturing process in their literature studies have been summarize according to the issues and other methods they applied along with TDABC.



Table 2.17 The application of TDABC.

| Author (Year) | Issues | Method |
|---|---|---|
| Baroma and El-Feky (2023) | Current conventional costing methods are out of date. | Value stream costing (VSC), ABC, TDABC |
| Pereira et al. (2022) | Lack of effective control practices, such as knowledge of the costs of the purchasing process. | ABC, TDABC |

Baroma and El-Feky were aimed to test the impact of integrating the TDABC allocation method in a lean environment to improve the competitive position of lean firms in a condition of shared resources. From the findings, it stated that TDABC costing method is more accurate than the traditional overhead allocation method. It is also more accurate than the one computed using the ABC method. TDABC develops a cause-and-effect relationship that links costs to their time-consuming resources. It also helps the studied factory identify value adding and non-value adding activities as well as develop a time related cost drivers that can act as indicators that can support lean accounting performance measures used (Baroma & El-Feky, 2023).

Pereira and colleagues stated that the solution to ABC's problems is not to abandon the concept. The new procedure begins, as in the traditional ABC approach, by estimating the cost of capacity supply. TDABC approach identifies different departments, their costs, and their practical capacity, which can be defined as the amount of time employees can work without idle time. The practical capacity is often estimated as a percentage, say 80% or 85% of theoretical capacity. By dividing the total cost by the practical capacity, the cost per unit of time is calculated. Costs are then assigned to the cost object by multiplying the cost per unit of time by the time required to do the activity (Pereira et al., 2022).

Table 2.18 Summary of research motivation.

| **Author (Year)** | **Method** | **Activity map** | **Cost driver** | **Time equation** | **Capacity cost rate** | **Unused capacity** | **Forecasting** |
|---|---|---|---|---|---|---|---|
| Almeida and Cunha (2017) | √ | √ | X | X | X | X | X |
| Pereira et al. (2022) | √ | √ | X | √ | X | X | X |
| Alami (2023) | √ | X | X | X | X | X | X |
| Baroma and El-Feky (2023) | √ | √ | X | X | X | X | X |
| Saeed et al. (2023) | X | X | X | X | X | X | X |
| Pinueh (2023) | √ | √ | √ | √ | √ | √ | √ |

By referring to Table 2.18, only Saeed et al. (2023) did not involve all criteria as the research was conducted only to show the method's effectiveness when applying in manufacturing industry. Meanwhile the other works, at least did research study on activity map of method used. Almeida and Cunha (2017) and Baroma and El-Feky (2023) have involved advance studies which include cost driver in their research. Then, only Pereira (2022) include cost driver and capacity cost rate.

Therefore, this current study intends to fill the gap on ABC and TDABC elements which have not been discussed by the previous five authors. This study focuses on all six elements which are activity map, cost driver, time equation, capacity cost rate, unused capacity, and forecasting. Through ABC method, activity map and analysis would be clearly identified as well as assigning cost categories. Based on the identified activities, the cost drivers would be determined accordingly. Detail understanding on the activity flow in the process is needed so that the time equations can be placed objectively according to activities. By using information from capacity cost rate, time equation and unused capacity, the forecasting element of TDABC can be used to contribute more information to the company.

However, there are some criteria that are challenging which are to determine cost driver for each activity and to analyse unused capacity. To select cost driver, the important issue is what factor that brought high cost to that specific activity in the production. Meanwhile for unused capacity, the analysis of used cost, used time and practical capacity must be conducted first in order to analyse the unused capacity.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

In this chapter, all steps required to apply activity-based costing (ABC) and time driven activity-based costing (TDABC) method are discussed. The purpose of this methodology is to ensure that all processes of this research follow all the required steps from the beginning until the end of this project. The steps carried out in this study are summarized in the flowchart as shown in Figure 3.1. Phase 1 required general research criteria to analyst previous research work in aspect of ABC and TDABC methods, respectively. Subsequently, the development hypothesis is done to forecast outcomes depending on the importance of input and output. Phase 2 is on site observation which involves selection of company endorsement, company selection and data collection. Phase 3 specifically involves data analysis which involves the identification of activities, time allocation, resources, and determination of cost driver and analysis of capacity utilization if related. Through this phase 3, it is more focused on objectives to be achieve. Eventually, step 4 summaries and discusses the outcomes of this thesis.

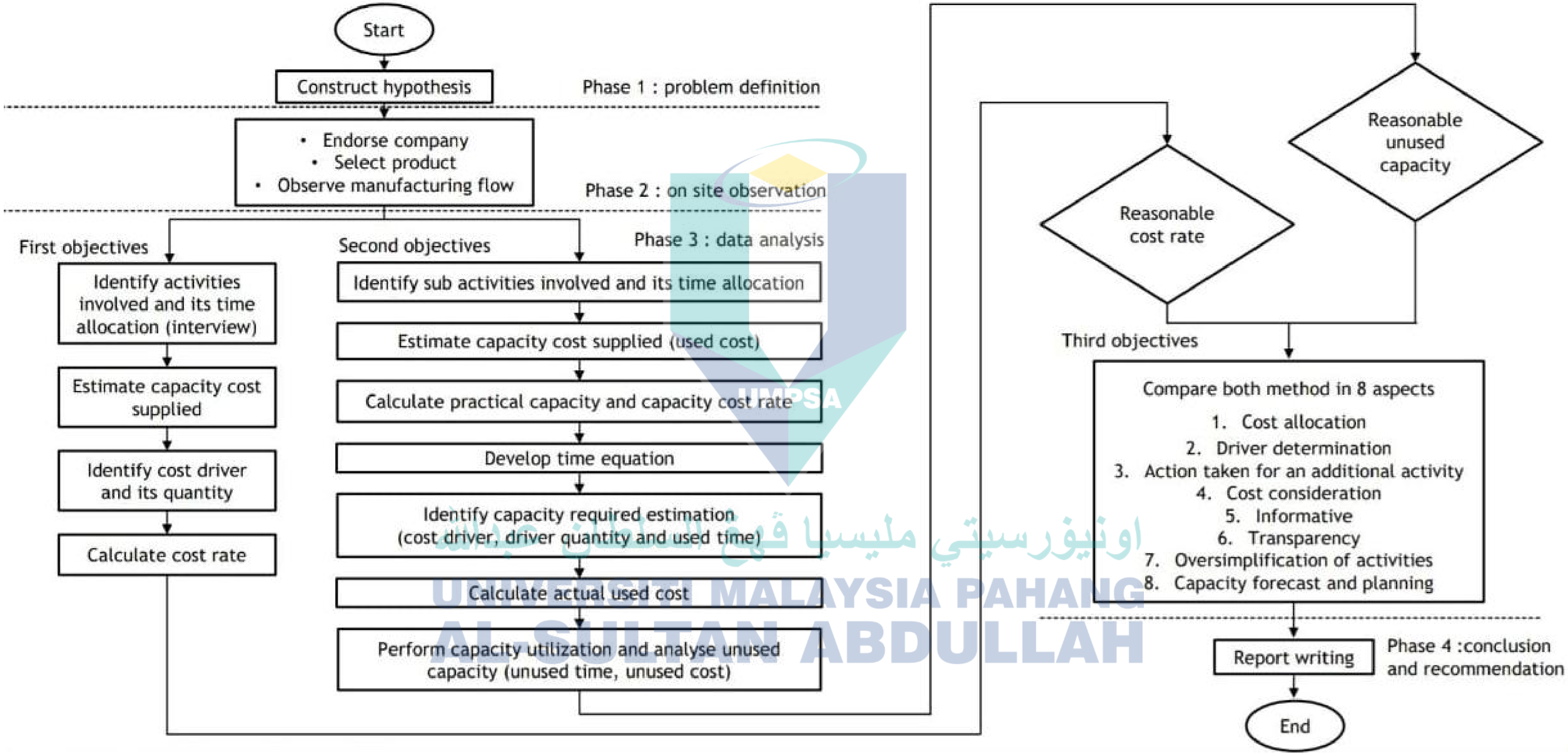


Figure 3.1 The research flowchart process.

## 3.2 Phase 1: Problem definition

Each description of the hypothesis is a potential outcome of the research objectives.

Hypothesis 1: ABC methodology

The accuracy of ABC method depends on the determination of cost driver and the cost driver quantity. The more accurate the cost driver (selection and quantity) estimation, the more accurate the cost per unit of the product.

Hypothesis 2: TDABC methodology

The accuracy of TDABC method depends on the estimation of practical capacity, the formulation of time equation and the analysis of capacity utilization. The more accurate the information is, the more accurate the cost per unit of the product.

Hypothesis 3: Comparison for both method

As logically, when there is more calculation information we can reconsider (taken into aspects) or obtained, the more practical the system is.



## 3.3 Phase 2: On site observation

### 3.3.1 Company background

The endorsement company is a professional manufacturing company in Pasir Gudang, Johor. The company was established in June 1995. The main company production are printer assembly and printed circuit board assembly (PCBA). The company also provide other types of operation and services such as trading and warehouse. Over the years, they have handling more than 15,000 parts in trading and be as supplier to more than 300 companies.

The company milestone began with SMT assembly and wire-harness production in 2012, then their first customers is cooperating with Panasonic in 2013. Next, in 2014, they installed third SMT line with high-end Panasonic configuration and expanded their customer base with SDTV, Next Century and Smith in 2015. In 2019, they develop new business with new customer SII and CAPE. Then, in 2020, they continue upgrade their operations which including medical and industry 4.0 up until today.

Figure 3.2 The company view from gate.

The company remains strong and competent despite on-going industry challenges. As shown in Figure 3.2, it is the entrance into the company. Recent reorganization of the management team has led them to become more effective in collaborating with one another, and this helps them to innovate and build a better tomorrow.



### 3.3.2 Selection of electronic component

The component chosen as the subject of this study is a PCBA. There are several types of PCBA in the company, consequently model B6x is selected for this study.

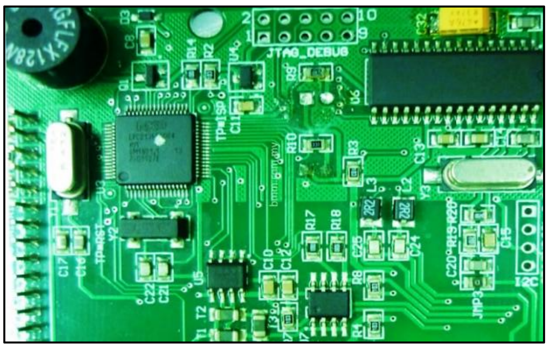

Figure 3.3 Examples of PCBA.

### 3.3.3 Interview form

The activity analysis is needed to increase the quality improvement of team's requirements in term of time and resources used. Here are some related questions to achieve the objectives of this study.

Objectives 1

1. How many departments involved in PCBA production?
2. What are the main activities for each department and the estimated time used?
3. How much workers are involved in each department?
4. How much is the employee's monthly basic salary?
5. How many regular working days for each employee for one month?
6. What is the estimated monthly value (MYR) for maintenance costs, raw material costs and consumables cost in each department?
7. Which machine require weekly, monthly or yearly maintenance?
8. What are the raw materials involved?
9. What are the main consumables for each activity?
10. What is the maximum and minimum quantity for B6x production in a day?
11. What is the average production quantity of B6x that is rejected?



Objectives 2

1. How many working hours for each employee for one shift?
2. How many unproductive hours per employee for one shift?
1. What are the sub activities for each main activity and the estimated time used?

### 3.3.4 Data collection

This research has identified the manufacturing flow of PCBA's production model B6x which consists of 19 steps as shown in Figure 3.4.

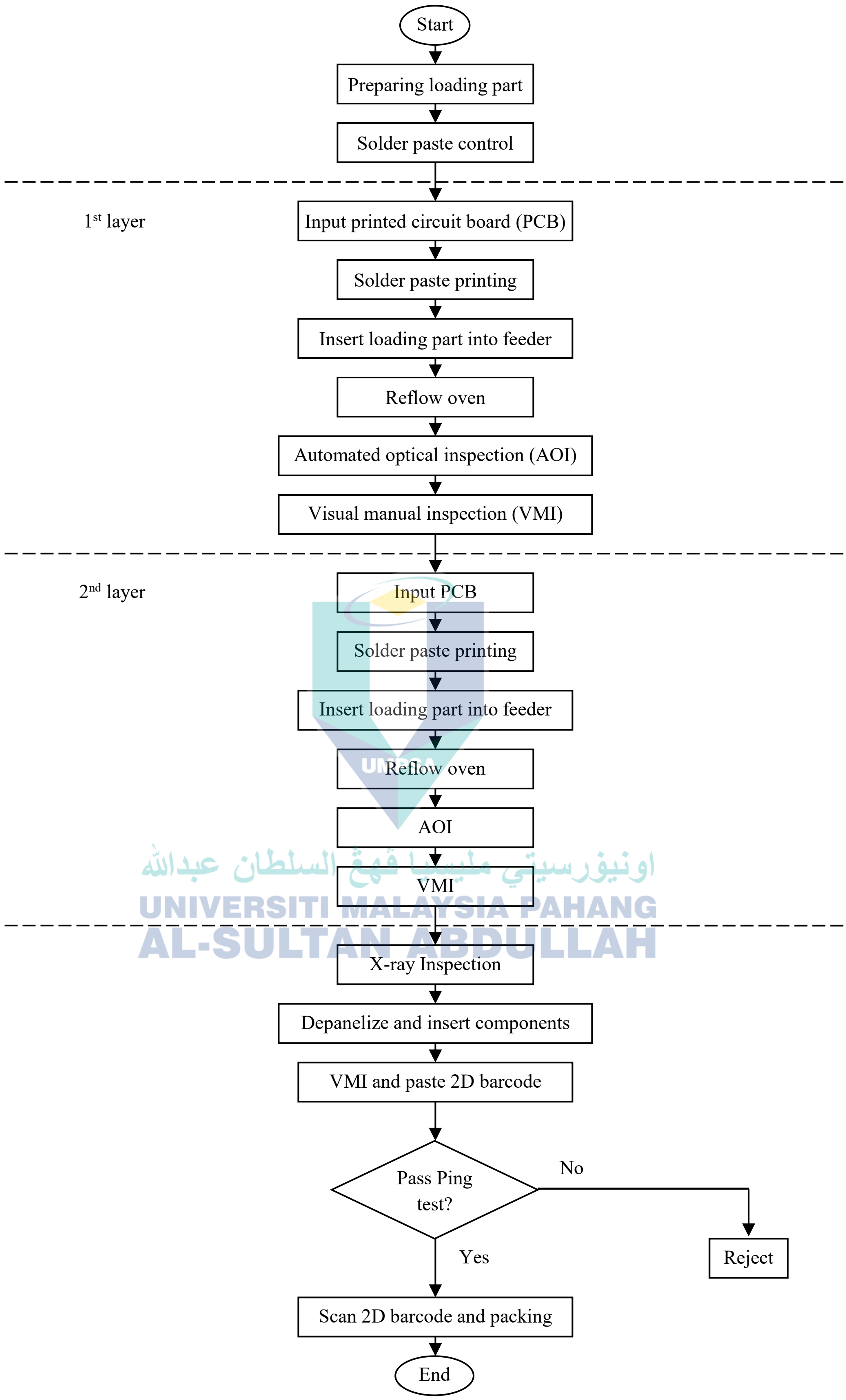


Figure 3.4 Flowchart of manufacturing flow of PCBA's production.

The process to produce PCBA B6x begins at workstation 1 which is preparing loading part. There are different types of components were used in PCBA B6x such as resistors, capacitors, ferrite chips, and transistors. These components were called parts in the production, and they are in types of joint tape. Different parts have different numbers which are used to represent their size of components. In these workstations, workers used the specified number of parts and separated them, so that can be used in the workstation 6 which is insert loading part into feeder. Next, the components are then gone through dry cabinet to make sure all readings are followed their expected reading. In this process, the reading must take 3 time/shift, and record its temperature and humidity graph. If they found reading out of specification, the worker needs to close the door of dry cabinet for 30 minutes and take the reading again.

Then at workstation 2, the worker needs to prepare solder before running the PCBA B6x production. The process is called solder paste control. This process is about solder paste handling after issued out from refrigerator. There are several steps they need to go through which are must make sure the solder paste container have correct FIFO sticker use by month, withdraw solder paste from the refrigerator at least maximum 4 hours to be thaw, strictly must stir after thaw, the solder paste must be stir about 2 minutes using solder paste mixer machine before be used in production, and lastly, any activity needs to update in sticker of solder paste shelf-life control and stock card. Strictly, the solder paste must be used within 24 hours in production after it opened.



At workstation 3, input raw PCB into auto loader machine by using PCB magazine. Before inserting the raw PCB into auto loader, several steps need to be carried out which are visual check on PCB and prevent dust or foreign objects on PCB by using roller dust.

The next process is where the solder paste printing occurs in workstation 4. Firstly, need to set up printer for printing and inspecting, and confirm the solder paste printed on PCB. Secondly, quality control needs to do verification of printing. Lastly, the production worker needs to inspection for abnormality, solder paste printing condition and cleaning stencil that been used so that the solder paste does not dry and stick on it.

In workstation 5, the prepared loading part that has been carried out in workstation 1 previously, can be inserted into the feeder, therefore this process is called insert the loading parts. This process only involves two activities which are check value and part number of material loading on feeder and scan barcode P/N versus machine type versus ID operator to prevent wrong use similar part number.

At workstation 6, the PCBA B6x will undergo reflow oven to melt the solder and heat the joining surfaces, without overheating and damaging the electrical components.

Workstation 7 is called AOI. The operational description for this workstation is to test the PCB at several stages of assembly by using the AOI machine as well as conduct an auto inspection.

Next, VMI will be conducted to the PCB in this workstation 8. The purpose of this process is to reduce and prevent such defects in future and to check the appearance of all parts material and solder conditions on PCB.

Meanwhile at workstation 9, x-ray inspection will be conducted and the main target for this process is to detect porosity and voids in solder and geometric measurement of solder thickness and volume.



Then in workstation 10, due to the PCBA B6x model production is in form of twin, this workstation which called as de-panelize process, will cut the PCB per panel. After the cutting activities, the worker must check the quality cutting and appearance. The appearance means cover the aspects of no crack on component and no overcut or undercut. Also, in this workstation, there are several components that need to be insert manually such as RJ 45 and amj probe. First, put the PCBA into the wave pallet. Insert the related components and make sure the component fits completely into the hole and ensure no components are lifted or stuck on pallet. Next, close it with a cover wave pallet. And lastly, enter it into wave solder through conveyor. After that, the PCBA B6x needs a special process which is solderability check. Check and touch up the solder if necessary and paste Kapton tape if needed.

The PCBA B6x undergoes VMI process again and paste 2D barcode. This VMI process is to check the overall appearance of PCBA. The appearance aspect includes cleaning the flux using solvent, cloth, or brush if any, no solder short, no missing part, no flux or no solder ball. After appearance check, paste 2D barcode for every product of PCBA B6x. Also, in this workstation, to make sure current capacity, performance, component value and impedance are within proper and expected tolerance level, ping test must be conducted. Failed short test will be heard of beep of the multimeter if the PCBA B6x pass the ping test.

Lastly, at the last workstation, which is scan 2D barcode and packing, label bin and bubble bag are used to wrap the PCBA B6x to minimize impact during movements.

## 3.4 Data analysis

There are two phases of data analysis which are by using ABC method and TDABC method. This study firstly discusses ABC method which consists of five steps and then proceeds with TDABC method which consists of eight steps.

### 3.4.1 ABC steps

In this study, there are five steps of implementing ABC system. The first step of implementing ABC is to do a manufacturing flow analysis on the production line. In this step, all activities on the production line are identified and observed.

Secondly, the time proportion for each activity was decided. Time proportion means the time needed by the operator to complete the task given. The time proportion is collected as an average, by interviewing 10 operators of the company and conducting self observation.

Thirdly, the cost of all resources was estimated by calculating capacity cost. Capacity cost means cost calculation of all the resources such as labor, equipment, and technology which are supplied to the department or process. Thus, in this study labor costs, maintenance costs, material costs, and consumable costs are selected as capacity cost that needs to be considered. Here is a little bit explanation for each type of cost selected:

1. Labor cost is the amount of salary of the operator. As for labor cost in this study, the duration is one year which also equals 12 months.

2. Maintenance cost is the cost of machineries' regular service or when replacement part needed during the machine down. As for maintenance cost, there are three types of maintenance service schedules conducted under this company study which are weekly, monthly, and yearly.

3. Material cost is the cost of imported raw material used for the product production. The raw material cost, in respect of each component, is calculated by multiplying the gross weight by the material cost per unit weight. Another calculation method for the total of component raw material cost is the total direct material cost per component.

4. Consumable cost is the cost of material or equipment used but not incorporated in the product. Generally, material cost has two types which are direct material cost and indirect material cost. Here, indirect material cost was considered.

Fourthly, the cost drivers and cost rate are determined. Cost driver is determined by taking the factors that influence the cost in an activity. Cost driver rates are calculated by using Equation 3.1.



$$\text{Cost driver rates} = \frac{\text{Cost of selected resources}}{\text{Quantity driver}} \tag{3.1}$$

Lastly, forecast the product cost. Using cost driver rate, product cost can be forecast. Thus, this work complied with the first objective which is to determine the cost driver rate using ABC for costing development.

### 3.4.2 TDABC steps

TDABC system consists of eight steps of implementation. For step 1, identification of activities and sub activities involved. Then identify its time proportion (minutes). Step 2, estimate cost of resources supplied.

Then continuing the third step of TDABC by doing the estimation of practical capacity. Practical capacity means the quantity of resources (typically, personnel or equipment) that truly perform work need to be identified.

As an example, assume that the department employs 28 front line people (this does not count supervisors or support staff). Each front line employee works an average of 20 days per month (60 days per quarter) and is paid for 7.5 hours of work each day. Each employee shows up at work, therefore, for about 450 hours, or 27,000 minutes per quarter. Not all the time paid for is available for productive work. Employees in that department spend about 75 minutes per day on breaks, training, and education. Thus, the practical capacity for each employee is about 22,500 minutes per quarter (375 minutes per day multiplied by 60 days per quarter). So here, we can conclude the department has a practical capacity of 630,000 minutes in terms of labor (Kaplan & Anderson, 2007). Table 3.1 shows the summary of above explanation.



Table 3.1 Example on how practical capacity in aspect of labour conducted.

| No. | Lists | Calculation |
|---|---|---|
| 1. | Total of employee | 28 |
| 2. | Total f workday per month | 20 |
| 3. | Total of month under study (quarter) | 20 x 3 = 60 |
| 4. | Total of work hours per day | 7.5 |
| 5. | Total of work hour per day (quarter) | 7.5 x 60 = 450 |
| 6. | Total of work minutes per day (quarter) | 450 x 60 = 27,000 |
| 7. | Total of unproductive hour per day | 1.25 |
| 8. | Total of productive hour per day | 7.5-1.25 = 6.25 |
| 9. | Total of productive hour per day (quarter) | 6.25 x 60 = 375 |
| 10. | Total of productive minutes per day (quarter) | 375 x 60 = 22,500 |
| 11. | Practical capacity for labor (minutes per quarter) | 22,500 x 28 = 630,000 |

The fourth step is calculating the capacity cost rate (CCR). The capacity cost rate (MYR per minute) can be obtained by using Equation 3.2. The cost of all resources supplied is an assumption, and we used it as base roots for all the calculations ahead.

$$\text{Capacity cost rate} = \frac{\text{Cost of all resources supplied}}{\text{practical supplied}} \tag{3.2}$$

From previous example of practical capacity which is equal to 630,000 minutes and let's assume that the cost of all resources supplied is $567,000. So, the calculated CCR is $0.9/minutes as shown in Equation 3.3.

$$\text{CCR} = \frac{\$567{,}700}{630{,}000 \text{ minutes}} = \$0.9/\text{minutes} \tag{3.3}$$

The fifth step is formulating the time equation by using TDABC time equation as shown in Equation 3.4.

$$T_t = \beta_0 + \beta_i \chi_i \tag{3.4}$$

Where:

$T_t$ = the time needed to perform an activity (minute)

$\beta_0$ = the standard time to perform the basic activity (minute)

$\beta_i$ = the estimated time to perform the incremental activity (minute)

$\chi_i$ = the quantity of the incremental activity (time)

For the sixth step, let's assume company A run customer service and they have three activities which are processing customer orders, handling customer inquiry and performing credit checks. Each activity takes 8 minutes, 44 minutes, and 50 minutes, respectively. Therefore, the time equation is as shown in Equation 3.5.

$$\text{Customer service time (minutes)} = \sum \text{time (minutes) each of activity involved} \tag{3.5}$$

$$\text{Customer service} = (8 \times \text{number of orders}) + (44 \times \text{number of inquiry}) + (50 \times \text{number of credit checks})$$

Seventh step, by using the same example, we have the information of CCR equal to 0.9, so the calculation of total cost can be conducted as shown in Figure 3.5 which then can be used to reveals the percentage of practical capacity (total cost get by using cost driver rate divided by total minutes from earlier practical capacity) and percentage of unused capacity can be calculated.

| Activity | Unit Time | Quantity | Total Minutes | Total Cost |
|---|---|---|---|---|
| Process customer order | 8 | 49,000 | 392,000 | $352,800 |
| Handle customer inquiry | 44 | 1,400 | 61,600 | 55,440 |
| Perform credit check | 50 | 2,500 | 125,000 | 112,500 |
| Used capacity | | | 578,600 | $520,740 |
| Unused capacity (8.2%) | | | 51,400 | 46,260 |
| Total | | | 630,000 | $567,000 |

Figure 3.5 Total cost need to conduct calculation of unused capacity.

From the Figure 3.5, its shows how total minutes and total cost calculation in two aspects can be calculated. Firstly, in aspect of first activity as shown in Equation 3.6 and Equation 3.7.

$$\text{Total minutes each activity} = \text{unit time} \times \text{quantity of acitivity} \tag{3.6}$$
$$\text{Total minutes for 1st activity} = 8 \times 49{,}000 \ = \ 392{,}000 \text{ minutes}$$

$$\text{Total cost} = \text{total minutes} \times \text{cost driver rate} \tag{3.7}$$
$$\text{Total cost for 1st activity} = 392{,}000 \times 0.9 \ = \ \$352{,}800$$

Continuing the calculation of total minutes and total cost for second and third activity using the same equations, the results are shown in Equation 3.8 and Equation 3.9.

$$\text{Total minutes for 2nd activity} = 44 \times 1{,}400 \ = \ 61{,}600 \text{ minutes} \tag{3.8}$$
$$\text{Total cost for 2nd activity} = 61{,}600 \times 0.9 \ = \ \$55{,}440$$

$$\text{Total minutes for 3rd activity} = 50 \times 2{,}500 = 125{,}000 \text{ minutes} \qquad 3.9$$

$$\text{Total cost for 3rd activity} = 125{,}000 \times 0.9 = \$112{,}500$$

Secondly, in aspects of one whole company (used capacity) are as shown in Equation 3.10 and Equation 3.11. Then, by using other information that has been calculated to find unused capacity and determine capacity utilization.

$$\text{Total minutes for the company} = \sum \text{all activities involved} \qquad 3.10$$

$$\text{Total minutes} = \text{1st activity} + \text{2nd activity} + \text{3rd activity}$$

$$\text{Total minutes} = 392{,}000 + 61{,}600 + 125{,}000$$

$$\text{Total minutes (used capacity)} = 578{,}000 \text{ minutes}$$

$$\text{Total cost for the company} = \sum \text{all activities involved} \qquad 3.11$$

$$\text{Total cost} = \text{1st activity} + \text{2nd activity} + \text{3rd activity}$$

$$\text{Total cost} = 352{,}800 + 55{,}440 + 112{,}500$$

$$\text{Total cost (used capacity)} = \$520{,}740$$

To determine unused capacity in terms of time and cost, there are two equations that need to be used which are Equation 3.12 and Equation 3.13.

$$\text{Unused capacity (time)} = \text{practical capacity} - \text{total minutes (used capacity)} \qquad 3.12$$

$$\text{Unused capacity (time)} = 630{,}000 - 578{,}600 = 51{,}400 \text{ minutes}$$

$$\text{Unused capacity (cost)} = \text{unused capacity (time)} \times \text{CCR} \qquad 3.13$$

$$\text{Unused capacity (cost)} = 51{,}400 \times 0.9 = \$46{,}260$$

The last step in TDABC method is the analysis of capacity utilization. This capacity utilization can be used for forecasting the company product cost.

### 3.4.3 Comparison

A comparative study is carried out to prove the differences between ABC and TDABC based on eight aspects of costing sustainment as can be seen below. Further explanation will be discussed in Chapter 4.4.

1. Cost allocation
2. Driver determination
3. Action taken for an additional activity
4. Cost consideration
5. Informative
6. Transparency
7. Oversimplification of activities
8. Capacity forecast and planning

## 3.5 Phase 4: Conclusion and recommendations

This phase concludes the findings of this work on every step of ABC and TDABC implementations. The comparative study of ABC and TDABC is concluded as well. The research questions and objective would be coordinated with the findings of this work. The future recommendation for further study will be explained in Chapter 5.3.

## 3.6 Summary

This chapter conveys the methodology of implementing process of ABC and TDABC for this research. Description of the detailed processes and methods of analyzing data using ABC and TDABC system were discussed. The comparative features of this study are pointed out as well. Thus, the methodology of this work covers all three objectives in this study.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter outlines the implementation of activity-based costing (ABC), time driven activity-based costing (TDABC) and comparative study between ABC and TDABC.

## 4.2 Implementation of ABC method

### 4.2.1 Time allocation

For every workstation, the time allocated by the operator to complete the task given is identified as shown in Table 4.1 for all activities. The time study for ABC method is attached at Table 1, Appendix B.

Table 4.1 Time allocation in terms of percentage and minutes.

| No. | Activities | Time (%) | Time (min) |
|---|---|---|---|
| 1. | Preparation loading part | 23.44 | 30 |
| 2. | Solder paste control | 3.13 | 4 |
| 3. | Input PCB | 3.91 | 5 |
| 4. | Solder paste printing | 19.53 | 25 |
| 5. | Insert loading part | 15.63 | 20 |
| 6. | Reflow oven | 7.81 | 10 |
| 7. | Automated optical inspection (AOI) | 7.81 | 10 |
| 8. | Visual manual inspection (VMI) | 3.91 | 5 |
| 9. | X-ray inspection | 3.91 | 5 |
| 10. | De-panelize | 4.69 | 6 |
| 11. | VMI and ping test | 3.13 | 4 |
| 12. | Packaging | 3.13 | 4 |
| | TOTAL | 100 | 128 |

The largest time allocation by operators is at preparation loading part workstation which is 23.44%, followed by solder paste printing which is 19.53% and third major workstation is insert loading part which is 15.63%.

### 4.2.2 Capacity cost estimation

The objective of capacity cost is to calculate the cost of all the resources such as personnel, supervision, equipment, and technology supplied to the department or process. In this study, labor costs, maintenance costs, material costs, and consumable costs are selected as an aspect of capacity cost that needs to be considered. Details of costs incurred in each activity are in Table 4.2 which shows the annual expenses for the PCBA B6x production for each activity.

Here is a slight explanation for each type of cost respectively. Labor cost is the amount of salary of the operator. Maintenance cost is the cost of machineries' regular service or when replacement part needed during the machine down. Material cost is the cost of imported raw material used for the product production. Consumable cost is the cost of material or equipment used but not incorporated in the product. Generally, material cost has two types which are direct material cost and indirect material cost. Here, indirect material cost was considered.



Table 4.2 Capacity cost for every workstation.

| No. | Workstation | Labor (MYR) | Maintenance (MYR) | Raw material (MYR) | Consumables (MYR) | All resources supplied (MYR) |
|---|---|---|---|---|---|---|
| 1. | Preparation loading part | 54,000 | 25.13 | 240,000 | 240.00 | 294,265.13 |
| 2. | Solder paste control | 36,000 | 25.13 | - | - | 36,025.13 |
| 3. | Input PCB | 72,000 | 50.26 | - | 552.88 | 72,603.14 |
| 4. | Solder paste printing | 144,000 | 4,850.26 | - | 792.00 | 149,642.26 |
| 5. | Insert loading part | 144,000 | 2,462.83 | - | 60.00 | 146,522.83 |
| 6. | Reflow oven | 108,000 | 615.71 | - | - | 108,615.71 |
| 7. | AOI | 108,000 | 615.71 | - | - | 108,615.71 |
| 8. | VMI | 72,000 | 25.13 | - | 578.01 | 72,603.14 |

Table 4.2 Continued.

| No. | Workstation | Labor (MYR) | Maintenance (MYR) | Raw material (MYR) | Consumables (MYR) | All resources supplied (MYR) |
|---|---|---|---|---|---|---|
| 9. | X-ray inspection | **72,000** | **603.14** | **-** | **-** | **72,603.14** |
| 10. | De-panelize | 90,000 | 50.26 | - | - | 90,050.26 |
| 11. | VMI and ping test | 36,000 | 25.13 | - | - | 36,025.13 |
| 12. | Packaging | 36,000 | 25.13 | - | - | 36,025.13 |
| | TOTAL | 972,000 | 9,373.82 | 240,000 | 2,222.89 | 1,233,596.71 |

### 4.2.3 Cost driver and rate determination

The cost driver is determined by assuming that the time allocated by each operator at each workstation takes about the same level of effort. It is chosen based on the consideration of the cost that affects the most on the workstation. Next, Table 4.3 shows the cost driver rates for the PCBA B6x production using ABC method.

The cost driver quantity is the estimated quantities of products produced for a year in all 16 processes. Cost driver rates are calculated by dividing the assigned cost and the cost quantity driver for each process.



Table 4.3 Cost driver rates for each workstation.

| No. | Workstation | Cost driver | All resources supplied (MYR) | Cost driver quantity | Cost driver rate (MYR) |
|---|---|---|---|---|---|
| 1. | Preparation loading part | Electronic component (quantity) | 294,265.13 | 83,640 | 3.52 |
| 2. | Solder paste control | Stirring machine (hours) | 36,025.13 | 2,040 | 17.66 |
| 3. | Input PCB | Labor (salary) | 72,603.14 | 18,000 | 4.03 |
| 4. | Solder paste printing | SP and SPI machine (hours) | 149,642.26 | 2,040 | 73.35 |
| 5. | Insert loading part | Pick and place machine (hours) | 146,522.83 | 2,040 | 71.82 |
| 6. | Reflow oven | Oven (hours) | 108,615.71 | 2,040 | 53.24 |
| 7. | AOI | AOI saki checker (hours) | 108,615.71 | 2,040 | 53.24 |

Table 4.3 Continued.

| No. | Workstation | Cost driver | All resources supplied (MYR) | Cost driver quantity | Cost driver rate (MYR) |
|---|---|---|---|---|---|
| 8. | VMI | Labor (salary) | 72,603.14 | 18,000 | 4.03 |
| 9. | X-ray inspection | XD 7500 machine (hours) | 72,603.14 | 2,040 | 35.59 |
| 10. | De-panelize | Labor (salary) | 90,050.26 | 18,000 | 5.00 |
| 11. | VMI and ping test | Labor (salary) | 36,025.13 | 18,000 | 2.00 |
| 12. | Packaging | Labor (salary) | 36,025.13 | 18,000 | 2.00 |
| | TOTAL | | 1,223,596.71 | | |

### 4.2.4 Forecast product cost

Using the product cost information in 2023, the product cost can be forecasted. For example, in the following year, the predicted product cost can be detemine if the demand of the PCBA increases as much as 10%, while maintaining the production line process, number of labor and equipment. Table 4.4 shows the forecast of product cost respect to the demand quantity using cost rate. The production line is expected to produce 96,000 quantities of PCBA. As the demand quantity of the product is increase by 10%, the total cost of production is predicted to be RM 1,345,837.68 while the unit product cost is forecast at RM 14.02.



Table 4.4 PCB's forecast cost.

| No. | Workstation | Cost driver | Cost driver quantity | Cost driver rate (MYR) | Forecast cost (MYR) |
|---|---|---|---|---|---|
| 1. | Preparation loading part | Electronic component (quantity) | 92,004 | 3.52 | 323,854.08 |
| 2. | Solder paste control | Stirring machine (hours) | 2,244 | 17.66 | 39,629.04 |
| 3. | Input PCB | Labor (salary) | 19,800 | 4.03 | 79,794.00 |
| 4. | Solder paste printing | SP and SPI machine (hours) | 2,244 | 73.35 | 164,597.4 |
| 5. | Insert loading part | Pick and place machine (hours) | 2,244 | 71.82 | 161,164.08 |
| 6. | Reflow oven | Oven (hours) | 2,244 | 53.24 | 119,470.56 |

Table 4.4 Continued.

| No. | Workstation | Cost driver | Cost driver quantity | Cost driver rate (MYR) | Forecast cost (MYR) |
|---|---|---|---|---|---|
| 7. | AOI | AOI saki checker (hours) | 2,244 | 53.24 | 119,470.56 |
| 8. | VMI | Labor (salary) | 19,800 | 4.03 | 79,794.00 |
| 9. | X-ray inspection | XD 7500 machine (hours) | 2,244 | 35.59 | 79,863.96 |
| 10. | De-panelize | Labor (salary) | 19,800 | 5.00 | 99,000.00 |
| 11. | VMI and ping test | Labor (salary) | 19,800 | 2.00 | 39,600.00 |
| 12. | Packaging | Labor (salary) | 19,800 | 2.00 | 39,600.00 |
| | TOTAL | | | | 1,345,837.68 |
| | | | | | 14.02 |

The forecast of total cost production of PCBA is the summation of forecast cost from all 12 activities. The forecast unit product cost is obtained by dividing the total of MYR1,345,837.68 with the expected demand which is 96,000. Thus, a single unit of a PCBA is forecasted to cost as much as MYR14.02.

### 4.2.5 Strength of ABC

Throughout the process, the current company cost information is analysed and compared with cost information by ABC method. It is discovered that the company applied their costing on activity based rather than volume-based. Lead time for each workstation is used to generate the product cost.

The company may have implemented the costing using activity-based, however, the cost drivers are not significantly pointed out. Meanwhile, ABC method is able to point out cost drivers in every workstation. Therefore, this work complied with first objective which is to identify the cost drivers of ABC for costing development.

Table 4.5 shows comparison finding between two products which is both products use ABC method to do costing analysis. The details of analysis are as follows.

Table 4.5 Comparison findings between different products using ABC.

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Aspects</th><th colspan="2">Finding between current study with previous study</th></tr>
<tr><th>Current study<br>(product: PCB)</th><th>Previous study<br>(product: magnetic inductor)</th></tr>
<tr><td>1.</td><td><u>Cost allocation</u><br>1st stage<br>Allocate total resources cost supplied to each activity.<br>- Total resources cost for PCB: MYR1,223,596.71<br>- Total resources cost for magnetic inductor: MYR3,795,467.12<br>2nd stage<br>Allocate activity cost into cost object (cost driver rate)</td><td>Total number of activity involved: 12<br>Total number of cost considered: 4<br>Ex: insert loading part (5/12)<br>1st stage (resources cost)<br>Labor cost: MYR144,000<br>Maintenance cost: MYR2,462.83<br>Raw material cost: -<br>Consumables cost: MYR60<br>2nd stage (cost object)<br>Resources cost: MYR146,522.83<br>Cost driver quantity: 2,040<br>Cost driver rate: MYR71.82</td><td>Total number of activity involved: 13<br>Total number of cost considered: 4<br>Ex: laser marking (11/13)<br>1st stage (resources cost)<br>Labor cost: MYR24,000<br>Maintenance cost: MYR626.53<br>Raw material cost: -<br>Consumables cost: -<br>2nd stage (cost object)<br>Resources cost: MYR24,626.53<br>Cost driver quantity: 4,800,000<br>Cost driver rate: MYR0.01</td></tr>
<tr><td>2.</td><td><u>Driver determination</u><br>Determined by allocating the time taken per activity.</td><td>Total time taken (min): 128<br>Ex: solder paste control (2/12)<br>Time taken (min): 4<br>Time taken (%): 3.13</td><td>Total time taken (min): -<br>Ex: flattening (2/13)<br>Time taken (min): -<br>Time taken (%): 1.27</td></tr>
<tr><td>3.</td><td><u>Action taken for an additional activity</u><br>Need to survey the added activity's time taken, and modify the total time taken for 1 production line.</td><td>Example: input PCB (3/12)<table><tr><th>No.</th><th>Activity</th><th>Time (min)</th></tr><tr><td>3.</td><td>Input PCB</td><td>5</td></tr><tr><td>xx</td><td>xx</td><td>xx</td></tr></table>Total time taken: 128 + xx</td><td>Example: flattening (2/13)<table><tr><th>No.</th><th>Activity</th><th>Time (%)</th></tr><tr><td>2.</td><td>Flattening</td><td>1.27</td></tr><tr><td>xx</td><td>xx</td><td>xx</td></tr></table></td></tr>
</table>

Table 4.5 Continued.

| No. | Aspects | Finding between current study with previous study | |
|---|---|---|---|
| | | Current study<br>(product: PCB) | Previous study<br>(product: magnetic inductor) |
| 4. | <u>Cost consideration</u><br>By identifying the time taken for each activity. | Method: Observation<br>Ex: Reflow oven (6/12)<br>Time allocation: 7.81% | Method: Survey and observation<br>Ex: Winding (1/13)<br>Time allocation: 16.51% |
| 5. | <u>Informative</u><br>Able to give cost driver data. | The data can be used to determine the product rate and next, be able to forecast the product cost in term of future decision making. | |
| 6. | <u>Transparency</u><br>Ability to display the detail of activity's duration.<br>(p/s: without time equation) | Method: in minutes and percentage<br>Ex: automated optical inspection (7/12)<br>Time taken (min): 10<br>Time taken (%): 7.81 | Method: in percentage<br>Ex: trimming (3/13)<br>Time taken (%): 1.27 |
| 7. | <u>Oversimplification of activities</u><br>By concerning the number of drivers used. | Method: single cost driver<br>Ex: x-ray inspection (9/12)<br>Driver: XD 7500 machine<br>Cost driver unit: hours | Method: single cost driver<br>Ex: soldering (5/13)<br>Driver: material's amount<br>Cost driver unit: gram |
| 8. | <u>Capacity forecast and planning</u><br>Ability to illustrate the appropriate cost analysis. | The analysis can be used as reference price for future in aspect of pricing decision. | |
| | | Method: using cost driver rate<br>As shown in Table 4.4 | Method: using time allocation<br>As shown in Figure 4.1 |

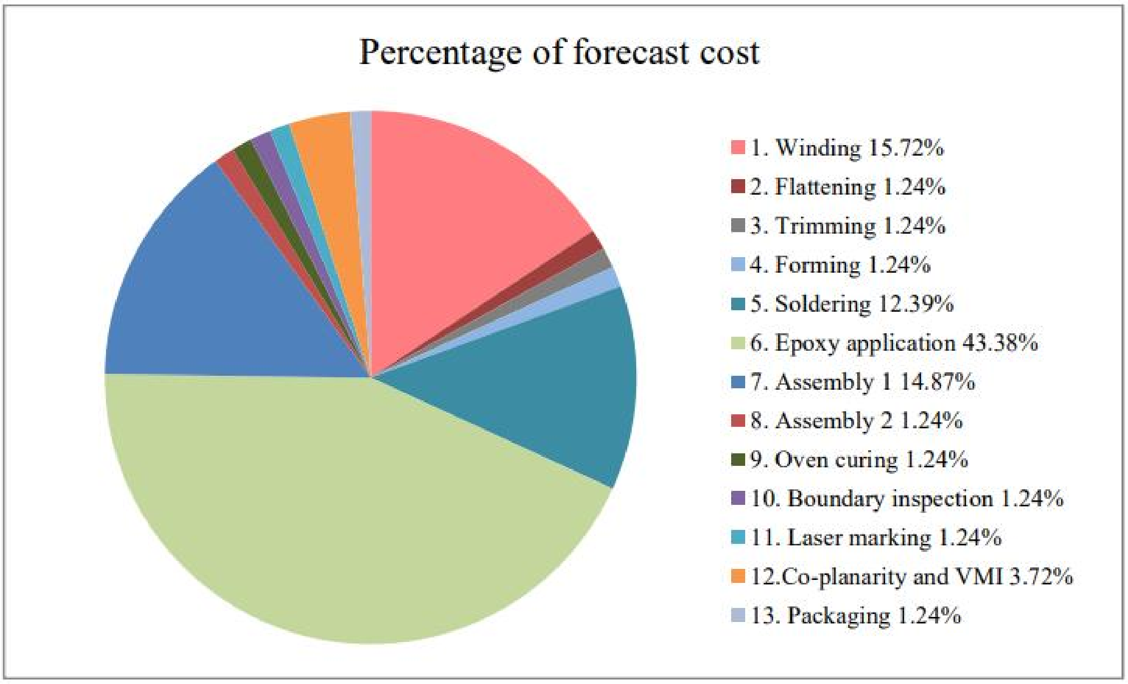


Figure 4.1 Percentage of forecast cost in previous study.

## 4.3 Implementation of TDABC method

### 4.3.1 Activities allocation with multiple drivers



To build a accurate costing method to cost object, the use of multiple drivers is needed in each activity which is lead to TDABC method shown in Table 4.6.

Table 4.6 Main activities with sub activities (multiple drivers).

| No. | Main activities | Sub-activities |
|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system<br>2. Prepare part for the production |
| 2. | Solder paste control | 1. Prepare the solder before running into production<br>2. Update sticker of solder paste shelf-life control |
| 3. | Input PCB | 1. Visual check on PCB<br>2. Input PCB into auto loader machine |
| 4. | Solder paste printing | 1. Set up printer for printing<br>2. Verify the printing<br>3. Inspect for abnormality |

Table 4.6 Continued.

| No. | Main activities | Sub-activities |
|---|---|---|
| 5. | Insert loading part | 1. Prepare loading part into feeder<br>2. Scan barcode of machine type and ID operator<br>3. Confirm part for each feeder follow by loading list |
| 6. | Reflow oven | 1. Reflow the PCBA through oven<br>2. Check thermal profile and solder after reflow |
| 7. | AOI | 1. Automatic inspection on PCBA<br>2. Paste reject sticker on PCBA if found detect spot at AOI's screen |
| 8. | VMI | 1. Manual check on PCBA appearance<br>2. Manual soldering if needed<br>3. Verify the PCBA in good condition |
| 9. | X-ray inspection | 1. Check porosity and void in solder<br>2. Check geometric measurement of solder thickness and volume |
| 10. | De-panelize | 1. Cut PCBA per panel<br>2. Check the quality cutting and appearance |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA<br>2. Paste 2D barcode<br>3. Make sure the PCBA pass ping test<br>4. Put into reject tray if PCBA failed ping test |
| 12. | Packaging | 1. Scan 2D barcode<br>2. Input complete PCBA into bin |



### 4.3.2 Capacity cost supplied (CCS)

For capacity cost of TDABC method, can refer Table 4.7 which have been conducted previously in ABC method. The table shows the total CCS for PCBA model B6x is MYR1,225,596.71 and the breakdown of the value into sub-activities for TBABC method analysis.

Table 4.7 The used cost of PCBA production.

| No. | Main activities | Sub-activities | Labor (RM) | Maintenance (RM) | Raw material (RM) | Consumables (RM) | All resources supplied (RM) |
|---|---|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | 36,000 | 25.13 | - | 240 | 36,265.13 |
| | | 2. Prepare part for the production | 18,000 | - | 240,000 | - | 258,000.00 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | 18,000 | - | - | - | 18,000.00 |
| | | 2. Update sticker of solder paste shelf-life control | 18,000 | 25.13 | - | - | 18,025.13 |
| 3. | Input PCB | 1. Visual check on PCB | 36,000 | - | - | 552.88 | 36,552.88 |
| | | 2. Input PCB into auto loader machine | 36,000 | 50.26 | - | - | 36,050.26 |
| 4. | Solder paste printing | 1. Set up printer for printing | 36,000 | 4,850.26 | - | 792.00 | 41,642.26 |
| | | 2. Verify the printing | 18,000 | - | - | - | 18,000.00 |
| | | 3. Inspect for abnormality | 18,000 | - | - | - | 18,000.00 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | 72,000 | 2,462.83 | - | - | 74,462.83 |
| | | 2. Scan barcode of machine type and ID operator | 36,000 | - | - | 60 | 36,060.00 |
| | | 3. Confirm part for each feeder follow by loading list | 36,000 | - | - | - | 36,000.00 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | 54,000 | 615.71 | - | - | 54,615.71 |
| | | 2. Check thermal profile and solder after reflow | 54,000 | - | - | - | 54,000.00 |
| 7. | AOI | 1. Automatic inspection on PCBA | 72,000 | 615.71 | - | - | 72,615.71 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 36,000 | - | - | - | 36,000.00 |

Table 4.7 Continued.

| No. | Main activities | Sub-activities | Labor (RM) | Maintenance (RM) | Raw material (RM) | Consumables (RM) | All resources supplied (RM) |
|---|---|---|---|---|---|---|---|
| 8. | VMI | 1. Manual check on PCBA appearance | 36,000 | - | - | - | 36,000.00 |
| | | 2. Manual soldering if needed | 18,000 | 25.13 | - | 578.01 | 18,603.14 |
| | | 3. Verify the PCBA in good condition | 18,000 | - | - | - | 18,000.00 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | 36,000 | 301.57 | - | - | 36,301.57 |
| | | 2. Check geometric measurement of solder thickness and volume | 36,000 | 301.57 | - | - | 36,301.57 |
| 10. | De-panelize | 1. Cut PCBA per panel | 54,000 | 50.26 | - | - | 54,050.26 |
| | | 2. Check the quality cutting and appearance | 36,000 | - | - | - | 36,000.00 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | 9,000 | - | - | - | 9,000.00 |
| | | 2. Paste 2D barcode | 9,000 | - | - | - | 9,000.00 |
| | | 3. Make sure the PCBA pass ping test | 9,000 | 25.13 | - | - | 9,025.13 |
| | | 4. Reject PCBA if any | 9,000 | - | - | - | 9,000.00 |
| 12. | Packaging | 1. Scan 2D barcode | 18,000 | 25.13 | - | - | 18,025.13 |
| | | 2. Input complete PCBA into bin | 18,000 | - | - | - | 18,000.00 |
| | TOTAL | | 974,000 | 9,373.82 | 240,000 | 2,222.89 | 1,225,596.71 |

### 4.3.3 Productive capacity

The company's working hours are from Monday to Friday, 8.30 a.m. to 6.00 p.m. The operators work for 8 hours per day, excluding 1 hour 30 minutes break daily, for 20 days a month. Therefore, the practical capacity per year is 100,800 minutes for each operator can be calculated as shown in Equation 4.1 until 4.4, while the practical capacity for each sub-activity is shown in Table 4.8.

$$\text{Practical capacity} = \text{productive time per day (minutes)} \times \text{total days} \tag{4.1}$$

$$\text{Productive time} = \text{working hour (minutes)} - \text{unproductive hour (minutes)} \tag{4.2}$$

$$\text{Productive time} = (8.5 \text{ hours} \times 60) - (1.5 \text{ hours} \times 60)$$

$$\text{Productive time} = 510 \text{ minutes} - 90 \text{ minutes} = 420 \text{ minutes}$$

$$\text{Total days} = 5 \text{ days in a week} \times 4 \text{ weeks in a month} \times 12 \text{ months in a year} \tag{4.3}$$

$$\text{Total days} = 240 \text{ days}$$

$$\text{Practical capacity per year} = 420 \text{ minutes} \times 240 \text{ days} = 100{,}800 \text{ minutes} \tag{4.4}$$



### 4.3.4 Capacity cost rate calculation

Capacity cost rate for each activity and sub-activity are as portrayed in the Table 4.8. Capacity cost rate is calculated by dividing cost of all resources supplied with practical capacity.

Table 4.8 Capacity cost rate.

| No. | Main activities | Sub-activities | Cost of all resources supplied (RM) | Practical capacity (min) | Capacity cost rate (RM) |
|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | 36,265.13 | 201,600 | 0.1799 |
| | | 2. Prepare part for the production | 258,000.00 | 100,800 | 2.5595 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | 18,000.00 | 100,800 | 0.1786 |
| | | 2. Update sticker of solder paste shelf-life control | 18,025.13 | 100,800 | 0.1788 |
| 3. | Input PCB | 1. Visual check on PCB | 36,552.88 | 201,600 | 0.1813 |
| | | 2. Input PCB into auto loader machine | 36,050.26 | 201,600 | 0.1788 |
| 4. | Solder paste printing | 1. Set up printer for printing | 41,642.26 | 201,600 | 0.2066 |
| | | 2. Verify the printing | 18,000.00 | 100,800 | 0.1786 |
| | | 3. Inspect for abnormality | 18,000.00 | 100,800 | 0.1786 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | 74,462.83 | 403,200 | 0.1847 |
| | | 2. Scan barcode of machine type and ID operator | 36,060.00 | 201,600 | 0.1789 |
| | | 3. Confirm part for each feeder follow by loading list | 36,000.00 | 201,600 | 0.1786 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | 54,615.71 | 302,400 | 0.1806 |
| | | 2. Check thermal profile and solder after reflow | 54,000.00 | 302,400 | 0.1786 |
| 7. | AOI | 1. Automatic inspection on PCBA | 72,615.71 | 403,200 | 0.1801 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 36,000.00 | 201,600 | 0.1786 |

Table 4.8 Continued.

| No. | Main activities | Sub-activities | Cost of all resources supplied (RM) | Practical capacity (min) | Capacity cost rate (RM) |
|---|---|---|---|---|---|
| 8. | VMI | 1. Manual check on PCBA appearance | 36,000.00 | 201,600 | 0.1786 |
| | | 2. Manual soldering if needed | 18,603.14 | 100,800 | 0.1846 |
| | | 3. Verify the PCBA in good condition | 18,000.00 | 100,800 | 0.1786 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | 36,301.57 | 201,600 | 0.1801 |
| | | 2. Check geometric measurement of solder thickness and volume | 36,301.57 | 201,600 | 0.1801 |
| 10. | De-panelize | 1. Cut PCBA per panel | 54,050.26 | 302,400 | 0.1787 |
| | | 2. Check the quality cutting and appearance | 36,000.00 | 201,600 | 0.1786 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | 9,000.00 | 50,400 | 0.1786 |
| | | 2. Paste 2D barcode | 9,000.00 | 50,400 | 0.1786 |
| | | 3. Make sure the PCBA pass ping test | 9,025.13 | 50,400 | 0.1791 |
| | | 4. Reject PCBA if any | 9,000.00 | 50,400 | 0.1786 |
| 12. | Packaging | 1. Scan 2D barcode | 18,025.13 | 100,800 | 0.1788 |
| | | 2. Input complete PCBA into bin | 18,000.00 | 100,800 | 0.1786 |

### 4.3.5 Time equation formulation

To calculate the estimated production time, it is necessary to develop a time equation as shown in Equation 4.5 and 4.6 by using information from Table 4.9. The time study for TDABC method is attached at Table 2, Appendix B.

Table 4.9 Time equation based on time allocation and variable.

| No. | Main activities | Sub-activities | Time (min) | Time equation |
|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | 5 | $5x_1$ |
| | | 2. Prepare part for the production | 25 | $25x_2$ |
| 2. | Solder paste control | 1. Prepare the solder before running into production | 3 | $3x_3$ |
| | | 2. Update sticker of solder paste shelf-life control | 1 | $1x_4$ |
| 3. | Input PCB | 1. Visual check on PCB | 1 | $1x_5$ |
| | | 2. Input PCB into auto loader machine | 4 | $4x_6$ |
| 4. | Solder paste printing | 1. Set up printer for printing | 15 | $15x_7$ |
| | | 2. Verify the printing | 5 | $5x_8$ |
| | | 3. Inspect for abnormality | 5 | $5x_9$ |
| 5. | Insert loading part | 1. Prepare loading part into feeder | 12 | $12x_{10}$ |
| | | 2. Scan barcode of machine type and ID operator | 1 | $1x_{11}$ |
| | | 3. Confirm part for each feeder follow by loading list | 2 | $2x_{12}$ |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | 8 | $8x_{13}$ |
| | | 2. Check thermal profile and solder after reflow | 2 | $2x_{14}$ |
| 7. | AOI | 1. Automatic inspection on PCBA | 5 | $5x_{15}$ |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 5 | $5x_{16}$ |
| 8. | VMI | 1. Manual check on PCBA appearance | 2 | $2x_{17}$ |
| | | 2. Manual soldering if needed | 1 | $1x_{18}$ |
| | | 3. Verify the PCBA in good condition | 2 | $2x_{19}$ |
| 9. | X-ray inspection | 1. Check porosity and void in solder | 3 | $3x_{20}$ |
| | | 2. Check geometric measurement of solder thickness and volume | 2 | $2x_{21}$ |
| 10. | De-panelize | 1. Cut PCBA per panel | 3 | $3x_{22}$ |
| | | 2. Check the quality cutting and appearance | 3 | $3x_{23}$ |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | 1 | $1x_{24}$ |
| | | 2. Paste 2D barcode | 1 | $1x_{25}$ |
| | | 3. Make sure the PCBA pass ping test | 1 | $1x_{26}$ |
| | | 4. Put into reject tray if PCBA failed ping test | 1 | $1x_{27}$ |
| 12. | Packaging | 1. Scan 2D barcode | 2 | $2x_{28}$ |
| | | 2. Input complete PCBA into bin | 2 | $2x_{29}$ |

Time equation formulation 4.5

$$\begin{aligned}&= \sum \text{sub activity in activity}_1 + \sum \text{sub activity in activity}_2 \\ &+ \sum \text{sub activity in activity}_3 + \sum \text{sub activity in activity}_4 \\ &+ \sum \text{sub activity in activity}_5 + \sum \text{sub activity in activity}_6 \\ &+ \sum \text{sub activity in activity}_7 + \sum \text{sub activity in activity}_8 \\ &+ \sum \text{sub activity in activity}_9 + \sum \text{sub activity in activity}_{10} \\ &+ \sum \text{sub activity in activity}_{11} + \sum \text{sub activity in activity}_{12}\end{aligned}$$

$$= (5x_1 + 25x_2) + (3x_3 + 1x_4) + (1x_5 + 4x_6) + (15x_7 + 5x_8 + 5x_9) + (12x_{10} + 1x_{11} + 2x_{12}) + (8x_{13} + 2x_{14}) + (5x_{15} + 5x_{16}) + (2x_{17} + 1x_{18} + 2x_{19}) + (3x_{20} + 2x_{21}) + (3x_{22} + 3x_{23}) + (1x_{24} + 1x_{25} + 1x_{26} + 1x_{27}) + (2x_{28} + 2x_{29}) \quad 4.6$$

### 4.3.6 Capacity required estimation

To calculate used and unused capacity, it is necessary to know cost driver and its driver quantity for every each of sub-activity as shown in Table 4.10. The estimated driver quantity for each activity was obtained by observation of the operators during the production run.

Table 4.10 Cost driver and driver quantity for each sub-activity.

| No. | Main activities | Sub-activities | Cost driver | Quantity |
|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | Scanning (quantity) | 40 |
| | | 2. Prepare part for the production | Electronic component (quantity) | 83,600 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | Stirring machine (hours) | 2,000 |
| | | 2. Update sticker of solder paste shelf-life control | Sticker label (quantity) | 40 |
| 3. | Input PCB | 1. Visual check on PCB | Labor (salary) | 9,000 |
| | | 2. Input PCB into auto loader machine | Labor (salary) | 9,000 |
| 4. | Solder paste printing | 1. Set up printer for printing | Screen printing machine (hours) | 2,000 |
| | | 2. Verify the printing | Consumables (quantity) | 20 |
| | | 3. Inspect for abnormality | Consumables (quantity) | 20 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | Pick and place machine (hours) | 1,000 |
| | | 2. Scan barcode of machine type and ID operator | Scanning (quantity | 40 |
| | | 3. Confirm part for each feeder follow by loading list | Pick and place machine (quantity) | 1,000 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | Oven (hours) | 2,000 |
| | | 2. Check thermal profile and solder after reflow | Thermal profile (quantity) | 40 |

Table 4.10 Continued.

| No. | Main activities | Sub-activities | Cost driver | Quantity |
|---|---|---|---|---|
| 7. | AOI | 1. Automatic inspection on PCBA | AOI saki checker (hours) | 2,000 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | Sticker label (quantity) | 40 |
| 8. | VMI | 1. Manual check on PCBA appearance | Labor (salary) | 18,000 |
| | | 2. Manual soldering if needed | Consumables (quantity) | 20 |
| | | 3. Verify the PCBA in good condition | Consumables (quantity) | 20 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | XD 7500 machine (hours) | 1,020 |
| | | 2. Check geometric measurement of solder thickness and volume | XD 7500 machine (hours) | 1,020 |
| 10. | De-panelize | 1. Cut PCBA per panel | Labor (salary) | 18,000 |
| | | 2. Check the quality cutting and appearance | Consumables (quantity) | 40 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | Labor (salary) | 9,000 |
| | | 2. Paste 2D barcode | Sticker label (quantity) | 40 |
| | | 3. Make sure the PCBA pass ping test | Labor (salary) | 9,000 |
| | | 4. Reject PCBA if any | Reject (quantity) | 40 |
| 12. | Packaging | 1. Scan 2D barcode | Scanning (quantity) | 40 |
| | | 2. Input complete PCBA into bin | Labor (salary) | 18,000 |

From the data estimation in Table 4.10, the calculation of actual used time per sub-activity as shown in Table 4.11, can be calculated by multiplying of each quantity driver with their respective time.



Table 4.11 Time used capacity.

| No. | Main activities | Sub-activities | Cost driver | Quantity | Time (min) | Used time (min) |
|---|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | Scanning (quantity) | 40 | 5 | 200 |
| | | 2. Prepare part for the production | Electronic component (quantity) | 83,600 | 25 | 2,090,000 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | Stirring machine (hours) | 2,000 | 3 | 6,000 |
| | | 2. Update sticker of solder paste shelf-life control | Sticker label (quantity) | 40 | 1 | 40 |
| 3. | Input PCB | 1. Visual check on PCB | Labor (salary) | 9,000 | 1 | 9,000 |
| | | 2. Input PCB into auto loader machine | Labor (salary) | 9,000 | 4 | 36,000 |

Table 4.11 Continued.

| No. | Main activities | Sub-activities | Cost driver | Quantity | Time (min) | Used time (min) |
|---|---|---|---|---|---|---|
| 4. | Solder paste printing | 1. Set up printer for printing | Screen printing machine (hours) | 2,000 | 15 | 30,000 |
| | | 2. Verify the printing | Consumables (quantity) | 20 | 5 | 100 |
| | | 3. Inspect for abnormality | Consumables (quantity) | 20 | 5 | 100 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | Pick and place machine (hours) | 1,000 | 12 | 12,000 |
| | | 2. Scan barcode of machine type and ID operator | Scanning (quantity) | 40 | 1 | 40 |
| | | 3. Confirm part for each feeder follow by loading list | Pick and place machine (quantity) | 1,000 | 2 | 2,000 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | Oven (hours) | 2,000 | 8 | 16,000 |
| | | 2. Check thermal profile and solder after reflow | Thermal profile (quantity) | 40 | 2 | 80 |
| 7. | AOI | 1. Automatic inspection on PCBA | AOI saki checker (hours) | 2,000 | 5 | 10,000 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | Sticker label (quantity) | 40 | 5 | 200 |
| 8. | VMI | 1. Manual check on PCBA appearance | Labor (salary) | 18,000 | 2 | 36,000 |
| | | 2. Manual soldering if needed | Consumables (quantity) | 20 | 1 | 40 |
| | | 3. Verify the PCBA in good condition | Consumables (quantity) | 20 | 2 | 40 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | XD 7500 machine (hours) | 1,020 | 3 | 54,000 |
| | | 2. Check geometric measurement of solder thickness and volume | XD 7500 machine (hours) | 1,020 | 2 | 120 |
| 10. | De-panelize | 1. Cut PCBA per panel | Labor (salary) | 18,000 | 3 | 9,000 |
| | | 2. Check the quality cutting and appearance | Consumables (quantity) | 40 | 3 | 40 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | Labor (salary) | 9,000 | 1 | 9,000 |
| | | 2. Paste 2D barcode | Sticker label (quantity) | 40 | 1 | 40 |
| | | 3. Make sure the PCBA pass ping test | Labor (salary) | 9,000 | 1 | 9,000 |
| | | 4. Reject PCBA if any | Reject (quantity) | 40 | 1 | 40 |
| 12. | Packaging | 1. Scan 2D barcode | Scanning (quantity) | 40 | 2 | 80 |
| | | 2. Input complete PCBA into bin | Labor (salary) | 18,000 | 2 | 36,000 |

### 4.3.7 Used cost capacity

From previous data, the calculation of practical capacity and capacity utilization can be calculated as displayed in Table 4.12 and Table 4.13.

Table 4.12 The practical capacity of PCBA production.

| No. | Main activities | Sub-activities | Cost driver | Quantity | Used time (min) | CCR (RM) | Total cost (RM) |
|---|---|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | Scanning (quantity) | 40 | 200 | 0.1799 | 35.98 |
| | | 2. Prepare part for the production | Electronic component (quantity) | 83,600 | 2,090,000 | 2.5595 | 5349355 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | Stirring machine (hours) | 2,000 | 6,000 | 0.1786 | 1071.6 |
| | | 2. Update sticker of solder paste shelf-life control | Sticker label (quantity) | 40 | 40 | 0.1788 | 7.152 |
| 3. | Input PCB | 1. Visual check on PCB | Labor (salary) | 9,000 | 9,000 | 0.1813 | 1631.7 |
| | | 2. Input PCB into auto loader machine | Labor (salary) | 9,000 | 36,000 | 0.1788 | 6436.8 |
| 4. | Solder paste printing | 1. Set up printer for printing | Screen printing machine (hours) | 2,000 | 30,000 | 0.2066 | 6198 |
| | | 2. Verify the printing | Consumables (quantity) | 20 | 100 | 0.1786 | 17.86 |
| | | 3. Inspect for abnormality | Consumables (quantity) | 20 | 100 | 0.1786 | 17.86 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | Pick and place machine (hours) | 1,000 | 12,000 | 0.1847 | 2216.4 |
| | | 2. Scan barcode of machine type and ID operator | Scanning (quantity) | 40 | 40 | 0.1789 | 7.156 |
| | | 3. Confirm part for each feeder follow by loading list | Pick and place machine (quantity) | 1,000 | 2,000 | 0.1786 | 357.2 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | Oven (hours) | 2,000 | 16,000 | 0.1806 | 2889.6 |
| | | 2. Check thermal profile and solder after reflow | Thermal profile (quantity) | 40 | 80 | 0.1786 | 14.288 |

Table 4.12 Continued.

| No. | Main activities | Sub-activities | Cost driver | Quantity | Used time (min) | CCR (RM) | Total cost (RM) |
|---|---|---|---|---|---|---|---|
| 7. | AOI | 1. Automatic inspection on PCBA | AOI saki checker (hours) | 2,000 | 10,000 | 0.1801 | 1801 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | Sticker label (quantity) | 40 | 200 | 0.1786 | 35.72 |
| 8. | VMI | 1. Manual check on PCBA appearance | Labor (salary) | 18,000 | 36,000 | 0.1786 | 6429.6 |
| | | 2. Manual soldering if needed | Consumables (quantity) | 20 | 40 | 0.1846 | 7.384 |
| | | 3. Verify the PCBA in good condition | Consumables (quantity) | 20 | 40 | 0.1786 | 7.144 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | XD 7500 machine (hours) | 1,020 | 54,000 | 0.1801 | 9725.4 |
| | | 2. Check geometric measurement of solder thickness and volume | XD 7500 machine (hours) | 1,020 | 120 | 0.1801 | 21.612 |
| 10. | De-panelize | 1. Cut PCBA per panel | Labor (salary) | 18,000 | 9,000 | 0.1787 | 1608.3 |
| | | 2. Check the quality cutting and appearance | Consumables (quantity) | 40 | 40 | 0.1786 | 7.144 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | Labor (salary) | 9,000 | 9,000 | 0.1786 | 1607.4 |
| | | 2. Paste 2D barcode | Sticker label (quantity) | 40 | 40 | 0.1786 | 7.144 |
| | | 3. Make sure the PCBA pass ping test | Labor (salary) | 9,000 | 9,000 | 0.1791 | 1611.9 |
| | | 4. Reject PCBA if any | Reject (quantity) | 40 | 40 | 0.1786 | 7.144 |
| 12. | Packaging | 1. Scan 2D barcode | Scanning (quantity) | 40 | 80 | 0.1788 | 14.304 |
| | | 2. Input complete PCBA into bin | Labor (salary) | 18,000 | 36,000 | 0.1786 | 6429.6 |
| | | | | | 2,361,200 | | 5,399,577.39 |

Table 4.13 Capacity utilization of PCBA production.

| No. | Main activities | Sub-activities | Practical capacity (min) | Used time (min) | Unused time (min) | CCR (RM) | Unused cost (RM) |
|---|---|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | 201,600 | 200 | 201,400 | 0.1799 | 36,231.86 |
| | | 2. Prepare part for the production | 100,800 | 2,090,000 | -1,989,200 | 2.5595 | -5,091,357.40 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | 100,800 | 6,000 | 94,800 | 0.1786 | 16,931.28 |
| | | 2. Update sticker of solder paste shelf-life control | 100,800 | 40 | 100,760 | 0.1788 | 18,015.89 |
| 3. | Input PCB | 1. Visual check on PCB | 201,600 | 9,000 | 192,600 | 0.1813 | 34,918.38 |
| | | 2. Input PCB into auto loader machine | 201,600 | 36,000 | 165,600 | 0.1788 | 29,609.28 |
| 4. | Solder paste printing | 1. Set up printer for printing | 201,600 | 30,000 | 171,600 | 0.2066 | 35,452.56 |
| | | 2. Verify the printing | 100,800 | 100 | 100,700 | 0.1786 | 17,985.02 |
| | | 3. Inspect for abnormality | 100,800 | 100 | 100,700 | 0.1786 | 17,985.02 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | 403,200 | 12,000 | 391,200 | 0.1847 | 72,254.64 |
| | | 2. Scan barcode of machine type and ID operator | 201,600 | 40 | 201,560 | 0.1789 | 36,059.08 |
| | | 3. Confirm part for each feeder follow by loading list | 201,600 | 2,000 | 199,600 | 0.1786 | 35,648.56 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | 302,400 | 16,000 | 286,400 | 0.1806 | 51,723.84 |
| | | 2. Check thermal profile and solder after reflow | 302,400 | 80 | 302,320 | 0.1786 | 53,994.35 |
| 7. | AOI | 1. Automatic inspection on PCBA | 403,200 | 10,000 | 393,200 | 0.1801 | 70,815.32 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 201,600 | 200 | 201,400 | 0.1786 | 35,970.04 |

Table 4.13 Continued.

| No. | Main activities | Sub-activities | Practical capacity (min) | Used time (min) | Unused time (min) | CCR (RM) | Unused cost (RM) |
|---|---|---|---|---|---|---|---|
| 8. | VMI | 1. Manual check on PCBA appearance | 201,600 | 36,000 | 165,600 | 0.1786 | 29,576.16 |
| | | 2. Manual soldering if needed | 100,800 | 40 | 100,760 | 0.1846 | 18,600.30 |
| | | 3. Verify the PCBA in good condition | 100,800 | 40 | 100,760 | 0.1786 | 17,995.74 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | 201,600 | 54,000 | 147,600 | 0.1801 | 26,582.76 |
| | | 2. Check geometric measurement of solder thickness and volume | 201,600 | 120 | 201,480 | 0.1801 | 36,286.55 |
| 10. | De-panelize | 1. Cut PCBA per panel | 302,400 | 9,000 | 293,400 | 0.1787 | 52,430.58 |
| | | 2. Check the quality cutting and appearance | 201,600 | 40 | 201,560 | 0.1786 | 35,998.62 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | 50,400 | 9,000 | 41,400 | 0.1786 | 7,394.04 |
| | | 2. Paste 2D barcode | 50,400 | 40 | 50,360 | 0.1786 | 8,994.30 |
| | | 3. Make sure the PCBA pass ping test | 50,400 | 9,000 | 41,400 | 0.1791 | 7,414.74 |
| | | 4. Reject PCBA if any | 50,400 | 40 | 50,360 | 0.1786 | 8,994.30 |
| 12. | Packaging | 1. Scan 2D barcode | 100,800 | 80 | 100,720 | 0.1788 | 18,008.74 |
| | | 2. Input complete PCBA into bin | 100,800 | 36,000 | 64,800 | 0.1786 | 11,573.28 |
| | | | 5,040,000 | 2,365,160 | 2,674,840 | | -4,247,912.19 |

Next, from the calculation of capacity utilization, information of unused capacity which are unused time and unused cost can be obtain. To get unused time, practical capacity (min) times with used time (time) while, to get unused cost, the cost of resources supplied subtract with used cost.

With this two information, the company can use the data to improve the company performance in term of cost usage in production and number of workers for each workstation. Then, forecast cost also can be calculated as shown in Appendix F which is cost per unit is equal to RM2.66, by dividing total forecast cost with quantity production in year of 2023.

### 4.3.8 Strength of TDABC

Throughout the process, the current company cost information is analyzed and compared with cost information by using TDABC method. It is discovered that the company capacity utilization needs to be improved in order to stay strong compete with current competition among industry companies.

Table 4.14 shows comparison finding between two products which is both products use TDABC method to do costing analysis. The details of analysis are as follows.

Table 4.14 Comparison findings between different products using TDABC.

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Aspects</th><th colspan="2">Finding between current study with previous study</th></tr>
<tr><th>Current study<br>(product: PCB)</th><th>Previous study<br>(product: magnetic inductor)</th></tr>
<tr><td>1.</td><td><u>Cost allocation</u><br>Only involved single stage. By using the value of total resources cost achieved in previous method (ABC), the calculation is then breakdown into actual used time and actual total cost per sub-activity.<br>(p/s: time equation, TE, and capacity cost rate, CCR)</td>
<td>Total number of activity involved: 12<br>Total resources cost: MYR1,223,596.71<br>Ex: preparation loading part (1/12)<br><br>$\text{Time used} = \text{quantity driver} \times \text{TE}$<br>$\text{CCR} = \frac{\text{total resources cost}}{\text{practical capacity}}$<br>$\text{Total cost} = \text{time used} \times \text{CCR}$<br><br>Involved 2 sub activities<br>1.Scan barcode P/N into system
<table><tr><th>Time used (min)</th><th>CCR (MYR)</th><th>Total cost (MYR)</th></tr><tr><td>200</td><td>0.1799</td><td>35.98</td></tr></table>
2.Prepare part for production
<table><tr><th>Time used (min)</th><th>CCR (MYR)</th><th>Total cost (MYR)</th></tr><tr><td>2,090,000</td><td>2.5595</td><td>5349355</td></tr></table></td>
<td>Total number of activity involved: 13<br>Total resources cost: MYR3,795,467.12<br>Ex: winding (1/13)<br><br>$\text{Time used} = \text{quantity driver} \times \text{TE}$<br>$\text{CCR} = \frac{\text{total resources cost}}{\text{practical capacity}}$<br>$\text{Total cost} = \text{time used} \times \text{CCR}$<br><br>Involved 1 sub-activity<br>1.The wire are winded using CNC machine
<table><tr><th>Time used (min)</th><th>CCR (MYR)</th><th>Total cost (MYR)</th></tr><tr><td>1,043.71</td><td>2.53</td><td>2,640.59</td></tr></table></td></tr>
<tr><td>2.</td><td><u>Driver determination</u><br>Determined by allocating the time equation per sub-activity.</td>
<td>Ex: solder paste control (2/12)<br><br>Involved 2 sub activities
<table><tr><th>No.</th><th>Sub-activity</th><th>TE</th></tr><tr><td>1.</td><td>Prepare solder</td><td>$3x_3$</td></tr><tr><td>2.</td><td>Update sticker</td><td>$1x_4$</td></tr></table></td>
<td>Ex: solder paste control (2/13)<br><br>Involved 2 sub activities
<table><tr><th>No.</th><th>Sub-activity</th><th>TE</th></tr><tr><td>1.</td><td>Pickup coil</td><td>$10x_2$</td></tr><tr><td>2.</td><td>Flatten coil</td><td>$0.22x_3$</td></tr></table></td></tr>
</table>

Table 4.14 Continued.

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Aspects</th><th colspan="2">Finding between current study with previous study</th></tr>
<tr><th>Current study<br>(product: PCB)</th><th>Previous study<br>(product: magnetic inductor)</th></tr>
<tr><td>3.</td><td><u>Action taken for an additional activity</u><br>Need to estimate the unit time for the new activity and add the unit time with new variable into the total time equation of sub activities, $TE_{total}$.</td><td>Ex: add 1 new activity which is consist of 1 sub-activity<br>Total sub activities (before): 29<br>Total sub activities (after): 30<br>$\mathrm{TE_{total}} = 5x_1 + 25x_2 + 3x_3 + 1x_4 + 1x_5 + 4x_6 + 15x_7 + 5x_8 + 5x_9 + 12x_{10} + 1x_{11} + 2x_{12} + 8x_{13} + 2x_{14} + 5x_{15} + 5x_{16} + 2x_{17} + 1x_{18} + 2x_{19} + 3x_{20} + 2x_{21} + 3x_{22} + 3x_{23} + 1x_{24} + 1x_{25} + 1x_{26} + 1x_{27} + 2x_{28} + 2x_{29} + XXXx_{30}$</td><td>Ex: add 1 new activity which is consist of 1 sub-activity<br>Total sub activities (before): 17<br>Total sub activities (after): 18<br>$\mathrm{TE_{total}} = 0.12x_1 + 10x_2 + 0.22x_3 + 10x_4 + XXXXXX + 0.13x_5 + 0.17x_6 + 0.72x_7 + 0.18x_8 + 0.15x_9 + 2.7x_{10} + 0.07x_{11} + 0.14x_{12} + 0.8x_{13} + 0.05x_{14} + 0.05x_{15} + 0.52x_{16} + 3x_{17}$</td></tr>
<tr><td>4.</td><td><u>Cost consideration</u><br>By concerning on cost breakdown process.</td><td>TDABC skip survey and observation process because it is only depending on cost breakdown process. The process starts from total resources cost supplied into cost of each sub activities involved.</td><td></td></tr>
<tr><td>5.</td><td><u>Informative</u><br>Able to give actual time used and actual total cost .</td><td>The data can be used to deliver the information of each sub activities in term of its efficiency and productivity. Also, with the data obtained, capacity utilization can be analyzed which concerning on unused time and unused cost.</td><td></td></tr>
<tr><td>6.</td><td><u>Transparency</u><br>Ability to display the detail of activity's duration by using time equation, TE.</td><td>Ex: automated optical inspection (7/12)<br><br>Involved 2 sub activities<table><tr><th>No.</th><th>Sub-activity</th><th>TE</th></tr><tr><td>1.</td><td>Inspection</td><td>$5x_{15}$</td></tr><tr><td>2.</td><td>Reject if defect</td><td>$5x_{16}$</td></tr></table><br><table><tr><th>No.</th><th>Time used (min)</th><th>Time unused (min)</th></tr><tr><td>1.</td><td>100,000</td><td>393,200</td></tr><tr><td>2.</td><td>200</td><td>201,400</td></tr></table></td><td>Ex: trimming (3/13)<br><br>Involved 2 sub activities<table><tr><th>No.</th><th>Sub-activity</th><th>TE</th></tr><tr><td>1.</td><td>Pickup coil</td><td>$10x_4$</td></tr><tr><td>2.</td><td>Flatten coil</td><td>$0.13x_5$</td></tr></table><br><table><tr><th>No.</th><th>Time used (min)</th><th>Time unused (min)</th></tr><tr><td>1.</td><td>4,800</td><td>118,800</td></tr><tr><td>2.</td><td>312,000</td><td>58,800</td></tr></table></td></tr>
</table>

Table 4.14 Continued.

| No. | Aspects | Finding between current study with previous study | |
|---|---|---|---|
| | | Current study (product: PCB) | Previous study (product: magnetic inductor) |
| 7. | <u>Oversimplification of activities</u><br>By relating number of drivers used. | Method: multiple cost driver<br>Ex: x-ray inspection (9/12)<br><br>Involved 2 sub activities<br>1.Check porosity and void in solder<br>Cost driver: XD 7500 machine<br>Cost driver unit: hours<br>Cost driver quantity: 1,020<br><br>2.Check geometric measurement of solder thickness and volume<br>Cost driver: XD 7500 machine<br>Cost driver unit: hours<br>Cost driver quantity: 1,020 | Method: multiple cost driver<br>Ex: soldering (5/13)<br><br>Involved 2 sub activities<br>1.Pick up the coil<br>Cost driver: amount of flux used<br>Cost driver unit: litre<br>Cost driver quantity: 432<br><br>2.Flatten the coil<br>Cost driver: amount of solder used<br>Cost driver unit: kilogram<br>Cost driver quantity: 2,400 |
| 8. | <u>Capacity forecast and planning</u><br>Ability to give more detail information in respect of cost analysis. | Method applied is capacity utilization analysis. The method able to give information such as time used, time unused, total cost and unused cost. The analysis can be used as reference price for future in aspect of pricing decision. | |

## 4.4 Comparative study

Considering data and information acquired at the company, the following eight elements summarize the key differences between ABC and TDABC. Every element is discussed by emphasizing the key differences between ABC and TDABC.

### 4.4.1 Cost allocation

The process of categorizing, gathering, and distributing costs to cost objects is known as cost allocation. In ABC, there are two phases. The indirect costs are first assigned to the activity centers, and then, using the activity drivers, the following phase distributes these centers' costs to the cost objects. The activity center's direct and indirect costs are listed in Table 4.15. There are 12 activities and four cost categories which are labor, maintenance, raw materials, and consumables. Every workstation's total cost of resources provided is MYR1,223,596.71

Table 4.15 Labor, maintenance, raw material and consumables cost.

| No. | Workstation | Labor (MYR) | Maintenance (MYR) | Raw material (MYR) | Consumables (MYR) |
|---|---|---|---|---|---|
| 1. | Preparation loading part | 54,000 | 25.13 | 240,000.00 | 240.00 |
| 2. | Solder paste control | 36,000 | 25.13 | - | - |
| 3. | Input PCB | 72,000 | 50.26 | - | 552.88 |
| 4. | Solder paste printing | 144,000 | 4,850.26 | - | 792.00 |
| 5. | Insert loading part | 144,000 | 2,462.83 | - | 60.00 |
| 6. | Reflow oven | 108,000 | 615.71 | - | - |
| 7. | Automated optical inspection (AOI) | 108,000 | 615.71 | - | - |
| 8. | Visual manual inspection (VMI) | 72,000 | 25.13 | - | 578.01 |
| 9. | X-ray inspection | 72,000 | 603.14 | - | - |
| 10. | De-panelize | 90,000 | 50.26 | - | - |
| 11. | VMI and ping test | 36,000 | 25.13 | - | - |
| 12. | Packaging | 36,000 | 25.13 | - | - |
| | TOTAL | 972,000 | 9,373.82 | 240,000.00 | 2,222.89 |

Assigning an activity center to a cost object is the next stage. The calculation of the cost driver rate in relation to the activity center is displayed in Table 4.16.

Table 4.16 Cost driver rates for selected activities.

| No. | Workstation | Cost driver | All resources supplied (MYR) | Cost driver quantity | Cost driver rate (MYR) |
|---|---|---|---|---|---|
| 4. | Solder paste printing | SP and SPI machine (hours) | 149,642.26 | 2,040 | 73.35 |
| 5. | Insert loading part | Pick and place machine (hours) | 146,522.83 | 2,040 | 71.82 |
| 6. | Reflow oven | Oven (hours) | 108,615.71 | 2,040 | 53.24 |

Regarding TDABC, the cost is allocated in a single step. The entire amount of time is spent in TDABC to assign costs to the various tasks. Table 4.17 displays an activity together with the amount of both time and cost required to perform it. 2,090,200 minutes were utilized for the preparation loading part, that costs MYR11,746,024.

Table 4.17 TDABC capacity utilization for selected activity.

| Main activities | Sub-activities | Practical capacity (min) | Used time (min) | Unused time (min) | Total cost (MYR) | Unused cost (MYR) |
|---|---|---|---|---|---|---|
| 1. Preparation loading part | 1. Scan barcode into system | 201,600 | 200 | 201,400 | 35.98 | 36,231.86 |
| | 2. Prepare part for the production | 100,800 | 2,090,000 | -1,989,200 | 5349355 | -5,091,357.40 |
| TOTAL | | 302,400 | 2,090,200 | -1,787,800 | 5,349,390.98 | -5,055,125.54 |

Table 4.18 and Table 4.19 provide the information to determine how time is used, as seen in Table 4.17. In Table 4.19, the standard of time for preparation loading part is shown which is 7 minutes where, $x_1$ and $x_2$ are the variable of time of this activity.

Table 4.18 Standard time of preparation loading part activity.

| Main activities | Sub-activities | Time equation |
|---|---|---|
| 1. Preparation loading part | 1. Scan barcode into system | $5x_1$ |
| | 2. Prepare part for the production | $25x_2$ |

The data representing the time variable in the preparation loading part activity is presented in Table 4.19. The amount of the driver, 8,697.6 kg, is the time variable.

Table 4.19 Time variable of preparation loading part activity.

| Main activities | Variance | Sub-activities | Cost driver | Quantity |
|---|---|---|---|---|
| 1. Preparation loading part | $x_1$ | 1. Scan barcode into system | Scanning (quantity) | 40 |
| | $x_2$ | 2. Prepare part for the production | Electronic component (quantity) | 83,600 |

The total cost of resources supplied for the preparation loading part activity is shown in Table 4.20, with a value of MYR294,265.13. A practical capacity of 302,400 minutes is provided. Utilizing the information acquired, a capacity cost rate of MYR6.744 is calculated for winding activity. As shown in Table 4.17, the activity's total cost is determined by the capacity cost rate.



Table 4.20 Capacity cost rate for preparation loading part activity.

| Main activities | Sub-activities | Cost of all resources supplied (MYR) | Practical capacity (min) | CCR (MYR) |
|---|---|---|---|---|
| 1. Preparation loading part | 1. Scan barcode into system | 36,265.13 | 201,600 | 0.1799 |
| | 2. Prepare part for the production | 258,000.00 | 100,800 | 2.5595 |
| TOTAL | | 294,265.13 | 302,400 | 2.7394 |

Indeed, the TDABC allocates cost in one stage where the process is connected directly to the time and cost with respect to the activity itself.

### 4.4.2 Driver determination

Cost driver is the activity that contributes the most of cost in an activity. Both ABC and TDABC have drivers in the costing but are determined with different methods. For ABC, the driver is determined by the time allocated per activity as in Table 4.21. The time allocated for flattening activity is 3.13% of all 12 activities identified in ABC. The time allocation is collected as an average, by interview session and self observation at the workstation.

Table 4.21 Percentage of time allocation for solder paste control activity.

| No. | Activity | Time allocation (%) |
|---|---|---|
| 2. | Solder paste control | 3.13 |

One of important step in TDABC is constructing a time equation comprises of all sub-activities involved. Table 4.22 demonstrates solder paste control and the sub-activities occur at the workstation with standard time and variables. There are two sub-activities in this workstation, therefore two equations produced are $3x_3$ and $1x_4$.

Table 4.22 Standard time and variable for solder paste control activity.

| Main activities | Sub-activities | Time equation |
|---|---|---|
| 2. Solder paste control | 1. Prepare the solder before running into production | $3x_3$ |
| | 2. Update sticker of solder paste shelf-life control | $1x_4$ |



In Table 4.23, the variable for solder paste control activity is described. To produce the time equations, the value of $x_3$ and $x_4$ is substitute with quantity of 2,000 and 40, respectively.

Table 4.23 Variables of solder paste control.

| Main activities | Sub-activities | Cost driver | Variance | Quantity |
|---|---|---|---|---|
| 2. Solder paste control | 1. Prepare the solder before running into production | Stirring machine (hours) | $x_3$ | 2,000 |
| | 2. Update sticker of solder paste shelf-life control | Sticker label (quantity) | $x_4$ | 40 |

Thus, the determination of driver in ABC and TDABC is different that the driver in ABC is subjective to the time estimations through surveying process. The determination of driver in TDABC is objective because it uses the time equations with respect to each activity and sub-activity.

### 4.4.3 Action taken for an additional activity

Additional activity is any new activity added to the production line. ABC and TDBC act differently when have an additional activity on the production line. For ABC, this method needs to do a thorough resurvey on the activities that involved with the additional activity. Additional activity affects time allocation for all workstations as shown in Table 4.24, when a new activity is added, the total percentage of time allocation changes.

Table 4.24 Percentage of time allocation for ABC.

| No. | Activity | Time allocation (%) |
|---|---|---|
| 3. | Input PCB | 3.91 |
| xx | xx | xx |

With TDABC, when a new activity is added, only the unit time for the new activity must be estimated and a thorough subsequent resurvey, which is the case for ABC, is avoided. Once a new activity is added, a new time and variable is added to the original equation as shown in Equation 4.7. Therefore, with TDABC, the process is simpler and removes time consuming process.

$$
\begin{aligned}
\text{Time equation} \\
&= (5x_1 + 25x_2) + (3x_3 + 1x_4) + (1x_5 + 4x_6) \\
&+ (15x_7 + 5x_8 + 5x_9) + (12x_{10} + 1x_{11} + 2x_{12}) \\
&+ (8x_{13} + 2x_{14}) + (5x_{15} + 5x_{16}) + (2x_{17} + 1x_{18} + 2x_{19}) \\
&+ (3x_{20} + 2x_{21}) + (3x_{22} + 3x_{23}) \\
&+ (1x_{24} + 1x_{25} + 1x_{26} + 1x_{27}) + (2x_{28} + 2x_{29})
\end{aligned} \tag{4.7}
$$

### 4.4.4 Cost consideration

This sub-topic is focusing on cost consideration of steps in ABC and TDABC. In ABC, for every workstation, the time allocated by operators to complete the task given is identified. The time allocation is collected as an average, by interviewing the operators and by observation. In Table 4.25, it is shown the time allocation for reflow oven activity which is 7.81% of all other 12 activities. This is the result from the surveying process.

Table 4.25 Time allocation for selected activity.

| No. | Activities | Time (%) |
|---|---|---|
| 6. | Reflow oven | 7.81 |

In TDABC, it simplifies the costing process by skipping the possible interviews or surveys made to the employees for allocating the resource costs to the activities. In this manner, TDABC avoids the costly, time-consuming, and subjective activity surveying task of ABC (Kaplan & Anderson, 2007). Thus, TDABC allows employees to concentrate more on the production time, so that the company gains a sustainable competitive advantage.



### 4.4.5 Informative

A system is considered informative when it is able to deliver useful or interesting information. It is understood that a method is more informative than the other when it offers more information to the management especially in terms of capacity utilization. In ABC, cost driver information is highlighted as it is used as rate and to forecast the product cost. It is beneficial to the company for decision making in the future.

By using time equation and capacity cost rate, the capacity utilization analysis can be done. This is useful as it delivers information of efficiency and productivity of every activity and sub-activity. Therefore, TDABC can benchmark the efficiency of production activities and gives more information about the idle capacity.

### 4.4.6 Transparency

Transparency is an ability to show in detail the duration of an activity. ABC and TDABC both have time allocated for the activities but differ in the method to display the time needed. Table 4.26 displays the time equation for automated optical inspection activity, $5x_4$ and $5x_5$.

Table 4.26 Time equations of TDABC.

| **Main activities** | **Sub-activities** | **Time equation** |
|---|---|---|
| 7. AOI | 1. Automatic inspection on PCBA | $5x_{15}$ |
| | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | $5x_{16}$ |

The value of $x_4$ and $x_5$ are substitute with the value in Table 4.27 which are 2,000 and 40, respectively.

Table 4.27 Variables of time in TDABC.

| **Main activities** | **Variance** | **Sub-activities** | **Cost driver** | **Quantity** |
|---|---|---|---|---|
| 7. AOI | $x_{15}$ | 1. Automatic inspection on PCBA | AOI saki checker (hours) | 2,000 |
| | $x_{16}$ | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | Sticker label (quantity) | 40 |



Eventually, in Table 4.28, the used and unused time of the activities are obtained. For first sub-activity in automated optical inspection activity, there are 10,000 minutes of used time and 393,200 minutes of unused time. Thus, TDABC is able to portray transparency better than ABC in showing duration of time for activities.

Table 4.28 Used time and unused time in TDABC.

| **Main activities** | **Sub-activities** | **Used time (min)** | **Unused time (min)** |
|---|---|---|---|
| 7. AOI | 1. Automatic inspection on PCBA | 10,000 | 393,200 |
| | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 200 | 201,400 |
| | | 10,200 | 594,600 |

However, Gong and colleagues (2011) stated that ABC is transparent. The method uses cost drivers to allocate indirect costs to products, thus the method is transparent.

### 4.4.7 Oversimplification of activities

For oversimplification of activity feature, it will be discussing in term of the number of drivers used. ABC assumes that each activity uses a single cost driver, but in practice, an activity can have multiple cost drivers. In contrast, TDABC can use multiple cost drivers, in the form of time drivers, for an activity. In Table 4.29, ABC assumes single cost driver for x-ray inspection.

Table 4.29 Cost driver for selected activity.

| Workstation | Cost driver |
|---|---|
| 9. X-ray inspection | XD 7500 machine (hours) |

On the contrary, as shown in Table 4.30, TDABC uses more than one cost driver for x-ray inspection activity. There are two drivers which are machine hours used for checking element. Firstly, check porosity and void in solder. Secondly, check geometric measurement of solder thickness and volume and amount of solder used.



Table 4.30 Variation cost driver for x-ray inspection activity.

| Main activities | Variance | Cost driver | Quantity |
|---|---|---|---|
| 9. X-ray inspection | $x_{20}$ | XD 7500 machine (hours) | 1,020 |
| | $x_{21}$ | XD 7500 machine (hours) | 1,020 |

### 4.4.8 Capacity forecast and planning

Forecast and planning step is crucial as it predicts the future action and scenario. Both ABC and TDBAC have the ability to forecast, however, the depth of the information sets a level between the two methods. For example, ABC is able to forecast using cost driver rates to determine the product unit cost. The company would have insight of appropriate cost and price for future references. According to Table 4.31, the product unit cost is generated in MYR for each activity.

Table 4.31 Product per unit cost by using ABC method.

| No. | Workstation | Cost driver | All resources supplied (MYR) | Cost driver quantity | Cost driver rate (MYR) |
|---|---|---|---|---|---|
| 1. | Preparation loading part | Electronic component (quantity) | 294,265.13 | 83,640 | 3.52 |
| 2. | Solder paste control | Stirring machine (hours) | 36,025.13 | 2,040 | 17.66 |
| 3. | Input PCB | Labor (salary) | 72,603.14 | 18,000 | 4.03 |
| 4. | Solder paste printing | SP and SPI machine (hours) | 149,642.26 | 2,040 | 73.35 |
| 5. | Insert loading part | Pick and place machine (hours) | 146,522.83 | 2,040 | 71.82 |
| 6. | Reflow oven | Oven (hours) | 108,615.71 | 2,040 | 53.24 |
| 7. | Automated optical inspection (AOI) | AOI saki checker (hours) | 108,615.71 | 2,040 | 53.24 |
| 8. | Visual manual inspection (VMI) | Labor (salary) | 72,603.14 | 18,000 | 4.03 |
| 9. | X-ray inspection | XD 7500 machine (hours) | 72,603.14 | 2,040 | 35.59 |
| 10. | De-panelize | Labor (salary) | 90,050.26 | 18,000 | 5.00 |
| 11. | VMI and ping test | Labor (salary) | 36,025.13 | 18,000 | 2.00 |
| 12. | Packaging | Labor (salary) | 36,025.13 | 18,000 | 2.00 |
| | TOTAL | | 1,223,596.71 | | |



As for TDABC, Table 4.32 displays the details of solder paste printing activity. It shows information on used time, unused time, total cost and unused cost for each sub-activities in the activities. TDABC separates the used resources and unused resources. By doing that, TDABC gained knowledge on the performance of each activity in PCBA production. In TDABC, forecast can be done using reference of capacity utilization. Therefore, TDABC can be point of reference for efficiency of production activities and provides evidence about the idle capacity.

Table 4.32 Capacity utilization of solder paste printing activity.

| Main activities | Sub-activities | Practical capacity (min) | Used time (min) | Unused time (min) | Total cost (MYR) | Unused cost (MYR) |
|---|---|---|---|---|---|---|
| 4. Solder paste printing | 1. Set up printer for printing | 201,600 | 30,000 | 171,600 | 6,198.00 | 35,452.56 |
| | 2. Verify the printing | 100,800 | 100 | 100,700 | 17.86 | 17,985.02 |
| | 3. Inspect for abnormality | 100,800 | 100 | 100,700 | 17.86 | 17,985.02 |
| TOTAL | | 403,200 | 30,200 | 373,000 | 6,233.72 | 71,422.60 |

### 4.4.9 Summary

In conclusion, this study proves that ABC is a transparent method and the method can forecast unit product cost by using cost driver rate. In the other hand, TDABC is a method with objective cost driver determination, removes time consuming process, have multiple cost drivers and able to forecast and planning using analysis of capacity utilization. Therefore, the comparative study complied with the third objective which is to compare ABC and TDABC costing sustainment by using the features.



However, there are two aspects that challenging to obtain which are cost driver quantity and estimation of raw material cost. This is because the company not share their actual number, they only give estimation value. Therefore, to have 100% accurate about these two methods are impossible.

# CHAPTER 5

# CONCLUSION

## 5.1 Introduction

The purpose of this study is to observe, analyse and compare these both method of activity-based costing (ABC) and time-driven activity-based costing (TDABC) in order to decide which method is more appropriate to be applied in production environment.

Firstly, activity-based costing (ABC) was used to calculate the cost driver rate of printed circuit board assembly (PCBA). The calculation was done by considering all elements that related to each activity involved which are identifying the time taken, conducting the capacity cost, finding the cost driver and determining the cost driver quantities. As the result, the highest time taken is activity number 4, solder paste printing and brought to highest cost driver in all activity involved.

Secondly, time-driven activity-based costing (TDABC) method involves the calculation of capacity cost rate and time equation. The calculation of capacity cost rate involves two aspects which are multiple drivers and productive capacity supplied resources. While for time equation formulation, it is determined by considering the time taken for each sub-activities involved. From the time taken, variable $x$ is added to it. Thus, the unused capacity can be conducted and give information of unused time and unused cost for each sub activities. As the result, in activity number 4, solder paste printing's costs are well defined due to the results of unused time and unused cost are only slightly different with its actual used time and used cost.

Thirdly, TDABC is selected as the best practice due to its appealing outcomes from comparison made in several aspects which are cost allocation, driver determination, action taken for an additional activity, cost consideration, informative, transparency, oversimplification of activities, and capacity forecast.

## 5.2 Fulfillment of research objectives

Table 5.1 shows the fulfillment of the research objectives.

Table 5.1 The fulfillment of study.

| Objectives | Results | Objectives achieved |
|---|---|---|
| To **determine** the cost driver rate of printed circuit board assembly (PCBA) using activity-based costing (ABC) method. | The cost driver rate for activity number 1, preparation loading part is 3.52 while for activity number 4, solder paste printing was a quite higher which is 73.82. | CHAPTER 4<br>Section 4.2.3<br>Table 4.3 |
| To **analyse** the unused capacity of PCBA's production through capacity cost rate and time equation in time-driven activity-based costing (TDABC) method. | The unused capacity analysis gives two information which are unused time and unused cost. The unused time and unused cost for preparation loading part activity are -1,787,800 minutes and MYR -10,499,733.60 respectively, which can be said that the previous costing method over defined the costing cost. While, the unused time and unused cost for solder paste printing activity are 776,200 minutes and MYR 1,711,402.40 respectively, which can be said that this activity costing cost is well defined as it is only slightly different with its actual used time and used cost. | CHAPTER 4<br>Section 4.4.7<br>Table 4.12, Table 4.13 |
| To **propose** the best practice of either using ABC or TDABC in a PCBA's production by comparing selected features in both method. | One of selected features that has been compared is determination of driver. For ABC, the driver is determined by the time allocated per activity, while TDABC uses time equation. ABC's driver for activity number 2, solder paste control is 3.13% while TDABC's driver with standard time and variables are $3x_3$ and $1x_4$, separately. Then, to produce the time equations, the value of $x_3$ and $x_4$ are substitute with quantity of 2,000 and 40, respectively. | CHAPTER 4<br>Section 4.5<br>Table 4.15, Table 4.16,<br>Table 4.17, Table 4.18,<br>Table 4.19, Table 4.20,<br>Table 4.21, Table 4.22,<br>Table 4.23, Table 4.24,<br>Table 4.25, Table 4.26,<br>Table 4.27, Table 4.28,<br>Table 4.29, Table 4.30,<br>Table 4.31, Table 4.32 |

## 5.3 Recommendation

TDABC is widely used in various area such as engineering, medical, social science, economics and management. However, there is lack of TDABC application in production environment. As TDABC is able to improve costing of production environment, therefore it should be more research in the production environment with various types of integration or algorithm.

To be specific or to have more similarity when comparing the accuracy or adaptability of TDABC method, more research in same area with same product should be conduct. Thus, it can be conclude that TDABC method is surely relevant to be applied in any production environment with varies types of products.

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# APPENDICES

## Appendix A: List of findings

Table 1 ABC papers.

| No. | Author (Year) | Area | Methods | Issues | Findings |
|---|---|---|---|---|---|
| 1. | Chia et al. (2010) | Social science | ABC/M | To examine the change agents' behavioral intentions in the implementation of an activity-based costing/ management (ABC/M). | The results indicate that performance expectancy and social influence all have a significant positive impact on change agents' intentions to promote ABC/M systems. |
| 2. | Pike (2011) | Social science | User satisfaction survey, embedded system, stand-alone system, ad-hoc system, ABC | User perceptions of Activity-based costing (ABC) performance for three different types of system in a major information and communication provider. | These findings suggest that system type used is an important factor in assessing ABC performance. |
| 3. | Khataen (2011) | Production | ABC, Decision support system, Mixed-integer programming, System dynamics | This model for order management is better fit and compatible with today's competitive, and constantly changing, business environment. | The presented hybrid modelling used ABC approach and be able to perform on-time cost analysis. |
| 4. | Carli et al. (2013) | Agricultural | Direct costing, ABC | Cost analyses appear not particularly developed in actual Farm Management Information Systems (FMIS). | Farms would benefit from the conceptual model that combines different decision variables. |
| 5. | Martha et al. (2014) | Production | ABC, TCA | Small and medium-sized firms (SMEs) are competitive, and they need to develop strategies to control their costs. | Mexican SMEs recognized the compatibility and usefulness of ABC in costing management. |
| 6. | Shigaev (2015) | Social science | ABC | Realization of the two-stage cost allocation scheme of activity-based costing in Russian accounting system. | Accounting entries was prepared for activity-based costing and related customer profitability report to improve efficiency and effectiveness of business operations. |
| 7. | Esmalifalak et al. (2015) | Medical | Using three systems of ABC which are traditional (TABC), fuzzy (FABC), and Monte Carlo (MCABC) | The systems are imprecise abstractions of reality and because precise input data are rarely if ever available, all output values are subject to uncertainty. | The systems were compared and the data shows that utilizing FABC and MCABC systems in a large hospital with considerable uncertain information can lead to the significantly different cost estimates from TABC. |
| 8. | Tsai (2015) | Production | ABC | Lack of justification for manufacturing systems, selecting the best production project in terms of sustainability. | ABC traced sustainable overhead costs to cost objects, and provided better overview of cost. |

Table 1 Continued.

| No. | Author (Year) | Area | Methods | Issues | Findings |
|---|---|---|---|---|---|
| 9. | Mendoza et al. (2016) | Medical | ABC | Cost allocation was complex due to the number of surgical procedures that varied in time and supplies used. | ABC model that made the real needs of the hospital evident would help the hospital compete for new resources. |
| 10. | Chih (2016) | Technology | Multiple criteria decision-making (MDCM), ABC, Zero-one goal programming (ZOGP) | The demands for protecting the environment as well as for economic benefits are embedded in sustainable transport infrastructure selection, which in turn will increase the sustainable transport infrastructure quality and value. | the integrated model (MCDM with ABC) gave hand in transport infrastructure project managers accurately understand how to allocate resources and funding for energy-saving activities. |
| 11. | Lau (2016) | Production | ABC | The company might overlook critical building blocks. | ABC measured accurate and relevant product, process, service and activity costs. |
| 12. | Almeida and Cunha (2017) | Production | ABC | Nowadays, companies face a lot of pressure to increase productivity and lower production costs. | The ABC costing system led to the obtaining of a wide set of information, with high detail, relevance and usefulness. |
| 13. | Martini (2017) | Medical | Total inpatient program (TIM), Early-discharge outpatient model (EDOM), ABC | To identify the resources usedfor each activity and then from which cost pools are drawn for each resource. | Both models used ABC approach. However, using EDOM, the cost of ASCT is approximately the half of the TIM model. |
| 14. | Lu (2017) | Production | Volume-based costing (VBC), ABC | The case company losing competitive advantage because of higher list price than other companies. | ABC approach provided more accurate cost information that will help to set the competitive price strategy. |
| 15. | Alves et al. (2018) | Medical | Conduct a search for studies that used ABC or TFABC | Cancer patient care demands use of new technologies, which are key to add value and to allow health organizations to provide qualified and reliable care services. | Oncology costs mostly involved ABC and TDABC. |
| 16. | Yang (2018) | Social science | Mixed integer linear programming (MILP), Life cycle assessment (LCA), ABC | To reduce the use of energy and developing new electricity sources. | The integrated model MILP which used ABC and LCA approach can help green power suppliers on how to allocate resources and funding for energy-saving activities. |

Table 1 Continued.

| No. | Author (Year) | Area | Methods | Issues | Findings |
|---|---|---|---|---|---|
| 17. | Tsai (2019) | Production | ABC, green production decision model (GPDM) | To overcome to the increasingly serious problems of a lack of workers, the need to control costs, and environmental issues. | The ABC approach helped in term of effectively control costs and increase productivity. |
| 18. | Niasti (2019) | Production | ABC | To determine costs based on the resources they consume. | ABC gave a true insight into the organizational costs. |
| 19. | Kaiser (2019) | Social science | ABC | To describe the role factor models and activity-based cost models play in offshore operating cost estimation. | Factor models are easy to implement in spreadsheets and allow for diverse applications. ABC models apply work decomposition methods and engineering to estimate cost. |
| 20. | Alami et al. (2020) | Production | ABC, TCA, Mixed integer linear programming (MILP) | Increase in products offering and processes automation in today's manufacturing era. | The proposed ABC model provides better competitive advantage in terms of hourly rates. |
| 21. | Yang (2020) | Technology | ABC | To find the key determinants that provide an optimal portfolio of IoT-oriented Intelligent Building Management System (IBMS) adoptive strategies for decision-makers. | ABC done evaluation and extracts the suitable cost drivers during the life cycle of an intelligent building management system. |
| 22. | Duran (2020) | Social science | ABC, Life-cycle costing (LCC) | To have a more realistic demand and a more accurate computation of the logistics costs associated with the different types of spare parts. | The AB-LCC model allowed the estimation of the present value of the direct, holding and logistics costs, using an ABC approach throughout the entire life-cycle. |
| 23. | Quesado (2021) | Medical | ABC | Need to properly manage the resources at their disposal and control their costs. | This study gave the possibility to systematize the literature about ABC and its application. |
| 24. | Voigt (2021) | Medical | ABC | Analysis was undertaken to understand if reusable ECTR equipment is a less-expensive analysis. | Activity-based costing, which allows for the characterization of procedural costs including pre-, intra-, and post procedure. |
| 25. | Tewfik (2021) | Medical | ABC | Current method has elevated cost. | Allows to determine cost of each single hospitalization event by the correct allocation of resources employed. |
| 26. | Mattatti (2022) | Agricultural | ABC | Farmers face low accuracy because agricultural machinery is subjected to the high variability. | ABC helped farmers to make more thoughtful decisions about crop, land, and farm operations management. |

Table 1 Continued.

| No. | Author (Year) | Area | Methods | Issues | Findings |
| --- | --- | --- | --- | --- | --- |
| 27. | Tsai (2022) | Production | ABC, Theory of constraints (TOC), Mathematical programming | Tire industry is under increasing pressure to reduce carbon emissions and formulate sustainable development plans. | The proposed model improved the accuracy of cost estimation, act as decision-making that gave consideration of carbon taxes cost and carbon rights, also maximized the company's profits. |
| 28. | Gong (2022) | Social science | Failure mode effect criticality analysis (FMECA), ABC | Spare parts planning classification systems based only on cost may not withstand the test of time. | The improved ABC resulted in maintenance work more efficient, targeting the most critical components, and can reduce administrative costs for enterprises. |
| 29. | Nirmala (2022) | Production | ABC, VED, Economic order quantity (EOQ) | Sri Devi Snacks is the startup and it is in the developing stage. | ABC, VED and EOQ gave the firm plan for the inventory management and have a proper control mechanism. |
| 30. | Tran et al. (2022) | Social science | Conduct qualitative survey | Examines the factors in the application of the ABC method. | The initial impression is that when the importance of cost information increased, the proportion of enterprises applying ABC probably increased. |

Table 2 TDABC papers.

| No. | Year (Author) | Area | Method | Issues | Findings |
|---|---|---|---|---|---|
| 1. | Seiringer et al. (2016) | Social science | Demonstration the successful inclusion of trust-based risk factors into service costing. | To include risk factors associated with the trustworthiness of customer input. | Capable to compute a provider's costs for the changing customer. |
| 2. | Yu et al. (2016) | Medical | Process maps was created using medical record time stamps. | To identify cost-reduction opportunities in simple appendicitis management. | Triage-based standing delegation orders, advanced practice providers, and same day discharge protocols are proposed. |
| 3. | Grego et al. (2016) | Medical | Pharmaceutical services supply patterns were studied through an observational study. | To optimize health care systems management. | TDABC model gives new insights on management and costs of community pharmacies. |
| 4. | Namazi (2016) | Social science | Published works related from the period 2004 - 2015 are analyzed. | To evaluate the degree of accuracy of the proponents' arguments concerning its usefulness. | To verify the usefulness of TDABC in industry especially in term of examining the assumptions and effects of significant variables. |
| 5. | Cheavers et al. (2016) | Medical | Advanced practice provider (APP) model was developed. | To quantify the actual cost and profitability of a procedure. | TDABC can be implemented to evaluate clinical processes and can result in practice change. |
| 6. | Anzai et al. (2017) | Medical | TDABC utilize process mapping from industrial engineering and ABC. | To access the costs of performing an abdomen and pelvis computed tomography (AP CT). | Potential opportunities to reduce the costs include increasing the efficiency of utilization of CT. |
| 7. | Keel et al. (2017) | Medical | Qualitative methods were employed to analyse data. | To explore why TDABC has been applied in health care. | TDABC is more able to address complexity in health care. However, indirect costs should be reported separately from direct costs. |
| 8. | Woutersa et al. (2017) | Production | Practical capacity was used to compute rates and is based on a hybrid of machining and labor times. | To assess profitability of products on a more comprehensive basis than the contribution margins of products. | Help to better understand the limitations of TDABC and it highlights the role of data discovery for the design of costing systems. |
| 9. | Frank et al. (2017) | Medical | A multi-disciplinary team was created. | To improve operational implementation in radiation oncology. | The data can provide insight into process variation and opportunities. |
| 10. | Helmers et al. (2017) | Medical | Applying TDABC method | To analyse the concern that associated with the increased cost. | The cost concern is not costly when all factors are considered |

Table 2 Continued.

| No. | Year (Author) | Area | Method | Issues | Findings |
|---|---|---|---|---|---|
| 11. | Barros and Ferreira (2017) | Production | By designing a pilot TDABC model | To examine the suitability and the complexity of TDABC | TDABC is able to deal with the variability of industrial processes |
| 12. | Wouters and Stecher (2017) | Production | Use practical capacity of TDABC into the computer rates. | To better understand and the limitations of TDABC. | Understanding the limitations of TDABC which is the time equation not be able to apply into the company machine. |
| 13. | Alves et al. (2018) | Medical | Only English-Portuguese-language articles were retrieved. | To examine how ABC and TDABC have been applied to access and manage cancer costs. | These ABC and TDABC provide more accurate cost information in complex environments with resources focusing on skills and implicit knowledge. |
| 14. | Reynolds et al. (2018) | Production | The generic steps for TDABC were adapted. | To devise a framework for SMEs with resource constraints. | It was practical to implement TDABC in the company. |
| 15. | Ostadi et al. (2019) | Medical | By applying fuzzy logic in the TDABC model. | To overcome the limitations and deficiencies associated with data estimation in TDABC input data. | The proposed model FLTDABC provide additional information in the case of uncertainty and imprecise data. |
| 16. | Heaton et al. (2019) | Medical | By using prospective observation cohort study. | To determine emergency medicine physician documentation costs with and without scribes. | TDABC methodology demonstrated that scribes afford a cost-effective solution clinical documentation. |
| 17. | Bastoa et al. (2019) | Medical | Captured activity data from high turnover surgery allocated. | To assess value of parallel induction redesign. | Parallel induction design reduces as none-operative time. |
| 18. | Stefanini et al. (2019) | Medical | To better organize their services in the final attempt to maximize both effectiveness and efficiency. | Proposed process mining based methodology. | This approach assists the hospital managers in decision-making related to the identification. |
| 19. | Pyne et al. (2019) | Medical | Pragmatic approach was used. | To operationalize the conduct of the implementation activities, track the resources consumed and estimate associated costs. | It provides granular cost information which could be used to identify and address the inefficiencies in the implementation process. |
| 20. | Kissa et al. (2019) | Social science | Adopted quantitative and qualitative methods. | To provide high quality services despite their limited budget. | Given information which activities demand more time and are costly. |

Table 2 Continued.

| No. | Year (Author) | Area | Method | Issues | Findings |
|---|---|---|---|---|---|
| 21. | McClintock et al. (2019) | Medical | Review TDABC methodology being used in urology surgery. | To show the feasibility and potential benefit of TDABC use and study its limitations. | TDABC should not be viewed as a replacement to CCA, but rather as a tool to augment the current system. |
| 22. | Roberto (2019) | Medical | TDABC | To determine cost involved and improve its performance. | TDABC able to determine the total costs and can be used as decision making. |
| 23. | Bodar et al. (2020) | Technology | Process maps were created with interdisciplinary team. | To determine the true cost of a robot-assisted laparoscopic pyeloplasty (RALP). | TDABC defined the magnitude of cost variation based on robot utilization of a RALP. |
| 24. | Silva Etges et al. (2020) | Medical | A qualitative approach was used to analyzed different methodological of TDABC and its effective contribution. | To estimate its impact on the value-based healthcare concept. | 18 studies reported that TDABC contributed to value-based initiatives, especially cost-saving findings. |
| 25. | Ogliari et al. (2020) | Medical | Pubmed and Scopus database were used. | To estimate CCRs and distribute indirect costs. | There is no explanation of overhead costing accurate methods. |
| 26. | Koolmes et al. (2020) | Medical | Full cycle costs of evaluated for 4 consolidative treatment regimens. | To evaluate single institution resource cost of consolidative radiotherapy (RT). | This method relevant in context of the anticipated mandate of alternative payment models. |
| 27. | Grady et al. (2020) | Medical | Process mapping participants are stratified. | To determine the true cost of CF, to map the process of care received by children with CF. | Gain real-time data from the true patient/parent. |
| 28. | Lewis et al. (2020) | Medical | Sensitivity analyses were performed. | To quantify cost drivers for thoracic duct embolization. | Potentially modifiable drivers of overall cost. |
| 29. | Zonotto et al. (2020) | Medical | 15 patients were monitored and analyzed. | To evaluate costs of the entire cycle of patients care. | It motivates the review of health reimbursement policies. |
| 30. | Zamrud (2021) | Production | Application of ABC and TDABC in magnetic inductor's production. | To compare the advantages of ABC and TDABC in costing sustainment. | Both have their strength according to the industry needs. |
| 31. | Todd (2020) | Medical | TDABC | To maximize outcomes per dollar spent. | TDABC can be used to estimate relative internal cost. |
| 32. | Zaini et al. (2020) | Production | TDABC | A lot of factors contribute the challenge to the ideal of lean production line. | TDABC can be used to identify the estimation capacity used either over or underused. |

Table 2 Continued.

| No. | Year (Author) | Area | Method | Issues | Findings |
|---|---|---|---|---|---|
| 33. | Zaini et al. (2020) | Production | TDABC | The rate setting is inadequate to outline the relation between resources supplied and the capacity in operation. | TDABC able to calculate time efficiency, evaluate idle capacity and separately listing the resources used and not used. |
| 34. | Cidav et al. (2021) | Medical | Demonstration TDABC based on a process map with core OSMT intervention activities and associated procedures. | To determine the programmatic costs of telehealth OSMT. | Future efforts to replicate, disseminate, and implement the OSMT intervention should anticipated funding for nonclinical components of the intervention. |
| 35. | Koolmees et al. (2021) | Medical | A process map of ACLR was constructed. | To compare the cost of care of anterior cruciate ligament reconstruction (ACLR). | For TDABC method, the direct fixed cost was the main cost driver. |
| 36. | Kukreja et al. (2021) | Medical | Retrospectively reviewed a random sample of 101 patients. | To determine the major costs driver of radical cystectomy. | The major cost is the inpatient stay. |
| 37. | Fang et al. (2021) | Medical | Retrospective cohort cost-analysis study of patients. | To assess the costs associated. | Understanding the costs is essential when considering the value. |
| 38. | Karabachev et al. (2021) | Medical | A retrospective observational analysis. | To compare the surgical outcomes as well as operative times and associated in patients with and without ioPTH. | The use of ioPTH did not improve the success rate of minimally invasive parathyroid surgery, while increasing operative times and cost. |
| 39. | Michael (2021) | Medical | TDABC | To compare the direct costs of two different medical method. | TDABC can be used to analyse individual procedures and episodes of care. |
| 40. | Ogliari et al. (2021) | Technology | Visual basics for applications language in Microsoft excel was used for coding. | To automatize measures and analyse of costs using data collected. | The accurate costs measured can still be improved by developing a more standardized process. |
| 41. | Alvin (2021) | Medical | ABC, TDABC | To compare the relative value of 3 analgesic pathways for total knee arthroplasty. | TDABC able to determine the value of 3 different analgesic pathways by comparing relative costs and outcomes data. |
| 42. | Mark (2021) | Medical | TDABC | To evaluate costs in early-stage breast cancer. | TDABC can be used to evaluate resource requirements for different radiation therapy and help identify opportunities to reduce costs. |

Table 2 Continued.

| No. | Year (Author) | Area | Method | Issues | Findings |
|---|---|---|---|---|---|
| 43. | Pereira et al. (2021) | Social science | Bibliography survey was carried out on costs in public administration and procurement. | To analyse the cost of bidding processes. | Being consolidated as an instrument of great value for a procurement process. |
| 44. | Gonzalez et al. (2022) | Medical | A time and effort analysis were performed. | To determine hours needed for completion of forms. | Time analysis using TDABC can be an efficacious tool for calculating time length to complete CIBMTR forms. |
| 45. | Wise et al. (2022) | Medical | The Western Ontario rotator cuff index was collected at both the initial preoperative baseline assessment. | To perform patient-level value analysis (PLVA) within the setting of RCR over the 1-year episode of care. | PLVA quantifies the ratio of functional improvement to the TDABC-estimated cost of care at the patient level. |
| 46. | Gabriella (2022) | Medical | TDABC | To compare models used for the delivery of PB-IORT by utilizing TDABC. | TDABC technique can be used to evaluate the cost of given medical treatment. |
| 47. | Corey (2022) | Medical | ABC, TDABC | To estimate the marginal cost differences and care delivery. | TDABC was used to improve efficiency in health care workflow by measuring costs required while adding a time variable. |
| 48. | Gargano (2022) | Medical | TDABC | Evolving towards value-based healthcare requires monitoring patient-centred outcomes per currency spent on providing care. Despite the effort, the communication is still challenging. | TDABC was used to measure all costs incurred in an OI patient's journey. |
| 49. | Trimarchi (2022) | Medical | TDABC | To analyse the absorption of economic resources. | TDABC was adopted for human resources and equipment costs allocation. |
| 50. | Benjamin (2022) | Medical | TDABC | To explore RT delivery costs for cervical cancer. | TDABC measured the true cost of RT by quantifying and aggregating resources utilization. |

Appendix B: Time study

Table 1 ABC papers.

| **No.** | **Activities** | **Worker 1** | **Worker 2** | **Worker 3** | **Average time (min)** |
|---|---|---|---|---|---|
| 1. | Preparation loading part | 29 | 30 | 31 | 30 |
| 2. | Solder paste control | 4.5 | 4 | 3.5 | 4 |
| 3. | Input PCB | 5 | 4 | 6 | 5 |
| 4. | Solder paste printing | 20 | 30 | 25 | 25 |
| 5. | Insert loading part | 22 | 20 | 18 | 20 |
| 6. | Reflow oven | 10 | 8 | 12 | 10 |
| 7. | Automated Optical inspection (AOI) | 8.5 | 12 | 9.5 | 10 |
| 8. | Visual manual Inspection (VMI) | 5 | 4.5 | 5.5 | 5 |
| 9. | X-ray inspection | 5 | 5 | 5 | 5 |
| 10. | De-panelize | 6 | 7 | 5 | 6 |
| 11. | VMI and ping test | 5 | 3 | 4 | 4 |
| 12. | Packaging | 3.5 | 4 | 4.5 | 4 |
| | TOTAL | | | | 128 |

Table 2 TDABC paper.

| No. | Main activities | Sub-activities | Worker 1 | Worker 2 | Worker 3 | Average time (min) |
|---|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | 5 | 4 | 6 | 5 |
| | | 2. Prepare part for the production | 25 | 20 | 25 | 25 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | 2.5 | 2.5 | 4 | 3 |
| | | 2. Update sticker of solder paste shelf-life control | 1 | 1 | 1 | 1 |
| 3. | Input PCB | 1. Visual check on PCB | 1 | 1 | 1 | 1 |
| | | 2. Input PCB into auto loader machine | 4.5 | 4 | 3.5 | 4 |
| 4. | Solder paste printing | 1. Set up printer for printing | 15 | 17 | 13 | 15 |
| | | 2. Verify the printing | 6 | 4 | 5 | 5 |
| | | 3. Inspect for abnormality | 5 | 4.5 | 5.5 | 5 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | 12 | 14 | 10 | 12 |
| | | 2. Scan barcode of machine type and ID operator | 1 | 1 | 1 | 1 |
| | | 3. Confirm part for each feeder follow by loading list | 2.5 | 2 | 1.5 | 2 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | 8 | 8 | 8 | 8 |
| | | 2. Check thermal profile and solder after reflow | 1.5 | 2.5 | 2 | 2 |
| 7. | AOI | 1. Automatic inspection on PCBA | 5 | 5 | 5 | 5 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 4 | 5 | 6 | 5 |
| 8. | VMI | 1. Manual check on PCBA appearance | 2 | 3 | 1 | 2 |
| | | 2. Manual soldering if needed | 1 | 1 | 1 | 1 |
| | | 3. Verify the PCBA in good condition | 2.5 | 2 | 1.5 | 2 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | 2 | 4 | 3 | 3 |
| | | 2. Check geometric measurement of solder thickness and volume | 1.5 | 2 | 2.5 | 2 |

Table 2 Continued.

| No. | Main activities | Sub-activities | Worker 1 | Worker 2 | Worker 3 | Average time (min) |
|---|---|---|---|---|---|---|
| 10. | De-panelize | 1. Cut PCBA per panel | 3 | 4 | 2 | 3 |
| | | 2. Check the quality cutting and appearance | 3 | 2 | 4 | 3 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | 1 | 1 | 1 | 1 |
| | | 2. Paste 2D barcode | 1 | 1 | 1 | 1 |
| | | 3. Make sure the PCBA pass ping test | 1 | 1 | 1 | 1 |
| | | 4. Put into reject tray if PCBA failed ping test | 1 | 1 | 1 | 1 |
| 12. | Packaging | 1. Scan 2D barcode | 2.5 | 2 | 1.5 | 2 |
| | | 2. Input complete PCBA into bin | 2 | 2.5 | 1.5 | 2 |

Appendix C: Interview answer

1. How many departments involved in PCBA production?

   = two. SMT and MT department.

2. What are the main activities for each department and the estimated time used?

   = total 12 main activities. As shown in Appendix B.

3. How many workers are involved in each department?

   = SMT 41, MT 13.

4. How much is the employee's monthly basic salary?

   = RM1500.

5. How many regular working days for each employee for one month?

   = 20 days.

6. Which machine require weekly, monthly or yearly maintenance?

   = SP machine, SPI machine, PNP machine (weekly), loader machine, AOI SAKI checker, XD 7500 inspection (monthly), oven, stirring machine (yearly).

7. What are the raw materials involved?

   = PCB board, capacitors, inductors, resistors, LED.

8. What are the main consumables for each activity?

   = tinner, solvent 450, solder iron, kester 5252.

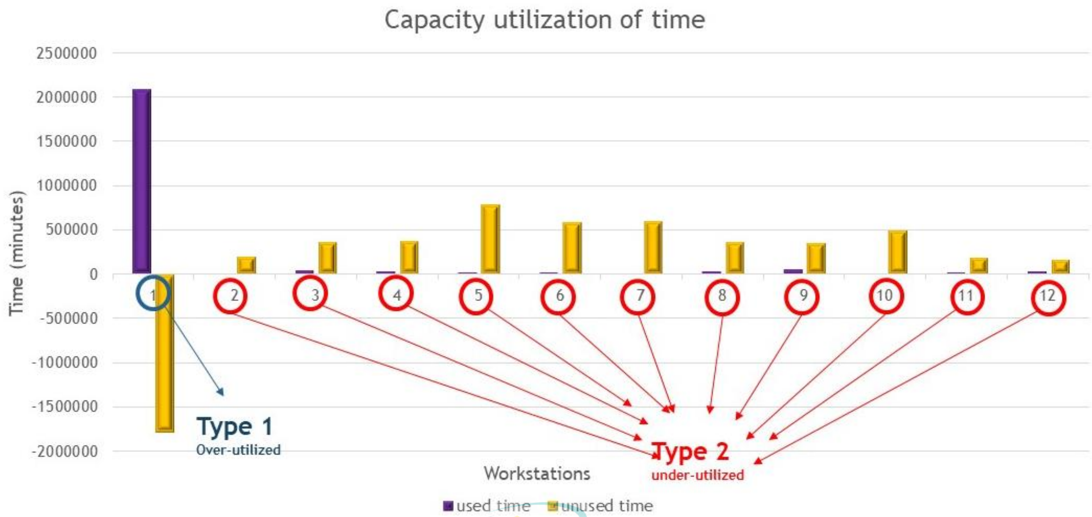
9. What is the maximum and minimum quantity for B6x production in a day?

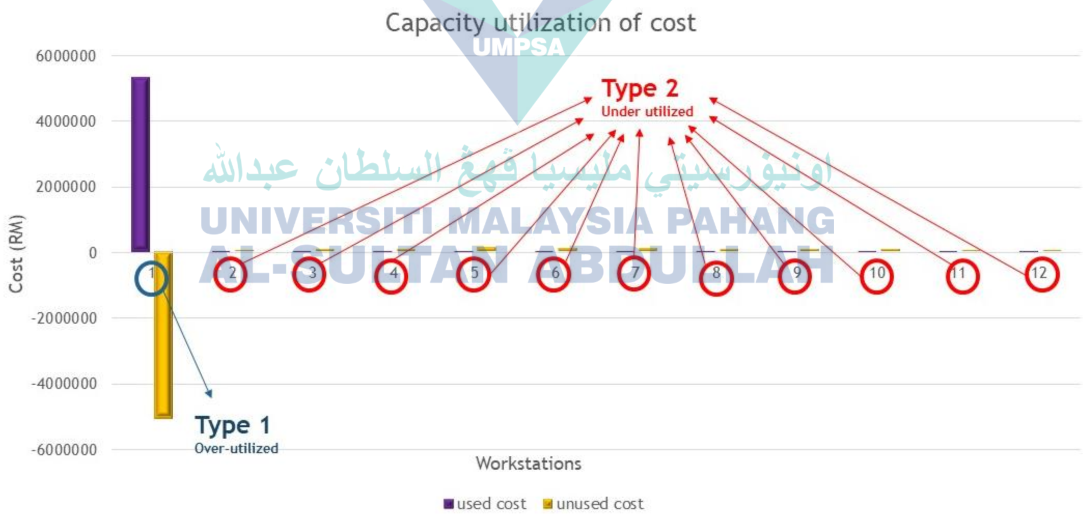
   = 408pcs maximum, 289pcs minimum.

10. What is the average production quantity of B6x that is rejected?

    = 200pcs maximum a day, 15pcs minimum a day.

Appendix D: Graph analysis of unused capacity.



Appendix E: Forecast cost using TDABC method

Table 1 TDABC forecast analysis.

| No. | Main activities | Sub-activities | Quantity | CCR (RM) | Forecast cost (RM) |
|---|---|---|---|---|---|
| 1. | Preparation loading part | 1. Scan barcode into system | 40 | 0.1799 | 7.9156 |
| | | 2. Prepare part for the production | 83,600 | 2.5595 | 235,371.62 |
| 2. | Solder paste control | 1. Prepare the solder before running into production | 2,000 | 0.1786 | 392.92 |
| | | 2. Update sticker of solder paste shelf-life control | 40 | 0.1788 | 7.8672 |
| 3. | Input PCB | 1. Visual check on PCB | 9,000 | 0.1813 | 1,794.87 |
| | | 2. Input PCB into auto loader machine | 9,000 | 0.1788 | 1,770.12 |
| 4. | Solder paste printing | 1. Set up printer for printing | 2,000 | 0.2066 | 454.52 |
| | | 2. Verify the printing | 20 | 0.1786 | 3.9292 |
| | | 3. Inspect for abnormality | 20 | 0.1786 | 3.9292 |
| 5. | Insert loading part | 1. Prepare loading part into feeder | 1,000 | 0.1847 | 203.17 |
| | | 2. Scan barcode of machine type and ID operator | 40 | 0.1789 | 7.8716 |
| | | 3. Confirm part for each feeder follow by loading list | 1,000 | 0.1786 | 196.46 |
| 6. | Reflow oven | 1. Reflow the PCBA through oven | 2,000 | 0.1806 | 397.32 |
| | | 2. Check thermal profile and solder after reflow | 40 | 0.1786 | 7.8584 |

Table 1 Continued.

| No. | Main activities | Sub-activities | Quantity | CCR (RM) | Forecast cost (RM) |
|---|---|---|---|---|---|
| 7. | AOI | 1. Automatic inspection on PCBA | 2,000 | 0.1801 | 396.22 |
| | | 2. Paste reject sticker on PCBA if found detect spot at AOI's screen | 40 | 0.1786 | 7.8584 |
| 8. | VMI | 1. Manual check on PCBA appearance | 18,000 | 0.1786 | 3,536.28 |
| | | 2. Manual soldering if needed | 20 | 0.1846 | 4.0612 |
| | | 3. Verify the PCBA in good condition | 20 | 0.1786 | 3.9292 |
| 9. | X-ray inspection | 1. Check porosity and void in solder | 1,020 | 0.1801 | 202.0722 |
| | | 2. Check geometric measurement of solder thickness and volume | 1,020 | 0.1801 | 202.0722 |
| 10. | De-panelize | 1. Cut PCBA per panel | 18,000 | 0.1787 | 3,538.26 |
| | | 2. Check the quality cutting and appearance | 40 | 0.1786 | 7.8584 |
| 11. | VMI and ping test | 1. Overall appearance check on PCBA | 9,000 | 0.1786 | 1,768.14 |
| | | 2. Paste 2D barcode | 40 | 0.1786 | 7.8584 |
| | | 3. Make sure the PCBA pass ping test | 9,000 | 0.1791 | 1,773.09 |
| | | 4. Reject PCBA if any | 40 | 0.1786 | 7.8584 |
| 12. | Packaging | 1. Scan 2D barcode | 40 | 0.1788 | 7.8672 |
| | | 2. Input complete PCBA into bin | 18,000 | 0.1786 | 3,536.28 |
| | **TOTAL** | | | | 255,620.0768 |

Cost per unit

$$= \frac{\text{forecast cost}}{\text{quantity production 2023}}$$

$$= \frac{\text{RM255,620.0768}}{96{,}000}$$

$= \text{RM2.66}$

Appendix F: List of publications

1. **Pinueh, N. S.**, Abu, M. Y., Saad, S.K.M., Aris, N.H. and Sari, E. (2024). Methadone Flexi Dispensing (MFlex) Intelligence System utilizing the Mahalanobis-Taguchi System. *Journal of Modern Manufacturing Systems and Technology* (revised).

2. **Pinueh, N. S.**, Abu, M. Y., Aris, N.H., Jamil, M.A.M., Sari, E. (2024). Comparison of activity-based costing and time-driven activity-based costing for printed circuit board assembly production. *Journal of Theoretical and Applied Information Technology* (under review).

3. Aris, N. H., Abu, M. Y., Jamil, M. A. M., Zaini, S. N. A. M., **Pinueh, N. S.,** Muhamad, W. Z. A. W. . . . Sari, E. (2023). Application of Mahalanobis-Taguchi system in rainfall distribution. *Journal of Modern Manufacturing Systems and Technology, 7*(2), 1-8.

4. Jamil, M. A. M., Abu, M. Y., Zaini, S. N. A. M., Aris, N. H., **Pinueh, N. S.,** Muhamad, W. Z. A. W. . . . Jaafar, N. N. (2023). Application of Mahalanobis-Taguchi system in rainfall trends at UMP Gambang campus. *Mekatronika, 5*(2), 17-24.