

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

NUR SYAFIKAH PINUEH<sup>1</sup>, MOHD YAZID ABU<sup>2\*</sup>, NURUL HAZIYANI ARIS<sup>3</sup>, MUHAMMAD ARIEFFUDDIN MOHD JAMIL<sup>4</sup>, EMELIA SARI<sup>5</sup>

<sup>1,2,3,4</sup>Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26600 Pekan, Pahang, Malaysia

<sup>5</sup>Universitas Trisakti, Faculty of Industrial Technology, Department of Industrial Engineering, 11440 Kyai Tapa No 1, West Jakarta, Indonesia

E-mail: <sup>1</sup>nursyafikahpinueh@gmail.com, <sup>2\*</sup>myazid@umpsa.edu.my, <sup>3</sup>haziyaniaris@gmail.com, <sup>4</sup>Muhdarieffuddin46@gmail.com, <sup>5</sup>emelia@trisakti.ac.id

\*Corresponding author

## ABSTRACT

The number of resources employed determines product costs in traditional costing analysis (TCA). TCA is flawed because manufacturing overhead may be substantially larger than the basis of allocation, therefore a little change in resource volume causes a big change in overhead. Thus, activity-based costing (ABC) was created to solve TCA's cost allocation issues by analyzing overhead expenses and cost drivers more thoroughly. Many cost factors may be utilized to identify overhead causes and reduce overhead expenses. ABC was theoretically inappropriate to overlook spare capacity that may help forecasting. For that reason, time-driven activity-based costing (TDABC) has been studied because it maximizes capacity cost rate and time equations to create underused capacity information. This purpose of this study observes, analyses, and compares ABC and TDABC methods to determine which is more effective for production. Four steps comprise this study's approach. Phase 1 defines the problem, while phase 2 involves data collecting on location. Phase 3 implements ABC and TDABC methodologies and compares their costing analyses. The last phase, phase 4 concludes this research. As a result, this study shows ABC is transparent and can forecast unit product cost using cost driver rate. TDABC has objective cost driver determination, eliminates time-consuming processes, various cost drivers, and capacity utilization analysis for forecasting and planning. Thus, the comparative study met the third purpose of comparing ABC and TDABC costs sustainment utilizing numerous aspects. Finally, TDABC is the best practice because it provides better information than ABC in cost allocation, driver determination, action taken for an additional activity, cost consideration, informative, transparency, oversimplification of activities, and capacity forecast.

**Keywords:** ABC, TDABC, PCBA, Cost Allocation, Cost Forecasting

## 1. INTRODUCTION

A schematic is a diagram that is used to represent electrical or electronic circuits. It is made up of component symbols that are united by lines. Lines are conductive channels that allow electrical current to travel between passive components like resistors and capacitors and integrated circuits like microcontrollers. A schematic is basically a sketch. The schematic drawing must be built into its physical components and linkages to regulate fan speed or blink a light-emitting diode. Simple schematics use

breadboards, whereas larger circuit designs require Printed circuit board (PCBs) [1].

PCBs mostly connect and support circuit components. It is simple to recognize them as the green-colored board, which is a common component seen in electrical gadgets. To match the final design form factor, various active components such operational amplifiers, batteries and passive components are installed on PCBs based on design parameters. Form factor defines the size, shape, and other physical features of the PCB as a whole in any hardware design. For PCB form factors, chassis,

mounting systems, and board layouts are considered. Interconnects made of copper are used to build connections between the components that are located on a PCB. These interconnects serve as the conduit for the electrical signals [2].

Three crucial procedures must be performed to create a functioning PCB. First, create a design specification for the circuit, then a circuit schematic, lastly a PCB layout the final design that will be constructed. The second aspect is the manufacturing process. It is imperative that the manufacturing process of the PCB adhere to the design specifications. The two basic procedures are making the insulating PCB foundation with metal connection and electrically and physically attaching the electronic components. And last, the testing procedure. Test the design and PCB to see whether it works. Simulation and physical testing are two types of testing that are carried out at various stages during the design and manufacturing processes [3].

An expert in the printed circuit board sector believes that German-speaking nations might experience growth of between 6% and 7%. France, Spain, and Italy might expand 9-10%, while Central Europe could grow 10-13%. The PCB sector was hit by numerous causes in 2019, and output declined 1.7% to US\$61.3 billion. COVID-19 affects slowed growth in early 2022. Michael Gasch expects semiconductors to expand double-digits despite global concerns. Consequently, the increase of PCB should be anywhere between 5-8% [4]. Recently, communications and automotives have driven worldwide PCB and PCBA demand. Communications including business, computers, and telecom make over 60% of the worldwide PCB industry and are likely to remain dominant. Due to current automotives' more integrated and complex features, PCB's automotive application is predicted to develop quickest in 2021 [5].

In 2019, global PCB output fell marginally due to trade frictions, terminal demand reduction, and currency rate depreciation in 2018. PCBs are primarily used in mobile phones. The expansion of businesses that come after PCB making is a major factor that helps these companies grow. Taiwanese PCB businesses including Zhending, Xinxing, and Huatong have joined the world's top ten PCB manufacturers ranking due to the module factories and semiconductor companies' importance in the personal computer and mobile phone industry chain. The biggest PCB maker in the world in 2019 was Zhending, which is connected to Apple's business.

Overall, 5G is continuing fueling industrial economic growth in 2020, The 2020 worldwide PCB output value growth rate is expected to be 2%. Global PCB output is predicted to expand 5% annually from 2020 to 2025 that might reach US\$80 billion in 2025 [6].

Manufacturing sales rose 28.8% to RM43.3 billion in January 2010 from RM33.6 billion in January 2009. 76 industries out of 116 covered in the study increased their sales value by 65.5% year-over-year in the current month. The five major industries whose sales value increased significantly were Semi-Conductor Devices (54.5%). Television and radio receivers, sound or video recording or reproducing apparatus, and associated goods (70.6%), other basic industrial chemicals except fertilizers and nitrogen compounds (60.5%), electronic valves, tubes and PCB (29.4%), and refined petroleum products (7.4 %) [7].

## 2. LITERATURE REVIEW

### 2.1 Activity-Based Costing

A system known as ABC is used to assign costs to cost objects. This is accomplished by first tracing costs to activities, and then tracing costs to cost objects. Cost objects are items, departments, projects, activities, and others for which costs are measured and assigned [8]. ABC systems in manufacturing organisations recognise unit, batch, product-sustaining, and facility-sustaining operations. Activities like as assembly and individual testing of each unit are examples of activities that consume resources at the unit level. Batch-level tasks include production run preparations and sample testing of a specified number of units. Product sustaining comprises design and materials procurement. Regardless of the quantity of units that will be manufactured or the number of batches, design work is necessary for each and every product. The final level sustains the facility. It covers many items manufactured at the same facility. Activities such as general maintenance and facility management are included in the category of facility-sustaining activities [9].

Cooper and Kaplan proposed ABC to fix TCA management systems. TCA systems commonly miscalculate production and service costs. Thus, management made judgements based on erroneous data, especially when numerous products were involved. ABC uses cause and effect links to objectively assign expenses instead of broad percentages. Once activity expenses are established, they are assigned to each product that used the

activity. ABC generally finds areas with high overhead expenses per unit and focuses on reducing costs or charging more for expensive items [10]. Cost allocation, fixed costs, variable costs, cost drivers, and cost driver rates are the five elements that need to be taken into consideration when using ABC as a result of costing calculations. Indirect expenses are harder to assign to items than direct labour and materials. Cost allocation requires weighting when products use common resources differently. The cost driver measures how each product uses a shared activity. For instance, bank tellers' costs may be assigned to each product by assessing how long its counter transactions take and then the quantity of each sort of transaction [11].

ABC gives a number of advantages, including the improvement of management systems and the effective use of resources strategically. As the management system develops, the research framework and implementation method of ABC system may help companies and industries analyse [12]. Meanwhile, resource allocation strategy is emerging the ABC to evaluate process resources and activity traces using mathematical constraints, including unit-, batch-, project-, and environment-level activity constraints [13]. There are also various disadvantages to ABC, which include time demanding and difficulties in assigning overhead charges. The time consuming is because the measurements of development team inputs and system performance need to be acquired via a questionnaire to both developers and users of the systems [14]. Difficulties assigning overhead costs to products and consumers, such the CEO's compensation. Business-sustaining costs are not allocated to products or consumers since there is no specific solution. Even if it helps products, it does not require substantial overhead costs [15]. [26] proved that by integrating the optimization and costing through remanufacturing process, a better decision can be achieved. Therefore, [27] concluded that ABC is a useful approach because it produces a cost with accurate allocation of overhead, provides cost information on the cost drivers and produces accurate manufacturing cost and profitability information.

## 2.2 Time-Driven Activity-Based Costing

In the context of a process, TDABC refers to the capability of measuring the changes that arise as a consequence of variations in activities and expressing those differences via time and cost such knowledge boosts execution efficiency. TDABC optimises costing by removing the requirement to

interview and poll personnel to allocate resource costs to activities before driving them down to cost objects. Two estimates are used by TDABC to allocate resource costs to cost objects. First, the TDABC model evaluates the cost of all staff, supervision, occupancy, equipment, and technology given to this department or process. The capacity cost rate is calculated by dividing this total cost by the time available from department personnel. Second, TDABC estimates cost object resource capacity demand to shift departmental resource charges to cost objects using the capacity cost rate. Work processes are simulated using the TDABC model. It may capture far more variance and complexity than a standard ABC model without requiring additional data estimations, storage, or processing. TDABC lets an organisation embrace complexity instead of using simplistic, erroneous ABC models of its complex businesses [16].

TDABC has various advantages, including being applicable to any sector with complicated cost items. TDABC can simulate complicated operations with several sub-steps using resource-specific cost rates [17]. Next, increase the accuracy of the cost allocation. TDABC is a modified version of ABC that immediately allocates resource costs from cost objects using an hourly cost rate formula, eliminating the need for employee interviews to allocate costs to activities. This approach turns cost drivers into time equations, which describe activity time [18]. However, TDABC lacks the ability to detect activities in the first implementation stage, such as practical capacity costs and non-productive time [19]. Departmental non-productive time also makes the expenses are incorporated into the cost of capacity supplied and the cost per minute, so their overall cost is not estimated independently, concealing their costs [20].

## 2.3 Contribution of previous study

Several studies have been conducted on ABC and TDABC. Each author provides distinctive results and contributions. Since this study focuses on six key areas; the application of types method, activity map, cost driver, time equation, capacity cost rate, unused capacity and forecasting, it utilises these areas a point of reference for previous studies.

There were five authors selected, which are [21], [22], [23], [24], and [25]. From these studies, only [23] did not involve all criteria, as the research was conducted only to show the method's effectiveness when applied in production industry, while the other studies at least did research on the activity map of the method used. In the next work by

[21] and [25], the research studies involved advanced studies that included cost drivers in the research, while [24] included cost drivers and capacity cost rates. Therefore, this current study intends to fill the gap on ABC and TDABC elements, which had not been discussed by the five authors.

Production companies are among the most important contributors to the country's economic stability. As a consequence, in order to more properly determine the cost of loss and profit, a manufacturing organisation must employ the most accurate cost calculation technique available. Most production companies use TCA, and this method can cause factory overhead to be set higher than the basic allocation. So, how does determining the cost driver rate of a company using ABC make their costing more accurate? However, ABC ignores unused capacity in the costing method, which makes TDABC better because it can generate unused capacity for forecasting. Therefore, this study was conducted to examine which method is more effective in terms of cost allocation, driver determination, action taken for an additional activity, cost consideration, informativeness, transparency, oversimplification of activities, and capacity forecast for production companies.

### 3. METHODOLOGY

#### 3.1 Data Collection

The data collection is conducted at the company in Pasir Gudang, Malaysia. The company started in June 1995. The firm focuses on printer and PCBA assembly. In addition to these sorts of operations and services, the company also offers other products and services, such as trade and warehouse. 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 1 shows the examples of PCBA used in industry.

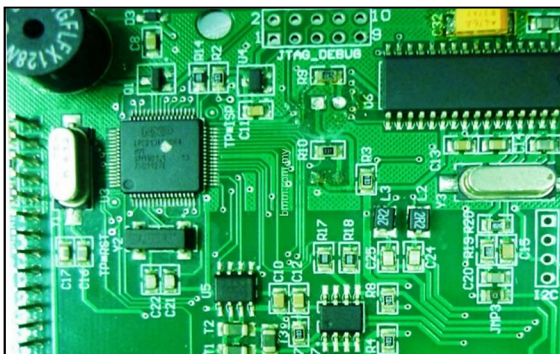


Figure 1: Examples of PCBA

This research has identified the manufacturing flow of PCBA's production model B6x which consists of 19 steps as shown in Figure 2.

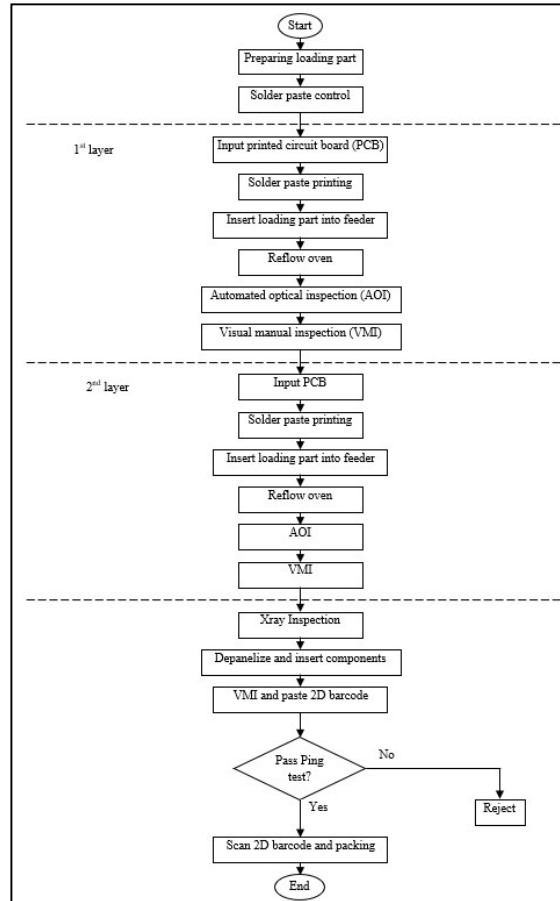


Figure 2: Flowchart of Manufacturing Flow of PCBA's Production

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, and they are called numbers of parts. 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/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 vs machine type vs 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-penalize 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.

### 3.2 ABC Methodology

In this study, there are five steps of implementing ABC system. Firstly, manufacturing flow analysis. 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 by observing myself.

Thirdly, the cost of all resources was estimated by conducting the calculation of 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.

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 1.

$$\text{cost driver rates} = \frac{\text{cost of selected resources}}{\text{quantity driver}} \quad (1)$$

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.

### 3.3 TDABC Methodology

TDABC system consists of eight steps of implementation. For step1, 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.

The fourth step is calculating the capacity cost rate (CCR). The capacity cost rate (MYR per minute) can be obtained by using Equation 2. The cost of all resources supplied is an assumption, and we used it as base roots for all the calculations ahead.

$$\text{Capacity cost rate} = \frac{\text{Cost of all resources supplied}}{\text{practical supplied}} \quad (2)$$

The fifth step is formulating the time equation by using TDABC time equation as shown in Equation 3.

$$Tt = \beta_0 + \beta_i \chi_i \quad (3)$$

Where:

$Tt$  = 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, calculate the customer service time of the company. Therefore, the time equation is as shown in Equation 4.

$$\text{Customer service time (minutes)} = \sum \text{time (minutes)} \times \text{each of activity involved} \quad (4)$$

Seventh step, 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.

Then, the total minutes and total cost calculation in 2 aspects can be calculated. Firstly, in aspect of each activity as shown in Equation 5 and Equation 6. Secondly, in aspects of 1 whole company (used capacity) as shown in Equation 7 and Equation 8. Then by using other information that has been calculated to find unused capacity and determine capacity utilization.

$$\text{Total minutes each activity} = \text{unit time} \times \text{quantity of activity} \quad (5)$$

$$\text{Total cost} = \text{total minutes} \times \text{cost driver rate} \quad (6)$$

$$\text{Total minutes for the company} = \sum \text{all activities involved} \quad (7)$$

$$\text{Total cost for the company} = \sum \text{all activities involved} \quad (8)$$

To determine unused capacity in terms of time and cost, there are two equations that need to be used which are shown in Equation 9 and Equation 10.

$$\text{Unused capacity (time)} = \text{practical capacity} - \text{total minutes (used capacity)} \quad (9)$$

$$\text{Unused capacity (cost)} = \text{unused capacity (time)} \times \text{CCR} \quad (10)$$

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

#### 4. RESULTS AND DISCUSSION

##### 4.1 ABC Discussion

For every workstation, the time allocated by the operator to complete the task given is identified as shown in Table 1 for all activities.

Table 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	Xray 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%.

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 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 2 types which are direct material cost and indirect material cost. Here, indirect material cost was considered.

Table 2: Capacity cost for every workstation

Workstation	Labor (RM)	Maintenance (RM)	Raw material (RM)	Consumables (RM)	All resources supplied (RM)
1. Preparation loading part	54,000.00	25.13	240,000.00	240.00	294,265.13
2. Solder paste control	36,000.00	25.13	-	-	36,025.13
3. Input PCB	72,000.00	50.26	-	552.88	72,603.14
4. Solder paste printing	144,000.00	4,850.26	-	792.00	149,642.26
5. Insert loading part	144,000.00	2,462.83	-	60.00	146,522.83
6. Reflow oven	108,000.00	615.71	-	-	108,615.71
7. AOI	108,000.00	615.71	-	-	108,615.71
8. VMI	72,000.00	25.13	-	578.01	72,603.14
9. Xray inspection	72,000.00	603.14	-	-	72,603.14
10. De-penalize	90,000.00	50.26	-	-	90,050.26
11. VMI and ping test	36,000.00	25.13	-	-	36,025.13
12. Packaging	36,000.00	25.13	-	-	36,025.13
TOTAL	972,000.00	9,373.82	240,000.00	2,222.89	1,233,596.71

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, the ABC

system calculated the following cost driver rates as shown in Table 3 which shows the cost driver rates for the PCBA B6x production using ABC.

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.

Therefore, cost driver rate for each workstation of PCB production can be determine using ABC method by taking consideration four main aspects which are time used, total cost resources supplied, the cost driver and the cost driver quantity.

Table 3: Cost Driver Rates for Each Workstation

Workstation	Cost driver	All resources supplied (RM)	Cost driver quantity	Cost driver rate (RM)
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
8. VMI	Labor (salary)	72,603.14	18,000	4.03
9. Xray 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 TDABC Discussion

To build an 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.

Table 4: Main Activities with Sub Activities

Main activities	Sub activities
1. Preparation loading part	1. Scan barcode into system 2. Prepare part for the production
2. Solder paste control	1. Prepare the solder before running into production 2. Update sticker of solder paste shelf-life control
3. Input PCB	1. Visual check on PCB 2. Input PCB into auto loader machine
4. Solder paste printing	1. Set up printer for printing 2. Verify the printing 3. Inspect for abnormality
5. Insert loading part	1. Prepare loading part into feeder 2. Scan barcode of machine type and ID operator 3. Confirm part for each feeder follow by loading list
6. Reflow oven	1. Reflow the PCBA through oven 2. Check thermal profile and solder after reflow
7. AOI	1. Automatic inspection on PCBA

	2. Paste reject sticker on PCBA if found detect spot at AOI's screen
8. VMI	1. Manual check on PCBA appearance 2. Manual soldering if needed 3. Verify the PCBA in good condition
9. Xray inspection	1. Check porosity and void in solder 2. Check geometric measurement of solder thickness and volume
10. De-penalize	1. Cut PCBA per panel 2. Check the quality cutting and appearance
11. VMI and ping test	1. Overall appearance check on PCBA 2. Paste 2D barcode 3. Make sure the PCBA pass ping test 4. Put into reject tray if PCBA failed ping test
12. Packaging	1. Scan 2D barcode 2. Input complete PCBA into bin

For capacity cost of TDABC method, can refer Table 2 which have been conducted previously in ABC method. The table shows that the total CCS for PCBA model B6x is RM1223596.71 and we used the value for TBABC method analysis.

Based on Equation 11, PCRS can be calculated by multiplication of total minutes used under observation (1year) with total workers per day.



$PCRS = \text{productive time per day (minutes)} \times$   
 $\text{total days} \times \text{number of workers per day}$

(11)

Table 5 shows the calculation for the actual CCR. Based on previously ABC method stated in Table 1 and the time is then divided into sub activities.

Table 5: Calculation for The Actual CCR

Main activities	Time (min)	Sub activities	Time (min)
1. Preparation loading part	30	1. Scan barcode into system	5
		2. Prepare part for the production	25
2. Solder paste control	4	1. Prepare the solder before running into production	3
		2. Update sticker of solder paste shelf-life control	1
3. Input PCB	5	1. Visual check on PCB	1
		2. Input PCB into auto loader machine	4
4. Solder paste printing	25	1. Set up printer for printing	15
		2. Verify the printing	5
		3. Inspect for abnormality	5
5. Insert loading part	20	1. Prepare loading part into feeder	12
		2. Scan barcode of machine type and ID operator	1
		3. Confirm part for each feeder follow by loading list	2
6. Reflow oven	10	1. Reflow the PCBA through oven	8
		2. Check thermal profile and solder after reflow	2
7. AOI	10	1. Automatic inspection on PCBA	5
		2. Paste reject sticker on PCBA if found detect spot at AOI	5
8. VMI	5	1. Manual check on PCBA appearance	2
		2. Manual soldering if needed	1
		3. Verify the PCBA in good condition	2
9. Xray inspection	5	1. Check porosity and void in solder	3
		2. Check geometric measurement of solder thickness and volume	2
10. De-penalize	6	1. Cut PCBA per panel	3
		2. Check the quality cutting and appearance	3
11. VMI and ping test	4	1. Overall appearance check on PCBA	1
		2. Paste 2D barcode	1
		3. Make sure the PCBA pass ping test	1
		4. Put into reject tray if PCBA failed ping test	1
12. Packaging	4	1. Scan 2D barcode	2
		2. Input complete PCBA into bin	2

To calculate the estimated production time, it is necessary to develop a time equation as shown in Table 6.

Table 6: Time Equation Based on Time Allocation and Variable

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 <sub>9</sub>
5. Insert loading part	1. Prepare loading part into feeder	12	12x <sub>10</sub>
	2. Scan barcode of machine type and ID operator	1	1x <sub>11</sub>
	3. Confirm part for each feeder follow by loading list	2	2x <sub>12</sub>
6. Reflow oven	1. Reflow the PCBA through oven	8	8x <sub>13</sub>
	2. Check thermal profile and solder after reflow	2	2x <sub>14</sub>
7. AOI	1. Automatic inspection on PCBA	5	5x <sub>15</sub>
	2. Paste reject sticker on PCBA if found detect spot at AOI's screen	5	5x <sub>16</sub>
8. VMI	1. Manual check on PCBA appearance	2	2x <sub>17</sub>
	2. Manual soldering if needed	1	1x <sub>18</sub>
	3. Verify the PCBA in good condition	2	2x <sub>19</sub>
9. Xray inspection	1. Check porosity and void in solder	3	3x <sub>20</sub>
	2. Check geometric measurement of solder thickness and volume	2	2x <sub>21</sub>
10. De-penalize	1. Cut PCBA per panel	3	3x <sub>22</sub>
	2. Check the quality cutting and appearance	3	3x <sub>23</sub>
11. VMI and ping test	1. Overall appearance check on PCBA	1	1x <sub>24</sub>
	2. Paste 2D barcode	1	1x <sub>25</sub>
	3. Make sure the PCBA pass ping test	1	1x <sub>26</sub>
	4. Put into reject tray if PCBA failed ping test	1	1x <sub>27</sub>
12. Packaging	1. Scan 2D barcode	2	2x <sub>28</sub>
	2. Input complete PCBA into bin	2	2x <sub>29</sub>

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 7. The estimated driver quantity for each activity was obtained by observation of the operators during the production run.

Table 7: Cost Driver and Driver Quantity for Each Sub Activity

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
		Thermal profile (quantity)	40

	2. Check thermal profile and solder after reflow		
7. AOI	1. Automatic inspection on PCBA 2. Paste reject sticker on PCBA if found detect spot at AOI's screen	AOI saki checker (hours) Sticker label (quantity)	2,000 40
8. VMI	1. Manual check on PCBA appearance 2. Manual soldering if needed 3. Verify the PCBA in good condition	Labor (salary) Consumables (quantity) Consumables (quantity)	18,000 20 20
9. Xray inspection	1. Check porosity and void in solder 2. Check geometric measurement of solder thickness and volume	XD 7500 machine (hours) XD 7500 machine (hours)	1,020 1,020
10. De-penalize	1. Cut PCBA per panel 2. Check the quality cutting and appearance	Labor (salary) Consumables (quantity)	18,000 40
11. VMI and ping test	1. Overall appearance check on PCBA 2. Paste 2D barcode 3. Make sure the PCBA pass ping test 4. Reject PCBA if any	Labor (salary) Sticker label (quantity) Labor (salary) Reject (quantity)	9,000 40 9,000 40
12. Packaging	1. Scan 2D barcode 2. Input complete PCBA into bin	Scanning (quantity) Labor (salary)	40 18,000

From the data estimation in Table 7, the calculation of actual used time per sub activity as shown in Table 8, can be calculated by multiplying of each quantity driver with their respective time.

Table 8: Used and Unused Capacity

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
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
10. De-penalize	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
		Sticker label (quantity)	40	1	40
	2. Paste 2D barcode	Labor (salary)			
	3. Make sure the PCBA pass ping test		9,000	1	9,000
	4. Put into reject tray if PCBA failed ping test	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

From previous data, the calculation of practical capacity and unused capacity can be calculated as shown in Table 9 and Table 10.

Therefore, the analysis of unused capacity (unused time, unused cost) of PCBA production can

be done by taking consideration two main aspects which are CCR and time equation. The calculation of CCR need the data cost of resources supplied and practical supplied while time equation is determine based on time used and variables for each cost driver.

Table 9: The practical capacity of PCBA production

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	1.1240	224.80
	2. Prepare part for the production	Electronic component (quantity)	83,600	2,090,000	5.6200	11,745,800.00
2. Solder paste control	1. Prepare the solder before running into production	Stirring machine (hours)	2,000	6,000	0.6744	4,060.40
	2. Update sticker of solder paste shelf-life control	Sticker label (quantity)	40	40	0.2248	8.99
3. Input PCB	1. Visual check on PCB	Labor (salary)	9,000	9,000	0.2488	2,023.20
	2. Input PCB into auto loader machine	Labor (salary)	9,000	36,000	0.8992	32,371.20
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
10. De-penalize	1. Cut PCBA per panel	Labor (salary)	18,000	9,000	0.6744	36,417.60
	2. Check the quality cutting and appearance	Consumables (quantity)	40	40	0.6744	80.93
11. VMI and ping test	1. Overall appearance check on PCBA	Labor (salary)	9,000	9,000	0.2248	2,023.20
	2. Paste 2D barcode	Sticker label (quantity)	40	40	0.2248	8.99
	3. Make sure the PCBA pass ping test	Labor (salary)	9,000	9,000	0.2248	2,023.20
	4. Put into reject tray if PCBA failed ping test	Reject (quantity)	40	40	0.2248	8.99
12. Packaging	1. Scan 2D barcode	Scanning (quantity)	40	80	0.4496	35.97
	2. Input complete PCBA into bin	Labor (salary)	18,000	36,000	0.4496	16,185.60
TOTAL				2,361,200		12,035,587.36

Table 10: Unused Capacity of PCBA Production

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	100,800	200	100,600	1.1240	113,074.40
	2. Prepare part for the production	201,600	2,090,000	-1,888,400	5.6200	-10,612,808.00
		302,400	2,090,200	-1,787,800		-10,499,733.60
2. Solder paste control	1. Prepare the solder before running into production	100,800	6,000	94,800	0.6744	63,933.12
	2. Update sticker of solder paste shelf-life control	100,800	40	100,760	0.2248	22,650.85
		201,600	6,040	195,560		86,583.97
3. Input PCB	1. Visual check on PCB	201,600	9,000	192,600	0.2488	43,296.48
	2. Input PCB into auto loader machine	201,600	36,000	165,600	0.8992	148,907.52
		403,200	45,000	358,200		278,787.97
...	...	...	...	...	...	...
...	...	...	...	...	...	...
...	...	...	...	...	...	...
10. De-penalize	1. Cut PCBA per panel	302,400	54,000	248,400	0.6744	167,520.96
	2. Check the quality cutting and appearance	201,600	120	201,480	0.6744	135,878.11
		504,000	54,120	449,880		303,399.07
11. VMI and ping test	1. Overall appearance check on PCBA	50,400	9,000	41,400	0.2248	9,306.72
	2. Paste 2D barcode	50,400	40	50,360	0.2248	11,320.93
	3. Make sure the PCBA pass ping test	50,400	9,000	41,400	0.2248	9,306.72
	4. Put into reject tray if PCBA failed ping test	50,400	40	50,360	0.2248	11,320.93
		201,600	18,080	183,520		41,255.30
12. Packaging	1. Scan 2D barcode	100,800	80	100,720	0.4496	45,283.71
	2. Input complete PCBA into bin	100,800	36,000	64,800	0.4496	29,134.08
		201,600	36,080	165,520		74,417.79
GRAND TOTAL		5,644,800	2,361,200	3,283,600		-5,264,150.59

4.3 Comparison of ABC and TDABC

There are eight features that describe the main differences of ABC and TDABC using data and information that had been gathered at the company. The eight features are cost allocation, cost driver determination, action taken for an additional activity, cost consideration, informative, transparency, oversimplification of activities and capacity forecast and planning. Throughout the discussion, each feature is discussed by highlighting the main differences of ABC followed by TDABC.

First, cost allocation is a process of classifying, collecting and assigning cost to cost objects. There are 2 stages in ABC. The first stage allocates the indirect costs to the activity centres and the second stage assigns the allocated costs of these centres to the cost objects, using the activity drivers. The direct and indirect cost being allocated to the activity centre. There are 12 activities and 4 category of cost which is labor, maintenance, raw material and consumable. The total of all cost resources supplied for every workstation is MYR 1,223,596.71. Next, the second stage, it is to assign activity center to cost



object. The cost driver rate is calculated with respect to the activity center. Table 11 shows the cost allocation of ABC for workstation 5 which is insert loading part.

Table 11: Cost Allocation of ABC

Total number of activities involved	12
Total number of costs considered	4
1 <sup>st</sup> stage (resources cost)	
Labor cost	MYR144,000
Maintenance cost	MYR2,462.83
Raw material cost	-
Consumables cost	MYR60
2 <sup>nd</sup> stage (cost object)	
Resources cost	MYR146,522.83
Cost driver quantity	2,040
Cost driver rate	MYR71.82

As for TDABC, the allocation of cost is in one stage. In TDABC, total time taken is used to allocate cost to the activities. Table 12 shows the usage of time for preparation loading part workstation is 2,090,200 minutes with total cost of MYR 11,746,024.

Table 12: Cost Allocation of TDABC

Total number of activities involved		12		
Total resources cost		MYR1,223,596.71		
Involved two sub activities	1.Scan barcode P/N into syst	Time used (min)	CCR (MYR)	Total cost (MYR)
		200	1.12	224.80
	2.Prepare part for p	Time used (min)	CCR (MYR)	Total cost (MYR)
		2,090,000	5.62	11,745,800

Second, 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. 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 by observation at the workstation. Table 13 shows the driver determination in solder paste control workstation.

Table 13: Driver Determination of ABC

Total time taken (min)	128
Time taken (min)	4
Time taken (%)	3.13

While TDABC treats each activity using a time equation. Table 14 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 which is  $3x_3$  and  $1x_4$ .

Table 14: Driver Determination of TDABC

No.	Sub-activity	Time Equation
1.	Prepare solder	$3x_3$
2.	Update sticker	$1x_4$

Third, additional activity is any new activity added to the production line. ABC and TDABC 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 15, when a new activity is added, the total percentage of time allocation changes.

Table 15: Time Allocation for ABC

No.	Activity	Time allocation (min)
3.	Input PCB	5
xx	xx	xx
Total time taken: $128 + xx$		

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. Therefore, with TDABC, the process is simpler and removes time consuming process. Table 16 shows the new time allocation when a sub-activity is added.

Table 16: Time Allocation for TDABC

Total sub-activities (before)	29
Total sub-activities (after)	30
$TE_{total} = 5x_1 + 25x_2 + 3x_3 + 1x_4 + 1x_5 + 4x_6 + 15x_7 + 5x_8 + 5x_9$ $+ 12x_{10} + 1x_{11} + 2x_{12} + 8x_{13} + 2x_{14} + 5x_{15} + 5x_{16} + 2x_{17}$ $+ 1x_{18} + 2x_{19} + 3x_{20} + 2x_{21} + 3x_{22} + 3x_{23} + 1x_{24} + 1x_{25}$ $+ 1x_{26} + 1x_{27} + 2x_{28} + 2x_{29} + XXXx_{30}$	

Fourth 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 17, 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 17: 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 [16]. Thus, TDABC allows employees to concentrate more on the production time, so that the company gains a sustainable competitive advantage.

Fifth, 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.

Sixth, 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 18 displays the activity duration for automated optical inspection activity of ABC while TDABC as shown in Table 19 for time equation  $5x_4$  and  $5x_5$ .

Table 18: Activity Duration of ABC

Method	In minutes and percentage
Time taken (min)	10
10 Time taken (%)	7

Table 19: Time Equation for TDABC

No	Sub-activity	TE	Time used (min)	Time unused (min)
1	Inspection	$5x_4$	100,000	393,200
2	Reject if defect	$5x_5$	200	201,400

Seventh, oversimplification of activity feature 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 20, ABC assumes single cost driver for x-ray inspection.

Table 20: ABC Cost Driver for X-Ray Inspection Activity

Workstation	Cost driver
9. Xray inspection	XD 7500 machine (hours)

On the contrary, as shown in Table 21, TDABC uses more than one cost driver for x-ray inspection activity. There are two drivers which are machine hours used to check first, porosity and void in solder then second, geometric measurement of solder thickness and volume and amount of solder used.

Table 21: TDABC 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

Eighth, 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 22, the product unit cost is generated in MYR for each activity.

Table 22: Product Per Unit Cost by Using ABC Method

Workstation	Cost driver	All resources supplied (RM)	Cost driver quantity	Cost driver rate (RM)
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
8. VMI	Labor (salary)	72,603.14	18,000	4.03
9. Xray inspection	XD 7500 machine (hours)	72,603.14	2,040	35.59
10. De-penalize	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 23 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.

Therefore, from both comparisons, TDABC is decided to be the best practice as it is appealing the best as 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.

Table 23: Capacity Utilization of Solder Paste Printing Activity

Main activities	Sub activities	Practical capacity (min)	Used time (min)	Unused time (min)	Total cost (RM)	Unused cost (RM)
4. Solder paste printing	1. Set up printer for printing	403,200	30,000	373,200	101,160.00	1,258,430.40
	2. Verify the printing	201,600	100	201,500	112.40	226,486.00
	3. Inspect for abnormality	201,600	100	201,500	112.40	226,486.00
		806,400	30,200	776,200	101,384.80	1,711,402.40

## 5. CONCLUSION

In the current era, which upholds the involvement of automation systems in production, production companies are supposed to not only consider direct labor and direct material as prime costs (TCA) but also include overhead costs as prime costs in their costing.

Therefore, this current study intends to test the feasibility and impact of the ABC and TDABC methods in production field and, besides, to fill the gap on ABC and TDABC elements that had not been discussed in the previous studies by fully describing the costing method at the company. This study focuses on all six elements, which are activity map, cost driver, time equation, capacity cost rate, unused

capacity and forecasting. This study shows that through the ABC method, activity maps and analyses can be clearly identified, as well as cost categories. Next, based on the identified activities, the cost drivers can be determined accordingly. As for TDABC, a detailed understanding of the activity flow in the process is needed so that the time equations can be placed objectively according to the activities. Last but not least, by using information from CCR, time equations, and unused capacity, the forecasting element of TDABC can be generated to contribute more information to the company's pricing decisions in future.

### FUTURE RESEARCH

The results of this study should be given credit because it relates to the costing method of the production company, as less study was conducted in this field. Next, due to limitations of time, this study only considers one shift production; thus, future studies may consider conducting the study for the night shift in order to observe the difference level of effort (human resources) between the day shift and the night shift. Last but not least, the gender of the worker may be taken into consideration in order to observe whether either gender has a big effect on production's productivity (practical capacity).

### ACKNOWLEDGEMENT

This research was fully supported by PGRS230321 and the authors fully acknowledged Universiti Malaysia Pahang Al-Sultan Abdullah for the approved fund which makes this research viable.

### REFERENCES:

- [1] R. Keim, "What Is a Printed Circuit Board (PCB)?", 2020, All about circuits. <https://allaboutcircuits.com>
- [2] S. Bhunia, & S. Tehranipoor, "Hardware Security: A Hands-On Learning Approach", *Elsevier Inc.*, 2019, <https://doi.org/10.1016/C2016-0-03>
- [3] I. Grout, "Digital Systems Design with FPGAS", *Elsevier Ltd.*, 2008, <https://doi.org/10.1016/B978-0-7506-8397-5.X0001-3>
- [4] Jennifer, "The European PCB Industry : A Trip Down Memory Lane – Data4PCB / Custer Consulting Group", *EMS Now.com.*, 2022, <https://www.emsnow.com/the-european-pcb-industry-a-trip-down-memory-lane-data4pcb-custer-consulting-group>
- [5] L. Liu, "Global PCB Market: Growth, Trends, and Forecasts", *EE Times Europe*, 2021, <https://www.eetimes.eu/the-pcb-market-growth-trends-and-forecasts/>
- [6] Rocket PCB, "Analysis of the global PCB industry market status and development prospects in 2020", 2020, <https://www.rocket-pcb.com/global-pcb-industry-market-status-and-development-trend>
- [7] Department of Statistics Malaysia Official Portal, "Monthly Manufacturing Statistics Malaysia", 2023 <https://shorturl.at/eqrwz>
- [8] T. Lee, & J. Kao, "Application of simulation technique to activity-based costing of agricultural systems : a case study. *Agricultural Systems*", Vol. 67, No. 2, 2001, pp. 71-82. [https://doi.org/10.1016/S0308-521X\(00\)00042-1](https://doi.org/10.1016/S0308-521X(00)00042-1)
- [9] T. Raz, & D. Elnathan, (1999). "Activity based costing for projects", *International Journal of Project Management*, Vol.17, No. 1, 1999, pp. 61–67. [https://doi.org/10.1016/S0263-7863\(97\)00073-2](https://doi.org/10.1016/S0263-7863(97)00073-2)
- [10] R. S. Kaplan, & S. R. Anderson, "Time-driven activity-based costing: A simpler and more powerful path to higher profits", *Harvard Business School Press Boston, Massachusetts*, 2007
- [11] M. Schoute, "The relationship between product diversity, usage of advanced manufacturing technologies and activity-based costing adoption", *British Accounting Review*, Vol. 43, No. 2, 2011, pp. 120–134. <https://doi.org/10.1016/j.bar.2011.02.002>
- [12] T. Lu, S. Wang, M. Wu, & F. Cheng, "Competitive Price Strategy with Activity-Based Costing - Case Study of Bicycle Part Company", *Procedia CIRP*, Vol. 63, 2017, pp. 14–20. <https://doi.org/10.1016/j.procir.2017.03.102>
- [13] C. Yang, "Computers and Operations Research An optimization portfolio decision model of life cycle activity-based costing with carbon footprint constraints for hybrid green power strategies", *Computers and Operations Research*, Vol. 96, 2018, pp. 256–271. <https://doi.org/10.1016/j.cor.2018.03.003>
- [14] R.H. Pike, M. E. Tayles, N. Naha, & A. Mansor, "Activity-based costing user satisfaction and type of system : A research note". *The British Accounting Review*, Vol. 43, No. 1, 2011, pp. 65–72. <https://doi.org/10.1016/j.bar.2010.12>
- [15] R. S. Kaplan, & W. J. Bruns, "Accounting and Management: Field Study Perspectives",

- Harvard Business School Press, Boston, United States*, 1987
- [16] R. S. Kaplan, & S.R. Anderson, "Time-driven activity-based costing: A simpler and more powerful path to higher profits", *Harvard Business School Press Boston, Massachusetts*, 2007
- [17] N. Defourny, S. Hoozée, J. F. Daisne, & Y. Lievens, (2022). "Developing time-driven activity-based costing at the national level to support policy recommendations for radiation oncology in Belgium", *Journal of Accounting and Public Policy*, Vol. 42, 107013, 2022, <https://doi.org/10.1016/j.jaccpubpol.2022.107013>
- [18] R. J. V. Alves, A. P. B. D. S. Etges, G. B. Neto, & C. A. Polanczyk, "Activity-Based Costing and Time-Driven Activity-Based Costing for Assessing the Costs of Cancer Prevention, Diagnosis, and Treatment: A Systematic Review of the Literature", *Value in health regional issues*, Vol. 17, 2018, pp. 142–147. <https://doi.org/10.1016/j.vhri.2018.06.001>
- [19] M. Gervais, Y. Levant, & C. Ducrocq, "Time-Driven Activity-Based Costing (TDABC): An Initial Appraisal through a Longitudinal Case Study", *Journal of Applied Management Accounting Research*, Vol. 8, No. 2, 2010, pp. 1–20
- [20] V. J. Pereira, S. F. Amâncio-Vieira, P. H. P. Capucho, V. L. T. Suguihiro, & J. P. Tridapalli, "Cost management in the supply chain: An analysis of the costs of different types of municipal procurement", *Social Sciences and Humanities Open*, Vol. 5, No. 1, 2022, 100260. <https://doi.org/10.1016/j.ssaho.2022.100260>
- [21] A. Almeida, & J. Cunha, "The implementation of an activity-based costing system in a manufacturing company", *Procedia Manufacturing*, Vol. 13, 2017, pp. 932-939. <https://doi.org/https://doi.org/10.1016/j.promfg.2017.09.162>
- [22] D. Alami, "Traditional and activity based aggregate job costing model", *Procedia CIRP*, Vol. 93, 2020, pp. 610-615. <https://doi.org/10.1016/j.procir.2020.04.148>
- [23] A. M. M. Saeed, A. Widyaningsih, & A. S. D. Khaled, "Activity-Based Costing (ABC) in the Manufacturing Industry: A Literature Review.", *Journal of Developing Economies*, Vol. 8, No. 2, 2023, pp. 261-270. <https://doi.org/10.20473/jde.v8i2.40426>
- [24] V. J. Pereira, S. F. Amâncio-Vieira, P. H. P. Capucho, V. L. T. Suguihiro, & J. P. Tridapalli, "Cost management in the supply chain: An analysis of the costs of different types of municipal procurement", *Social Sciences and Humanities Open*, Vol. 5, No. 1, 2022, 100260. <https://doi.org/10.1016/j.ssaho.2022.100260>
- [25] B. S. M., Baroma, & M. I. El-Feky, "The integration of Time Driven-Activity Based Costing (TD-ABC) in a Lean Manufacturing System for Case Study in Egypt.", *EKB Journal Management System*, Vol. 43, No. 2, 2023, pp. 1-25. <https://doi.org/10.21608/caf.2023.305352>
- [26] M.Y. Abu, N.S. Norizan & M.S. Abd Rahman (2018). "Integration of Mahalanobis-Taguchi system and traditional costing accounting for remanufacturing crankshaft". *IOP Conf. Series: Materials Science and Engineering*, Vol. 342, pp. 1-9.
- [27] M.Y. Abu, K.R. Jamaludin & M.A. Zakaria (2017). "Characterisation of activity based costing on remanufacturing crankshaft". *International Journal of Automotive and Mechanical Engineering*. Volume 14, Issue 2, pp. 4211-4224.