Universiti Malaysia PAHANG
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JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY

Homepage: http://journal.ump.edu.my/jmmst

ASSESSMENT THE UNUSED CAPACITY USING TIME DRIVEN ACTIVITY BASED COSTING IN AUTOMOTIVE MANUFACTURING INDUSTRY

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Articles Info:
Received **1 February 2020**
Received in revised form **24 February 2020**
Accepted **27 March 2020**
Available Online **1 March 2020**

Keywords:
Time driven activity based costing; Costing structure; Automotive industry

ABSTRACT

Automotive Manufacturing Industry usually known implementing all six sigma method and lean manufacturing. However, actual practicality in the world of manufacturing, there are a lot of factors contributes that become the challenge to the ideal of lean production line. Not exclude those factors, there is no methods to identify the possible lost cost by the factors. This research is to identify the used and unused capacity exist in production line that considering factors affecting the production line at real time. Time-driven activity-based costing (TDABC) is identified as one of the powerful tools to analyze the actual condition of production. Cost-driver rate is defined in Phase 3 where the highest capacity cost rate calculated is RM0.67 per minutes which involving Station 3, Station 5, Station 7 and Station 8. The least capacity cost rate is RM0.33 per minutes recorded by Station 0(Preparation), Station 2 and Station 6. Ten time equations for each station at trim line is developed. During the development of time equation, criticality of Station 7 when it became the only station affected with all thirteen factors listed can be seen as station that needed focus for improvement or target for lean manufacturing. In regards of the relevancy of applying Time-Driven Activity-Based Costing, as a whole, TD-ABC can be used to identify the estimation capacity used either over or underused. Not only unused capacity is identified, but result shows Station 0 is overused by 2932 minutes equals to RM967.56. Therefore, based on the result obtained, station with overused capacity and several stations with underused capacity gives a clear overview to the management of the company for better investment strategy.

INTRODUCTION

According to Department of Statistics Malaysia, Malaysia's manufacturing sales was RM69.9 billion, growth of 6.8 percent compared to previous year. With automotive manufacturing sector in the seventh sub-sector recorded 11.2 per cent sales from total manufacturing sales. Comparing to March 2019 alone, Aprils' sales shows increment of 3.7 percent. Costing in manufacturing prime objective is to determine a product cost. It made up by integrating the calculation from multiple department such as cost engineering, industrial engineering, design and manufacturing cost. The implementation of integrated management system is really important because it reduces operating time, audit and assessment time, and reduces time used to review the procedure and document [1]. Thus, modular design assisted to reduce the lead time or costs associated with designing the entire family of products [2]. Traditional manufacturing costing is based on two conventional approach – process costing and job-order costing. Activity-based costing developed is supplementary of these traditional costing. Since its emergence in the mid-1980s, activity-based costing (ABC) has been the subject of numerous scientific publications. Academics, professional associations and consultants have fostered the spread of ABC in professional circles [3, 4]. [5] stressed that ABC is perfect tool for manager for a better decision in regards of product design, product price, marketing and continuous production improvement which also supported by [6]. ABC systems are often implemented to reduce costs in operational departments in controlled and simultaneous manner [7], [6] confirming from their survey that ABC serves short-term output management and able to improve the service quality. [8] developed a distinctive pattern of crankshaft and identify the critical and non-critical parameter of crankshaft based on the Mahalanobis Taguchi System (MTS), then applied the ABC as a method of estimation for the re-manufacturing cost of crankshaft to prove that the integration of MTS-ABC was interesting. According to [9], the ABC model is used to improve the overhead management system significantly by providing the best management decision-making information. If a company or organization that manufactures a variety of products has more than one variant, in this case the cost of multiple indirectly involved in valuation and valuation should be based on inventory, the implementation of ABC is more accurate [10]. [11] note that the definition of ABC itself provides the benefits it offers, as this technique focuses on the additional provisions for certain products and service within the organization. This has led to a high-calibre management accounting (ABC/M Activity Based costing/Management) for more than decades [12]. But, while the adoption is widespread, some studies, most of which are based on surveys, have reported that there are many difficulties in introducing the ABC system [6]. Among the reasons supporting this claim, the barriers to change are often called and [13] argues that the resistance may have political and cultural origin or due to lack of relevance. In addition, technical difficulties associated with modelling. Although this difficulty is well-known and hopefully, the literature dealing with ABC's successful implementation shows mixed results [14]. A board understanding of the origins of the difficulties encounters in the implementation of ABC appears to be less in the cost system literature. First, ABC's flexibility is often regarded as one of the main benefits of this method. Various studies have shown that the reasons for the introduction of ABC are investigated [15]. The fact that ABC, as a sophisticated method, has accomplished several purposes to be able to use it in a different way is clear. Second, the use of cost systems for various purposes is seen as a way of overcoming the difficulties of implementation. For example, it is seen as a way to maximize relevance, so that the use of ABC can contribute to a variety of purposes to overcome obstacles [16]. Finally, with the introduction of cost systems for various purposes, both for accounting and administrative requirements, the need to provide the consistent information throughout the respected organization. Although acceptance and popularity based on the theoretical benefits are quite a number of companies achieving uniform efficiency and there is quite a typical study showing cases where the execution failed [17]. Given this fact, there are many contributions and various reasons caused by the lack of modelling in practice. Although some of the shortcomings of their terms of reference [18] others show their relative importance in making decisions [19] or the magnitude associated with the implementation of Cost. In complex organizations requires the ABC model, which represents the author as a traditional ABC model, estimates of different cost drivers. A broad activity dictionary, which requires periodic measurements that use too much time and too much resources, reduces confidence in the model itself. According to the author, the main problem is the implementation difficulty. Comparison between traditional costing methods and ABC methods shows that the company has no known hidden losses which is due to the fact that the product costs exceed the legal costs [20]. However, estimation the ABC model is difficult because the current accounting system does not support data collection [21]. Time-Driven Activity Based Costing (TDABC) is introduced by [22]. The last conceptual spin and seemingly last on the ABC model is the emergence of the cost of handling the Kaplan's time, known as the initial TDABC. It is the father of the original model, Kaplan, which offers a new compact version, taking into account the major constraint of the model, in particular the cost that is not balanced for its proper implementation. The basic concept of TDABC is processing map, generate time equation from the process map and lastly calculate the capacity cost rate (CCR) [23]. Hence, we can forecast the production capacity to fulfil the different demand and decide the best strategy to optimize the budgeting and reduce the cost. TDABC generates the cost of production using two parameters which are the unit of resources input (labor and non-labor) and the time and quantity of resources required for every stage of manufacturing. The process map is a planning and management tool that visualizes the flow or series of the work from the beginning stages until the end. It determines who is responsible for the tasks, what is the standard of the work involved in every stage in order to identify which area can be improved in the future. After the process map is done, the time equation of each series or stages will be developed. Therefore, each equation reflects the required time for a specific event to perform which also known as standard time. Since the production process tasks can consume machinery time, human labor time or both and cause the equation more complex. Time equation also allows the company to predict the future with different scenarios to analytically calculate the capacity of the resource to fulfill the future demand or production plans. Time equations define the standard time for a specific event and are structured as follows:

$$\text{T for activity} = \beta_0+\beta_1 X_1+\ldots+\beta_n X_n \qquad (1)$$

Whereby:

β_0 is the time for the basic activity while β_i the time for additional sub-activities that are may or may not be multiplied with their time driver X_i depending on product characteristics [26]. The second principle of TD-ABC model is to calculate the capacity cost rate. The capacity cost rate can be calculated using the formula below.

$$\text{Capacity Cost Rate} = \text{Cost of Capacity Supplied} / \text{Practical Capacity of Resources Supplied} \qquad (2)$$

There are two key elements required which are the cost of capacity supplied and the practical capacity. The cost capacity supplied associated with the department or station includes the occupancy, technology and other equipment costs. Meanwhile, the practical capacity referring to the work efficiency and can be estimated somewhat arbitrarily of a certain percentage like 80% theoretically. The remaining percentage allowing the personnel time such as break, unrelated chitchat to direct work performed or meetings. Then, the capacity cost rate can be calculated by dividing the capacity cost with the practical capacity obtained previously. [24] performed a capacity planning and product allocations in order to optimize the number of testers while achieving the production target for a better tester utilization. [25] explored the focus area of TDABC among published works that can be used as a guideline. At [26], time-driven ABC's are implemented in various fields to generate increased operations. According to this author, TDABC does not replace traditional bench-marking methods; On the contrary, it improves. Unlike traditional bench-marking, where only macro results are displayed, TDABC separates process differences to reveal causes. A case study by [27] shows in the logistics industry how internal benchmarks in four warehouses have been carried out positively to identify inefficiencies and potential synergies. According to this previous study, TDABC can upgrade bench-marking models by providing accurate and detailed information on sources of inefficiency and poor performance, and demonstrating the effect of capacity utilization on the figures. In fact, to the best of our knowledge, [28] illustrated the model of TDABC in small manufacturing company that produce a highly specific product. From the above research, they able to understand the limitation of the model, namely the use of time equation. They also able to understand the development of TD-ABC process in complex and data-rich manufacturing context. However, using only this measure for manufacturing companies is difficult, as a machinery time must also be considered, which means that two practical capacities must be calculated and two time equations must be created for each production process [29]. Work by [30-35] proved that TDABC is a good costing method in order to determine accurate cost of product diversification.

METHODOLOGY

This work consists of three phases as shown in Figure 1. Phase 1 consists of identification of process and development of process mapping in the automotive manufacturing company. The objective is to find the appropriate scope to focus for detail analysis. The complete flow of automotive manufacturing industry starts with body shop, paint shop, assembly shop and, final and finish shop. However, this work only focused on assembly shop which consist of three main area such as trim line, mechanical line, sub-assembly trim and sub-assembly mechanical. Trim line consists of ten stations starting from Station 0 or known as Station Preparation until Station 9. Sub-Assembly Trim consists of Sub-Assembly Door, Sub-Assembly Cockpit and Sub-Assembly Seat. Sub-Assembly Cockpit and Sub-Assembly Seat are among CKD parts that has been locally assemble by third party. Sub-Assembly Cockpit will intercepts to the main line at Station 4 while Sub-Assembly Seat will intercepts into the main line at Station 9. Sub-Assembly Door however, entering the main line at Mechanical Line Station 18. Mechanical Line consists of nine stations starting from Station 11 until Station 19. Sub-Assembly Mechanical consists of Sub-Assembly Engine, Sub Assembly Front Axle, Sub Assembly Rear Axle, Sub-Assembly Radiator. These five sub-assemblies known as Power Train and will intercepts the main line at Station 12 or marriage station. Other sub-assemblies mechanical are also Sub-Assembly Front Module and Sub-Assembly Tire. Each process will enter the main mechanical line at Station 14 and 15 respectively. Station 10 and Station 20 are quality inspection station where Station 10 is known as Trim Quality Gate and Station 20 is Mechanical Quality Gate. Again, the main subject of analysis and discussion will be on trim line area only as shown in Figure 1.

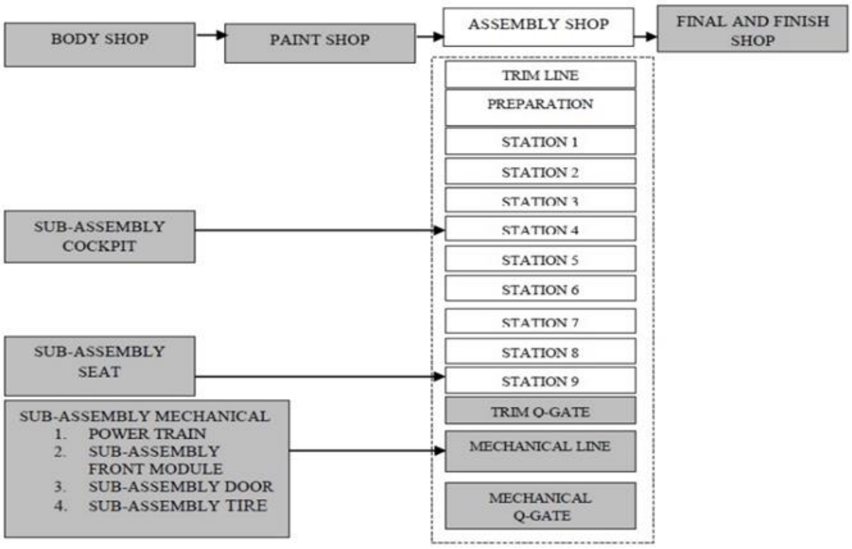

Figure 1 A process flow in automotive manufacturing company

Once the scope is identified, phase 2 is very important to develop the capacity cost rate. It consists of collection of data, direct and indirect cost i.e.working hour, salary rate and historical data. During phase 3, the collected data is processed and analyzed to identify the unused capacity with respect to the duration and cost.

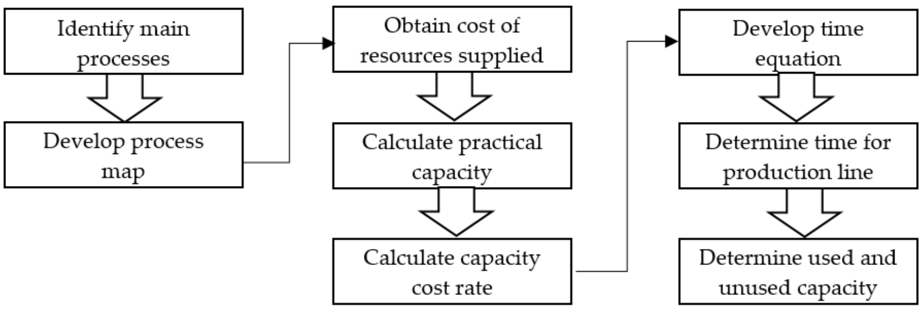

Figure 2 A flow chart of research methodology

Phase 1:
1. Identifying main processes in production line and defining focus of study.
2. Develop a process map associated with production incorporated with capacity supplying resources including personnel, facilities, equipment and consumables.
Phase 2:
1. Obtain the direct cost (i.e. salary and maintenance) to determine the cost of capacity supplied.
2. Determine time (minutes) required for productive work in a year without non-value activities to estimate the practical capacity of supplied resources.
3. Develop capacity cost rate for the production line.
Phase 3:
1. Develop time equation to represents the basic time required for each activity with the incremental time associated with each variation that can occur.
2. Multiply the capacity cost rate with the time equation to determine the cost of a resource being used.
3. Determine used an unused capacity in production line.

RESULT AND DISCUSSION

Man, material, method, machine and environment or known as 4M1E are prime tool used by engineering in all production analysis. With respect to man, Station 7 has four operators at which all operators are skilled operator for complex processes. It breakdowns into twelve major steps. Steps at Station 7are preparation of windshield and rear glass, which subjected to the scope of material. Element of material can be divided into two categories namely vehicle parts and consumable material. For preparation of windshield and rear glass, it is subjected to vehicle parts, which later will be assembled to the main body. After that, process of gluing the windshield. This process is among the most critical process in assembly line. Gluing process require high skilled operator and equipped with heated-sealant machine. Apart of the machine, heated-sealant is the gluing material that fall into categories of consumable materials. The gluing process is subjected to a very particular quality specification thus increase the criticality of the gluing method. Next process is the assembly of windshield. This process also requires skilled operator and is subjected to quality specification. Certain specification of gap and transition of the windshield to the body must be achieved within 5 minutes of assembly otherwise, the gluing material will be hardening. Right method of windshield adjustment is needed. The same elements applied to the process of preparation, gluing and assembly of rear glass. All other processes at Station 7 are busbar partition wall center, sealing air duct, engine hood seal, water deflector at roof and headunit installation. All this process are happening at the area of engine compartment or front area of internal body (cockpit area). To develop time equation, factors are identified based on 4M1E elements. The factors then assigned to related stations and time constant is defined for each stations. The standard time for the process has been pre-determine via engineering analysis. In this study, standard time for all studied stations are taken as is from the factory engineering department and summarized in Table 1.

Table 1 Summary of standard time each station

Station	Takt time (min)
0	34.07
1	28.23
2	30.00
3	34.00
4	30.00
5	27.00
6	18.15
7	29.28
8	32.31
9	20.00

The factors below is derived which seem impacted to production takt time. Scope of Man contributes to the number of absent operator (X_5) and number of skilled operator absence (X_{11}). This two factor is put separated as certain high skilled process require skilled operator and the absenteeism of this special skilled operator affected the production line differently depends on the complexity of the process. Scope of Material is described in waiting period for material readiness (X_2), at which the material here is refer to consumable material and non-vehicle-parts. Vehicle-part is explained in number of wrong assembled part (X_6) and number of defective part (X_7). X_6 and X_7 are put as different factor for the source of the issue and the consequences is different. Effect of method to the takt time is described as number of additional checking due to additional info (X_3), number of adjustment needed (X_8), number of additional inspection due to dynamic checking (X_{10}) and number of second hand check required (X_{12}). X_3, X_{10}, and X_{12} is similar in terms of nature of work, however is different in terms of the source of checking instruction and purpose and impact to the process. X_3 purely come from the mother plant, checking and recording to be sent back to mother plant. X_{10} is due to local instruction mainly when mistakes and damage caused by the assembly method perform locally. X_{12} is a mandatory checking for safety related process and each stations have their respective number of safety related item to be checked. There are 4 factors under the scope of machine – X_1; number of machine breakdown, X_4; machine setup, X_9; number of Preventive Maintenance or Autonomous Maintenance (PM/AM) performed, and X_{13}; number of broken jig and tool. Machine breakdown and broken jig give a different impact since these two are different category of equipment. Machine setup is a daily activity performed by operator prior to operation while PM/AM is performed by qualified maintenance personnel at interval time. All the factors are summarized in Table 2.

Table 2 Derivation of factors affecting time variables

Notation	Description	4M1E Category
X_1	Number of machine breakdown (Qty)	MACHINE
X_2	Waiting period for material readiness (Fq)	MATERIAL
X_3	Number of additional checking part (due to Add Info)	METHOD
X_4	Machine setup (Fq)	MACHINE
X_5	Number of normal operator absenteeism in station (Fq)	MAN
X_6	Number of wrong assembles part (Fq)	METHOD
X_7	Number of defective part (Fq)	MATERIAL
X_8	Number of adjustment needed (Fq)	METHOD
X_9	Number of PM/AM (Fq)	MACHINE
X_{10}	Additional inspection period/process checking (due to local error)	METHOD
X_{11}	Number of skilled operator absenteeism in station (Fq)	MAN
X_{12}	Number of second hand check needed/unit (Fq)	METHOD
X_{13}	Number of broken jig and tool (Qty)	MACHINE

As shown in Table 3, there are seven factors affecting all stations which are number of additional checking part (due to Add Info) ; X_3, Number of normal operator absenteeism in station ; X_5, Number of wrong assembles part ; X_6, Number of defective part ; X_7 Additional inspection process checking (due to local error) ; X_{10} , Number of second hand check needed per unit; X_{12}, and Number of broken jig and tool ; X_{13}. This is because the factors are essential 4M element that exist in all stations. Meanwhile, other six factors are station-bounded due to special processes exist in the particular station. Number of machine breakdown; X_1, Machine setup; X_4, and Number of PM/AM ; X_9 are mostly bounded to Station Preparation, Station 1, Station 4, Station 7 and Station 9 because these stations have equipment for their particular process. Machine setup; X_4 also bounded to Station 2. Station Preparation has an engraving machine for VIN number engraving process, Station 4 has a cockpit handling manipulator for cockpit installation, Station 7 has a heated hydraulic sealant applicator machine for gluing process and Station 9 has a seat handling manipulator for seat installation. Station 2 has a sealant-heated device for DVD base mat assembly which require device setup. Relatively, these mentioned stations with equipment also affected by the remaining factors. Waiting period for material readiness; X_2 for Station 2 and Station 7 for the heating process completed. Number of adjustment needed; X_8 and Number of skilled operator absenteeism in station; X_{11} are for Station Preparation during striker adjustment and Station 7 for glass installation adjustment. Number of skilled operator absenteeism in station; X_{11} affecting for Station 4 and Station 9 since handling manipulators required skilled operator while Station 2 and 7 require skilled operator for gluing application.

Table 3 Summary of factor-affecting stations

Notation	Description	Frequency									
		Workstation									
		0	1	2	3	4	5	6	7	8	9
X_1	Number of machine breakdown (Qty)	■	■			■			■		■
X_2	Waiting period for material readiness (Fq)			■					■		
X_3	Number of additional checking part (due to Add Info)	■	■	■	■	■	■	■	■	■	■
X_4	Machine setup (Fq)	■	■	■		■			■		■
X_5	Number of normal operator absenteeism in station (Fq)	■	■	■	■	■	■	■	■	■	■
X_6	Number of wrong assembles part (Fq)	■	■	■	■	■	■	■	■	■	■
X_7	Number of defective part (Fq)	■	■	■	■	■	■	■	■	■	■
X_8	Number of adjustment needed (Fq)	■							■		
X_9	Number of PM/AM (Fq)	■	■			■			■		■
X_{10}	Additional inspection period/process checking (due to local error)	■	■	■	■	■	■	■	■	■	■

X_{11}	Number of skilled operator absenteeism in station (Fq)										
X_{12}	Number of second hand check needed/unit (Fq)										
X_{13}	Number of broken jig and tool (Qty)										

Based on the factors established and station defined to the factors, a time constant is assigned to the effective factors with a few assumptions. The assumptions made by interviewing the engineer of Line 2 and from historical data if recorded. Number of additional checking part (due to Add Info); X_3, Additional inspection period per process checking; X_{10} and Number of second hand check needed per unit; X_{12} take 0.5min each checking. The checking interval is taken per shift. Secondly, Number of normal operator absenteeism in station ; X_5 and Number of wrong assembles part; X6 , will increase takt time to 5 minutes. Number of defective part; X_7,will increase takt time to 10 minutes . Additional 5 minutes compared to wrong assembled part for salvage procedure of defective parts need to be done. Lastly, Number of broken jig and tool; X_{13} will increase takt time to 10 minutes. That is the minimum downtime allowable for jig and tool. Other than that, the downtime taken based on historical data of the lowest time recorded or average time recorded. By this, any production issue involving line stoppage or major downtime is neglected. Summary of factor-affecting station with time constant as shown in Table 4.

Table 4 Factor-affecting station with time constant

Notation	Description	Frequency									
		Workstation									
		0	1	2	3	4	5	6	7	8	9
X_1	Number of machine breakdown (Qty)	30	15			30			20		15
X_2	Waiting period for material readiness (Fq)			15					15		
X_3	Number of additional checking part (due to Add Info)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
X_4	Machine setup (Fq)	10	5	5		5			5		5
X_5	Number of normal operator absenteeism in station (Fq)	5	5	5	5	5	5	5	5	5	5
X_6	Number of wrong assembles part (Fq)	5	5	5	5	5	5	5	5	5	5
X_7	Number of defective part (Fq)	10	10	10	10	10	10	10	10	10	10
X_8	Number of adjustment needed (Fq)	15							15		
X_9	Number of PM/AM (Fq)	15	15			15			15		15
X_{10}	Additional inspection period/process checking (due to local error)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
X_{11}	Number of skilled operator absenteeism in station (Fq)			10		10			20		10
X_{12}	Number of second hand check needed/unit (Fq)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
X_{13}	Number of broken jig and tool (Qty)	10	10	10	10	10	10	10	10	10	10

Based on the factor-affected station and time constant, time equation is established for each station including the standard time for each station. Total unit per year multiplies the standard time while checking-related factors is multiply by unit per shift since the interval of checking are taken by shifts. Table 5 shows the time equation for respective workstations.

Table 5 Time equation for each workstation

Workstation	Time equation
0	$34.07(UPY)+30X_1+0.5(UPS)X_3+10X_4+5X_5+5X_6+10X_7+15X_8+15X_9+0.5(UPS)X_{10}+0.5(UPS)X_{12}+10X_{13}$
1	$28.23(UPY)+15X_1+0.5(UPS)X_3+5X_4+5X_5+5X_6+10X_7+15X_9+0.5(UPS)X_{10}+0.5(UPS)X_{12}+10X_{13}$
2	$30.00(UPY)+15X_2+0.5(UPS)X_3+5X_4+5X_5+5X_6+10X_7+0.5(UPS)X_{10}+10X_{11}+0.5(UPS)X_{12}+10X_{13}$
3	$34.00(UPY)+0.5(UPS)X_3+5X_5+5X_6+10X_7+0.5(UPS)X_{10}+0.5(UPS)X_{12}+10X_{13}$
4	$30.00(UPY)+30X_1+0.5(UPS)X_3+5X_4+5X_5+5X_6+10X_7+0.5(UPS)X_{10}+10X_{11}+0.5(UPS)X_{12}+10X_{13}$
5	$20.00(UPY)+15X_1+0.5(UPS)X_3+5X_4+5X_5+5X_6+10X_7+15X_9+0.5(UPS)X_{10}+10X_{11}+0.5(UPS)X_{12}+10X_{13}$
6	$18.15\ (UPY)+0.5(UPS)X_3+5X_5+5X_6+10X_7+0.5(UPS)X_{10}+0.5(UPS)X_{12}+10X_{13}$
7	$29.28(UPY)+20X_1+15X_2+0.5(UPS)X_3+5X_4+5X_5+5X_6+10X7+15X_8+15X_9+0.5(UPS)X_{10}+20X_{11}+0.5(UPS)X_{12}+10X_{13}$
8	$32.31(UPY)+0.5(UPS)X_3+5X_5+5X_6+10X_7+0.5(UPS)X_{10}+0.5(UPS)X_{12}+10X_{13}$
9	$20.00(UPY)+15X_1+0.5(UPS)X_3+5X_4+5X_5+5X_6+10X_7+15X_9+0.5(UPS)X_{10}+10X_{11}+0.5(UPS)X_{12}+10X_{13}$

Practical capacity of supplied resources that are calculated based on time required for productive work in a year without non-value activities. For this study, the practical capacity is obtained from the factory working hour, which is 490 minutes. By taking into consideration of 85% working efficiency, the practical capacity is 416.5 minutes per day. The factory annual working days is 238 days. Overtime production is neglected. Since, stations operated according to working hour and is arranged in continuous and interdependent manner, all stations would have similar practical capacity – 416.5 minutes. For total 238 working days, the practical capacity is 99127 minutes per year. Cost of capacity is taken by salary of total operators for each stations. Salary of the management level such as line managers and engineers is excluded since the nature of the job is indirect to the production assembly process. Example of calculation Station Body Preparation with two operators of salary RM10 per hour, with 6.94 hours working time per day (416.5 minutes per day) - total cost per day for all operators is calculated as RM138.83. Capacity cost rate is calculated by dividing cost of capacity with practical capacity each stations. Calculating - Body Preparation has a capacity cost rate 0.33 (RM/mins). The similar method is applied for all stations and the summary is tabulated as in Table 6.

Table 6 Summary of practical capacity, cost of capacity and capacity cost rate for each station

Workforce	Quantity	Cost/hour (RM)	Salary/Operator/Day	Cost of capacity (RM)	Practical capacity/Day (mins)	Practical capacity (mins)	Capacity cost rate (RM/min)
Manager							
Engineer							
Penghulu							
Multi							
Operator							
Preparation	2	10	69.42	138.83	416.5	99127	0.33
Station 1	3	10	69.42	208.25	416.5	99127	0.50
Station 2	2	10	69.42	138.83	416.5	99127	0.33
Station 3	4	10	69.42	277.67	416.5	99127	0.67
Station 4	3	10	69.42	208.25	416.5	99127	0.50
Station 5	4	10	69.42	277.67	416.5	99127	0.67
Station 6	2	10	69.42	138.83	416.5	99127	0.33
Station 7	4	10	69.42	277.67	416.5	99127	0.67
Station 8	4	10	69.42	277.67	416.5	99127	0.67
Station 9	3	10	69.42	208.25	416.5	99127	0.50

There is no specific record from the factory that can be categorized into the factors established in this study. Therefore, the frequency of the occurrence for all the factors are made by a few assumptions. These assumptions are based on (1) the least case scenario occur in the factory taken by interviewing the engineer of Line 2, (2) initial historical data recorded in the factory and average for a year span of production and (3) allowable or acceptable occurrence sets in the factory process flow. Based on rule number 1, number of additional checking part (due to Add Info); X_3, the occurrence is assuming at least one case happen every quarter, making total of four cases occur throughout the year. With minimum three cases per week, having twelve –month of four weeks (48 weeks), Number of wrong assembles part, X_6 is recorded to have at least 144 cases in one year per station. On the other hand, Number of defective part, X_7 is taken to have four cases per month, making it 48 cases per year for all stations. Additional inspection period per process checking (due to local error). Lastly, Number of broken jig and tool, X_{13} – the assumption made to have one jig or tools broken every month. This made twelve cases on average for all station throughout the year. For X_8, Number of adjustment needed for Station 1 occur at least three times per month, total up to 36 times per year of adjustment needed while Station 7 only two times per month, making it 24 times per year. For Number of skilled operator absenteeism in station, X_{11}, assuming every operators taking their one-day leave per month scheme every month, each operator is having twelve-day leave throughout the year. Thus, Station 2, Station 4, Station 7 and Station 9 have different frequency of absenteeism according to the number of operator consisted in that station. Based on rule number 2, additional inspection period/process checking due to local error, X_{10},is taken from historical data, by average is having at least two cases per month making it twelve cases per year for all stations. Number of second hand check needed per unit , X_{12} is taken from recorded traveller for all stations. The traveller consist of number of stamping needed for each safety-related process known as second hand check. Number of machine breakdown, X_1 , only Station 7 has twice breakdown cases for the year, other equipment only one breakdown cases for Station 0, Station 1, Station 4 and Station 9. Based on rule number 3, number of normal operator absenteeism in station , X_5, assuming every operators taking their one day leave per month scheme every month, each operator is having twelve day leave throughout the year. Thus, each station have different frequency of absenteeism according to the number of operator consisted in the station. Waiting period for material readiness, X_2 affecting Station 2 and Station 7 due to existence of consumable material at that station. The material preparation is done every beginning of the shift repeating every day for 238 working days. Similar concept applied for Machine setup, X_4 as Station 0, Station 1, Station 2, Station 4 , Station 7 and Station 9. Although, Station 2 has an equipment, but it requires no preventive and predictive maintenance. It making only Station 0, Station 1, Station 4, Station 7 and Station 9 affected by Number of PM/AM, X_9 once a month. The summary of the occurrence for each factors is tabulated in Table 7.

Table 7: Summary of occurrence for each factors

		Frequency									
Notation	Description	0	1	2	3	4	5	6	7	8	9
X_1	Number of machine breakdown (Qty)	1	1			1			2		1
X_2	Waiting period for material readiness (Fq)			238					238		
X_3	Number of additional checking part (due to Add Info)	4	4	4	4	4	4	4	4	4	4
X_4	Machine setup (Fq)	238	238	238		238			238		238
X_5	Number of normal operator absenteeism in station (Fq)	24	36	24	48	36	48	24	48	48	36

X_6	Number of wrong assembles part (Fq)	144	144	144	144	144	144	144	144	144	144
X_7	Number of defective part (Fq)	48	48	48	48	48	48	48	48	48	48
X_8	Number of adjustment needed (Fq)	36							24		
X_9	Number of PM/AM (Fq)	12	12			12			12		12
X_{10}	Additional inspection period/process checking (due to local error	24	24	24	24	24	24	24	24	24	24
X_{11}	Number of skilled operator absenteeism in station (Fq)			24		36			48		36
X_{12}	Number of second hand check needed/unit (Fq)	3	17	8	4	25	24	25	20	9	11
X_{13}	Number of broken jig and tool (Qty)	12	12	12	12	12	12	12	12	12	12

Based on 12 unit per shift (UPS) and 238 working days, total unit per year (UPY) is 2856 units. This data then altogether with frequency is included in the time equation as shown in Table 8.

Table 8 Time equation for each workstation with total time

Workstation	Time equation	Total time (mins)
0	$34.07(2856)+30(1)+0.5(12)(4)+10(238)+5(24)+5(144)+10(48)+15(36)+15(12)+0.5(12)(24)+0.5(12)(3)+10(12)$	102059
1	$28.23(2856)+15(1)+0.5(12)(4)+5(238)+5(36)+5(144)+10(48)+15(12)+0.5(12)(24)+0.5(12)(17)+10(12)$	83779.88
2	$30.00(2856)+15(238)+0.5(12)(4)+5(238)+5(24)+5(144)+10(48)+0.5(12)(24)+10(24)+0.5(12)(8)+10(12)$	92316
3	$34.00(2856)+0.5(12)(4)+5(48)+5(144)+10(48)+0.5(12)(24)+0.5(12)(4)+10(12)$	98856
4	$30.00(2856)+30(1)+0.5(12)(4)+5(238)+5(36)+5(144)+10(48)+0.5(12)(24)+10(36)+0.5(12)(25)+10(12)$	89078
5	$27.00(2856)+0.5(12)(4)+5(48)+5(144)+10(48)+0.5(12)(24)+0.5(12)(24)+10(12)$	78984
6	$18.15(2856)+0.5(12)(4)+5(24)+5(144)+10(48)+0.5(12)(24)+0.5(12)(25)+10(12)$	53594.4
7	$29.28(2856)+20(2)+15(238)+0.5(12)(4)+5(238)+5(48)+5(144)+10(48)+15(24)+15(12)+0.5(12)(24)+20(48)+0.5(12)(20)+10(12)$	91771.68
8	$32.31(2856)+0.5(12)(4)+5(48)+5(144)+10(48)+0.5(12)(24)+0.5(12)(9)+10(12)$	94059.36
9	$20.00(2856)+15(1)+0.5(12)(4)+5(238)+5(36)+5(144)+1(48)+15(12)+0.5(12)(24)+10(36)+0.5(12)(11)+10(12)$	60599

Used and unused capacity is calculated and the result is shown as in Table 9. Station 0 capacity has been over-used by 2932 minutes. This mean, production would make a production recovery to compensate the over-used capacity. This cost about RM967.56. The negative value in the table indicates over-used. For other station, all are under-utilized with highest unused capacity is recorded by Station 6 – 45 533 minutes. This mean, an amount of RM 15 025.89 is paid without productive output. Station 9, Station 5 and Station 1 are next top ranked with highest unused capacity recorded which are RM19 264, RM 13 495.81, and RM 7673.40 respectively. Although Station 6 has the highest unused capacity compared to Station 9, Station 9's capacity cost rate is 0.5 while Station 6 is 0.33, making the loss of cost for Station 9 is higher than Station 6. Station 7, based on time equation is affected by all thirteen factors, recorded unused capacity of 7356 minutes with cost valued RM 4928.52. Since the production line is arranged continuous and interdependently, over-used capacity by Station 0 is stopping other station for utilization. This made the lost doubled up during production recovery for 2932 minutes equal to almost seven production days.

Table 9 Used-Capacity vs Unused Capacity

	0	1	2	3	4	5	6	7	8	9
Practical capacity (min)	99127	99127	99127	99127	99127	99127	99127	99127	99127	99127
Used capacity (min)	102059	83780	92316	98856	89078	78984	53594	91771	94059	60599
Un-used capacity (min)	-2932	15347	6811	271	10049	20143	45533	7356	5068	38528
Actual cost (RM)	-967.56	7673.50	2247.63	181.57	5024.5	13495.81	15025.89	4928.52	3395.56	19264

CONCLUSIONS

The case study of real production line in automotive manufacturing industry is presented at which TD-ABC is implied to achieve three objectives. Firstly, the highest capacity cost rate calculated is RM0.67 per minutes which involving in Station 3, Station 5 ,Station 7 and Station 8. The least capacity cost rate is RM0.33 per minutes recorded by Station 0(Preparation), Station 2 and Station 6. Secondly, the development of time equation, criticality of Station 0 can be identified. Station 7 where the only station with affected with all thirteen factors listed can be seen as station that needed focus for improvement or target for lean manufacturing. Finally, with the implementation of the TD-ABC, Station 7 is identified as station with most affected factors, where it is affected by all thirteen factor listed. However, based on the results, Station 7 have only 7356 minutes of unused capacity. The unused capacity of Station 7 valued RM4928.52. On the other hand, not only unused capacity is identified, but unexpected result shows Station 0 to be over-used by 2932 minutes equals to RM967.56. By the nature of the continuous and interdependent line arrangement, it is impossible to improve stations with highest unused capacity when the productivity of the station is stopped by Station 0. This result of this research is useful to support any continuous activity suggested by line engineer for management proposal. All three phases of TD-ABC implementation can assist engineering decision making with a proper analysis.

ACKNOWLEDGEMENT

The author would like to be obliged to University Malaysia Pahang for providing financial assistance under RDU190156 and FRGS/1/2018/TK03/UMP/02/34.

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