sciendo

Using Fuzzy TOPSIS and Balanced Scorecard for Kaizen Evaluation

Ola I.S. El Dardery
School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, Alexandria, Egypt
Ismail Gomaa
School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, and Faculty of Commerce, Alexandria University, Alexandria, Egypt
Adel R. M. Rayan
School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, Alexandria, Egypt
Frendy
Graduate School of Management, Business School, NUCB, Nagoya, Aichi, Japan
Ghada El Khayat
Faculty of Commerce, Alexandria University, Alexandria, Egypt
Sara H. Sabry
School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, Alexandria, Egypt

Abstract

Background: Kaizen is a very important continuous improvement technique; however, measuring kaizen results/benefits have not been clearly and comprehensively addressed by the literature. **Objectives:** This paper aims to propose a kaizen measuring system by integrating a Balanced Scorecard (BSC) and a Fuzzy Technique for Order Performance by Similarity to Ideal Solution (Fuzzy TOPSIS). **Methods/Approach:** Three research instruments were distributed to kaizen experts to allocate kaizen benefits into the four BSC perspectives. The best measures of kaizen benefits were determined by employing the Fuzzy TOPSIS technique. **Results:** The results present a kaizen performance evaluation system where the benefits were allocated into the four BSC perspectives, and the best measure for each kaizen benefit was chosen using fuzzy TOPSIS. **Conclusions:** The research contributes to the literature by proposing a kaizen measurement system that will pair each benefit of using kaizen with BSC perspectives and measures, thus expanding the advantages of adopting kaizen to any sector or industry.

Keywords: Balanced Scorecard, Continuous improvement, Evaluation, Fuzzy TOPSIS, Kaizen, Performance measurement.
JEL classification: Q56, M41, H83
Paper type: Research article

Received: 18 Aug 2022
Accepted: 11 Dec 2022

Citation: El Dardery, O.I.S., Gomaa, I., Rayan, A.R.M., Frendy, El Khayat & G., Sabry, S.H. (2023). Using Fuzzy TOPSIS and Balanced Scorecard for Kaizen Evaluation. Business Systems Research, 14(1), 112-130.
DOI: https://doi.org/10.2478/bsrj-2023-0006

Introduction

Organizations have been competing to achieve superior performance. They are pressured to improve their performance and reduce their costs. Thus, the need for continuous improvement in every aspect of the operation is becoming more relevant.

The continuous improvement cycle includes both large improvements—known as innovation— and small improvements, commonly known as kaizen, or as some refer to, "little innovations" (Moore, 2007). Kaizen is a Japanese philosophy of encouraging all organizational levels to implement small improvements continuously to increase the efficiency, effectiveness, and adaptability of the operational process (Imai, 1986; Kumar & Pandey, 2013).

Several studies have attempted to measure innovation and create a benchmark for industries to follow (Hájek et al., 2018). However, when it comes to kaizen, only a few studies have attempted to measure it (Doolen et al., 2008; Gonzalez-Aleu et al., 2018; Liu & Farris, 2008). Unfortunately, no comprehensive measure has been developed because of the multidimensionality of the kaizen process and the intangibility of kaizen results.

As kaizen is implemented in every stage and process in any organization, it makes it very difficult to see its direct effect on the financial performance, as it could be easier to measure the waste and cost reduction. However, when it comes to improving employees' attitudes or increasing their motivation towards improvement, it could not be easy to measure that in financial terms, leading to having different evaluation tools for the same process and results. This makes measuring processes difficult for managerial accountants. Therefore, developing a comprehensive kaizen measuring system is essential for maintaining measurable, successful, competitive, and continuous improvement goals.

Multicriteria Decision Making (MCDM) techniques were employed to represent the direct involvement of decision-makers. The MCDM techniques are commonly used in evaluating management and economic decisions with high uncertainty and vagueness due to human judgments (Chandrahas et al., 2014; Tzeng & Huang, 2011; Wu et al., 2009).

Fuzzy theory is employed to interpret imprecise input by capturing the preference structure of decision-makers. In particular, the Fuzzy Technique for Order Performance by Similarity to Ideal Solution (Fuzzy TOPSIS) is employed with linguistic variables to deal with the concepts' ambiguity associated with subjective human judgments (Chandrahas et al., 2014; Saghafian & Hejazi, 2005; Tzeng & Huang, 2011).

This research proposes a novel approach to kaizen measurement literature by employing the fuzzy TOPSIS technique from the perspective of BSC to find the proper measures for kaizen evaluation.

The rest of this paper is organized as follows. In section 2, the Theoretical background discusses kaizen measurement, BSC for performance measurement, and fuzzy TOPSIS. Section 3 explains the data and research methodology, including benefits allocation in BSC and fuzzy TOPSIS for the selection of measures. Section 4 demonstrates the results. The last section summarises the findings, research limitations, and suggestions for potential future work.

Literature Review

Having presented the kaizen definition and importance in the previous section, this section concerns the literature review, where three subsections will be developed: kaizen measurement, BSC for performance measurement, and fuzzy TOPSIS.

Kaizen Measurement

To implement kaizen, small groups work together to achieve the goals of continuous improvement projects (CIPs). CIPs are defined as "systematic team-based processes, typically with a different background or from different departments, working to improve a process performance metric during a short period, such as days, weeks, or months" (Gonzalez-Aleu et al., 2018, p. 336). Kaizen's main goal is to increase efficiency by reducing costs, timely delivery, and increasing quality to enhance the company's market performance and customer satisfaction (Imai, 1997; Moore, 2007).

Ker and Wang (2015) explored the benefits of kaizen implementation in the healthcare sector that enhanced workflow by reducing the delay time and overall costs while increasing the quality and efficiency of managing healthcare services. Adams et al. (1999) implemented kaizen to eliminate unnecessary tools, machines, workforce, and any source of waste, resulting in reduced capital investment, factory space, and increased profitability.

Other studies (e.g., Bartel, 2011; Farris et al., 2009; Ghicajanu, 2009; Glover et al., 2008; Kumar & Pandey, 2013; Kumar et al., 2018; Nagaretinam, 2005; Thessaloniki, 2006) concluded that organizations can achieve several benefits if they implement the kaizen system effectively. Each study used kaizen for either cost reduction, improving production process efficiency, or both. However, the study of El Dardery et al. (2021) provided a comparison of the literature review related to kaizen benefits and found that the study of Vento et al. (2016) compiled Kaizen benefits mentioned in all previous studies and classified them into economic and human resources benefits, providing the largest, most comprehensive number of kaizen benefits.

Liu and Farris (2008) measured kaizen performance using data envelopment analysis and recommended using fuzzy logic for kaizen measurement in future studies. This study answers Liu and Farris' call by employing fuzzy TOPSIS for measuring and evaluating kaizen benefits, as no previous studies have designed a comprehensive evaluation system of kaizen benefits. Kaplan and Norton (2001) explained that traditional accounting measures are inappropriate for decision-making as they do not explicitly associate financial and non-financial results. Thus, the study employed a balanced scorecard framework to integrate financial and non-financial measures of kaizen.

BSC for Performance Measurement

Performance measurement is the process of periodic quantification of the effectiveness and efficiency of an action. It also reports the results to decision-makers to implement strategies and support decision-making (Raval et al., 2019). Having a continuous improvement process requires that cost management systems be more flexible and comprehensive. BSC balances the usage of quantitative and qualitative measures (Hájek et al., 2018) and integrates internal and external measures for performance evaluation (Raval et al., 2019) for strategic decision-making (Jassem et al., 2021).

Kaplan and Norton introduced BSC in the 1990s as a comprehensive measure to replace the financial measure, which focuses only on past performance without considering intangible values (Jassem et al., 2021; Kaplan & Norton, 1992; Taticchi & Balachandran, 2008). BSC improves competitiveness and enhances long-term profitability (Kaplan & Norton, 1993; Liu et al., 2014), as it depends on a set of cause-and-effect relationships (Bremser & Barsky, 2004).

BSC categorizes organizational strategies into four perspectives. The financial perspective concerns cost evaluation, return on investment (ROI), and revenue growth. The Customer/Stakeholder perspective measures customer profitability, satisfaction, and retention rate. The Internal Business Process perspective is related to measuring organizational internal changes to achieve its objectives. The fourth perspective is Learning and Growth, which measures employee performance enhancements, routine processes, skills, and training (Kalender & Vayvay, 2016).

BSC can be used for different measuring purposes. Raval et al. (2019) developed a BSC-based framework to identify the adoption of lean Six Sigma performance measures, while Wu et al. (2009) employed BSC with fuzzy MCDM to evaluate banking performance. Moreover, Hájek et al. (2018) used BSC and fuzzy TOPSIS to evaluate innovation performance, while Parsa et al. (2016) used BSC and fuzzy TOPSIS to evaluate the performance of national Iranian gas companies.

In response to the limitations of previous studies of not having a comprehensive kaizen measurement, this study aims to develop a comprehensive measurement system necessary to help managers quantify the outcomes of kaizen practices. Thus, the first research question can be stated as follows:

- *RQ1: How can kaizen benefits be allocated into BSC perspectives to frame a comprehensive kaizen evaluation system?*

Fuzzy TOPSIS

Decision-making is determining the best option out of the different alternatives where the judging criteria for those alternatives are available. For most issues, decision-makers want to make multiple-criteria decisions (Roudini, 2015; Saghafian & Hejazi, 2005). TOPSIS is an MCDM technique proposed by Hwang and Yoon (1981) to help objectively evaluate alternatives (Tzeng & Huang, 2011; Kore et al., 2017).

Unlike the analytic hierarchy process (AHP), TOPSIS allows the use of an unlimited number of alternatives and criteria in the decision-making process, and its simplicity made it one of the most frequently used MCDM techniques (Chandrahas et al., 2014; Hájek et al., 2018; Wu et al., 2009). Additionally, fuzzy TOPSIS has been extensively used in judgmental decision-making cases and has proven effective when dealing with vague, imprecise information (Yaakob, 2017).

TOPSIS is based on compensatory aggregation by applying weights to each criterion in a set of alternatives to compare those alternatives. The chosen alternative is the one that has the shortest geometric distance to the positive ideal solution (PIS) and the longest geometric distance to the negative ideal solution (NIS) (Arif-Uz-Zaman, 2012; Kore et al., 2017; Saghafian & Hejazi, 2005; Wu et al., 2009). In TOPSIS, the weights for criteria are known, but in real-life scenarios, they are not. Therefore, using linguistic rather than numerical values is more appropriate. Linguistic values may include low, medium, and high values.

Fuzzy set theory measures concepts' vagueness associated with the subjectivity of human judgments (Saghafian & Hejazi, 2005; Tzeng & Huang, 2011). As a result, using fuzzy numbers to analyze the criteria simplifies the evaluation process, as criteria are mostly incompatible. For fuzzy numbers, a conversion scale is used to transform linguistic terms into fuzzy numbers. A scale of 1 to 5 is commonly used for rating alternatives and weighing criteria. The intervals within the scale are chosen to have a unified representation from 1 to 5 for fuzzy numbers. For example, the five-point linguistic terms can be translated to fuzzy numbers, as in Table 1 (Arif-Uz-zaman, 2012; Awasthi et al., 2010; Govindan et al., 2013; Kore et al., 2017).

Table 1
Fuzzy Numbers for Linguistic Variables

Linguistic Alternatives	Linguistic Weights	Fuzzy Number
Strongly Disagree	Not Important	(1,1,3)
Disagree	Less Important	(1,3,5)
Neutral	Medium Important	(3,5,7)
Agree	Important	(5,7,9)
Strongly Agree	Very Important	(7,9,9)

Source: Arif-Uz-zaman (2012); Awasthi et al. (2010); Govindan et al. (2013); Kore et al. (2017)

The complex and vague nature of assessing performance indicators is why fuzzy techniques are integrated with BSC (Hájek et al., 2018). The four perspectives of BSC are considered equal weights as they are equally important and interdependent, as the performance in one perspective will affect the performance in other perspectives (Kaplan & Norton, 1992). As a result, the second research question can be stated as follows:

- *RQ2: How to determine the measures of each kaizen benefit and define the best measure for each benefit using Fuzzy TOPSIS to reach a comprehensive system to evaluate kaizen performance in organizations?*

Methodology

Research instruments

To achieve the objective of this paper, three research instruments were designed and distributed over the two stages of the study, targeting a sample of kaizen experts. An expert/judgmental sample is based on choosing experienced individuals in a certain area of interest (Singh, 2007), practising kaizen, and knowing its measurement process.

In the first stage, the first and second research instruments were designed. The first research instrument was used to answer the first research question and allocate the kaizen benefits selected from the literature review (Vento et al., 2016) to the four perspectives of BSC. A pilot study was conducted over one month in June 2021, and the feedback was used to make a few minor adjustments, such as adjusting the education level to include high school, as some Japanese workers have not obtained higher degrees. Also, definitions were added to the four BSC perspectives, and the kaizen performance question was adjusted to include the option of practising kaizen as a daily activity, as this is common in Japan.

The research instrument was then distributed among experts in kaizen to guarantee accurate results for allocating benefits and to collect proper kaizen benefits measures based on actual work experience. The research instrument, including LinkedIn, kaizen websites, and emails, was distributed online. The responses were collected over four months, targeting kaizen experts. There were 11 responses removed from the final sample for not passing the manipulation check question related to familiarity with kaizen practices. Thus, the final number of experts included in the sample of research instrument one was 69 respondents.

The second research instrument was designed to answer the part of the second research question related to determining the measures of each kaizen benefit. It includes all the measures previously collected through the first research instrument based on experts' actual usage to refine the measures before using them in the third research instrument. The research instrument was distributed via different online means over two months, and the final number of experts included in the sample of research instrument two was 17 respondents.

In the second stage, the third research instrument was designed to obtain data for weighing the importance of each kaizen benefit and ranking the measures of each benefit. These weights and ranks were used in fuzzy TOPSIS analysis. There were a limited number of respondents for this research instrument as not only kaizen experts were needed, but also a concise selection of data sources was required.

Sample

Previous studies related to TOPSIS used expert samples ranging from 3 to 30 experts. In contrast, the study of Wu et al. (2009) depended on the opinion of 12 experts, and Yaakob (2017) depended on 3 experts' opinions only, while Roudini (2015) and Dang et al. (2019) depended on the opinion of 10 experts. Finally, the study by Abbassinia et al. (2020) relied on the opinion of 30 experts. This study will depend on the opinion of 15 experts for the fuzzy TOPSIS analysis from the research instrument data collected over one month.

Fuzzy TOPSIS process

The steps of the fuzzy TOPSIS process are as follows (Parsa et al., 2016; Salih et al., 2019; Tavana et al., 2020):

First, the linguistic answers are converted into numbers, as in Table 1, to construct the decision matrix of alternatives (the measures for each benefit in this case). To clarify that, assume an expert group has K decision makers and ith benefit on jth measures. There are three to five measures (Collected via research instrument one, refined by research instrument two) for each of the 23 benefits mentioned in the study of Vento et al. (2016), and 15 experts/decision-makers, namely DM1 till DM15.

For a decision-making matrix, if $\tilde{x}$ denotes the linguistic terms for each measure, and a vector of three numbers represents each linguistic term for fuzzification, namely (a_{ij}, b_{ij}, c_{ij}), as seen in Table 1, then:

$$\tilde{x} = (a_{ij}, b_{ij}, c_{ij})$$

$$DM = \begin{bmatrix} a_{11}^1 & b_{11}^1 & c_{11}^1 \\ \vdots & \vdots & \vdots \\ a_{ij}^k & b_{ij}^k & c_{ij}^k \end{bmatrix} \qquad Decision-Making\ Matrix\ (1)$$

Second, the criteria weights from the rankings of benefits' importance as in Table 1. Afterwards, the combined decision matrix and the combined weighted matrix are constructed by getting the minimum value of first place among all members, then the average of values of the middle place, and finally, the maximum value of last place.

$$a_{ij} = \min_k\{a_{ij}^k\}, \qquad b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k, \qquad c_{ij} = \max_k\{c_{ij}^k\} \quad for\ the\ decision\ matrix\ (2)$$

$$w_{j1} = \min_k\{w_{j1}^k\}, \quad w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{j2}^k, \quad w_{j3} = \max_k\{w_{j3}^k\} \quad for\ the\ weights\ matrix\ (3)$$

Third, the normalized decision matrix is computed for the 23 benefits depending on the nature of each benefit, as some benefits need to be maximized, such as 'increasing profits', while others need to be minimized, such as 'cost reduction'.

$$\widetilde{r_{ij}} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad and c_j^* = \max_i\{c_{ij}\} \qquad for\ the\ benefit\ criteria \quad (4)$$

$$\widetilde{r_{ij}} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \quad and\ a_j^- = \min_i\{a_{ij}\} \qquad for\ the\ cost\ criteria \quad (5)$$

Fourth, the weighted normalized fuzzy decision matrix is computed by multiplying the normalized decision matrix by the combined weighted matrix.

$$\widetilde{v_{ij}} = \widetilde{r_{ij}} \times w_j \quad (6)$$

Fifth, the Fuzzy Positive Ideal solution (FPIS) and Fuzzy Negative Ideal (FNIS) were determined.

$$FPIS \quad A^* = \left(\widetilde{v_1^*}, \widetilde{v_2^*}, \cdots, \widetilde{v_n^*}\right) \quad where\ \widetilde{v_j^*} = \max_i\{v_{ij3}\} \quad (7)$$

$$FNIS \quad A^- = \left(\widetilde{v_1^-}, \widetilde{v_2^-}, \cdots, \widetilde{v_n^-}\right) \quad where\ \widetilde{v_j^-} = \min_i\{v_{ij1}\} \quad (8)$$

Sixth, the distance of each alternative from the FPIS and FNIS was determined.

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}\left[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2\right]} \qquad (9)$$

Seventh, computing the closeness coefficient for each alternative measure.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*} \qquad (10)$$

Ranking the measures based on their closeness coefficient from the highest to the lowest, where the highest measure is optimal for the benefit criteria, while the lowest measure is optimal for the cost criteria.

Results

The following section displays the main results and findings and is divided into preliminary and main analyses for each stage.

Stage One: BSC Framework for Kaizen Benefits Allocation

Preliminary Analysis

Cronbach's Alpha for the first research instrument items was 0.962, considered highly reliable (Omoush et al., 2020; Tsao et al., 2015). The Kaiser-Meyer-Olkin measure was used for sample adequacy to determine the variation percentage, and the resulting value was 0.791; Bartlett's sphericity significance test was 0.000 (Bartlett, 1954; Kaiser, 1974).

The sample descriptive statistics show that 55% of the respondents were from Egypt, while 45% were from Japan and other countries. The sectors covered included Manufacturing, Oil & Gas, Healthcare & Medicine, Real estate & Construction, Communications and information technology, Transportation and shipping services, educational services, Food, drinks, and tobacco. The final sample size was 69 participants, as mentioned before. Egypt was selected due to the recent attention from the industry and government towards implementing continuous improvement activities to achieve the SDGs. Moreover, it has been making progress in adopting kaizen with the help of JICA (GRIPS Development Forum, 2009). Also, kaizen has been recently introduced in the hospital sector (Ishijima et al., 2019). As for Japan, it was selected as the benchmark for kaizen best practices.

Main Analysis

The allocation was conducted by calculating the frequency of each benefit in each perspective; additionally, as a confirmation, the mode of each perspective was calculated. The perspectives were ranked 1 for Financial, 2 for Customer/ Stakeholder, 3 for Internal Business Process, 4 for Learning and Growth, and 5 for none of them (for cases where a respondent did not want to allocate any of the benefits into any of the 4 perspectives) Although the research instrument was disseminated in different countries, there were no significant differences in benefits allocation among countries. Kaizen's economic benefits are shown in Table 2, while human resource benefits are shown in Table 3.

Table 2
Kaizen Economic Benefits Allocation into BSC

Kaizen Economic Benefits (EB)	Final BSC perspective	The perspective with the Highest mode	BSC perspectives Frequencies				
			Financial	Customer/ Stakeholder	Internal business Process	Learning and Growth	Others
Reducing the delivery time	Customer/ Stakeholders	2	21	26	18	2	2
Achieving better economic balance	Financial	1	38	7	11	1	12
Increasing profits	Financial	1	43	10	6	2	8
Reducing production process stages	Internal Business Process	3	20	7	34	5	3
Decreasing failures in equipment and machinery	Financial	1	23	5	21	4	16
Cost reduction	Financial	1	47	6	7	4	5
Reducing operation cycles and design time	Internal Business Process	3	20	5	30	8	6
Productivity increase	Financial	1	26	8	20	5	10
Improving Cash inflows	Financial	1	54	3	6	2	4
Reducing defective products	Customer/ Stakeholders	2	16	18	17	11	7
Reducing movement distances	Internal Business Process	3	16	3	32	7	11
Reducing inventory waste	Financial	1	31	3	18	6	11
Reducing waiting time and materials transport waste	Internal Business Process	3	22	5	26	5	11

Source: Developed by the authors

Table 3
Kaizen Human Resource Benefits Allocation into BSC

Kaizen Human Resource Benefits (HB)	Final BSC perspective	The perspective with the Highest mode	BSC perspectives Frequencies				
			Financial	Customer/ Stakeholder	Internal business Process	Learning and Growth	Others
Increasing customer satisfaction	Customer/ Stakeholders	2	6	50	6	3	4
Employees' responsibility and commitment became more visible	Learning and Growth	4	8	8	17	25	11
Reducing accidents from inappropriate work conditions	Internal Business Process	3	10	3	27	11	18
Managers are more motivated to make continuous improvement changes	Learning and Growth	4	6	9	18	28	8
Improving communication between administrative staff	Internal Business Process	3	5	6	32	19	7
Increase employee collaboration.	Internal Business Process	3	6	8	28	14	13
Improvement changes have positively affected individuals	Learning and Growth	4	8	12	8	24	17
The company's employees participate in kaizen activities and/ or construct a new system.	Internal Business Process	3	7	8	20	17	17
Employee turnover has decreased.	Learning and Growth	4	16	7	11	22	13
Employees' self-esteem has increased.	Learning and Growth	4	7	8	11	27	16

Source: Developed by the authors

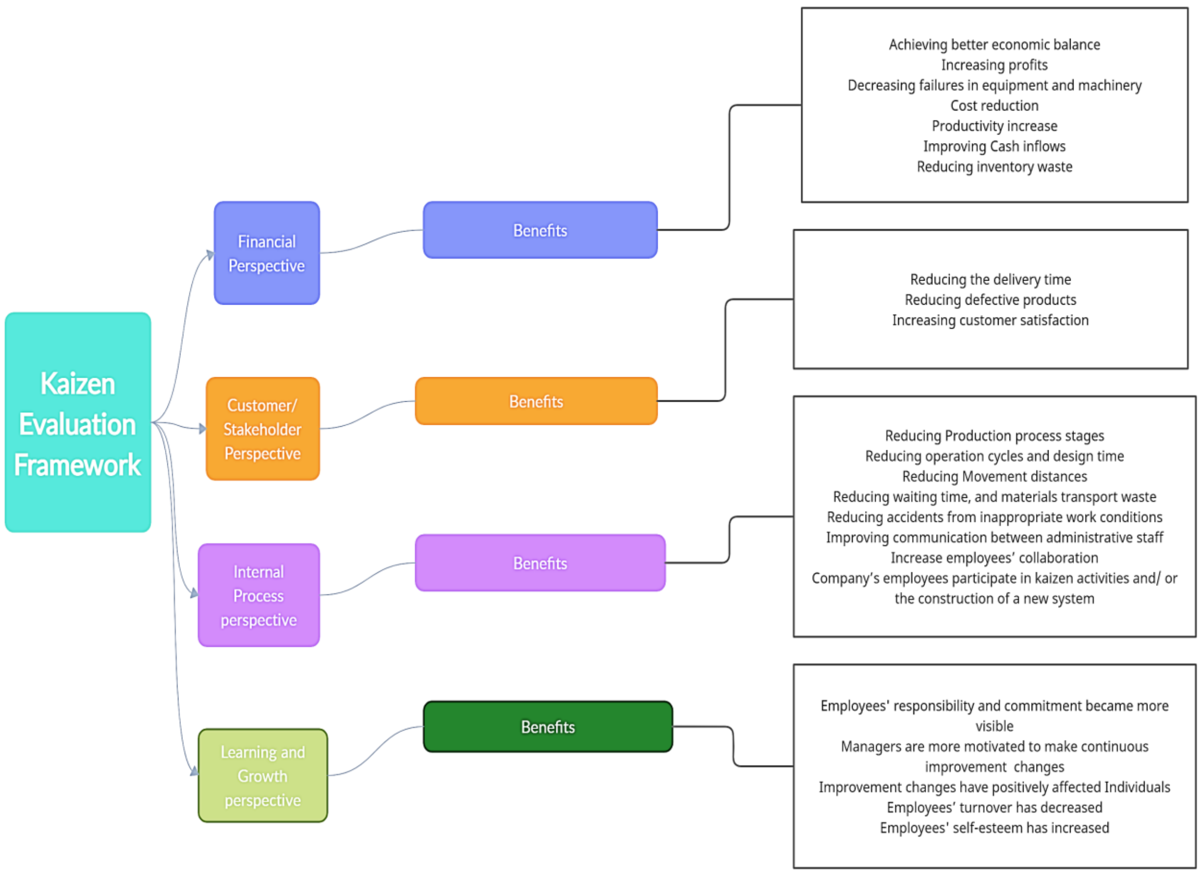
Figure 1 summarises the final allocation of benefits into BSC, where the financial perspective included only economic benefits and the learning and growth perspective included only human resource benefits. This can reflect the nature of the benefits as more related to financial or human aspects. As for the other two perspectives, they included both economic and human resource benefits.

As a result of this research instrument, for the open-ended questions related to adding the measures, it is noticed that for the economic benefits, several measures were provided by the respondents, unlike the human resource benefits, where only a few were mentioned. One possible explanation is that economic benefits can mostly be measured financially. In contrast, human resource benefits are measured by qualitative means, which makes it harder to express them in financial terms (the collected measures are mentioned in Table 4).

Cronbach's Alpha for the second research instrument item was 0.813, considered highly reliable (Omoush et al., 2020; Tsao et al., 2015). This research instrument was distributed via different online means, and the final sample consisted of only 17 who provided full, usable responses. The purpose of this research instrument was to refine the measures of kaizen benefits by asking the respondents to choose or add new measures via open-ended questions. The resulting measures were used to define the final measures for the third research instrument. The respondents were given a set of measures to choose the ones they use and add other used measures if they were not in the options list.

The research instrument results reduced some of the measures of economic benefits while increasing the number of human resource benefits measures. Finally, the 23 benefits had between three to five measures each, totalling 103, as shown in the third column in Table 4.

Figure 1
BSC for Kaizen Benefits Evaluation



Source: Author's Illustration

Table 4
Kaizen Benefits' Measures Collected Via Stage One

BSC Perspectives	Kaizen Benefits (Economic and Human Resources)	Measures Collected via the First Research instrument (Input in 2nd research instrument)	Measures Refined by the Second Research Instrument (Input in 3rd research instrument)
Financial perspective	Achieving better economic balance	1. Decrease process cost 2. ROI 3. IRR 4. financial return 5. Net profit (Profitability increases) 6. Balance of unit price vs. number of inquiries 7. Value stream and business impact	1. Decrease process cost 2. Return on Investment (ROI) 3. Internal rate of return (IRR) 4. Net profit (Profitability increases) 5. Value stream and business impact
	Increasing profits	1. Profit margin, Net profit 2. Monthly expenses 3. Cash revenue collection 4. budget controlling	1. Profit margin, Net profit 2. Monthly expenses 3. Cash revenue collection 4. budget controlling
	Cost reduction	1. Waste reduction 2. Manufacturing cost 3. Cost before vs. after 4. Net profit, Profitability increases, 5. Breakdowns, time off, and stops 6. deviation rates 7. Defect percentage	1. Waste reduction 2. Manufacturing cost 3. Cost before vs. after 4. Net profit, Profitability increases, 5. Breakdowns, time off, and stops
	Productivity increase	1. Material yield, process yield 2. waste reduction 3. Calculation of production quantities/working hours 4. Overall Operations Effectiveness (OOE) 5. Process performance 6. Value Stream 7. The number of products per employee	1. Material yield, process yield 2. waste reduction 3. Calculation of production quantities/working hours 4. Overall Operations Effectiveness (OOE) 5. The number of products per employee
	Improving Cash inflows	1. Inventory cycle cost 2. Automated system 3. Sales volume 4. Profitability increases 5. Monitoring customer behaviour 6. Business Impact	1. Inventory cycle cost 2. Automated system 3. Sales volume 4. Profitability increases 5. Business Impact
	Reducing inventory waste	1. Inventory cost, inventory life cycle 2. For the final product, Calculate the difference between what is produced and what was released to the customer after storing it; for raw materials, Calculate the Quantities of raw materials that were disposed of due to their expiration. 3. Process performance and effectiveness	1. Inventory cost, inventory life cycle 2. For the final product, Calculate the difference between what is produced and what was released to the customer after storing it; for raw materials, Calculate the Quantities of raw materials that were disposed of due to their expiration. 3. Process performance and effectiveness
Customer/ Stakeholders	Reducing the delivery time	1. tracing time 2. Lead time- calculate the timeline 3. delivery time after- delivery time before/delivery time before 4. Number of days before Versus after 5. increase customer satisfaction 6. increase customer orders 7. Reduce customer complaints about the delivery delay	1. tracing time 2. Lead time- calculate the timeline 3. delivery time after- delivery time before/delivery time before 4. increase customer satisfaction 5. Reduce customer complaints about the delivery delay

Customer/ Stakeholders	Reducing defective products	1. Defect percentage (Number of defective parts) = % of defects before VS after 2. Deviation ratios 3. quantities of waste 4. customer satisfaction, 5. Decrease non-conforming 6. Maintenance breakdowns affect the master box production 7. The amount of production per hour with the percentage of waste	1. Defect percentage (Number of defective parts) = % of defects before VS after 2. quantities of waste 3. customer satisfaction, 4. Decrease non-conforming 5. Maintenance breakdowns affect the master box production
	Increasing customer satisfaction	1. Sales transactions 2. sales KPIs 3. Complaint rate (Customer feedback with increased demand) 4. Net Promoter Score (NPS) is a customer loyalty and satisfaction measurement	1. sales transactions 2. sales KPIs 3. Complaint rate (Customer feedback with increased demand market surveys and feedback from customers) 4. Net Promoter Score (NPS) is a customer loyalty and satisfaction measurement. **5. On-Time in Full Delivery (OTIF)**
Internal Business Process	Reducing Production process stages	1. Cycle/s time before Versus after 2. rework reduction 3. Measuring the actual time of each process with the production quantity per hour 4. Takt time (the amount of time an item or service needs to be completed) 5. Process performance 6. Number of processes in production	1. Cycle/s time before Versus after 2. rework reduction 3. Measuring the actual time of each process with the production quantity per hour 4. Takt time (the amount of time an item or service needs to be completed) 5. Process performance
	Decreasing failures in equipment and machinery	1. Mean Time to Failure (MTTF) 2. malfunction record (equipment malfunctions and amount of production Reports every hour or two) 3. Mean Time to Repair (MTTR) 4. Overall Operations Effectiveness (OOE) 5. Failure rate FR 6. Breakdown's time 7. meantime between failure MTBF 8. Overall equipment effectiveness OEE	1. Malfunction record (equipment malfunctions and amount of production Report every hour or two) 2. Mean Time to Repair (MTTR) 3. Overall Operations Effectiveness (OOE) 4. Breakdown's time 5. Overall equipment effectiveness OEE
	Reducing operation cycles and design time	1. Setup time 2. Calculate timeline and lead time 3. Overall equipment effectiveness OEE 4. Project progress & % of adherence to target planned dates 5. Process performance	1. Setup time 2. Calculate timeline and lead time 3. Overall equipment effectiveness OEE 4. Project progress & % of adherence to target planned dates 5. Process performance
	Reducing Movement distances	1. product movement 2. Timesaving % 3. Increase production 4. Process performance 5. Motion Waste reduction	1. product movement 2. Timesaving % 3. Increase production 4. Process performance 5. Motion Waste reduction
	Reducing waiting time and materials transport waste	1. Process yield 2. process cycle 3. calculate wait time 4. Delay Cost reduction 5. Overall equipment effectiveness OEE 6. Process performance	1. Process yield 2. process cycle 3. calculate wait time 4. Delay Cost reduction 5. Process performance

Internal Business Process	Reducing accidents from inappropriate work conditions	1. Records of work stops. 2. No Of injury, the record of work accidents in quality, safety, and occupational health reports 3. industrial security report	1. Records of work stops 2. No Of injury, the record of work accidents in quality, safety, and occupational health reports 3. industrial security report 4. Frequency and severity of accidents 5. Risk Priority Number (RPN)
	Improving communication between administrative staff	1. Reduce wastage in production time 2. Efficiency report	1. Reduce wastage in production time 2. Efficiency report **3. Scrap rate** 4. **Interaction in daily meetings reduced the number of problems due to miscommunication.**
	Increase employee collaboration	1. Increase production 2. Processes interactions	1. Increase production/ Productivity 2. Processes interactions **3. Increase Efficiency**
	The company's employees participate in kaizen activities and/ or the construction of a new system	1. The extent of implementation of improvement projects 2. company's reputation 3. Processes review and upgrades 4. Projected sustainability	1. The extent of implementation of improvement projects 2. company's reputation 3. Processes review and upgrades 4. Projected sustainability **5. Audit plan**
Learning and Growth	Employees' responsibility and commitment became more visible	1. Employees efficiency 2. Increase production	1. Employees efficiency 2. Increase production **3. Achieving KPIs** **4. Performance appraisal**
	Managers are more motivated to make continuous improvement changes	1. Efficiency Report 2. Objectives achievement	1. Efficiency Report 2. Objectives achievement **3. Planning VS actually** **4. Cost reduced in terms of wastes (time, movements, scrap, rework)** 5. **Quality enhancement**
	Improvement changes have positively affected Individuals	1. Increased profit 2. Continuous improvement, especially in product quality 3. Employment turnover rate	1. Increased profit 2. Continuous improvement, especially in product quality 3. Employment turnover rate
	Employee turnover has decreased	1. Increase operations efficiency. 2. The empathy of Understanding Issues, Solutions, and Disagreements 3. Resignations 4. Employment rate	1. Increase operations efficiency 2. The empathy of Understanding Issues, Solutions, and Disagreements 3. Resignations 4. Employment rate
	Employees' self-esteem has increased	1. Employees are Thinking in Harmony about Improvements & Safety 2. Learning Curve increase 3. Resignation's rate	1. Employees are Thinking in Harmony about Improvements & Safety 2. Learning Curve increase 3. Resignation's rate

Note: The newly added measures resulting from 2nd research instrument are in bold
Source: Developed by the authors

Stage Two: Fuzzy TOPSIS Analysis for A Comprehensive Kaizen Evaluation System

Preliminary Analysis

Cronbach's Alpha for the third research instrument item was 0.953, which is considered highly reliable (Omoush et al., 2020; Tsao et al., 2015). This research instrument targeted a small group of experts, and the final sample included 15 kaizen experts.

Main Analysis

The experts were asked to rank the importance of kaizen benefits from not important to very important using a five-point Likert scale and choose the measures that they agreed on through a five-point Likert scale from strongly disagree to strongly. The responses were analyzed using the seven fuzzy TOPSIS equations on Microsoft Excel, previously mentioned. The results of this analysis are mentioned in the final measures in Table 5.

Table 5
Final Measures

BSC Perspectives	Kaizen Benefits (Economic and Human Resources)	Final Selected Measures Using Survey 3 Results, Analyzed by Fuzzy TOPSIS
Financial perspective	Achieving better economic balance	Net profit (Profitability increases)
	Increasing profits	Profit margin, Net profit
	Cost reduction	Cost before vs. after
	Productivity increase	Waste reduction
	Improving Cash inflows	Profitability increases
	Reducing inventory waste	Inventory cost, inventory life cycle
Customer/ Stakeholders	Reducing the delivery time	Lead time- calculate the timeline
	Reducing defective products	Quantities of waste
	Increasing customer satisfaction	On-Time in Full Delivery (OTIF)
Internal Business Process	Reducing Production process stages	Takt time (the amount of time an item or service needs to be completed)
	Decreasing failures in equipment and machinery	Malfunction record (equipment malfunctions and amount of production Report)
	Reducing operation cycles and design time	Calculate timeline and lead time
	Reducing Movement distances	Timesaving %
	Reducing waiting time and materials transport waste	Calculate wait time
	Reducing accidents from inappropriate work conditions	Frequency and severity of accidents
	Improving communication between administrative staff	Efficiency report
	Increase employee collaboration	Increase production/ Productivity
	The company's employees participate in kaizen activities and/ or the construction of a new system	The extent of implementation of improvement projects
Learning and Growth	Employees' responsibility and commitment became more visible	Achieving KPIs
	Managers are more motivated to make continuous improvement changes	Quality enhancement
	Improvement changes have positively affected Individuals	Increased profit
	Employee turnover has decreased	Increase operations efficiency
	Employees' self-esteem has increased	Learning Curve increase

Source: Developed by the authors

Discussions on the relevant kaizen benefits and measures for each BSC perspective are presented below. The research findings showed that the relevant kaizen benefits from ***the financial perspective*** included achieving better economic balance, increasing profits, and improving cash inflows. The increase in profitability can measure these benefits. Decreasing failures in equipment and machinery can be measured by tracing the malfunction record. Cost reduction is measured by comparing costs before and after each kaizen event. The reduction in waste measures productivity increase. Reducing inventory waste is measured by monitoring inventory cost and inventory life cycle.

The customer/stakeholders' perspective included the following benefits: reducing the delivery time, measured by calculating timeliness and lead time; reducing defective products, measured by quantities of waste before and after kaizen; and finally, increasing customer satisfaction, measured by On Time in Full Delivery (OTIF).

The benefits from ***the internal business process perspective*** include reducing production process stages, which was measured by calculating the takt time. Another benefit is reducing operation cycles and design time by calculating timeliness and lead time for operations. Moreover, one of the benefits is reducing movement distances measured by the percentage of timesaving. Additionally, reducing waiting time and materials transport waste is one of the benefits, which was measured by calculating the wait time. Another benefit was reducing accidents from inappropriate work conditions, measured by the frequency and severity of accidents. Also, some of the other benefits include improving communication between administrative staff measured by monitoring the changes in the efficiency report, increasing employees' collaboration measured by the increase in productivity, the company's employees' participation in kaizen activities, and/or the construction of a new system measured by the extent of implementing improvement projects.

The learning and growth perspective included the following benefits: improvement changes, which have positively affected Individuals, were measured by the increase in profit. Another benefit is that employees' responsibility and commitment became more visible, measured by achieving KPIs. Also, managers are more motivated to make continuous improvements measured by quality enhancement. Benefits also include decreased employee turnover, measured by increasing operations efficiency. The final benefit is that employees' self-esteem has increased, which was measured through the increase in the learning curve.

Conclusion

This research proposes a kaizen measurement system by integrating BSC and fuzzy TOPSIS. Kaizen benefits and measures allocation into BSC perspectives (financial, customer/stakeholder, internal business process, and learning and growth) will help managers make better strategic and operational decisions.

The research problem was to close the gap of not having a defined kaizen measure, hence introducing a kaizen measurement system. Using one of the MCDM techniques, namely fuzzy TOPSIS with BSC, three survey research instruments were implemented firstly to allocate kaizen benefits into BSC perspectives; secondly, to define kaizen measures from the practitioners' perspective; and finally, the last research instrument was to determine the importance of each benefit and rank their measures to be used as an input in fuzzy TOPSIS to reach the optimal measure of each benefit.

In summary, the managerial decision-making process depends on the quality of performance evaluation to gain sufficient knowledge about the strengths and weaknesses of different processes. Performance evaluation of kaizen activities was, till recently, directed with little attention as studies focused on measuring kaizen without integrating all possible kaizen measures into a measurement system. Gathering the benefits and measures under a BSC framework will help systematically evaluate kaizen performance. It will facilitate the selection of better kaizen activities from different alternatives. Finally, it will guarantee the sustainability of successful kaizen activities and enhance the kaizen evaluation process from the managerial accounting perspective.

Although the previously mentioned measures are comprehensive and should cover all kaizen activities implemented for different purposes, one limitation of this research is not being able to generalize the results due to the nature of the study. One important contribution of this research is using fuzzy TOPSIS and BSC to frame the set of kaizen benefits measures. However, there is still more to do, and future studies may extend this research firstly by testing the designed system in a specific industry or sector to validate its holistic and secondly by comparing the results of this BSC-fuzzy TOPSIS measurement with other MCDM techniques. Finally, testing the collected measures through other empirical studies.

Acknowledgement

We want to thank Mr Koike Motoi and Ms. Kawazoe Tomomi from the JICA office of Egypt Japan University of Science and Technology for translating and enhancing the Japanese version of the surveys. Also, we would like to thank the Japanese professors who contributed to this research in the pilot study or later stages.

References

1. Abbassinia, M., Kalatpour, O., Motamedzade, M., Soltanian, A., & Mohammadfam, I. (2020). A fuzzy analytic hierarchy process-TOPSIS framework for prioritizing emergency in a petrochemical industry. *Archives of Trauma Research*, 9(1), 35. https://doi.org/10.4103/atr.atr_85_19
2. Adams, M., Componation, P., Czarnecki, H., & Schroer, B. (1999). Lean manufacturing: How to start, support and sustain. SAE transactions, 1092-1097. https://doi.org/10.4271/1999-01-3362
3. Arif-Uz-Zaman, K. (2012). *A fuzzy TOPSIS based multi criteria performance measurement model for lean supply chain* (Doctoral dissertation, Queensland University of Technology).
4. Awasthi, A., Chauhan, S. S., & Goyal, S. K. (2010). A fuzzy multicriteria approach for evaluating environmental performance of suppliers. *International journal of production economics*, *126*(2), 370-378. https://doi.org/10.1016/j.ijpe.2010.04.029
5. Bartel, P. (2011). Kaizen in outpatient services at Kishwaukee Community Hospital.
6. Bartlett, M. S. (1954). A note on the multiplying factors for various χ 2 approximations. *Journal of the Royal Statistical Society. Series B (Methodological)*, 296-298.
7. Bremser, W. G., & Barsky, N. P. (2004). Utilizing the balanced scorecard for R&D performance measurement. *R and D Management*, *34*(3), 229–238. https://doi.org/10.1111/j.1467-9310.2004.00335.x
8. Chandrahas, V., Santosh, K. M., & Mahapatra, D. (2014). Use of Multicriteria Decision Making Method for the Selection of Optimum Maintenance Strategy. *Journal of Material Science and Mechanical Engineering (JMSME)*, *1*(2), 89–93.
9. Dang, V. T., Wang, J., & Van-Thac Dang, W. (2019). An integrated fuzzy AHP and fuzzy TOPSIS approach to assess sustainable urban development in an emerging economy. International *Journal of Environmental Research and Public Health*, *16*(16), 1–20. https://doi.org/10.3390/ijerph16162902
10. Doolen, T. L., Van Aken, E. M., Farris, J. A., Worley, J. M., & Huwe, J. (2008). Kaizen events and organizational performance: A field study. *International journal of productivity and performance management*, *57*(8), 637–658. https://doi.org/10.1108/17410400810916062
11. El Dardery, O. I. S., Gomaa, I., Rayan, A. R. M., Khayat, G. El., & Sabry, S. H. (2021). Sustainable balanced scorecard for Kaizen evaluation : Comparative study between Egypt and Japan. *International journal of economics and management engineering*, *15*(10), 917–926.
12. Farris, J. A., Van Aken, E. M., Doolen, T. L., & Worley, J. (2009). Critical success factors for human resource outcomes in Kaizen events: An empirical study. *International journal of production economics*, *117*(1), 42-65. https://doi.org/10.1016/j.ijpe.2008.08.051

13. Ghicajanu, M. (2009). The Kaizen philosophy in Romania. *Annals of the University of Petrosani : Economics*, *IX*(1), 275–278.
14. Glover, W. J., Van Aken, E. M., Farris, J. A., Doolen, T. L., & Worley, J. M. (2008). Kaizen event follow-up mechanisms and goal sustainability: preliminary results. In *IIE Annual Conference. Proceedings* (p. 1154). Institute of Industrial and Systems Engineers (IISE).
15. Gonzalez-Aleu, F., Van Aken, E. M., Cross, J., & Glover, W. J. (2018). Continuous improvement project within Kaizen: critical success factors in hospitals. *TQM Journal*, *30*(4), 335–355. https://doi.org/10.1108/TQM-12-2017-0175
16. Govindan, K., Khodaverdi, R., & Jafarian, A. (2013). A fuzzy multicriteria approach for measuring the sustainability performance of a supplier based on a triple bottom line approach. *Journal of Cleaner Production*, *47*, 345–354. https://doi.org/10.1016/j.jclepro.2012.04.014
17. GRIPS Development Forum. (2009). Introducing KAIZEN in Africa. In Introducing kaizen in Africa (Issue October, pp. 1–11). GRIPS Development Forum. https://doi.org/10.1039/9781849735575-00001
18. Hájek, P., Stříteská, M., & Prokop, V. (2018). Integrating balanced scorecard and fuzzy TOPSIS for innovation performance evaluation. *PACIS 2018 proceedings*.
19. Hwang, C. L., Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications.* Springer-Verlag: New York.
20. Imai, M. (1986). Kaizen: The key to Japan's competitive success.
21. Imai, M. (1997). Gemba Kaizen: A commonsense low-cost approach to management. McGraw-Hill Professional.
22. Ishijima, H., Nishikido, K., Teshima, M., Nishikawa, S., & Gawad, E. A. (2019). Introducing the "5S-KAIZEN-TQM" approach into public hospitals in Egypt. *International Journal of Health Care Quality Assurance*, *33*(1), 89–109. https://doi.org/10.1108/IJHCQA-06-2018-0143
23. Jassem, S., Zakaria, Z., & Che Azmi, A. (2021). Sustainability balanced scorecard architecture and environmental performance outcomes: a systematic review. *International Journal of Productivity and Performance Management*. https://doi.org/10.1108/IJPPM-12-2019-0582
24. Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrica*, *39*, 31-36.
25. Kalender, Z. T., & Vayvay, Ö. (2016). The fifth pillar of the balanced scorecard: Sustainability. *Procedia-Social and Behavioral Sciences*, *235*, 76-83. https://doi.org/10.1016/j.sbspro.2016.11.027
26. Kaplan, R., & Norton, D. (1992). *The balanced scorecard: Measures that drive performance*. Harvard Business Review.
27. Kaplan, R., & Norton, D. (1993). *Putting the balanced scorecard to work. Harvard Business Review*. Harvard Business Review.
28. Kaplan, R., & Norton, D. (2001). *The strategy-focused organization*. Harvard Business School Press.
29. Ker, J. I., & Wang, Y. (2015). Kaizen Policies in Healthcare Governance: Reducing Patient-Flow Delays in Outpatient Surgery Setting through Healthcare Information Technology. *Available at SSRN 2624133*. https://doi.org/10.2139/ssrn.2624133
30. Kore, N. B., Ravi, K., & Patil, S. B. (2017). A simplified description of fuzzy TOPSIS method for multi criteria decision making. *International Research Journal of Engineering and Technology (IRJET)*, *4*(5), 2047-2050.
31. Kumar, P., & Pandey, V. (2013). KAIZEN: A Case study in small scale organizations. *International Journal of Scientific Research Engineering & Technology (IJSRET) Volume*, *2*, 133-136.
32. Kumar, S., Dhingra, A., & Singh, B. (2018). Lean-Kaizen implementation: A roadmap for identifying continuous improvement opportunities in Indian small and medium-sized enterprises. *Journal of Engineering, Design, and Technology*, *16*(1), 143–160. https://doi.org/10.1108/JEDT-08-2017-0083
33. Liu, L., Ratnatunga, J., & Yao, L. J. (2014). Firm characteristics and balanced scorecard usage in Singaporean manufacturing firms. *International Journal of Accounting and Information Management*, *22*(3), 209–222. https://doi.org/10.1108/IJAIM-05-2013-0038

34. Liu, W. H., & Farris, J. A. (2008). Evaluating kaizen event performance using data envelopment analysis. *IIE Annual Conference and Expo 2008*, January 2017, 649–654.
35. Moore, R. (2007). 8-Kaizen. In: Moore, R. (2007). Selecting the Right Manufacturing Improvement Tools (pp. 159–172). Butterworth-Heinemann, Burlington.
36. Nagaretinam, M. (2005). Implementing Kobetsu Kaizen steps in manufacturing company Goodway Rubber Industries (M) Sdn Bhd. *Kolej Universiti Teknikal Kebangsaan Malaysia. Faculty of Manufacturing Engineering*, 87.
37. Omoush, M., Moflih, M., & Almetrami, R. (2020). Evaluating the Five Kaizen Success Measurements through Employees Work Improvement and its Effects on Overall Work and Quality of Services: Empirical Study of Insurance Companies in Jordan. *International Review of Management and Marketing*, *10*(4), 43. https://doi.org/10.32479/irmm.9994
38. Parsa, M., Jaferi, F., & Biranvand, M. (2016, September). Performance Evaluation using Balanced Scorecard (BSC) and Fuzzy TOPSIS technique Case Study: National Iranian Gas Company. In *Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management Detroit, Michigan, USA* (pp. 23-25) https://doi.org/10.31181/dmame1901013h
39. Raval, S. J., Kant, R., & Shankar, R. (2019). Benchmarking the Lean Six Sigma performance measures: a balanced score card approach. *Benchmarking: An International Journal*, 26(6), 1921-1947. https://doi.org/10.1108/BIJ-06-2018-0160
40. Roudini, M. (2015). *Application of fuzzy ahp and fuzzy topsis in selecting proper contractors: case of Sistan and Baluchistan province Gas Company* [Doctoral dissertation, Eastern Mediterranean University (EMU)-Doğu Akdeniz Üniversitesi (DAÜ)].
41. Saghafian, S., & Hejazi, S. R. (2005, November). Multicriteria group decision making using a modified fuzzy TOPSIS procedure. In *International Conference on Computational Intelligence for Modelling, Control and Automation and International Conference on Intelligent Agents, Web Technologies and Internet Commerce (CIMCA-IAWTIC'06)* (Vol. 2, pp. 215-221). IEEE. https://doi.org/10.1109/cimca.2005.1631471
42. Salih, M. M., Zaidan, B. B., Zaidan, A. A., & Ahmed, M. A. (2019). Survey on fuzzy TOPSIS state-of-the-art between 2007 and 2017. *Computers & Operations Research*, *104*, 207-227. https://doi.org/10.1016/j.cor.2018.12.019
43. Singh, K. (2007). *Quantitative social research methods*. Sage Publications Inc.
44. Taticchi, P., & Balachandran, K. R. (2008). Forward performance measurement and management integrated frameworks. *International Journal of Accounting & Information Management*, *16*(2), 140–154. https://doi.org/10.1108/18347640810913807
45. Tavana, M., Shaabani, A., & Valaei, N. (2020). An integrated fuzzy framework for analyzing barriers to the implementation of continuous improvement in manufacturing. *International Journal of Quality and Reliability Management*, *38*(1), 116–146. https://doi.org/10.1108/IJQRM-06-2019-0196
46. Thessaloniki, R. (2006). KAIZEN Definition & Principles in brief: A Concept & tool for employees in evolvement.
47. Tsao, L., Rau, P. L. P., & Ma, L. (2015). Development of a Quick Instrument Measuring Kaizen Culture (for Chinese. Procedia Manufacturing, 3(February 2016), 4708–4715. https://doi.org/10.1016/j.promfg.2015.07.567
48. Tzeng, G.-H., & Huang, J.-J. (2011). Multiple Attribute Decision Making: Methods and Applications. CRC Press.
49. Vento, M. O., Alcaraz, J. L. G., Macías, A. A. M., & Loya, V. M. (2016). The impact of managerial commitment and kaizen benefits on companies. *Journal of Manufacturing Technology Management*, *27*(5), 692–712. https://doi.org/10.1108/JMTM-02-2016-0021
50. Wu, H.-Y., Tzeng, G.-H., & Chen, Y.-H. (2009). A fuzzy MCDM approach for evaluating banking performance based on a Balanced Scorecard. *Expert Systems with Applications*, *36*, 10135–10147. https://doi.org/10.1016/j.eswa.2009.01.005
51. Yaakob, A. M. B. (2017). *Multi Criteria Decision Making Methodology for Fuzzy Rule Based Systems and Networks Using TOPSIS* [Doctoral dissertation, University of Portsmouth].

About the authors

Ola I.S. El Dardery PhD is Assistant Professor of Accounting and Information Systems, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, Alexandria, Egypt. The author can be contacted at **ola.eldardery@ejust.edu.eg**

Ismail Gomaa is a Professor of Accounting and Auditing at the School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, and Faculty of Commerce, Alexandria University, Alexandria, Egypt. The author can be contacted at **ismail.gomaa@ejust.edu.eg**

Adel R. M. Rayan is a Professor of Human Resources at the School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, Alexandria, Egypt. The author can be contacted at **adel.rayn@ejust.edu.eg**

Dr. Frendy is an Associate Professor of Accounting at the Graduate School of Management, Business School, NUCB, Nagoya, Aichi, Japan. The author can be contacted at **frendy_fa@gsm.nucba.ac.jp**

Ghada El Khayat works at the Computers and Information Systems Department, Chairperson, Faculty of Commerce, Alexandria University, Alexandria, Egypt. The author can be contacted at **ghada.elkhayat@alexu.edu.eg**

Sara H. Sabry is an Assistant Professor of Accounting and Information Systems at the School of International Business, Faculty of International Business and Humanities, Egypt Japan University of Science and Technology, Alexandria, Egypt. The author can be contacted at **sara.husein@ejust.edu.eg**