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Research Article

Frameworks for system integration by considering quality and cost in academic performance

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Abstract

In modern society, system integration, which enables multiple subsystems to function as one, is emerging in various fields such as industry, commerce, and infrastructure. Currently, the annual achievement assessment report, which combines both the annual work target (AWT) and a Likert scale assessment, is used to evaluate academicians' performance. However, this assessment involves human judgment, which is often considered unfair. The current system framework primarily focuses on quality elements, making it insufficient for a comprehensive evaluation. Therefore, a system integration framework that relies solely on quality elements is inadequate. This study proposes four integration frameworks that consider both quality and cost: conventional activity-based costing (ABC) integration, conventional time-driven activity-based costing (TDABC) integration, Mahalanobis-Taguchi system (MTS)-ABC integration, and MTS-TDABC integration. To implement system integration, 53 parameters from the quality element are mapped to 35 sub-activities from the costing model. The second objective of this study is to validate the effectiveness of these system integrations using data from a sample of grade DS51/52 academicians. Following the calculations, the total used cost for each integration model is determined and compared. Among them, the MTS-TDABC integration is identified as the ideal model, as its used cost of MYR 69,521 is the closest to the actual supplied resource cost of MYR 70,260. This study contributes to the evaluation of academicians' performance by offering a new perspective that integrates significant parameters with the corresponding sub-activities, leading to a more comprehensive and fair assessment system.

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1. Introduction

After the Ministry of Education introduced the Customer Charter in 1996, Malaysia began incorporating quality management (QM) principles in higher educational institutions (HEIs). According to the QM model, the Ministry aimed to establish a policy and quality division to oversee the nation's education policies at all levels. Strategically, it was anticipated that all HEIs would eventually adopt the same QM framework. To institutionalize the implementation of QM practices in Malaysian HEIs, several new legislations were enacted in the same year, including the New Education Act 1996, the Private Higher Educational Institutions Act 1996, the National Accreditation Board Act 1996, and the National Council on Higher Education Act 1996. To assess the efficiency of the QM system in private HEIs, the National Accreditation Board (Lembaga Akreditasi Negara, LAN) was established, while the Quality Assurance Division (QAD) was created for public HEIs (Cheah et al., 2020). However, with the adoption of the MQA Act 2007, both LAN and QAD were merged into a new agency, the Malaysian Qualifications Agency (MQA), which is now responsible for QM practices in both public and private HEIs (Cheah et al., 2020). The Malaysian Qualifications Framework (MQF) was implemented in accordance with the MQA Act 2007, designating MQA as the sole statutory quality assurance agency for programs and credentials offered by all public and private HEIs in Malaysia (Malaysian Qualifications Agency, 2019). To support HEIs in implementing the MQF and enhancing academic performance and institutional effectiveness, MQA has developed various guidelines, standards, and codes of practice (Malaysian Qualifications Agency, 2018).

System integration refers to the process of linking multiple subsystems into a single, unified system that functions as one. This approach enables the combination of various statistical techniques and engineering processes to significantly improve quality while reducing costs. By optimizing integration strategies in specific areas, organizations can maximize integration value at a relatively manageable cost (Jia et al., 2022). To promote the export of higher education, Kantola and Kettunen (2012) proposed a framework that integrates innovation pedagogy, higher education strategic planning, and research, development, and innovation (RDI). This integration technique is cost-effective as it leverages the existing business service structure. The benefits of student learning in RDI projects include reduced dropout rates, shorter study durations, improved knowledge transfer, enhanced student supervision, increased employment opportunities due to project-based experience, and the ability to export an integrated model of innovation pedagogy to other countries (Kantola & Kettunen, 2012).

2. Literature Review

Performance management (PM) is considered critical to achieving strategic goals in public and private organizations, institutions, and departments, both internationally and in South Africa (Tshukudu, 2014). However, PM systems in public service organizations, including higher education institutions (HEIs), are often underutilized due to political factors, limited resources, institutional differences, organizational capacity constraints, and the nature of public goods and services, all of which complicate their implementation (Melo & Figueiredo, 2019). These challenges may render the deployment of PM systems ineffective or even detrimental to public organizations. Meanwhile, there is a connection between PM and staff satisfaction. According to research, more intensive monitoring, advanced PM systems at HEIs, and productive interactions between stakeholders contribute to employees feeling more satisfied with their duties and performance (Decramer et al., 2013). In their study, Omar et al. (2023) explored the impact of the COVID-19 pandemic on talent development practices at a public HEI in Malaysia. Respondents who were asked about the university's PM practices during the pandemic indicated that it was carried out using a hybrid approach, primarily online with some face-to-face interactions. The PM process was based on structured planning, specifically the annual work target (AWT) (Omar et al., 2023). On the other hand, a different respondent stated that PM was conducted using a key performance indicator (KPI) assessment. KPIs are quantifiable indicators that, as described by Kairuz et al. (2016), can be used to evaluate an organization's performance in relation to its strategic and operational objectives. They highlight key aspects of a university's achievements. The institution's PM system, namely the annual achievement assessment report (Laporan Penilaian Prestasi Tahunan, LNPT), is used to evaluate KPIs annually and is also referred to as the E-Prestasi system.

According to Peng et al. (2019), there is no detailed systematic review of MTS's theoretical and applied research. Their study examines MTS in terms of key technologies, four operational processes, and application areas. The key technologies and their improvements include Mahalanobis distance (MD) and signal-to-noise (SN) ratio. The four operational processes are Mahalanobis space (MS) construction, MS optimization, diagnosis and prognosis, multi-class classification, and integration with other methods. The application areas include industrial production quality management, prognostics and health management, evaluation and decision-making management, and medical applications. Firstly, the potential causes of an abnormal observation were identified based on the Mason-Young-Tracy (MYT) decomposition method of weighted MD (Han et al., 2023). The MD of the repaired specimen ranged from approximately 5 to 20 and was significantly smaller than before the repair, indicating that the repaired part was nearing a healthy state (Watanabe et al., 2023). Furthermore, MD has been extended to the probabilistic linguistic environment, where probabilistic linguistic Hamming-MD (PLHMD) and probabilistic linguistic Euclidean-MD (PLEMD) measures have been defined (Zhang et al., 2023). The integration of the Binary Bitwise Artificial Bee Colony (BitABC) algorithm into the existing Taguchi's T-Method optimization technique has been found to enhance the SN ratio and improve the accuracy of the predicted integrated model (Harudin et al., 2021). Similarly, Ramlie et al. (2020) studied the fusion of a modified swarm intelligence technique called the Modified-Bees Algorithm (mBA) into the MTS optimization procedure, using the SN ratio as its objective function. An anomaly detection technique suitable for monitoring the condition of production equipment was proposed by Ohkubo & Nagata (2020), while Asakura et al. (2020) focused on the operational characteristics of a large-scale vertical transfer unit. Additionally, a classification method based on Taguchi's T-method has been explored for calculations involving small sample sizes (Nishino et al., 2021). MS optimization has been shown to improve scale measurement precision, reduce data collection costs, and speed up computation times. An alternative MD space has been used to classify complex metallic components according to their broadband vibrational spectra, indicating either high or unsatisfactory structural quality (Cheng et al., 2020). According to Sun et al. (2020), MTS optimization aims to identify key quality characteristics leading to anomalies and establish thresholds for anomaly detection. The MTS method enables the analysis of normal and abnormal raw data (Kamil et al., 2021). A multiclass model using Improved MTS (IMTS) has been proposed based on normal observations and MD for agricultural development (Deepa et al., 2020). By constructing multiple MD and Multi-Tree MTS (MTMTS) for multi-classification fault diagnosis of rolling bearings, researchers have been able to effectively assess the severity of rolling bearing faults under different conditions (Zhan et al., 2019). To adapt to increasingly complex data environments and broaden the scope of MTS studies, researchers have integrated MTS with other algorithms. Mei et al. (2021) developed MMTS by incorporating the concept of proper orthogonal decomposition (POD). Additionally, an integrated model combining Binary-tree and MTS (BT-MTS) has been proposed for fault detection in rolling bearings (Peng et al., 2019). MTS has been widely applied in industrial production to identify and optimize key factors. Reséndiz-Flores et al. (2019) combined MTS with binary particle swarm optimization and the gravitational search algorithm (BPSOGSA) to identify critical factors in a practical foam injection application within the automobile sector. MTS has also proven to be an effective method for classifying and optimizing the quality characteristics of mechanical parts (Mohd & Abu, 2020). With ongoing theoretical and practical advancements, MTS has increasingly been applied in prognostics and health management (PHM) for components and systems. Luo et al. (2023) developed a dynamic health status assessment method for power transformers based on MD. Furthermore, an MD-based condition-based maintenance (CBM) scheme has been introduced to detect, identify, and isolate failures in excavator components (Susanto & Kurniati, 2020). MTS has also been frequently utilized in management evaluation and decision-making. Yuan et al. (2020) proposed a comprehensive integrated energy system (IES) evaluation criterion and a new multi-criterion decision-making (MCDM) method by combining an improved fuzzy integral with prospect theory to assess IES scheme performance. In the education sector, the MTS model has been linked to factors such as the teacher-student ratio, the total number of full-time teachers, and the total number of classes, all of which contribute to the risk of school bankruptcy (Fu-Hsiang, 2019). Finally, disease diagnosis and prognosis remain among the primary application areas of MTS. A classification system based on MTS has been used for elbow motion classification based on mechanomyogram (MMG) signals, achieving high classification accuracy (Tochiki et al., 2020). Additionally, MTS has been suggested as a methodology to support healthcare diagnostics, including the rehabilitation of anterior cruciate ligament reconstruction (ACLR) patients (Sakeran et al., 2020). The robustness of the remanufacturing system on pattern recognition using MTS achieved faster decision-making than the existing direct manual inspection (Abu et al., 2013). MTS achieved robust and stable results without considering the full or reduced model (Abu & Jamaludin, 2013). By utilizing the MTS, the critical and non-critical parameters can be identified in the remanufacturing process (Abu et al., 2018). Adoption BitABC provided better performance than traditional MTS (Harudin et al., 2021).

According to Keel et al. (2017), the strengths of TDABC are categorized into several key areas: supporting operational improvement, informing reimbursement policy, accurately capturing the cost of care, managing inherent complexity, and being more efficient and simpler than traditional ABC. TDABC provides data to support the re-engineering of inefficient processes, process optimization, cost reduction, and budget planning in new market scenarios (Chirenda et al., 2021). The combination of Business Process Management (BPM) and TDABC analysis has helped library managers suggest ways to reduce process duration and improve resource utilization (Kissa et al., 2023). TDABC also produces evidence to support recommendations on optimal resource deployment, financing (Defourny et al., 2023), and quality assurance in healthcare services (Vargas et al., 2021). Understanding institution-level variations in cost and utilization is critical to the success of value-based reimbursement programs in spine surgery (Hwang et al., 2021). Furthermore, TDABC serves as a compelling methodology for hospitals to optimize cost-effectiveness independently of reimbursement policies (Carducci et al., 2021). In the education sector, insights from TDABC have helped managers make rational pricing decisions, strategic decisions, improve capacity utilization, reduce waste, and enhance actual resource utilization (Mahmood et al., 2021). In the finance sector, TDABC has been found to allocate costs to audit categories more efficiently than traditional costing methods (Erkek et al., 2022). Additionally, Mohsin et al. (2023) integrated lean production and TDABC to control product quality costs, eliminate waste, and balance cost and product quality. TDABC is also considered less complex for service companies compared to manufacturing firms (Koussaimi et al., 2019). The identification of specific cost drivers through TDABC in the healthcare sector enables targeted interventions to optimize value delivery (Koehler et al.,

2019) and provides a detailed analysis of direct and indirect costs (Tomà et al., 2021). One crucial strength of TDABC as a primary costing system is its greater efficiency compared to existing systems. It enables the comparison of capacities with available resources, leading to optimized strategies and reduced maintenance costs (Durán et al., 2020). TDABC also identifies opportunities to reduce costs and improve clinical efficiency (Dziemianowicz et al., 2021). TDABC is regarded as a solution to the shortcomings of traditional costing methods, which often distort managerial planning and control decisions (Abu et al., 2017). It can identify unused capacity and manufacturing cost losses (Kamil et al., 2019). Finally, TDABC is argued to be simpler than traditional ABC. Zhuang and Chang (2015) demonstrated this by comparing the expected profits of mixed integer programming-ABC (MIP-ABC) and mixed integer programming-TDABC (MIP-TDABC). The expected profit for MIP-ABC was $316,050, whereas for MIP-TDABC, it was higher at $324,295. Additionally, the cost of unused resources for MIP-ABC was significantly higher at $138,950, compared to $34,795 for MIP-TDABC. TDABC is considered less complex than other costing techniques as it requires only two parameters: the unit cost and the time required (Elshaer, 2022).

Consequently, this found found the gap and missing in the solution in the academic performance among related to quality and cost. The integration of the MTS and TDABC in academic performance significantly enhances performance by improving decision-making, resource allocation, and operational efficiency. By integrating these two systems, educational institutions can optimize resource allocation, as TDABC identifies time and cost distribution across academic activities while MTS ensures quality measurement in resource utilization.

3. Methodology

One of the MTS sub-methods for pattern recognition is known as RT method, which may divide objects into two groups. One of it is unit data for samples that are inside the unit space, or reference sample. Secondly, known as signal data for samples that are outside the unit space. Number of samples is acquired from the unit data and there is no restriction on how many numbers of sample required.
The two variables Y_1 and Y_2 may be estimated using prior sensitivity and the standard SN ratio. For Y_1, is applied directly as indicated in Eq. (1), whereas Y_2 must first be transformed as given below in order to assess any dispersion from the ideal circumstances, as shown in Eq. (2).

$$Y_{i1} = \beta_i \quad (1)$$

$$Y_{i2} = \frac{1}{\sqrt{\eta_i}} = \sqrt{\mathrm{V_{ei}}} \quad (2)$$

Eq. (3) and Eq. (4) shows the average of Y_1 and Y_2 for prediction of unit data origin.

$$\bar{Y}_1 = \frac{1}{n}(Y_{11} + Y_{21} + \cdots + Y_{n1}) \quad (3)$$

$$\bar{Y}_2 = \frac{1}{n}(Y_{12} + Y_{22} + \cdots + Y_{n2}) \quad (4)$$

Subsequently, MD is calculated based on Eq. (5) below. The larger the tolerance acquired, which is closer to the maximum scale tolerance, the larger the MD developed.

$$Mahalanobis\ distance, D^2 = \frac{YAY^T}{k} \quad (5)$$

Signal data can contain several elements, but they must have fewer samples than unit data. The remaining samples from unit data were defined as signal data, when the sensitivity, SN ratio, and MD were been calculated using the same Eq. (1)-(5), accordingly.
In order to assess the significance of any variables in relation to the output, T method was utilized. T method, in contrast to RT method, analyzed each sample independently and found no correlation between them. In other words, each grade has unit and signal data available.
From the number of samples in the unit data, the average value for each parameter and the average value of output can be found as shown in Eq. (6) and Eq. (7) below.

$$\bar{x}_j = \frac{1}{n}\left(x_{1j} + x_{2j} + \cdots + x_{nj}\right) \quad (6)$$

$$\bar{y} = m_0 = \frac{1}{n}\left(y_1 + y_2 + \cdots + y_n\right) \quad (7)$$

The average value of the parameters and output for the unit data was then used to normalize the signal data. By removing duplication, normalization aims to increase the flexibility of the data. Normalization was performed using Eq. (8) and Eq. (9).

$$X_{ij} = \acute{x}_{ij} - \bar{x}_j \quad (8)$$

$$M_i = \acute{y}_i - m_0 \quad (9)$$

Proportional coefficient β and SN ratio η were calculated for each parameter is shown in Eq. (10) and Eq. (11) below.

$$Proportional\ Coefficint, \beta_1 = \frac{M_1X_{11} + M_2X_{21} + \cdots + M_nX_{n1}}{r} \quad (10)$$

$$SN\ ratio\ \eta_1 = \begin{cases} \dfrac{\frac{1}{r}(S_{\beta 1} - V_{el})}{V_{el}} \\ 0 \end{cases} \quad (11)$$

$$(when\ S_{\beta 1} > V_{el})(when\ S_{\beta 1} \le V_{el})$$

The estimated accuracy of each parameter is measured by the SN ratio, which is weighted to get an integrated result. As a result, Eq. (12) may be used to determine the integrated estimated value of the signal data.

$$\text{Integrated estimate value}, \widehat{M}_i = \frac{\eta_1 \times \frac{X_{i1}}{\beta_1} + \eta_2 \times \frac{X_{i2}}{\beta_2} + \ldots + \eta_k \times \frac{X_{ik}}{\beta_k}}{\eta_1 + \eta_2 + \cdots + \eta_k} \quad (12)$$

The following Eq. (13) was used to get the integrated estimate SN ratio. Truthfully, the applicability of an orthogonal array should be the basis for the SN ratio of the integrated estimate value.

$$\text{Integrated estimate SN ratio}, \eta = 10 \log \left[\frac{\frac{1}{r}(S_\beta - V_e)}{V_e} \right] \quad (13)$$

The extent to which the integrated estimate SN ratio declines without the parameter was used to assess the relative value of each parameter. A two-level orthogonal array was employed for the assessment. It is possible to compare the SN ratio of the integrated estimate under various circumstances by using an orthogonal array. For instance, assume eight parameters were allocated as indicated in Table 1 below.

Table 1
Orthogonal array L8 and assignment of items

No.	Parameters							Integrated estimate SN ratio (db)
	1	2	3	4	5	7	8	
1	1	1	1	1	1	1	1	η_1
2	1	1	1	1	1	2	2	η_2
…	…	…	…	…	…	…	…	…
8	2	1	2	1	2	1	2	η_8

The flow low of data analysis in MTS as previously described is further summarized and illustrated in Figure 1.

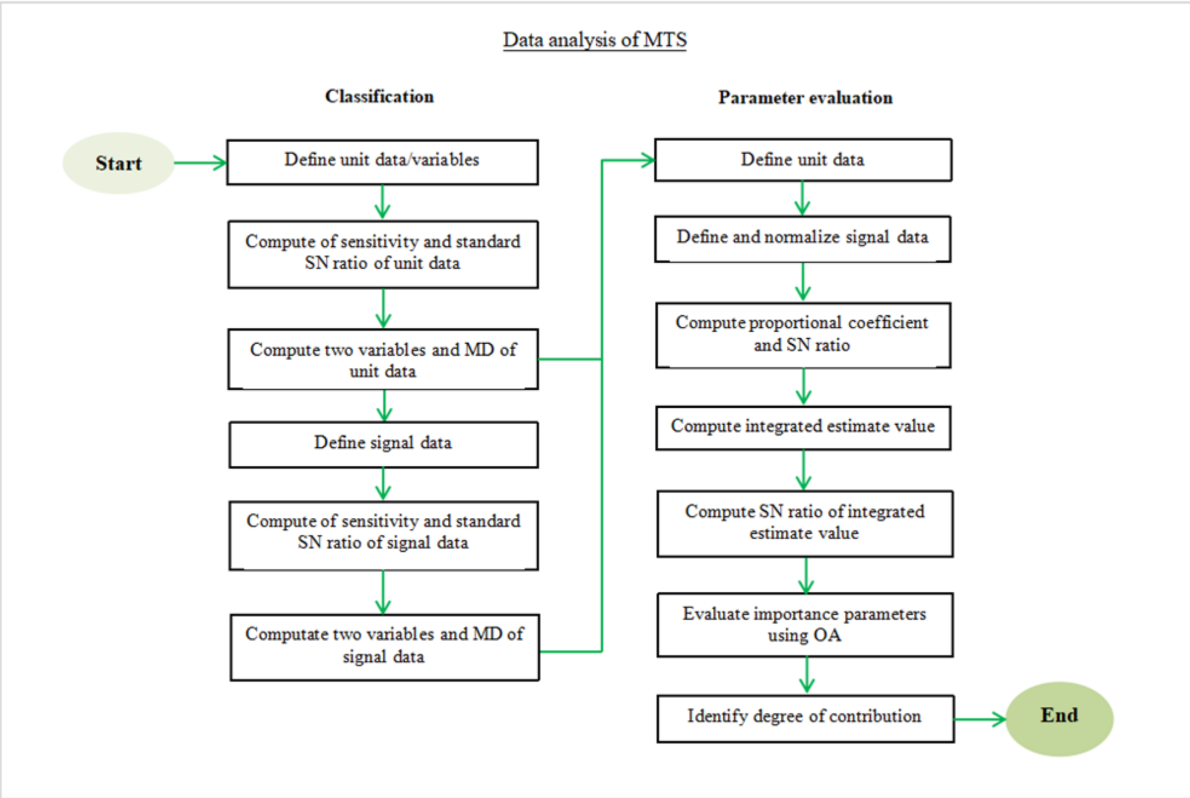

Fig. 1. MTS flowchart

On the other hand, TDABC as a costing method contains four steps. It started with identifying all activity centers, main activities and sub-activities involved to develop a correct flow of process mapping. The volume of the cost driver and the estimated duration of each sub-activity should be identified soon after a thorough process map has been developed for the purpose to generate time equations. These data can be gathered through employee interviews or on-site workplace observation. TDABC time equation is able to incorporate all the time needed to undertake all sub-activities in each activity center within a single mathematical model, as shown in Eq. (14).

$$T_t = \beta_0 + \beta_i X_i \quad (14)$$

Where:
T_t = the time needed to perform an activity (minute).

β_o = the standard time to perform the basic activity (minute).
β_i = the estimated time to perform the incremental activity (minute).
X_i = the quantity of the incremental activity (time).
Next, to calculate the cost of capacity, first of all is by identifying all costs involved in supplying this resource. Furthermore, in order to calculate CCR, the practical capacity which is working period of workers and all costs involved in supplying the resources need to be identified. Resource costs required are labor cost and overheads. The CCR is determined by dividing the expenditures associated with it by the practical capacity it provides, which is often expressed as an hourly or minutely cost. The following Eq. (15) can be used for calculating the CCR (MYR per minute).

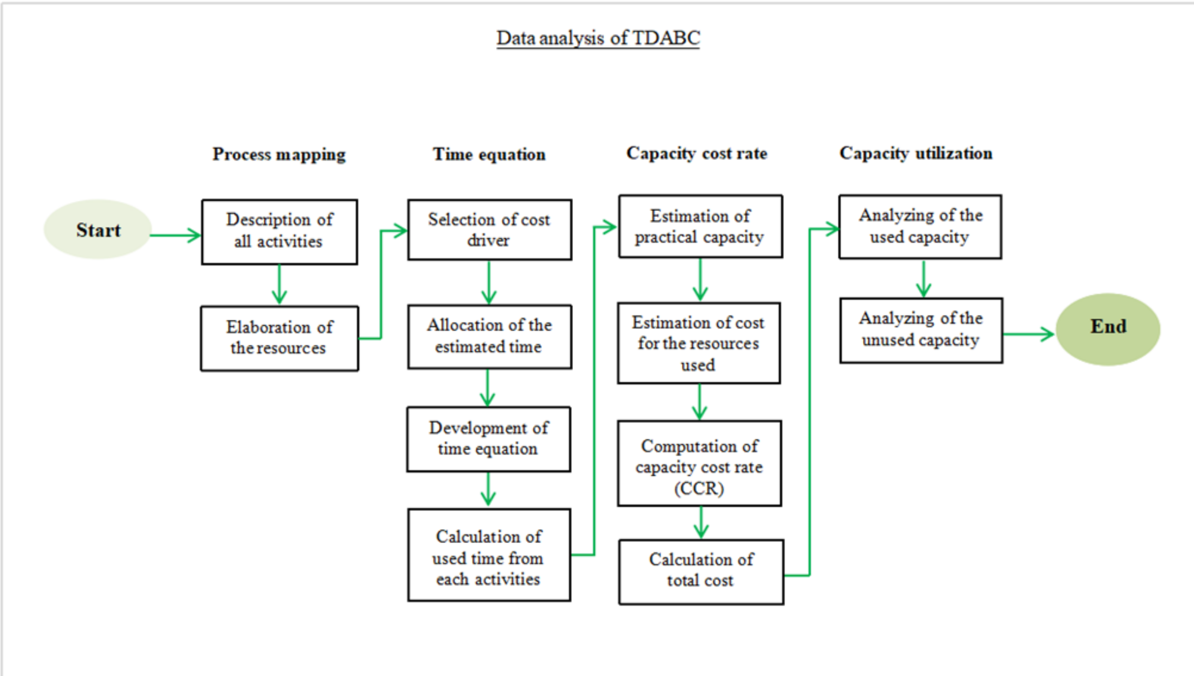

Fig. 2. TDABC flowchart

$$CCR = \frac{Cost\ of\ all\ resources\ supplied}{Practical\ capacity} \qquad (15)$$

The following Eq. (13) was used to get the integrated estimate SN ratio. Truthfully, the applicability of an orthogonal array should be the basis for the SN ratio of the integrated estimate value.
Last but not least is conducting capacity utilization analysis by calculating used capacity and unused capacity which associated to time and cost, respectively. When all of the capacity of time are multiplied by the CCR, both utilization and waste costs can possibly be calculated. Forecasting analysis is essential to determine the optimum utilization of resources and plays an important role in decision making process, such as for increasing the source of manpower and eliminating the unnecessarily process.
The flow of data analysis in TDABC, which consists of steps in determining capacity utilization is illustrated in
Following that, there is a framework of system integration flowchart as shown in Figure 3. Two different methods from each quality and cost elements are been identified. Potential output from quality model is been decided and matched with compatible output from cost element to develop efficient framework.

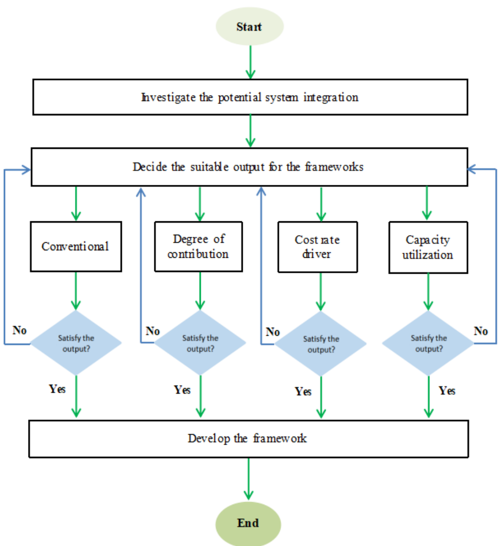

Fig. 2. Framework of system integration flowchart

In this work, the degree of contribution of parameter are been identified from quality model. On the other hand, the related sub-activities involved with those significant parameters will be considered as crucial integration element. The cost of all sub-activities are been identified from cost model. Then, the output from each system integration can be discovered and compared in order to select the best framework. Figure 4 exhibits a system integration flowchart.

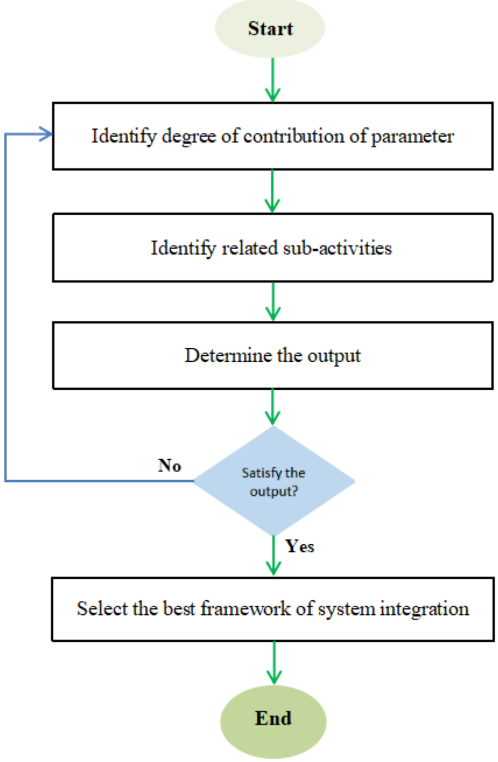

Fig. 3. System integration flowchart

4. Results and Discussions

4.1. Multiple Frameworks of System Integration

The process of combining numerous distinct sub-systems or sub-components into one comprehensive, bigger system so that the sub-systems can work together is known as system integration. In other terms, the system integration synergy enables the primary system to deliver the overall functionality desired by the organization. Cross-functional collaboration between all entities and integration are related (Bokrantz et al., 2020).

Furthermore, comparing the proposed solution to comparable system integrations will help demonstrate why it is superior to the competition. This study uses a traditional system that includes AWT evaluation and MTS in terms of quality. On the contrary hand, this work includes ABC and TDABC in terms of cost. By linking a quality technique with a costing process method, this work also demonstrates the possibility of system integration as shown in Figure 5.

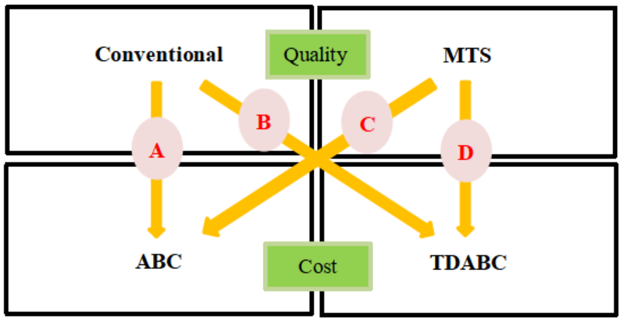

Fig. 4. Potential of system integration

Figure 6 then illustrates one of the possible system integration frameworks between MTS from quality element and TDABC from cost element.

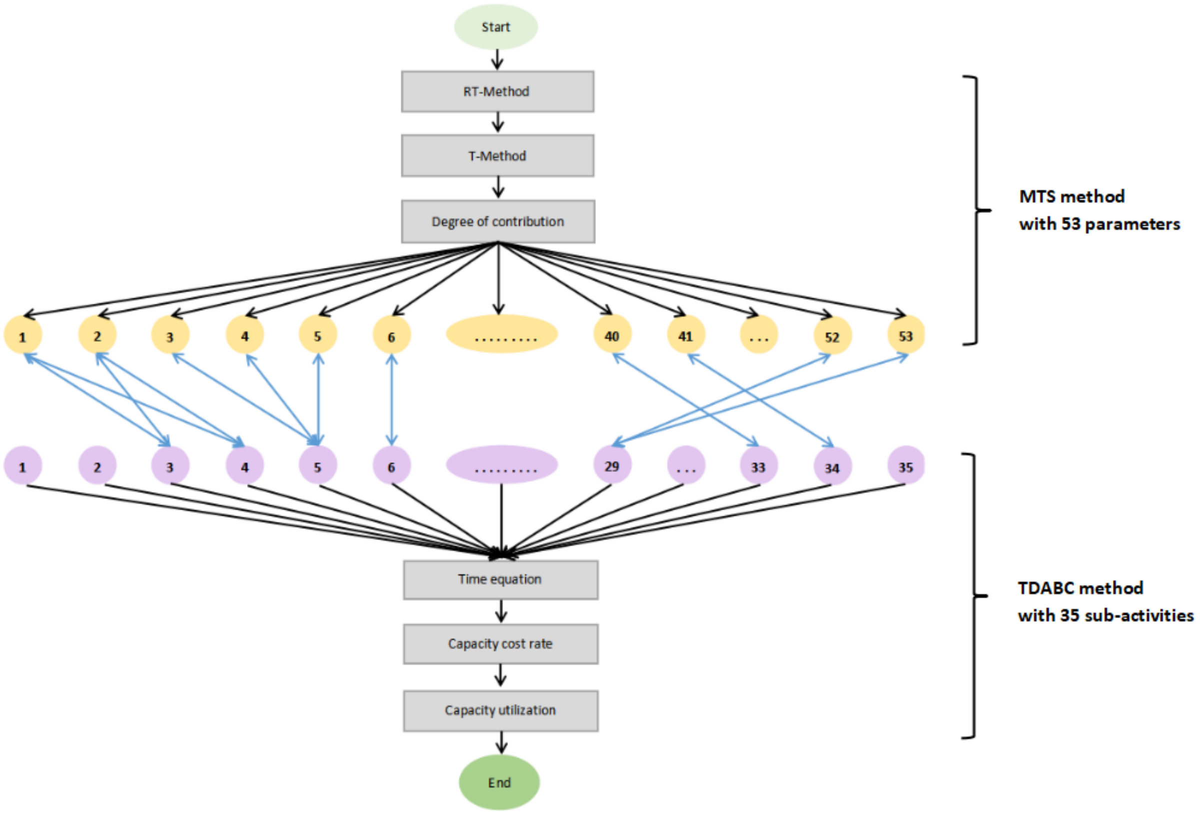

Fig. 5. An example of integration framework

4.1.1. Integration A (Conventional-ABC)

Integration A is the integration between conventional system and ABC system. Figure 7 exhibits the integration which shows the flow of analysis from indicator classification for quality element and resource allocation until final cost determination for cost element.

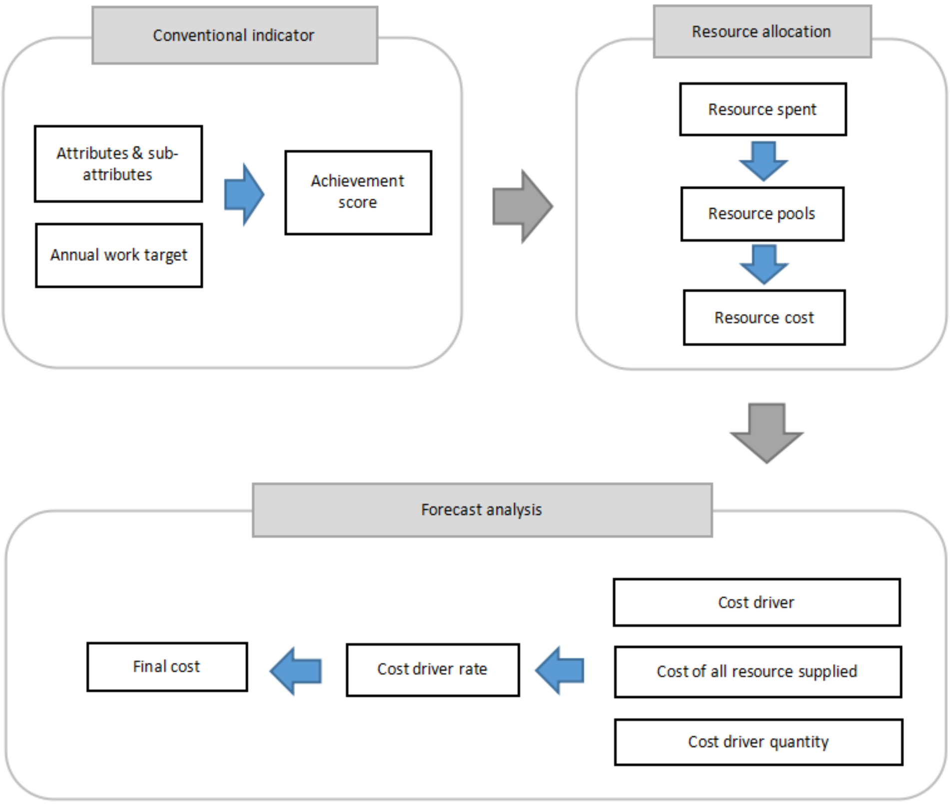

Fig. 6. Conventional and ABC integration

This system integration then been validated by using data from sample 14 of grade DS51/52. The conventional system assumed that all the parameters are equally significant and will substitute into ABC system which emphasized on the resource pool as shown in Table 2. Consequently, the total used cost for sample 14 of grade DS51/52 when using conventional-ABC integration is MYR 22,834.50.

Table 2
Costing structure under integration A

No.	Main activities / Sub-activities	Cost driver	Time allocation (%)	Cost of all resources supplied (MYR)	Cost driver quantity	Cost driver rate (MYR)	Total cost (MYR)
	Teaching and learning						
1.	Innovation	hours/program	2.50	1,756.50	0	1,756.50	0.00
2.	Publication and grant	hours/publication	3.33	2,342.00	0	2,342.00	0.00
3.	Undergrad and postgrad coursework	hours/credit hour	3.33	2,342.00	0	2,342.00	0.00
…..	…..	…..	..…	..…	..…	..…	..…
	Service to community						
33.	CSI	hours/program	6.67	4,684.00	0	4,684.00	0.00
34.	CSR	hours/program	6.67	4,684.00	0	4,684.00	0.00
35.	Yayasan UMPSA or equivalent	hours/program	3.33	2,342.00	0	2,342.00	0.00
	Total		100.00	70,260.00			22,834.50

4.1.2. Integration B (Conventional-TDABC)

Integration B is the integration between conventional system and TDABC system. Figure 8 exhibits the integration which shows the flow of analysis from indicator classification for quality element and time utilization until capacity utilization for cost element.

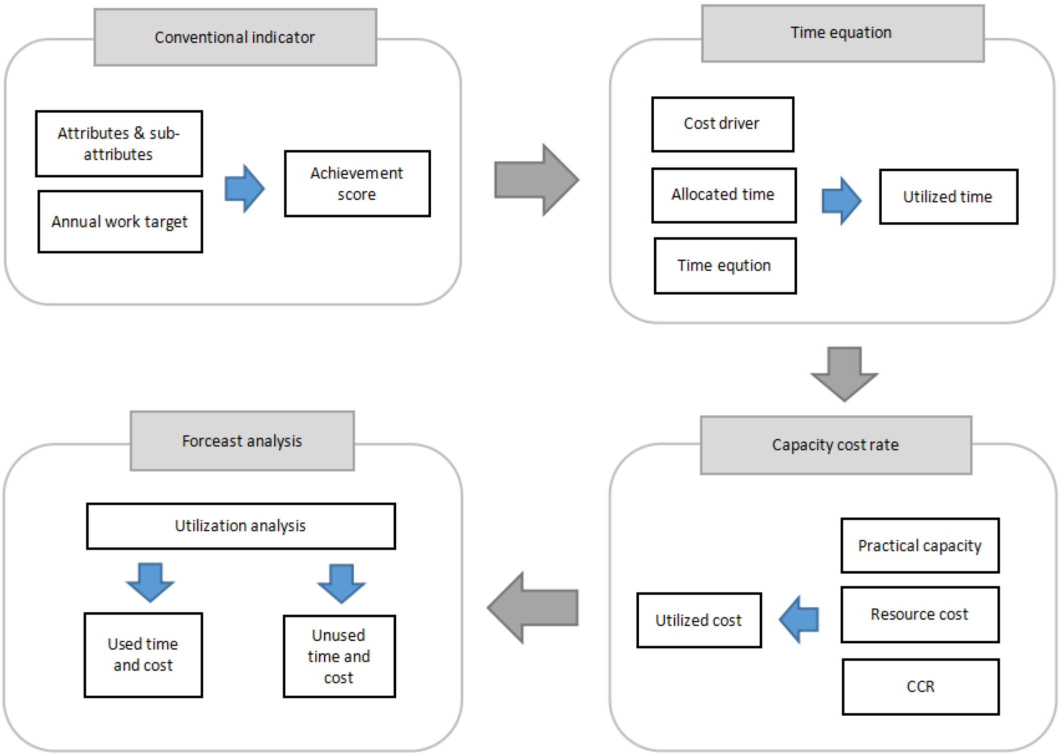

Fig. 7. Conventional and TDABC integration

Nonetheless, this system integration also been validated by using same sample from grade DS51/52. The conventional system assumed that all the parameters are equally significant and will substitute into TDABC system which emphasized on the capacity cost rate and time equation as shown in Table 3. Consequently, the total used cost for sample 14 of grade DS51/52 when using conventional-TDABC integration is MYR 23,856.68.

Table 3
Costing structure under integration B

No.	Main activities / Sub-activities	Practical capacity (hours)	Used time (hours)	Unused time (hours)	Capacity cost rate (MYR/hour)	Used cost (MYR)	Unused cost (MYR)
	Teaching and learning						
1.	Innovation	Nil	0	Nil	Nil	Nil	Nil
2.	Publication and grant	Nil	0	Nil	Nil	Nil	Nil
3.	Undergrad and postgrad coursework	Nil	0	Nil	Nil	Nil	Nil
…..	…..	…..	…..	…..	…..	…..	…..
	Service to community						
33.	CSI	Nil	0	Nil	Nil	Nil	Nil
34.	CSR	Nil	0	Nil	Nil	Nil	Nil
35.	Yayasan UMPSA or equivalent	Nil	0	Nil	Nil	Nil	Nil
	Total	1,920	652	1,268	36.59	23,856.68	46,396.12

4.1.3. Integration C (MTS-ABC)

Integration C is the integration between MTS system and ABC system. Figure 9 exhibits the integration which shows the flow of analysis from parameter classification until degree of contribution for quality element and resource cost allocation until final cost determination for cost element.

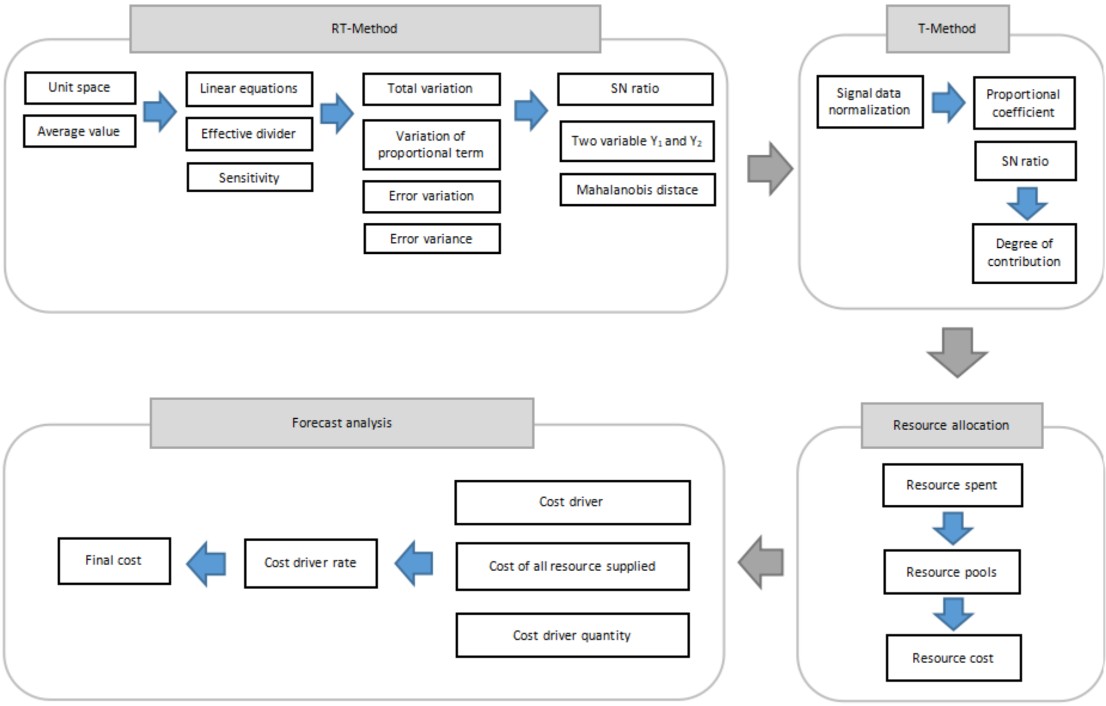

Fig. 8. MTS and ABC integration

Moreover, this system integration also been validated using the same sample. The MTS system proposed that every parameter shall indicates significant influence to certain sub-activities. Parameter 1 will influence to the sub-activity 3. Parameter 3 and 5 will influence to sub-activity 5. Parameter 6, 7, and 8 will influence to sub-activity 6. Parameter 9, 11, 12, and 13 will influence to the workstation sub-activity 8. Parameter 23 will influence to the sub-activity 16. Parameter 27 will influence to the sub-activity 24. Parameter 31 will influence to the sub-activity 25. Parameter 37 will influence to the sub-activity 12. Parameter 41 will influence to the sub-activity 34. Parameter 42 and 44 will influence to the sub-activity 27. Parameter 43 will influence to the sub-activity 27. Parameter 48 and 53 will influence to the sub-activity 29. All those parameters will substitute into ABC system which emphasized on the cost driver as shown in Table 4. Consequently, the new forecast cost for sample 14 of grade DS51/52 after using MTS-ABC integration is MYR 90,635.40.

Table 4
Costing structure under integration C

No.	Main activities / Sub-activities	Cost driver	Time allocation (%)	Cost of all resources supplied (MYR)	Cost driver quantity	Cost driver rate (MYR)	New cost driver quantity	New forecast cost (MYR)
	Teaching and learning							
1.	Innovation	hours/program	2.50	1,756.50	0	1,756.50	0	0.00
2.	Publication and grant	hours/publication	3.33	2,342.00	0	2,342.00	0	0.00
3.	Undergrad and postgrad coursework	hours/credit hour	3.33	2,342.00	0	2,342.00	2	4,684.00
…..	…..	…..	…..	…..	…..	…..	…..	…..
	Service to community							
33.	CSI	hours/program	6.67	4,684.00	0	4,684.00	0	0.00
34.	CSR	hours/program	6.67	4,684.00	0	4,684.00	2	9,368.00
35.	Yayasan UMPSA or equivalent	hours/program	3.33	2,342.00	0	2,342.00	0	0.00
	Total		100.00	70,260.00			36	90,635.40

4.1.4. Integration D (MTS-TDABC)

Integration D is the integration between MTS system and TDABC system. Figure 10 exhibits the integration which shows the flow of analysis from parameter classification until degree of contribution for quality element and time utilization until capacity utilization for cost element.

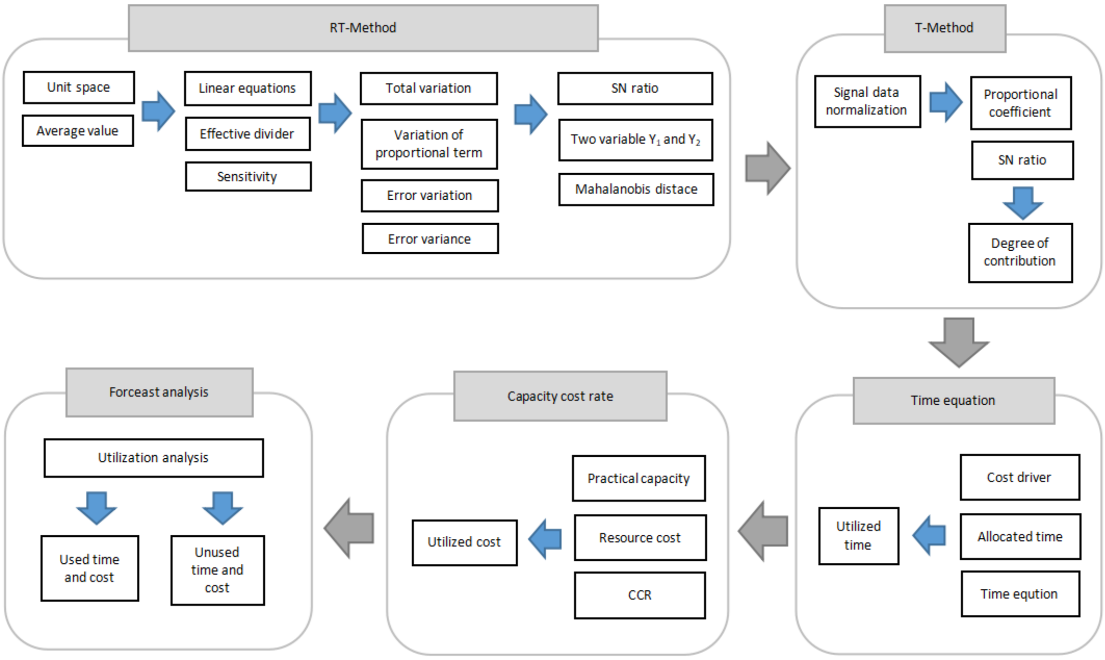

Fig. 9. MTS and TDABC integration

The MTS system proposed that every parameter shall indicates significant influence to certain sub-activities. Parameter 1 will influence to the sub-activity 3. Parameter 3 and 5 will influence to sub-activity 5. Parameter 6, 7, and 8 will influence to sub-activity 6. Parameter 9, 11, 12, and 13 will influence to the workstation sub-activity 8. Parameter 23 will influence to the sub-activity 16. Parameter 27 will influence to the sub-activity 24. Parameter 31 will influence to the sub-activity 25. Parameter 37 will influence to the sub-activity 12. Parameter 41 will influence to the sub-activity 34. Parameter 42 and 44 will influence to the sub-activity 27. Parameter 43 will influence to the sub-activity 27. Parameter 48 and 53 will influence to the sub-activity 29. All those parameters will substitute into TDABC system which emphasized on the time equation and capacity cost driver as shown in Table 5. Consequently, the new total used cost for sample 14 of grade DS51/52 after using MTS-TDABC integration is MYR 77,637.30.

Table 5
Costing structure under integration D

No.	Main activities / Sub-activities	Practical capacity (hours)	Time estimation (hours)	New cost driver quantity	New used time (hours)	New unused time (hours)	Capacity cost rate (MYR/hour)	New used cost (MYR)	New unused cost (MYR)
	Teaching and learning								
1.	Innovation	Nil	0	0	0	Nil	Nil	Nil	Nil
2.	Publication and grant	Nil	120	0	0	Nil	Nil	Nil	Nil
3.	Undergrad and postgrad coursework	Nil	14	2	28	Nil	Nil	Nil	Nil
…..	…..	…..	…..	…..	…..	…..	…..	…..	…..
	Service to community								
33.	CSI	Nil	30	0	0	Nil	Nil	Nil	Nil
34.	CSR	Nil	8	2	16	Nil	Nil	Nil	Nil
35.	Yayasan UMPSA or equivalent	Nil	0	0	0	Nil	Nil	Nil	Nil
	Total	1,920		36	1,900	20	36.59	69,521	731.80

From multiple integrations conducted from this work, all total used cost from each integration have been determined as shown in Table 6. It can be seen that any method incorporates with TDABC method will results in higher used cost compared to ABC method

Table 6
Total used cost through multiple integrations from sample 14 DS51/52

Method	Conventional		MTS	
	ABC	TDABC	ABC	TDABC
Type	Integration A	Integration B	Integration C	Integration D
Total used cost (MYR)	22,834.50	90,834.50	23,856.68	69,521.00

Therefore, this work concludes that integration D is the best integration model compared to others because the total used cost is the nearest to the actual cost of supplied resource which is MYR 70,260. In order to verify that MTS and TDABC have a significant contribution to the final cost, a comparison between types of integration from previous two works, Kamil [52] and Safeiee [53] in manufacturing research have been made as shown in Table 7.

Table 7
Cost through multiple integrations from previous works

Method		Cost per unit (MYR)			
		Conventional		MTS	
		ABC	TDABC	ABC	TDABC
Previous work	Component	Integration A	Integration B	Integration C	Integration D
Safeiee (2022)	Inductor	1.70	1.67	0.80	0.76
Kamil (2021)	Magnetic	2.50	-	-	2.00

The first comparison is between integration A and integration C, where conventional and MTS are compared when ABC has been fixed, in order to get the benefit of MTS. The MTS analyzes the degree of contribution for each parameter which influences an increase or decrease to the final cost, whereas conventional suggests all parameters are equally influential to the final cost. This demonstrates that the cost through integration C is significantly lower than integration A.

The second comparison of integrations A and B, where ABC and TDABC are compared when conventional has been fixed, is done to access the benefit of TDABC. Because the TDABC generates capacity cost rate from the associated cost of capacity provided and time equations with great flexibility, affecting the increment or decrement to the final cost, it demonstrates that the cost through integration B is much lower than integration A. In the meantime, ABC only has cost drivers that are capable of impacting the overall cost. Similar circumstances exist where integration D is less costly than integration C.

To access the benefit of MTS and TDABC, the third comparison is made between integration A and integration D. Integration A is actually the system being used by an electronic company while integration D is the proposed solution or the main work contribution from Kamil, (2021) and Safeiee, (2023) in the production environment. It shows that the cost through integration D is cheaper than integration A because the MTS considers degree of contribution for each parameter which influence to the increment or decrement to the final cost. Moreover, TDABC develops capacity cost rate from the related cost of capacity supplied and time equations with high flexibility which also influence to the increment or decrement to the final cost. This finding also has been supported by the cost per unit for both inductor and magnetic components through integration D is cheaper than integration A.

5. Conclusion

The current study aimed to integrate MTS and TDABC for capacity utilization measurement in an academic faculty. The initial objective was to apply MTS to measure abnormalities based on MD determination and diagnose the degree of contribution of each parameter. Meanwhile, TDABC was the second model utilized to analyze the capacity utilization of each sample. TDABC solutions are sophisticated enough to account for the many nuances that might affect sample costs and incorporate them into the final determinations. Moreover, this study introduces four novel integration frameworks that incorporate both quality and cost elements. The 53 significant parameters, categorized into positive and negative degrees of contribution, are mapped onto 35 sub-activities. Subsequently, the four frameworks—conventional ABC integration, conventional TDABC integration, MTS-ABC integration, and MTS-TDABC integration—are validated to determine the ideal system integration for evaluating academicians' performance. The calculation of total utilized capacity for each sample within the integration models was constructed and later compared. The model that produces a value closest to the actual capacity provided is then selected. This study addresses multiple gaps and, in doing so, makes important contributions. First, it extends the limited research on the integration of quality and cost elements in academic faculties and their impact on the education environment. To the best of the researcher's knowledge and based on searches in peer-reviewed databases, no prior study has empirically explored the ideal framework for integrating quality and cost elements in an academic setting. Existing research on quality and cost has primarily focused on areas such as tuition fee structures and financial management rather than academicians' performance. This work is among the first to consider an integrated framework of quality and cost as a critical mechanism for evaluating academicians' performance. Secondly, the theoretical lens for this study is the MTS model, which supports the proposed framework for integrating quality and cost. The MTS model has been found to be a powerful data mining method that employs MD and Taguchi's robust engineering philosophy to explore and analyze data in a multidimensional system. Based on the MTS model, this study classifies normal and abnormal samples using MD determination and identifies the significant parameters affecting each sample. Meanwhile, the second model, TDABC, is utilized to analyze the capacity utilization of each sample. TDABC solutions bypass the expensive, time-consuming, and subjective activity investigations typically required by traditional costing methods, making them more suitable for institutional cost accounting. Thirdly, this study proposes several newly developed conceptual frameworks, many of which visually depict the anticipated relationships between distinct concepts, constructs, or variables. In other words, the conceptual framework illustrates the researcher's perspective on integrating multiple techniques to connect quality and cost. This contribution advances the evaluation of academicians' performance by providing new insights into incorporating significant parameters with affected sub-activities.

The integration of the MTS and TDABC in academic performance analysis has significant managerial implications, particularly in enhancing decision-making, resource allocation, and performance optimization. MTS helps identify key performance indicators that distinguish high-performing while TDABC provides precise costing of educational activities. By combining these methodologies, institutions can adopt a data-driven approach to maximize academic impact while minimizing costs. Furthermore, system integration supports strategic benchmarking and continuous improvement by providing empirical data on institutional performance. Institutions can compare academic outcomes across departments, faculties, or campuses, implementing best practices based on cost and effectiveness.

In the future, similar models and mechanisms can be applied in different higher education environments, such as evaluating undergraduate students, non-academic staff in faculties, or medical personnel in university health centers. Future analyses should also be tested in contexts with greater accessibility and transparency of information.

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