JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY
E-ISSN: 2636-9575
VOLUME 8, ISSUE 2, SEPT, 2024, 1 – 11
DOI: https://doi.org/10.15282/jmmst.v8i2.10395

RESEARCH ARTICLE

A review on Mahalanobis-Taguchi system and time-driven activity-based costing for production environment

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ABSTRACT - Mahalanobis-Taguchi system (MTS) is a decision-making system that identifies patterns. The fundamental idea of MTS is to select a set of variables and then apply Mahalanobis distance to optimize each of the factors that contribute to the issue. Meanwhile, time-driven activity-based costing (TDABC) is an approach that defined as a costing model that provides the cost of activities based on the amount of time consumed per activity. The current study seeks to address several gaps and presents research motivation with a particular focus on the potential benefits that comes from employing these two approaches individually in a variety of disciplines. The content of this paper generally consists of studies of literature from 2013 to 2023 from the fields of agriculture, industrial, communication, education, health care, hospitality, and finance sectors. To begin, 74 and 140 research publications employing MTS and TDABC, respectively, have been discovered. From the findings, the industrial sector has the greatest proportion of using MTS technique with 60.81% for 45 from overall 74 articles. MTS is widely used in production environment, as it is a powerful method of optimization that revealed the criticality of parameters, thus can reduce the rejected product in a process. Whereas the health care industry has the largest percentage of articles using the TDABC approach in cost accounting systems, with 62.14% for 87 from total 140 articles. TDABC is popularly applied in health care primarily to estimate the cost of clinical procedures and visits in order to inform operational improvement.

ARTICLE HISTORY
Received : 29 Feb 2024
Revised : 7 June 2024
Accepted : 14 June 2024
Published : 30 Sept 2024

KEYWORDS

Capacity utilization
Degree of contribution
MTS
TDABC

1.0 INTRODUCTION

The Mahalanobis-Taguchi system (MTS) is a pattern recognition approach used to categorize and forecast multivariate systems. In 1936, an Indian statistician known as Prasanta Chandra Mahalanobis developed the Mahalanobis distance (MD), which has since been frequently utilized in multivariate anomaly identification by computing the distance between points and distributions. The MTS technique for exploring dimensionality reduction and diagnosis or prediction in multivariate systems has been invented by Genichi Taguchi, a Japanese quality engineer who combined the concept of MD with resilient design theory. Using a particular class of samples, MTS creates a continuous measuring scale as opposed to learning directly from the whole training data set. This allows for the development of a classification model and the resolution of the class imbalance problem. Given its simplicity of use and effectiveness, it has been widely utilized to optimize a variety of multivariate systems, including those for product quality testing, mechanical flaw detection, financial early-warning, medical diagnostics, and other disciplines [1].

MTS is subdivided into four steps, according to Sakeran et al. [2]. Firstly, MD was used to create a measurement scale and calculated for normal data. Secondly, to optimize the system, the MD was computed for the abnormal data, known as Mahalanobis space (MS) validation. Next, Taguchi approach, which incorporated orthogonal arrays (OA) and signal to noise (SN) ratio, was used. Lastly, the significant parameters by optimization or degree of contributions can be identified.

Direct and indirect costs must be considered when calculating the expenses of a product or service. Direct costs are defined in the business lexicon as expenses that are particularly attached to a single product, operation, or cost department. These expenses, also known as variable costs, encompass labour, material, and fuel costs and are established for each production unit but will alter when total output increases or decreases. On the contrary, indirect costs are expenses that cannot be assigned to a specific cost, activity, or object. These expenditures are also known as fixed costs or overhead costs, and include maintenance, security, surveillance, and rentals that are fixed for a certain length of time, such as one month or a year [3].

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Traditional cost accounting (TCA) was predicated on indirect costs to goods, with a concentration on direct labour. This method was created when raw resources and direct labour were the primary variables of production, technology was regarded stable, and the products that were available in the market were restricted [4]. Despite the fact that conventional accounting techniques are simple to use, they are thought to have quite a number of drawbacks. According to Kaplan and Bruns [5,] Activity-based costing (ABC) is a costing method that is sometimes referred to as operational activity-based management. ABC isolates indirect expenses and assigns them in order to reduce costs and increase asset utilization depending on activity drivers.

Since people construct their ABC models in various ways, the ABC application has its own problems [6]. These difficulties arise when larger businesses, who require more resources to complete this task, seek to continually use ABC. As a result, the expected cost-driver rates of ABC often outnumber the actual capacity utilization. Following that, Kaplan and Anderson [6] proposed a more simplified approach known as Time-driven activity-based costing (TDABC). TDABC supports companies in estimating the cost of each operation, product, or consumer through the utilization of time as an activity cost driver and the number of times an activity takes place. TDABC is comprised of four key components. The flow is divided into process mapping, time equation development, capacity cost rate establishment and forecast analysis [7].

2.0 APPLICATION AREA

2.1 Mahalanobis-Taguchi System

Reviews of the scientific literature comprised of 74 research publications published between 2013 and 2023 and using MTS as a classification and parameter evaluation technique were studied. The distribution was then subdivided into seven distinct sectors. Agriculture and industry are product-operating industries, whereas communication, education, health care, hospitality, and finance are service-operating sectors. The use of the MTS model across seven distinct industries is depicted in Figure 1.

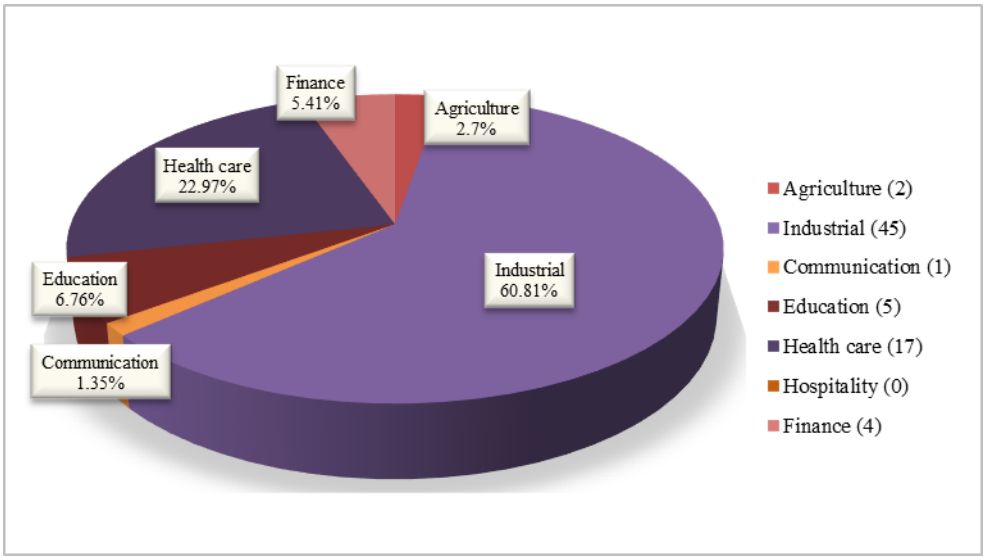

Figure 1. Total of MTS articles

The industrial sector has the greatest proportion of using MTS technique with 60.81% for 45 articles. It was followed by the health care sector (22.97% for 17 articles), education sector (6.76% for 5 articles), finance sector (5.41% for 4 articles), agricultural sector (2.7% for 2 articles), and communication sector (1.35% for 1 article). Meanwhile, no articles were discovered in the hospitality industry.

2.2 Time-Driven Activity-Based Costing

Literature reviews were conducted on a total of 140 research publications published between 2013 and 2023 that used TDABC as their cost accounting system. Figure 2 depicts the application of the TDABC approach in seven different fields.

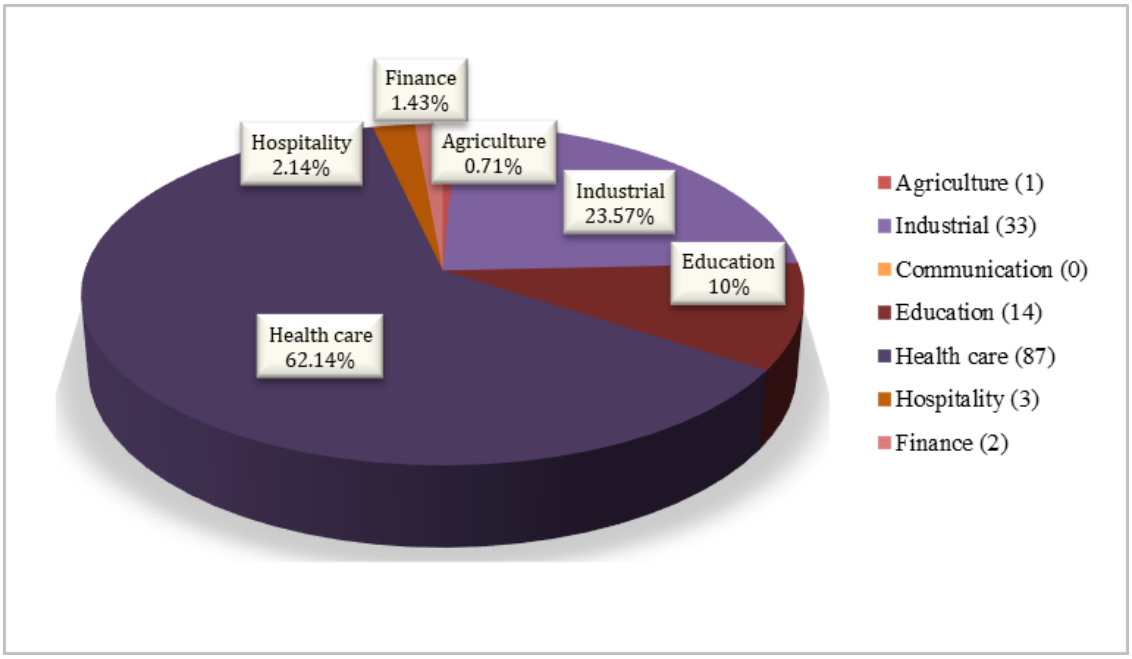

Figure 2. Total of TDABC articles

The health care industry has the largest percentage of articles using the TDABC approach in cost accounting systems, with 62.14% for 87 articles. It was followed by the industrial sector (23.57% for 33 articles), the education sector (10% for 14 articles), the hospitality sector (2.14% for 3 articles), the finance sector (1.43% for 2 articles), and the agricultural sector (0.71% for 1 article). At the same time, no percentage has been gained in the communication sector because no article has been found.

3.0 RESEARCH MOTIVATION

As there has been relatively limited work done by previous researchers, this study motivation has conducted an in-depth analysis of a literature review in the adoption of MTS and TDABC methodologies in many different fields. A pie chart that displays the overall number of journal articles for the two approaches used in this work serves as the foundation for the flow of research motivation. With 65.4% of 140 articles, TDABC has the greatest percentage. MTS is next with 34.6% of 74 items. There are 214 papers in total that were retrieved from open access sites reviewed in this literature study.

Following that, the flow is further divided into article papers that demonstrate the dispersion of MTS and TDABC systems in product and service operations. Service operation for MTS has a smaller percentage (36.49% from 27 research articles), whereas product operation has a higher rate (63.51% from 47 research articles). TDABC, on the other hand, has a much higher percentage of 75.71% from 106 research articles for service operation, compared to 24.29% from 34 research articles for product operation.

After then, the distribution was further divided into seven distinct sectors. Agriculture and industry are product-operating industries, whereas communication, education, health care, hospitality, and finance are service-operating sectors. In terms of MTS percentage, the industrial sector has the largest proportion (60.81% for 45 of 74 articles). However, there is no work found in the hospitality sector. Aside from that, the health care sector has the largest rate of using TDABC technique in cost accounting system compared to the other six sectors, with 62.14%, which is 87 from 140 research articles. In contrast, no research work has been found in the field of communications.

In the end, two Venn diagrams are created to illustrate the relationships between the chosen criteria in the methods and the total articles in the education sector, accordingly. Only one critical study from the education sector has similarities to this approach, according to MTS's overlapping centre. Nonetheless, the critical study in TDABC has five case examples. Figure 3 gives a further summary of the entire research purpose.

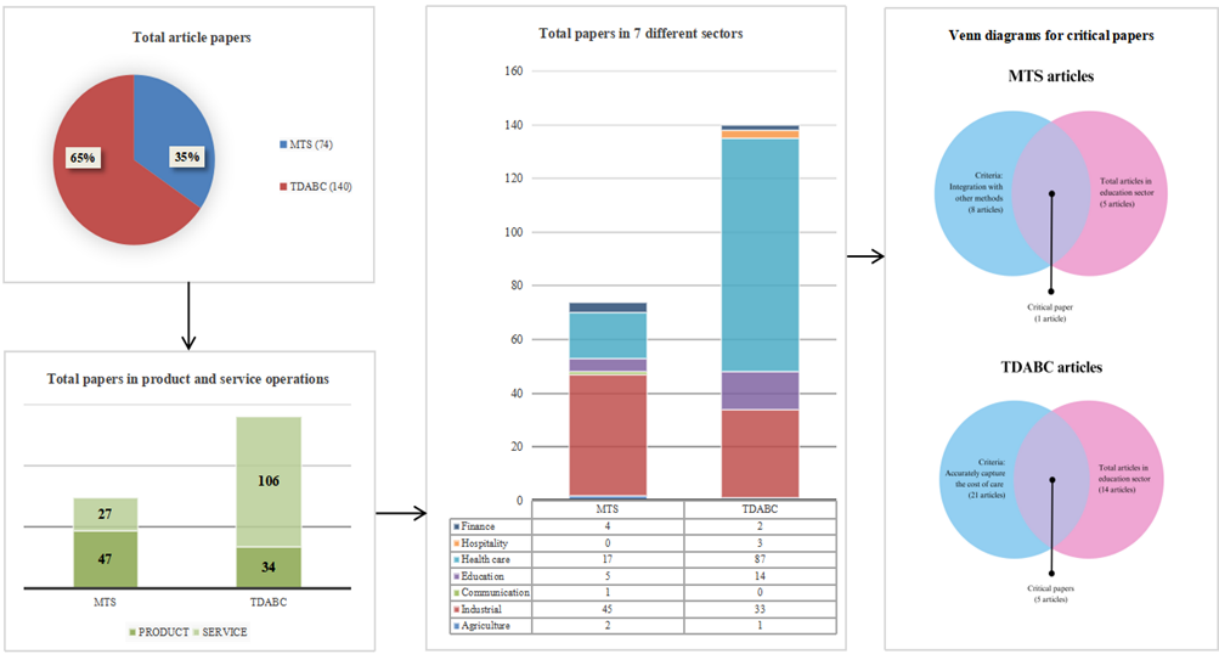

Figure 2. Research Motivation

3.1 Related Article for MTS

There is no a comprehensive systematic review of MTS research that addresses both theoretical and practical research, claimed Peng and colleagues [8]. Their research examines MTS from the standpoint of key technologies, four operational processes, as well as application areas. The key technologies that have been improved are MD and SN ratio. The four operation processes namely, MS construction, MS optimization, diagnosis and prognosis, multi-class classification, and integration with other methods. The application areas are industrial production quality management, prognostic and health management, evaluation and decision-making management, and medical applications. According to Peng and colleagues [8], there are 74 research publications from 2013 to 2023 that comprise 11 criteria obtained from theoretical and applied MTS research. Following that, the authors of those works were further identified based on the criteria, as summarized in Table 1.

Table 1. MTS Application under 11 criteria

No	Criteria	Author (year)
1	MD and its improvement	Zhang et al, (2023); Watanabe et al. (2023); Han et al. (2023); Saad et al. (2021); Xiao et al. (2020); Deraemaeker and Worden (2018); Gao et al. (2017); Govatati et al. (2015); Hadighi et al. (2013)
2	SN ratio and its improvement	Harudin et al. (2021); Ramlie et al. (2020); Zhuang et al. (2019); Snyder (2018)
3	MS construction	Ohkubo et al. (2021); Nishino et al. (2021); Asakura et al. (2020); Wang and Wu (2019)
4	MS optimisation	Cheng et al. (2020)
5	Diagnosis and prognosis depend on threshold	Sun et al. (2023); Kamil et al. (2021); Ramlie et al. (2021); Habib et al. (2020); Azmi et al. (2019); Chen and Chang (2019); Peng et al. (2018); Uemura et al. (2018); Wang et al. (2018); El-Banna (2017); Sikder et al. (2017)
6	Multi-class classification	Deepa et al. (2020); Wang et al. (2019); Zhan et al. (2019); Wang et al. (2018)
7	Medical applications	Tochiki et al. (2020); Sakeran et al. (2020); Sakeran et al. (2019); Muhamad et al. (2018); Haldar et al. (2017); Buenviaje et al. (2016)
8	Integration with other methods	Mao et al. (2020); Peng, Cheng, and Yao (2019); Peng, Zheng, and Liu (2019); Gu et al. (2019); Abu et al. (2018); Muhamad et al. (2018); Ordikhani and Habibi (2018); Muhamad et al. (2017); Res´endiz-Flores and L´opez-Quintero (2017)

9	Industrial production quality management	Reséndiz-Flores et al. (2020); Safeiee et al. (2020); Reyes-Carlos et al. (2018); Fukuda (2017); Peng et al. (2017); Ma et al. (2016)
10	Prognostics and health management (PHM)	Luo et al. (2023); Zhao et al. (2021); Susanto and Kurniati (2020); Han et al. (2020); Wang et al. (2019); Dong (2020), Lim et al. (2019); Huh et al. (2018); Souza (2018); Rizal et al. (2017)
11	Evaluation and decision-making management	Yuan et al. (2020); Kuo (2019); Kamil et al. (2020); Abu et al. (2018); Abu et al. (2016)

As shown in the preceding Table 1, one of the criteria, integration with other types of methods, has been selected as the element to construct the overall research motivation. With regard to the findings of the researcher, there are nine works in several different fields that comprised the specified criteria in their literature investigations.

To adapt to a more demanding data environment and broaden the MTS study area, several researchers merged MTS with additional algorithms. Mao et al. [9] built a modified MTS using the Proper Orthogonal Decomposition (POD) concept. In the meanwhile, a publication suggested an integrated model BT-MTS to identify rolling bearing defects by combining Binary-tree and MTS [10]. With the help of the Chaotic Quantum Particle Swarm Optimization (CQPSO) method, a multi-objective dimensionality reduction model based on the MD of Gram-Schmidt orthogonalization, and classification threshold is suggested [11]. By incorporating the chaotic mapping and binary particle swarm optimization algorithms, a more effective version of MTS-Chaotic Binary Particle Swarm Optimization (MTS-CBPSO) is generated [12]. The growth of the remanufacturing industry in Malaysia is significantly impacted by the integration of MTS and ABC [13]. The development of Random Binary Search (RBS) algorithm-based feature selection has aided MTS in resolving credit issues [14]. By integrating the concepts of MD and integer programming, Ordikhani and Habibi [15] established a novel technique for choosing significant variables. Furthermore, MTS and Kanri Distance Calculator (KDC) are ideal solutions for assessment since they serve as a method for selecting and deciding on relevant criteria [16]. The MTS-Gompertz Binary Particle Swarm Optimization (MTS-GBPSO) method offers the best detection of impact factors during the welding process of the mechanism for car seats [17].

Table 2. Published Works with the Criteria of Integration with other Method

No	Author (year)	Application	Integration Method		Number of Variable	Recognition Accuracy (%)
			MTS	Other		
1	Mao et al. (2020) [9]	Colonoscopy video information of gastrointestinal lesions.	MTS	Proper Orthogonal Decomposition (POD)	9	92.31
2	Peng, Cheng, and Yao [10]	Rolling bearing fault.	MTS	Binary-tree (BT)	4	96.67
3	Peng, Zheng, and Liu (2019) [11]	The steel plate fault data set.	MT-Gram-Schmidt system (MTGS)	Chaotic Quantum Particle Swarm Optimization (CQPSO)	25	80.23
4	Gu et al. (2019) [12]	Companies in financial distress.	MTS	Chaotic Binary Particle Swarm Optimization (CBPSO)	5	90.90
5	Muhamad et al. (2018) [14]	Credit scoring in finance sector.	MTS	Random Binary Search (RBS)	15	NIL
6	Abu et al. (2018) [13]	Crankpin of crankshafts in remanufacturing industry.	MTS	ABC	6	NIL

7	Ordikhani and Habibi (2018) [15]	Bad credit clients of a private bank.	MTS	Integer programming	10	84
8	Muhamad et al. (2017) [16]	MBA programme-based.	MTS	Kanri Distance Calculator (KDC)	7	91.67
9	Res´endiz-Flores and L´opez-Quintero (2017) [17]	Welding process for automobile seats mechanism.	MTS	Gompertz Binary Particle Swarm Optimization (GBPSO)	18	NIL

There are nine research publications emphasis MTS as a system that can be integrated with different methods in their literature investigations, as was previously addressed. The outcomes on the number of variables and recognition accuracy were then stated out and briefly summarized, as seen in Table 2.

3.2 Related Article for TDABC

The advantages of TDABC, according to Keel et al. [18], were broken down into supporting operational improvement, informing reimbursement policy, properly capturing the cost of care, managing the inherent complexity, being more effective, and simple than standard ABC. In order to discuss related articles from earlier works published from 2013 to 2023, this study employed similar criteria that were comparable to those. There are 140 research publications from 2013 to 2023 that comprise six criteria from the strengths of TDABC as claimed by Keel et al. [18]. Next, the authors of those works were further identified based on the criteria, as presented in Table 3.

Table 3. TDABC Application under Six Criteria

No	Criteria	Author (year)
1	Support operational improvement	Defourny et al. (2023); Kissa et al. (2023); Alves et al. (2021); Chirenda et al. (2021); Fang et al. (2021); Koolmees et al. (2021); Oraby (2021); Adıgüzel and Floros (2020); Blaschke et al. (2020); Bodar et al. (2020); Scott et al. (2020); Shankar et al. (2020); Vedernikova et al. (2020); Zamrud et al. (2020); Allin et al. (2019); Bobade et al. (2019); Ganorkar et al. (2019); Odhiambo et al. (2019); Ruhumuriza et al. (2018); Andreasen et al. (2017); Yu et al. (2017); Akhavan et al. (2016); Alaoui and Lindefors (2016); McBain et al. (2016); Siguenza-Guzman et al. (2016); Simsek and Vieira (2016); Thaker et al. (2016); Chen et al. (2015); Merguerian et al. (2015); Mwaikambo et al. (2015); Waters (2015); Campanale et al. (2014); Hoozee and Hansen (2014); Andrawis et al. (2013); French et al. (2013)
2	Inform reimbursement policy	Hwang et al. (2023); Carducci et al. (2021); Gonzalez et al. (2020); Devji et al. (2016); Tan et al. (2016); Bauer-Nilsen et al. (2018); Noain et al. (2017); Lievens et al. (2015)
3	Accurately capture the cost of care	Mahmood and Sabir (2023); Erkek et al. (2022); Mohsin et al. (2021); Dubron et al. (2021); Karabachev et al. (2021); Kamil et al. (2020); Zubek (2020); Andalya and Lesetedi (2019); Park et al. (2019); Kamil et al. (2019); Ostadi et al. (2019); Goense et al. (2017); Hamid et al. (2017); Helmers et al. (2017); French et al. (2016); Govaert et al. (2016); Yun et al. (2016); McLaughlin et al. (2014); Ozyurek and Dinc (2014); Siguenza-Guzman, den Abbeele, and Cattrysse (2014); Siguenza-Guzman et al. (2014)
4	Manage the complexity inherent	Toma et al. (2021); Cidav et al. (2020a); Zamrud et al. (2020); Abdelbar et al. (2019); Kissa et al. (2019); Koehler et al. (2019); Leigh et al. (2019); McClintock et al. (2019); Heaton et al. (2018); Martin et al. (2018); Anzai et al. (2017); Barros et al. (2017); Dyk et al. (2017); Haas and Kaplan (2017); Kaplan and Haas (2017); Linden et al. (2017); Afonso and Santana (2016); Laviana et al. (2016); Schutzer et al. (2016); Yu et al. (2016); Erhun et al. (2015); Chiarini (2014)

5	More efficient	Dziemianowicz et al. (2021); Kukreja et al. (2021); Adiguzel and Floros (2020); Cidav et al. (2020b); Duran et al. (2020); Keel et al. (2020); Nabi et al. (2020); Pezzi et al. (2020); Rakotondrajoa et al. (2020); Safeiee et al. (2020); Amiri and Khmidi (2019); Basto et al. (2019); Crocker-Buque et al. (2019); Etges et al. (2019); French et al. (2019); Gaitonde et al. (2019); Khan et al. (2019); Reveco et al. (2019); Afonso et al. (2018); Azar et al. (2017); Gonzalez et al. (2017); Isaacson et al. (2017); Ridderstråle (2017); Santana et al. (2017); Wouters and Stecher (2017); Ozyürek and Ulutürk (2016); Seiringer and Bauer (2016); Sharan et al. (2016); Soufhwee et al. (2016); Deen et al. (2015); Grant (2015); Kaplan et al. (2015); Kont (2015a); Kont (2015b); Pongwasit and Chompu-Inwai (2015); Adeoti and Valverde (2014); Askarany and Franklin-Smith (2014); Basuki and Riediansyaf (2014); Chang and Zhuang (2014); Mortaji et al. (2013); Sarokolaei et al. (2013)
6	Simple than traditional ABC	Elshaer (2020); Sundewi et al. (2019); Ardiansyah et al. (2017); Zhuang and Chang (2017); Crott et al. (2016); Tsai et al. (2016); Grego´rio et al. (2016); Bagherpour et al. (2013); Yilmaz et al. (2013)

As seen in the preceding Table 3, one of the criteria that correctly captures the cost of care was selected as the element to build the overall study motivation. In line with the findings of the researchers, there are 21 articles in various sectors that comprised the specified criteria in their literature investigations.

One of the benefits of TDABC deployment is the ability to accurately capture the cost of care. Managers in the education sector were assisted by information made available by TDABC in finding a venue for making logical price decisions, strategic decisions, capacity utilization reducing waste, and actual resource utilization [19, 25]. TDABC expenses related to all audit categories in the banking sector are less extensive than traditional approach [20]. Lean manufacturing and TDABC were combined by Mohsin et al. [21] to reduce production waste and regulate the cost of product quality while maintaining a high standard of quality. TDABC evaluates and understands the variability in childbirth costs and their related factors across the whole care cycle in the health care sector [22]. TDABC also evaluates the expenses of intraoperative parathyroid hormone (ioPTH) testing, which incorporates physician and staff time and resource consumption [23]. Furthermore, the capacity utilization of TDABC analysis displays the used and unused capacities of time and cost for all workstations that participate in the production of magnetic components [24, 28]. Managers created a framework for various pricing case strategies using TDABC [26]. TDABC is also a practical method for lowering the expenses of marketing resources, customer profitability, and pricing discrimination for customer groups [27]. Ostadi and associates [29] discovered that the FL-TDABC model accurately estimates costs in unpredictable settings by combining Fuzzy Logic and TDABC. The expenditures associated with each element of a patient's hospitalization were examined using TDABC, according to Goense et al. [30] and Govaert et al. [34]. Furthermore, TDABC and corresponding sensitivity analysis revealed a cost savings threshold of $863 for patient-specific instrumentation (PSI) pricing, with PSI being much less costly than standard referencing (SR) in the total ankle replacements (TARs) research [31]. When the TDABC was implemented, the real cost of anaesthesia-administered sedation in practice was only 9% to 24% higher [32]. TDABC assisted in the design of less expensive treatment [33, 35] and offered physicians with precise and effective procedures [36]. In addition, Ozyurek and Dinc [37] considered TDABC to be a reliable way of calculating product prices. The TDABC installation provided library management with critical information about cataloging, lending, and returning operating costs, as well as performance metrics, and drove resource allocation and process enhancements [38, 39].

Table 4. Published Works with the Criteria Accurately Capture the Cost of Care

No	Author (year)	Application	Capacity Utilization			
			Used Time (hours)	Unused Time (hours)	Used Cost	Unused Cost
1	Mahmood and Sabir (2023) [19]	Correlations between TDABC and achieving competitive advantage at private universities.	NIL	NIL	NIL	NIL
2	Erkek et al. (2022) [20]	Internal audit department of a private bank.	586,008	72,840	TL 1,174,429	TL 126,945
3	Mohsin et al. (2021) [21]	Product mix decision in battery industry.	36,960	NIL	IQD 1,579,297,200	NIL
4	Dubron et al. (2021) [22]	Childbirth cost at the maternity department.	203,596.53	NIL	EUR 390,859.26	NIL

5	Karabachev et al. (2021) [23]	Intraoperative parathyroid hormone (ioPTH) testing for primary hyperparathyrodism.	1.53 ± 0.47	NIL	$900.93 ± 261.49	NIL
6	Kamil et al. (2020) [24]	The manufacturing cost of magnetic component.	21,000	14,820	NIL	MYR 2,967,504.12
7	Zubek (2020) [25]	The role of management information in the educational system.	NIL	268,280	NIL	PLN 27,675,786
8	Andalya and Lesetedi (2019) [26]	Financial planning in a university.	1,080	NIL	BWP 7,530	NIL
9	Park et al. (2019) [27]	Marketing decisions in industrial service.	1,377.5	122.5	USD 209,750	USD 12,250
10	Kamil et al. (2019) [28]	Unused capacity assessment for magnetic components.	736,465.76	650,105.76	NIL	MYR 175,038,987.20
11	Ostadi et al. (2019) [29]	Hospital services costing.	11,511.13	NIL	IRR 3,942,997,716	IRR 103,543,567
12	Goense et al. (2017) [30]	Esophagectomy for cancer costing system.	2,160	NIL	EUR 59,167 ± 42,615	NIL
13	Hamid et al. (2017) [31]	Total ankle replacements (TAR) in health care service.	0.63	NIL	USD 863	NIL
14	Helmers et al. (2017) [32]	Gastrointestinal endoscopic procedures.	2.67	NIL	USD 711.99	NIL
15	French et al. (2016) [33]	Anesthesia care costs for outpatient oncology surgery.	2.85	NIL	NIL	NIL
16	Govaert et al. (2016) [34]	Colorectal cancer surgery in health care service.	NIL	NIL	EUR 13,145	NIL
17	Yun et al. (2016) [35]	Emergency medicine for patients with chest pressure and psychosis due to drug overdose.	15.22	NIL	USD 414.33	NIL
18	McLaughlin et al. (2014) [36]	A driver for provider engagement in costing activities and redesign initiatives.	6.36	NIL	USD 838.88	NIL
19	Ozyurek and Dinc (2014) [37]	Medical device manufacturer company.	18,739.67	483	TL 54.161,57	NIL
20	Siguenza-Guzman, den Abbeele, and Cattrysse (2014) [38]	Cataloguing processes in a campus library.	0.33 (average time)	NIL	EUR 17.51 (cost per minute)	NIL
21	Siguenza-Guzman et al. (2014) [39]	Lending and returning processes in the circulation department.	0.0058 (average time)	NIL	EUR 0.30 (cost per minute)	NIL

According to the earlier discussion, there are 21 research publications that highlight TDABC as a costing method that accurately captures the cost of care in their literature reviews. Table 4 lists and summarizes their findings on capacity utilization.

4.0 CONCLUSION

This study provides knowledge into several MTS and TDABC ideas from the standpoints of global objectives and primary causes of action in agricultural, industrial, communication, education, health care, hospitality, and finance. From the findings, the industrial sector has the greatest proportion of using MTS technique with 60.81% for 45 from overall 74 articles. MTS is widely used in production environments, as it is a powerful method of optimization that reveals the criticality of parameters, thus can reduce the rejected product in a process. Whereas the health care industry has the largest percentage of articles using the TDABC approach in cost accounting systems, with 62.14% for 87 from total 140 articles. TDABC is popularly applied in health care primarily to estimate the cost of clinical procedures and visits in order to inform operational improvement.

5.0 ACKNOWLEDGEMENTS

This research was fully supported by PGRS220364 and the authors fully acknowledged Universiti Malaysia Pahang Al-Sultan Abdullah for the approved fund which makes this research viable and effective.

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