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Investigating the Influence of Total Productive Maintenance Key Success Factors on the Social Sustainability Dimension of Manufacturing SMEs

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Abstract

Purpose- Key success factors (KSFs) of Total Productive Maintenance (TPM) have historically played a vital role in attaining economic and ecological sustainability but have overlooked social sustainability. Hence, this study analyses and ranks the most significant TPM KSFs for attaining social sustainability in manufacturing SMEs.

Design/methodology/approach- The research employs a deductive methodology to identify the relevant TPM KSFs and social sustainability indicators and then uses Fuzzy TOPSIS to rank the TPM KSFs in order to achieve social sustainability, followed by a sensitivity analysis to assess the methodological robustness.

Findings- The findings indicate that the top five TPM KSFs influencing social sustainability are employee health and safety, organizational culture, top management commitment, employee engagement and effective communication, and effective workplace management. In addition, the results indicate that effective equipment utilization is the least significant TPM key factor affecting social sustainability.

Originality- In the existing literature, little emphasis has been paid to social sustainability and how SMEs may implement these practices. This research adds to the current theory of TPM and social sustainability and sheds light on how SMEs might use TPM to advance toward more socially sustainable operations.

Implications- SME manufacturing managers don't need to worry about all of the TPM KSFs if they only concentrate on the ones that will have the most impact. If managers use the top 5 TPM KSFs as a starting point, they may create customized TPM training programs for their

companies. As a result, this will facilitate the efforts of their personnel toward social sustainability.

Keywords: Total Productive Maintenance, Social Sustainability, Fuzzy TOPSIS, Sensitivity Analysis, Deductive approach.

1. Introduction

Small and Medium Enterprises (SMEs) play an essential role in a country's economy, employment, and other factors that lead to growth over time (Hu *et al.*, 2015). SMEs serve as a growth engine for the community's socioeconomic stability, producing direct and indirect job opportunities (M.P. and P.R., 2020). The growing interest shown by academics in researching SMEs is driving this trend (Vázquez-Carrasco & López-Pérez, 2013). Gaining an edge in today's global business environment often requires a commitment to sustainable practices. As a result, businesses are starting to adopt more eco-friendly practices (Lee *et al.*, 2021; Yadlapalli *et al.*, 2018). The triple bottom line (TBL) dimensions of sustainability include economic, environmental, and social sustainability.

In particular, Peruzzini and Pellicciari (2017) highlight that businesses are focused on new sustainable manufacturing processes in order to achieve sustainable performance. The adoption of lean manufacturing (LM) has proved to be a crucial business strategy for many companies as they strive to attain sustainability and increase their level of competition (Filho and Barco, 2015). LM's business activities are one of the ways that the company helps achieve economic sustainability (Dieste *et al.*, 2021; Dey *et al.*, 2019a). In this particular instance, LM employs resource optimization to reduce waste, which impacts environmental sustainability (Kurdve and Bellgran, 2021; Dey *et al.*, 2019b). In addition, the research conducted by Nath and Agrawal (2020) on big businesses indicates that LM may have a favourable impact on the social sustainability of a firm. Previous studies have shown that LM improves environmental performance, which is important for environmental sustainability (Dieste et al., 2020). Researchers M.P. and P.R. (2020) looked at the influence of LM on many sustainability metrics and discovered that it had a beneficial effect on the overall sustainability performance of manufacturing SMEs. Data from the past indicates that any business, large or small, may become more sustainable by adopting lean principles. Total Productive Maintenance (TPM), Value Stream Mapping (VSM), and Kaizen are only a few techniques that contribute to LM's success.

According to the findings of research that Thanki et al. (2016) carried out on SMEs in India, Total Productive Maintenance (TPM) is one of the most successful lean strategies. TPM may reduce the amount of downtime by using a variety of maintenance philosophies, methods, and procedures (Tortorella *et al.*, 2021). Optimal machine use is crucial for maximizing productivity on the production floor (Jain et al., 2015). Many studies have shown TPM's positive impact on business operations (Furlan *et al.*, 2011; Netland and Ferdows, 2014).

The structure of TPM consists of eight pillars that include "autonomous maintenance, focused improvement, planned maintenance, quality maintenance, education and training, safety, health and environment, office TPM, and development management" (Jain *et al.*, 2014). These eight pillars reflect the core strength of TPM. TPM reduces wastes (non-value elements) with effective use of resources and preventive breakdown techniques (Heravi *et al.*, 2019). Amjad *et al.* (2021) conducted a longitudinal case study concluding that TPM practices are beneficial in generating more efficient and greener manufacturing. Chiarini (2014) indicates that TPM is a valuable maintenance tool, beneficial to reduce energy consumption. At the same time, it helps reduce various leakages and wastages by preventing process failures (Piercy and Rich, 2015). Garza-Reyes *et al.* (2018) conducted a study to investigate the effect of some lean techniques on various environmental sustainability indicators, such as material consumption, energy usage, toxic emissions, and non-product output. Their study concluded that TPM is the most effective lean practice to enhance environmental performance. Chen *et al.* (2019) conducted a global manufacturing survey to explore TPM's effect on environmental sustainability. Their study considered some environmental sustainability factors such as material, water, energy consumption, pollutant and waste emission, some ecological protocols, and their implementation. The study suggested that TPM has a strong influence on environmental sustainability.

Manufacturing companies may improve their operational performance (in terms of quality, cost, delivery, and adaptability) with the aid of TPM (Attri et al., 2013). Since TPM aids in waste reduction (Vukadinov et al., 2018), and since waste reduction aids in the lowering of non-value-added expenses, which leads to financial benefits (Yang et al., 2011). In their multivariate case study, M.P. and P.R. (2020) looked at three economic sustainability indicators: a rise in market value, a rise in profits, and a drop in operational costs. The findings indicate that TPM is a useful lean method that helps in all three aspects of economic sustainability. The study's focus on manufacturing SMEs provides evidence for the proposition that TPM adoption in this sector boosts economic growth. Some other earlier research also suggests the positive effect of TPM on the different indices of economic sustainability (Dieste *et al.*, 2021; Galeazzo and Furlan, 2018; Galeazzo, 2019; Sahoo and Yadav, 2018; Hofer *et al.*, 2012).

While there has been a lot of study on TPM and its effects on economic and environmental sustainability, there needs to be more research on TPM's influence on the social component of sustainability, especially in the context of manufacturing SMEs. To address this gap in the academic literature, the present research formulates its first research question as follows:

RQ1- What are the most important TPM KSFs that manufacturing SMEs should adopt to achieve social sustainability?

To our knowledge, no studies have examined the connection between TPM success elements and social sustainability. In order to fill this gap in the academic literature, this study contributes by determining and ranking the TPM key success factors (KSFs), based on their impact, on a variety of social sustainability indicators. This is accomplished through utilizing the Fuzzy TOPSIS methodology and the participation of professionals with more than ten years of TPM practice experience and knowledge. To this end, the present research addresses the following research question:

RQ2- How to prioritize TPM KSFs based on their effect on various social sustainability indicators of manufacturing SMEs?

A three-step procedure is followed in the present research to address the above research questions. First, key success TPM factors and social sustainability indicators (SSIs) were defined based on an extensive literature review and consultation with experts. Second, a Fuzzy TOPIS analysis was conducted to determine TPM KSFs ranking based on their influence on various SSIs. This step contributed to determining the most influential TPM KSFs to achieve social sustainability in manufacturing SMEs. Finally, a sensitivity analysis was performed to investigate the robustness of the method used in this study.

The rest of the paper is structured as follows: Section 2 presents the review of the literature relevant to the study, from which the research gap addressed by the study is established. Section 3 presents the research methodology followed in this study, while the results are introduced in Section 4. Section 5 covers the discussions and implications of the study. Finally, Section 6 presents the conclusions, limitations, and future research directions from this study.

2. Literature Review

Businesses have more widely recognized the need for proper maintenance management competition increases on both the global and regional levels (Singh *et al.*, 2016). In order to survive in such a cutthroat market, manufacturers must minimize wasteful operations such as product rework, scrap, and defects (Singh and Gupta, 2019). TPM significantly impacts manufacturing SMEs in terms of firm performance, reduced cost, high returns, and economic profitability (Singh and Saini, 2020). Godinho Filho *et al.* (2016) investigated the effect of lean practices on Brazilian manufacturing SMEs and found that TPM helps SMEs to improve their operational performance. Manufacturing SMEs implement TPM to create interactive performance management at the shop floor level, allowing for continual development in productive areas (Shahriar *et al.*, 2022; Vilarinho *et al.*, 2018). Thanki *et al.* (2016) explored the effect of lean-green practices on Indian manufacturing SMEs. Their study indicated that TPM was the most weighted lean practice to improve product quality and reduce cost. Sraun and Singh (2017) performed an empirical investigation on Indian manufacturing SMEs, which suggested that TPM implementation helps to improve productivity and other performance parameters such as organization achievements, cost, quality, delivery, and safety.

Some past scholars, such as Rahman *et al.* (2020) and Dora *et al.* (2014), observed the application of lean practices on small and medium food enterprises and suggested that implementing TPM in SMEs can enhance equipment availability. TPM may be an effective method of increasing the efficiency and sustainability of machinery (Singh *et al.*, 2008). Furthermore, the findings of Dora *et al.* (2014) indicate that TPM could help reduce material wastage and improve quality. This information supports the conclusion that TPM benefits SMEs and its adoption has expanded in this sector. TPM is an essential corporate operation method used by SMEs to improve production performance (Sharma and Sharma, 2013).

Each pillar of TPM has its role, and these pillars complement TPM deliverables. TPM uses preventive maintenance techniques that help to prevent machine breakdowns, leading to a reduced number of accidents within the workplace (Talapatra *et al.*, 2022a). It prevents injuries and deaths of workers and delivers a better health and safe environment for employees (Saha *et al.*, 2022; Wu *et al.*, 2015). TPM also promotes effective communication between employees and offers a swift relationship between different levels of employees (Agustiady & Cudney, 2018; Sahoo & Yadav, 2018The stress levels of workers may be lowered by improved coordination and realistic communication. For the sake of optimal productivity, all employees must take part (Pai *et al.*, 2018). Also, TPM is an important maintenance management technique that provides a safer environment for employees (Talapatra and Uddin, 2019; Vukadinov *et al.*, 2018). TPM helps reduce spills, leakages, wastes, toxic pollutants, and hazardous material emissions (Piercy and Rich, 2015), leading to better health for employees. One of the TPM pillars is health, safety, and environment (Nakajima, 1988), which is determined to deliver better health and safety for the employee. As a result of focusing on this pillar, businesses may create a more secure workplace for their employees.

Talapatra *et al.* (2022b) and Ullah *et al.* (2021) suggest that health, safety, and a safer work environment are the most influential key factors in achieving social sustainability. Past studies (Wickramasinghe & Perera, 2016; Prajogo & McDermott, 2011; Attri *et al.*, 2013; Shaaban & Awni, 2014) suggest that organizational culture is a significant factor in implementing TPM successfully in an organization. Wijethilake *et al.* (2021) determined that organizational culture plays a vital role in leading a firm toward economic sustainability, environmental sustainability, and social sustainability. Singh and Gurtu (2021) indicated that Employee engagement and effective communication, training and education, and top management commitment are the KSFs of TPM. Kiesnere and Baumgartner (2020) explored the role of top management involvement in firm's sustainable development. Their findings suggest that top management helps to promote the sustainable development of companies. Sundström and Mickelsson (2020) indicate that top management is important in achieving social sustainability of firms. Staniškienė and Stankevičiūtė (2018) suggested that employee involvement and effective communication lead to a firm towards social sustainability.

The above discussion suggests that TPM has the potential to deliver social sustainability outcomes within organizations, but studies in this area are still limited. On the other hand, the economic and environmental sustainability connection with TPM has been extensively investigated in previous studies, as evidenced by the aforementioned discussion. In terms of the social sustainability dimension, although evidence from the literature suggests that TPM can contribute to enhancing the social sustainability dimension of companies, this area has received limited attention from scholars and practitioners, especially within the context of manufacturing SMEs.

Even though previous studies have investigated LM practices and their relation to various sustainability performances, limited research has been conducted in relation to TPM and different sustainability dimensions. Despite this, some studies have measured the effect of TPM on environmental sustainability (Chen *et al.*, 2019), but past research has ignored the influence of various TPM KSFs on different sustainability indicators. For example, although some recent past studies have explored various TPM KSFs (Singh and Gurtu, 2021; Diaz-Reza *et al.*, 2018; Bakri *et al.*, 2018; Jain *et al.*, 2017; Gupta *et al.*, 2015; Piechnicki *et al.*, 2015; Gomez *et al.*, 2015; Sabry Shaaban and H. Awni, 2014; Singh and Ahuja 2013; Ng *et al.*, 2011), they have either identified the critical success factors from the literature or they have prioritized them with the help of pairwise comparisons. In this context, no previous research has prioritized the TPM critical success factors based on their influence on SSIs.

2.1 Research Gap

The previous discussion has led to the identification of the following research gaps:

RG1- Social sustainability has not been given enough attention, especially in SMEs, while implementing TPM.

RG2- Social sustainability indicators (SSIs), especially for SMEs, have not been explored in previous research while implementing TPM.

RG3- The effect of TPM KSFs on various SSIs of SMEs has not been considered in past research.

RG4- Past studies have missed identifying the influential TPM KSFs on achieving social sustainability.

3. Materials and Methods

The current research investigates the influence of various TPM KSFs on social sustainability indicators (SSIs) with the deducing approach, fuzzy TOPSIS, and sensitivity analysis. The detailed modelling framework of the investigation is shown in Figure 1. As indicated by this figure, in the first stage, the TPM KSFs and SSIs were determined. The second stage consisted of establishing the influence behaviour of TPM KSFs on various SSIs and ranking them according to these, whereas in stage 3, a sensitivity analysis was carried out to validate the robustness of the method.

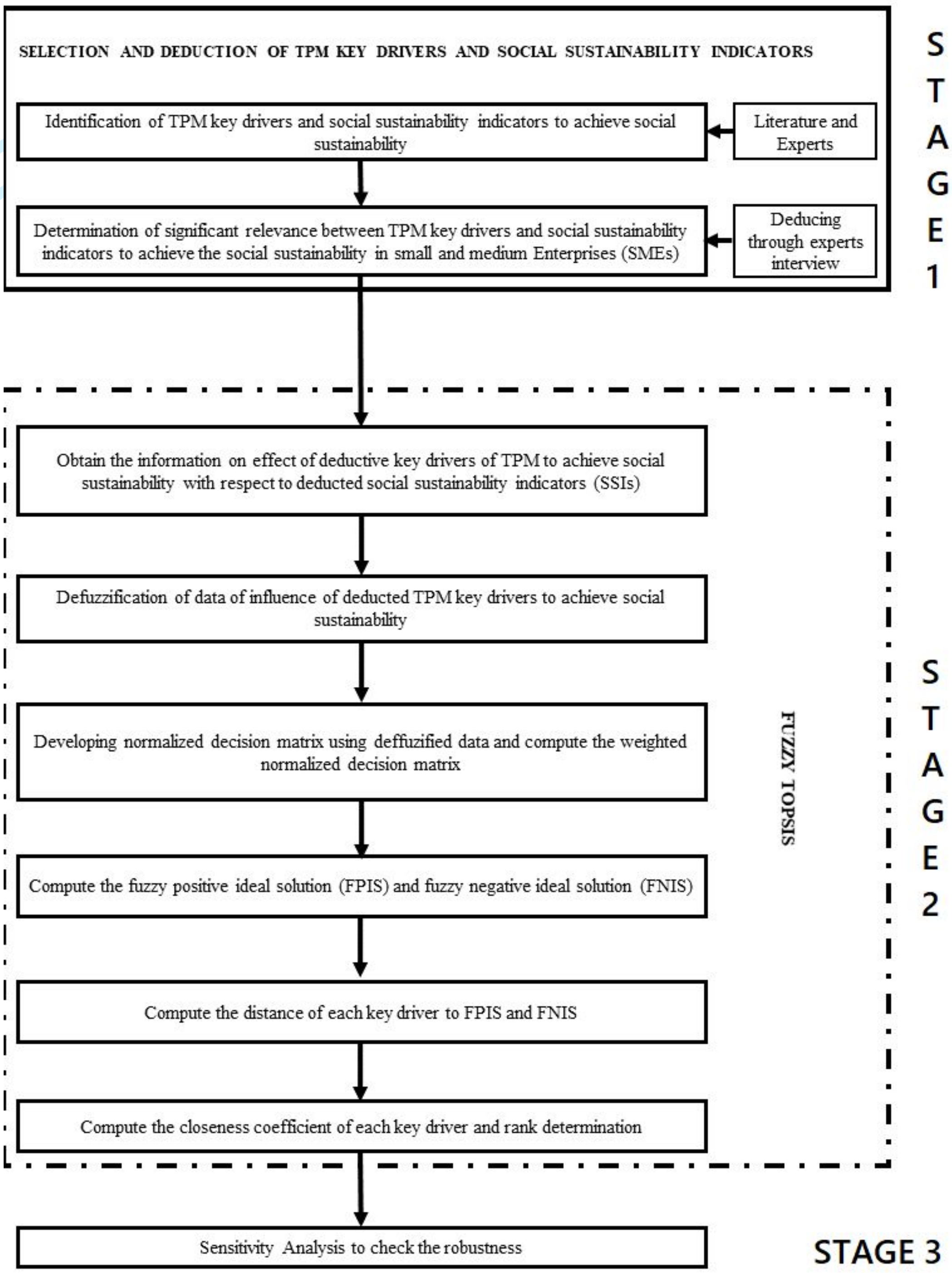

Figure 1. Research Methodology

3.1 Stage 1: Selection and Deduction of TPM KSFs and Social Sustainability Indicators (SSIs)

The findings from the study by Orji and Liu (2020) served as the basis for the first stage of the research approach. Thus, the TPM KSFs and SSIs were selected through an extensive literature review. Various TPM KSFs and SSIs have been previously proposed in the literature, but for this research, only relevant factors and indicators were selected based on the current background of the study, e.g., SSIs relevant to manufacturing SMEs and TPM KSFs relevant to social sustainability. The present research selected a total of 12 TPM KSFs and 11 SSIs. Table I presents the selected TPM KSFs, while Table II includes the selected SSIs from the literature.

"Insert Table I"

"Insert Table II"

After selecting the drivers and indicators, experts in the relevant field were contacted by email and phone. A total of 24 experts from various SMEs were selected, and 15 (with a response rate of 62.5%) were accepted to participate in the study, which is acceptable to justify the study following the fuzzy TOPSIS approach (Fallahpour *et al.*, 2017). The experts also deduced the TPM KSFs and SSIs to obtain the more suitable drivers and indicators for this study. Table III presents a profile summary of the experts who participated in the study.

"Insert Table III"

A questionnaire with "YES" and "NO" responses to deduct the TPM KSFs and SSIs was designed and circulated among the experts. The "YES" and "NO" answers were included in the questionnaire to evaluate the relevance of TPM KSFs and SSIs for Indian manufacturing SMEs. Based on their relevance, experts responded "YES" to keep the drivers/indicators and "NO" to discard the drivers/indicators. The experts' responses for the TPM KSFs are summarised in Table IV, while their responses for the deduction of SSIs are included in Table V.

"Insert Table IV"

"Insert Table V"

After receiving the responses from the experts, the deduction process to finalize the different TPM KSFs (alternatives) and SSIs (criteria) was completed by computing the threshold value for deducing the TPM KSFs in SMEs as follows:

[(Sum of Experts with Yes Response) / (Total Number of responses received for all KSFs including yes and no)] * 100

= [(12+12+11+11+12+11+12+13+15+14+2+3) / (15*12] * 100

= [(128) / (180)] * 100

= 71.11 %

The result of the computation of threshold value indicated that alternatives with less than 71.11% threshold value were to be deducted from the study. Consequently, the final ten alternatives included: Effective equipment utilization **(A_1)**, Quality improvement **(A_2)**, Preventive Breakdown **(A_3)**, Teamwork motivation **(A_4)**, Effective workplace management **(A_5)**, Employee engagement and effective communication **(A_6)**, Training and education **(A_7)**, Organizational culture **(A_8)**, Health and Safety of employees with safer working environment **(A_9)**, and Top management commitment **(A_{10}).**

Similarly, the computation of threshold value for deducing the Social Sustainability Indicators in SMEs was conducted as follows:

[(Sum of Experts with Yes Response) / (Total Number of responses received for all indicators including yes and no)] * 100

= [(15+14+12+13+12+11+11+11+12+3+2) / (15*11] * 100

= [(116) / (165)] * 100

= 70.30 %

The threshold value for the deduction of various criteria was 70.30%. Hence criteria with a value of less than the threshold were removed from the research. As a result, the final nine criteria considered for this study were: Health and safety of employee **(C_1)**, Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) **(C_2)**, Quality of life **(C_3)**, Stakeholder participation and satisfaction **(C_4)**, Improved Working Environment **(C_5)**, Appropriate/Fair Workload distribution for the Operator **(C_6)**, Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**, Minimize the repetition of Work **(C_8)**, Achieve operators wellbeing and job satisfaction **(C_9)**.

After selecting and deducting of the alternatives and criteria, the following stage involved investigating the influence of alternatives on the criteria.

3.2 Stage 2: Fuzzy TOPSIS (F-TOPSIS)

Stage 2 of the research methodology consisted in conducting a Fuzzy TOPSIS analysis to investigate the influence of alternatives on criteria. This analysis led to the ranking of alternatives based on their influence rating.

Fuzzy TOPSIS is predicated on the assumption that the optimal answer is the one that is both the closest to the positive ideal solution (PIS) and the furthest from the negative ideal solution (NIS). Using an MCDM tool to determine the importance of each criterion and then using TOPSIS to rank the options, is a standard procedure in studies devoted to decision assistance (Lahri et al., 2021). The technique is advantageous since it permits evaluating alternatives' efficacy in relation to both the best and worst possible outcomes for each criterion.

TOPSIS was introduced by Hwang and Yoon (1981) as one of the most used MCDM strategies for prioritizing potential solutions. Ideally, the selected alternative is located in close proximity to the PIS and as far away as feasible from the NIS. Here are some of the primary benefits of using this approach suggested by Roszkowska, 2011-

- “simple, rational, comprehensible concept,”
- “intuitive and clear logic that represents the rationale of human choice,”
- “ease of computation and good computational efficiency”
- “a scalar value that accounts for both the best and worst alternative’s ability to measure the relative performance for each alternative in a simple mathematical form.”

Thus, TOPSIS is a preferred method for ranking alternatives based on a set of criteria. The benefit of using a fuzzy method is that it allows allocating relative significance to features using fuzzy numbers rather than exact numbers, which is more appropriate for the real world in a fuzzy context. So, the TOPSIS extended to a fuzzy atmosphere, and this concept is highly well suited for solving team decision-making in a fuzzy context.

Therefore, TOPSIS is used to determine the optimal placement of prospective solutions. A fuzzy method offers the benefit of assigning relative priority to features using fuzzy numbers instead of exact values, which is more realistic in a fuzzy, real-world situation. Thus, TOPSIS was adapted to a fuzzy environment, and the resulting notion is well suited to the problem of resolving group decisions when uncertainty is present.

The impact ranking of the alternatives (enablers) was determined using a fuzzy TOPSIS analysis. In recent years, MCDM approaches have grown in favour of reviewing, evaluating, and rating a wide range of potential options. In order to accomplish a wide variety of goals, MCDM has been widely hailed as a useful technique (Dandage et al., 2018). The present research used a Fuzzy TOPSIS approach, which is an MCDM strategy, because to its usability, the fact that it takes just a few judgements to parameterize, and the fact that it does not restrict either the number of system criteria (indicators) or the alternatives (enablers) (Luthra et al., 2016). Numerous studies in the field of industrial production have made use of fuzzy topological data analysis (TOPA) (Prakash and Barua, 2015; Fallahpour et al., 2017).

The researchers used fuzzy TOPSIS to rank the multiple enablers of TPM based on their influence on different social sustainability criteria. Using their ratings on the system's criteria, Fuzzy TOPSIS analyses potential solutions based on their overall performance.

In this context, Fuzzy questionnaires are used to establish the ratings of each alternative in relation to the system criteria used in the Fuzzy TOPSIS technique. Fuzzy questionnaires were used in this study to examine the impact of the TPM KSFs on the social sustainability of manufacturing SMEs. A fuzzy linguistic scale was used to measure the influence of TPM KSFs on various SSIs. The linguistic scale and its interpretation in triangular fuzzy numbers are presented in Table VI. For example, if one expert thinks that alternative A_1 has a high effect (HE) on criteria C_3, then he/ she will score 4 in his questionnaire, and that response will be interpreted in TFN as (5,7,9).

"Insert Table VI"

Following this approach, all of the experts' responses were recorded and interpreted. The following steps were adapted for the computation of drivers prioritization from the Fuzzy TOPSIS approach (Nădăban *et al.*, 2016):

Step 1: Assigning the ratings to alternatives and criteria

This study assumed that it had a K-member decision group. The weight of criterion Cj was denoted $w^k_j = (w^k_{j1}, w^k_{j2}, w^k_{j3})$, and the fuzzy rating of the k^{th} decision-maker for alternative A_i with respect to criterion C_j was termed $x^k_{ij} = (a^k_{ij}, b^k_{ij}, c^k_{ij})$.

Step 2: Computation of aggregate fuzzy ratings for alternatives and aggregate fuzzy weights for criteria

The computation of aggregate fuzzy ratings $x_{ij} = (a_{ij}, b_{ij}, c_{ij})$ of ith alternative with respect to jth criteria were obtained as follows:

$$a_{ij} = \min_{k} \{a_{ij}^k\}, b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}^k, c_{ij} = \max_{k} \{c_{ij}^k\} \tag{1}$$

The computation of aggregate fuzzy weight $W_j = (w_{j1}, w_{j2}, w_{j3})$ with respect to criteria C_j were obtained as follows:

$$w_{j1} = \min_{k} \{w_{j1}^k\}, w_{j2} = \frac{1}{k}\sum_{k=1}^{k} w_{j2}^k, w_{j3} = \max_{k} \{w_{j3}^k\} \tag{2}$$

Step 3: Development of normalized fuzzy decision matrix

The normalized fuzzy decision matrix is represented by $R = [r_{ij}]$ where,

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ and } c_j^* = \max_{i}\{c_{ij}\} \text{ (benefit criteria)} \tag{3}$$

and

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ and } c_j^- = \min_{i}\{a_{ij}\} \text{ (cost criteria)} \tag{4}$$

Step 4: Computation of weighted normalized fuzzy decision matrix

The weighted normalized fuzzy decision matrix is $V = (v_{ij})$ where,

$$v_{ij} = r_{ij} \times w_j \tag{5}$$

Step 5: Computation of Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS)

The FPIS is presented as A^* and FNIS is presented as A^-, and calculated as follows:

$$A^* = (v_1^*, v_2^*, v_3^*, \ldots\ldots, v_n^*), where\ v_j^* = \max_i \{ v_{ij3} \} \quad (6)$$

$$A^- = (v_1^-, v_2^-, v_3^-, \ldots\ldots, v_n^-), where\ v_j^- = \min_i \{ v_{ij1} \} \quad (7)$$

Step 6: Computation of the distance from each alternative to the FPIS and the FNIS

Distance from each alternative A_i to FPIS is d_i^* and to FNIS is d_i^-. It was calculated as follows:

$$d_i^* = \sum_{j=1}^{n} d(v_{ij}, v_j^*)\ and\ d_i^- = \sum_{j=1}^{n} d(v_{ij}, v_j^-) \quad (8)$$

A vertex method was used to calculate the distance between two fuzzy numbers (FNs). If $x=(a_1, b_1, c_1)$ and $y=(a_2, b_2, c_2)$ were two FNs, then the distance between two FNs was calculated as follows:

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

Step 7: Computation of closeness coefficient CC_i for each alternative

The value of closeness coefficient CC_i for each alternative A_i was calculated as follows:

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

Step 8: Determine the rank of the alternatives

The best alternative was determined by the highest value of the closeness coefficient (CC_i).

3.3 Stage 3: Sensitivity Analysis

The sensitivity analysis approach followed in this study was adapted from (Han and Trimi, 2018). It was conducted to check the consistency of the results. Fuzzy TOPSIS is a subjective approach based on the qualitative inputs of experts (Nădăban *et al.*, 2016). Thus, a sensitivity analysis identifies any biases during the study. Nine criteria were defined in the study. For this reason, nine scenarios were created to check the robustness. In all nine scenarios, one criterion was given the highest weight (7,9,9) and the other eight were given the lowest weight (1,1,3). The inputs of experts will be the same, and the variation of criterion weight will do the analysis. If the ranking of alternatives in the sensitivity analysis differs for most of the scenarios, the study was considered not to be robust.

4. Results

4.1 Fuzzy TOPSIS analysis

Firstly, 15 decision-makers (experts) assigned the ratings to various alternatives and criteria, which were then converted into FNs, as per Table VI interpretation. In this study, 10 alternatives and 9 criteria were used, and the aggregate fuzzy weight of criteria was computed with Equation 2. Table VII presents the type of criterion and its aggregate fuzzy weight.

"Insert Table VII"

The fuzzy ratings of alternatives were then calculated with Equation 1. A combined decision matrix is presented in Table VIII.

"Insert Table VIII"

Since the criteria used in this study was beneficial, Equation 3 was used to develop the normalized fuzzy decision matrix. The results are presented in Table IX.

"Insert Table IX"

After developing the normalized fuzzy decision matrix, the study used Equation 5 to compute the weighted normalized fuzzy decision matrix, which is presented in Table X.

"Insert Table X"

The computation of FPIS and FNIS was completed through Equations 6 and 7. The results are presented in Table XI.

"Insert Table XI"

The distance from each alternative A_i to FPIS and FNIS was calculated with the help of Equations 8 and 9. The values of these distances to FPIS and FNIS are presented in Table XII.

"Insert Table XII"

Finally, the value of the closeness coefficient (CC_i) was calculated with Equation 10 to complete the ranked determination of alternatives. The results are presented in Table XIII.

"Insert Table XIII"

According to the value of the closeness coefficient shown in Table XIII, the ranking of TPM KSFs was determined, with A_9 being on the top ranking with the highest closeness coefficient value of 0.979. The ranking of TPM KSFs to achieve social sustainability resulted as follows: $A_9 > A_8 > A_{10} > A_6 > A_5 > A_4 > A_7 > A_3 > A_2 > A_1$. The result suggests that Effective equipment utilization (A_1) is the lowest closeness coefficient criterion, indicating that Effective equipment utilization (A_1) has the least influence on social sustainability over other KSFs of TPM.

4.2 Sensitivity Analysis

A sensitivity analysis was conducted to check the robustness of the study. Additionally, the sensitivity analysis helped to check the consistency of the method's implementation (Lima-Junior and Carpinetti, 2016). The sensitivity analysis was performed by changing the weight of the individual criteria while other criteria's weight was the same. The results are presented in Table XIV, and Figures 2 and 3. Table XIV indicates that for Scenario 1, the weight of criteria of 1, i.e. $C_1 = (7,9,9)$, whereas the weight of other criteria is (1,1,3).

"Insert Table XIV"

The sensitivity analysis for all 9 scenarios delivered the same TPM KSFs ranking as the original analysis. This suggested the consistency of the Fuzzy TOPSIS analysis and the unbiasedness of the experts. The analysis also suggested that the weight of the criteria did not affect the ranking of the drivers.

Finally, Figures 2 and 3 indicate that the method used in this study is robust and consistent by changing the weights of other criteria.

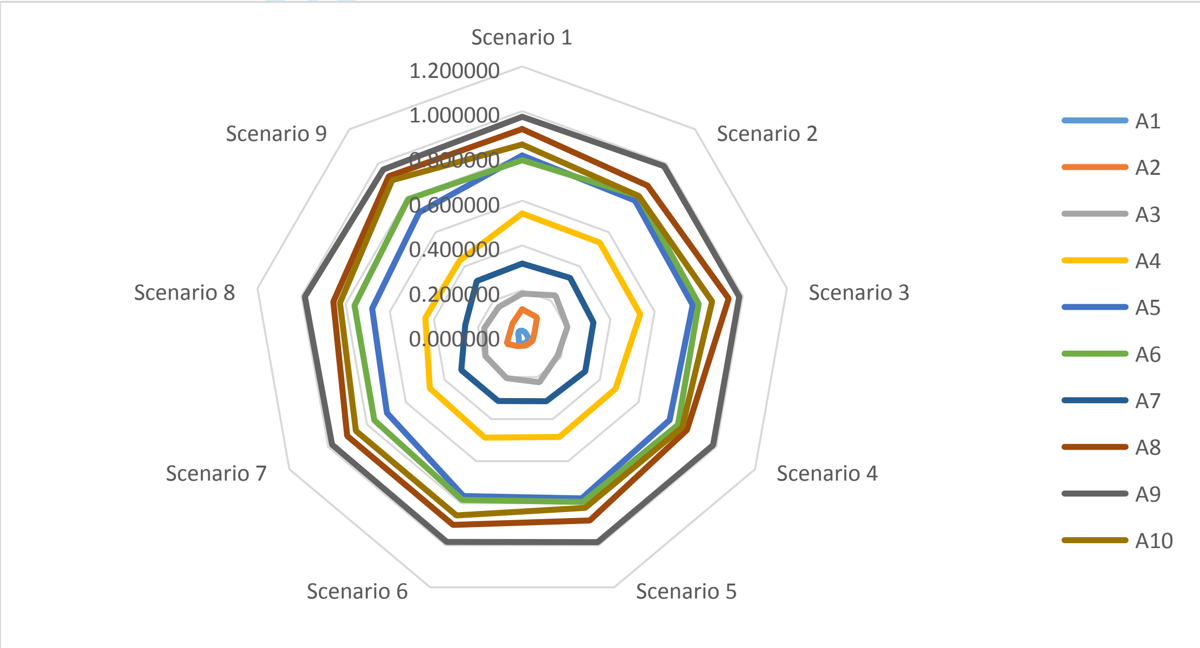

Figure 2. Radar diagram of sensitivity analysis

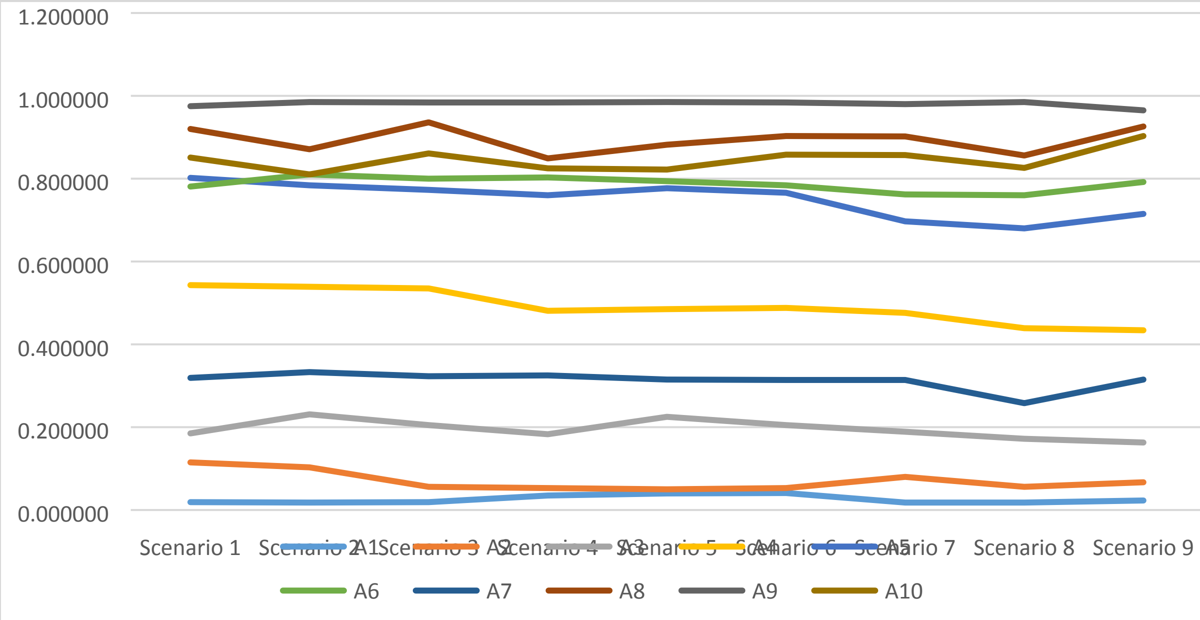

Figure 3. Behaviour of various alternatives in different scenarios

5. Discussion and implications

The results of the present study suggest that the health and safety of employees with a safer working environment (A_9) is the most significant TPM KSF for achieving social sustainability in manufacturing SMEs. It indicates that A_9 has the most influence on the social sustainability of manufacturing SMEs. This result also implies that A_9 should be prioritized to achieve social sustainability when implementing TPM. This outcome supports the findings of Ullah *et al.* (2021), Goel *et al.* (2020), Abid *et al.* (2020), Munny *et al.* (2019), Staniškienė and Stankevičiūtė (2018), and Radjiyev *et al.* (2015), which indicate that a healthy and safe work environment effectively contributes to the achievement of social sustainability in manufacturing SMEs. The possible reason for this finding could be attributed to improving the social performance score due to a healthy and safer work environment (Prasara-A and Gheewala, 2021). Also, this result is in line with the research of Hsu *et al.* (2017), which emphasizes a healthy and safer environment for the sustainable development of SMEs.

The second most important criterion from the findings is organizational culture, which indicates that this factor has considerable potential for delivering social sustainability in manufacturing SMEs while practicing TPM. This conclusion supports the findings of Wijethilake *et al.* (2021), Upadhaya *et al.* (2018), Erthal and Marques (2018), Sroufe (2017), Dubey *et al.* (2017), and Lozano (2013), which indicate that organizational culture leads firm towards sustainability. This could be due to the proactive role of cultural values (people-oriented changes, growth-oriented changes, productivity- and efficiency-oriented changes, and stability- and control-oriented changes), which have been found to help organizations transit towards the attainment of a better sustainability performance (Wijethilake *et al.*, 2021).

The third most influential criterion obtained from the findings is the commitment of top management. Top management commitment plays an important role in nurturpracticestice like TPM and leading the firm toward social sustainability. These findings confirm the past research of Kiesnere and Baumgartner (2020), Sundström and Mickelsson (2020), Henry *et al.* (2018, p.180), Kiron *et al.* (2017) and Kiesnere and Baumgartner (2019) as they indicate that top management commitment plays a vital role in achieving social sustainability and that it leads firms towards sustainable development. In this case, effective leadership of top management is needed to adjust structures, routines, decision-making processes, and strategies, which allows companies to incorporate sustainability as a long-term strategy (Kiesnere and Baumgartner, 2020).

The fourth and fifth resulting ranking criteria were employee engagement and effective communication and workplace management, respectively. These findings suggest that employee involvement and effective communication among them is an important factor that leads companies towards practicing social sustainability. Furthermore, workplace management plays an important role in achieving social sustainability in SMEs while practicing TPM. These findings support the previous research of Staniškienė and Stankevičiūtė (2018), Longoni *et al.*

(2014), and Boström (2011), which indicate that employee involvement and effective communication are important aspects of achieving social sustainability. Employee involvement and effective communication refer to the conditions under which employees can submit suggestions for improving organizational activities, receive information, and participate in decision-making, all of which have been found to enhance social sustainability (Staniškienė and Stankevičiūtė, 2018). The fifth finding supports the studies of Jilcha (2020). This study suggests that effective workplace management contributes to the sustainable development of firms. Workplace involves all the operations of companies, and its effective management leads to reducing events such as hazards and accidents, which consequently improve social sustainability outcomes.

The results of this study contributed to determining the top five influential TPM KSFs that can help SMEs to practice social sustainability. The theoretical and managerial implications of this study and its results are discussed in the following sections.

5.1 Managerial and theoretical implications

This research contributes to the growing body of literature on TPM and social sustainability, and it provides valuable insight into how manufacturing firms might take steps toward more sustainable practices without sacrificing the benefits of TPM. Research and its results are novel in that they are the first to attempt to address a knowledge vacuum in the academic literature by analyzing and highlighting the significance and consequences of TPM KSFs in manufacturing firms and gaining an understanding of their influence on SSIs. Thus, the research may serve as a template for future investigations on TPM KSFs in the SMEs of developing countries. Globally, in developed and developing nations, the connection between sustainability and industry is rising to the forefront of public discourse (Mathiyazhagan, 2021).

Despite this, there is still a lack of awareness about the possible influence that TPM practices might have on social sustainability.

The study's managerial implications are grounded in the context of SMEs. SMEs have traditionally prioritized long-term financial viability, even though the global industrial environment has increasingly prioritized long-term viability. Therefore, there needs to be more focus on sustainability and the potential transition of ancillary activities like shop floor operations (TPM procedures) to these methods. SMEs may use the results of this research to understand better which powerful TPM KSF can aid in their pursuit of social sustainability. This allows managers in SMEs to focus on the most important TPM enabler on the path to social sustainability rather than attempting to master all of them. They may, for instance, create specialized training programs in their companies based on the top 5 TPM enablers. It will provide their personnel and infrastructure with the tools they need to achieve social sustainability more effectively. Further, this study might be used by manufacturing company decision-makers and policymakers to evaluate the extent to which their own organizations practice social sustainability and to develop effective strategies for implementing TPM in order to enhance this aspect of their operations. These contributions benefit manufacturing managers who aim to effectively achieve social sustainability by deploying operational practices like TPM in their manufacturing SMEs. Due to the wide applicability of TPM, various manufacturing sectors where TPM has been applied, e.g., aerospace (Ceruti et al., 2019), textile (Wickramasinghe et al., 2016), food (Singh and Ahuja, 2017), automotive (Morales Méndez and Rodriguez, 2017), among others, as well as the service industry (Ali, 2019), are also likely to benefit from this study. All these sectors are under constant pressure to consider social sustainability as a corporate goal. The effective implementation of TPM provides them with this opportunity.

Our research also offers guidance to business managers on how to maximize the social sustainability of their manufacturing operations by using a set of TPM practices. Using this knowledge, managers may set priorities for the drivers in their SMEs that are consistent with the needs of social sustainability when applied to the manufacturing industry, the prioritizing of KSFs inside a TPM model allows for a sharper emphasis on the different drivers according to their ranking, leading to better results in terms of social sustainability. If we take the example of implementing TPM practices, top management can aid in two ways: first, it can aid in the implementation of TPM practices more effectively (as they are the major player when implementing new managerial practices within firms), and second, it can aid in the development of a tailored model in a way that firms can achieve social sustainability. The inference is that TPM methods may provide safer workplaces by lowering accident rates via closer monitoring of machinery in real-time. In addition, by emphasizing another KSF like "Health and Safety of employee with safer working environment," managers may pay more attention to the well-being of their staff, which in turn improves the work environment for SMEs. By emphasizing another KSF, "organizational culture," methods like TPM may flourish in an employee-centered setting. For this reason, "safety of employee and organizational culture" may guide SMEs to successful social sustainability.

The implications of this research might serve as a point of reference for corporations operating on a global scale. Large corporations have fewer impediments than SMEs due to their better infrastructure, structured supply chains, and organized operations. Therefore, it is highly conceivable that large businesses, as opposed to SMEs, may find it simpler to adopt top TPM KSFs in order to achieve social sustainability. As a result, the findings of this study may be useful in encouraging executives of major companies to place a greater emphasis not just on social sustainability but also on its achievement.

6. Conclusions, limitations and future research

6.1 Conclusions

This study focuses on the practical and theoretical challenges surrounding the impact of TPM on manufacturing SMEs' social sustainability. As a result, we have investigated the impact of TPM on the social sustainability dimension of manufacturing SMEs. As a result, as previously argued in Sections 1 and 2, this work fills a research gap and adds to our understanding of TPM and sustainability by exploring the effect of TPM on the social sustainability of manufacturing SMEs; identifying the required SSIs of manufacturing SMEs with the help of a deductive approach; exploring the effect of TPM KSFs on the social sustainability of manufacturing SMEs as opposed to large enterprises; prioritising the TPM KSFs based on their effect on various SSIs, which helps to identify the most influential TPM KSFs to achieve social sustainability in manufacturing SMEs.

Overall, the paper provides some insight into the managerial implications regarding the influence of TPM implementation on the social sustainability of manufacturing SMEs, encouraging in this way its consideration. For this reason, it provides trustworthy evidence for practitioners of the managerial factors that may play a significant role in achieving social sustainability through the effective implementation of TPM, especially with the topmost influential KSFs. Therefore, empirically testing the proposed concept by prioritizing the TPM KSFs based on their effect on various SSIs of manufacturing SMEs, and their propositions, could be considered as a next step to close the gap between theory and practice. Regarding the central focus of the paper, it is mainly concentrated on managerial aspects. Thus, an opportunity exists to investigate, define and rank the other attributes, e.g. Overall Equipment Effectiveness (OEE), Reliability-centred maintenance, and Resource allocation and prioritization of TPM that may also contribute to achieving social sustainability in manufacturing SMEs, and other sectors SMEs where TPM is commonly implemented. Also, some other MCDM techniques could be used to determine a cluster of influential drivers and KSFs of TPM to achieve various sustainability of SMEs.

6.2 limitations and future research

Despite its robust approach, this paper has some limitations. The first limitation is that the research only looked at manufacturing SMEs. Therefore, further study is needed to shed light on managerial considerations related to TPM's impact on social sustainability in industries other than manufacturing (such as services, logistics, etc.). This sort of research will shed light on how certain industry factors influence TPM's impact on societal sustainability. Second, academic and research specialists were not included since the survey focused primarily on professionals from the business world. Practical sources, knowledgeable academics, and researchers might support our endeavour. Only small and medium-sized Indian manufacturers were included in the analysis. Consequently, comparable studies might be done worldwide to provide a unified and all-encompassing strategy for the impact of TPM on social sustainability. Finally, it is recommended that researchers use a multi-case study research technique to confirm TPM's efficacy and influence on social sustainability in an actual industrial context. Therefore, by examining how particular operational practises and approaches, such as TPM, affect the social sustainability of manufacturing SMEs, this study has not only shed light on the operational excellence and sustainability fields, but also opened new areas for research into the relationship between them.

Disclosure statement
The authors did not report any possible conflicts of interest.

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Tables

Table I. KSFs of TPM

S.No.	KSFs	Citation
1.	Effective equipment utilization **(A_1)**	Jain *et al.*, 2015; Tortorella *et al.*, 2021; Vilarinho *et al.*, 2018; Wickramasinghe & Perera, 2016
2.	Quality improvement **(A_2)**	Nallusamy & Majumdar, 2017; Sabry Shaaban and H. Awni, 2014
3.	Preventive Breakdown **(A_3)**	Yücenur & Şenol, 2021; Wickramasinghe & Perera, 2016; Vukadinov *et al.*, 2018
4.	Teamwork motivation **(A_4)**	Shinde *et al.*, 2017; Santandreu-Mascarell *et al.*, 2013; Baird *et al.*, 2011; Piechnicki *et al.*, 2015
5.	Effective workplace management **(A_5)**	Gupta & Jain, 2015
6.	Employee engagement and effective communication **(A_6)**	Singh and Gurtu, 2021; Agustiady & Cudney, 2018; Wickramasinghe & Perera, 2016; Turanoglu Bekar *et al.*, 2016; Piechnicki *et al.*, 2015; Panneerselvam, 2012; Sahoo & Yadav, 2018; Hooi & Leong, 2017; Attri *et al.*, 2013; Bakri *et al.*, 2018
7.	Training and education **(A_7)**	Singh and Gurtu, 2021; Panneerselvam, 2012; Piechnicki *et al.*, 2015; Hooi & Leong, 2017; Vukadinov *et al.*, 2018; Attri *et al.*, 2013; Bakri *et al.*, 2018; Gupta *et al.*, 2015
8.	Organizational culture **(A_8)**	Singh and Gurtu, 2021; Wickramasinghe & Perera, 2016; Prajogo & McDermott, 2011; Attri *et al.*, 2013; Shaaban & Awni, 2014; Piechnicki *et al.*, 2015; Gupta *et al.*, 2015; Sabry Shaaban and H. Awni, 2014
9.	Health and Safety of employee with safer working environment **(A_9)**	Jasiulewicz-Kaczmarek, 2014; Jain *et al.*, 2014; Vukadinov *et al.*, 2018; Jasiulewicz-Kaczmarek, 2014; Jain *et al.*, 2017
10.	Top management commitment **(A_{10})**	Singh and Gurtu, 2021; Wickramasinghe & Perera, 2016; Díaz-Reza *et al.*, 2018; Shinde *et al.*, 2017; Shavarini *et al.*, 2013; Hooi & Leong, 2017; Attri *et al.*, 2013; Shaaban & Awni, 2014; Panneerselvam, 2012; Jain *et al.*, 2017; Bakri *et al.*, 2018; Piechnicki *et al.*, 2015; Gupta *et al.*, 2015; Sabry Shaaban and H. Awni, 2014
11.	Costs Minimization **(A_{11})**	Yücenur & Şenol, 2021; Hooi & Leong, 2017; Vukadinov *et al.*, 2018
12.	Maximize resource utilization **(A_{12})**	Tortorella *et al.*, 2021; Vilarinho *et al.*, 2018

Table II. Social Sustainability Indicators

S.No.	Indicators of Social Sustainability	Citation

1.	Health and safety of employee **(C_1)**	Radjiyev *et al.*, 2015; Ocampo, 2015; Hassan *et al.*, 2015; Hsu *et al.*, 2017
2.	Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) **(C_2)**	Zarte *et al.*, 2019; Latif *et al.*, 2017; Hassan *et al.*, 2015; Lin *et al.*, 2019
3.	Quality of life **(C_3)**	Hassan *et al.*, 2015; Hojnik *et al.*, 2020
4.	Stakeholder participation and satisfaction **(C_4)**	Hristov and Chirico, 2019
5.	Improved Working Environment **(C_5)**	Lin *et al.*, 2019
6.	Appropriate/Fair Workload distribution for the Operator **(C_6)**	Lin *et al.*, 2019
7.	Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**	Zarte *et al.*, 2019; Lin *et al.*, 2019; Hsu *et al.*, 2017; Latif *et al.*, 2017
8.	Minimize the repetition of Work **(C_8)**	Latif *et al.*, 2017
9.	Achieve operators wellbeing and job satisfaction **(C_9)**	Lin *et al.*, 2019; Ocampo, 2015
10.	Employee overall growth **(C_{10})**	Hojnik *et al.*, 2020
11.	Reduce employee turnover Ratio **(C_{11})**	Hojnik *et al.*, 2020

Table III. Experts Summary

Characteristics		**Number of Experts response**	**Percentage of experts response**
Age	25- 40 years	4	26.67%
	41- 60 years	11	73.33%
Education	Graduation	3	20%
	Post-Graduation	12	80%
Experience	10- 20 years	5	33.33%
	More than 20 years	10	66.67%
Level of management	Middle Management	6	40%
	Upper Management	9	60%

Table IV. Deduction summary for TPM KSFs in SMEs

Alternatives / KSFs	**Relevant to Small and Medium Enterprises (SMEs)**				
	Experts with "Yes" Response	**Percentage of "Yes" Response (%)**	**Experts with "No" Response**	**Percentage of "No" Response (%)**	**Total number of Response**

Effective equipment utilization (**A_1**)	12	80	3	20	15
Quality improvement (**A_2**)	12	80	3	20	15
Preventive Breakdown (**A_3**)	11	73.33	4	26.67	15
Team work motivation (**A_4**)	11	73.33	4	26.67	15
Effective workplace management (**A_5**)	12	80	3	20	15
Employee engagement and effective communication (**A_6**)	11	73.33	4	26.67	15
Training and education (**A_7**)	12	80	3	20	15
Organizational culture (**A_8**)	13	86.67	2	13.33	15
Health and Safety of employee with safer working environment (**A_9**)	15	100	-	-	15
Top management commitment (**A_{10}**)	14	93.33	1	6.67	15
Costs Minimization (**A_{11}**)	2	13.33	13	86.67	15
Maximize resource utilization (**A_{12}**)	3	20	12	80	15

Table V. Deduction summary for Social Sustainability Indicators (SSIs) in SMEs

Criteria/ SSIs	**Relevant to Small and Medium Enterprises (SMEs)**				
	Experts with "Yes" Response	**Percentage of "Yes" Response (%)**	**Experts with "No" Response**	**Percentage of "No" Response (%)**	**Total number of Response**
Health and safety of employee (**C_1**)	15	100	-	-	15
Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) (**C_2**)	14	93.33	1	6.67	15
Quality of life (**C_3**)	12	80	3	20	15
Stakeholder participation and satisfaction (**C_4**)	13	86.67	2	13.33	15

Improved Working Environment **(C_5)**	12	80	3	20	15
Appropriate/Fair Workload distribution for the Operator **(C_6)**	11	73.33	4	26.67	15
Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**	11	73.33	4	26.67	15
Minimize the repetition of Work **(C_8)**	11	73.33	4	26.67	15
Achieve operators wellbeing and job satisfaction **(C_9)**	12	80	3	20	15
Employee overall growth **(C_{10})**	3	20	12	80	15
Reduce employee turnover Ratio **(C_{11})**	2	13.33	13	86.67	15

Table VI. Interpretation of linguistic scale and TFN

Scale	**Scores**	**Triangular Fuzzy Number (TFN)**
Very Poor Effect (VPE)	1	(1,1,3)
Poor Effect (PE)	2	(1,3,5)
Medium Effect (ME)	3	(3,5,7)
High Effect (HE)	4	(5,7,9)
Very High Effect (VHE)	5	(7,9,9)

Table VII. Aggregate fuzzy weight allocation for various SSIs (criteria)

Criterion	**Criterion type**	**Aggregate Fuzzy Weight (W_j)**
C_1	Benefit	(3.000,6.330,9.000)
C_2	Benefit	(1.000,4.330,7.000)
C_3	Benefit	(3.000,6.600,9.000)
C_4	Benefit	(1.000,3.670,7.000)
C_5	Benefit	(1.000,5.400,9.000)
C_6	Benefit	(1.000,5.130,9.000)
C_7	Benefit	(1.000,4.600,9.000)
C_8	Benefit	(3.000,6.600,9.000)
C_9	Benefit	(1.000,4.730,9.000)

Table VIII. Combined Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	(1.400,2.867,4.867)	(1.267,2.467,4.467)	(1.267,2.467,4.467)	(1.800,3.267,5.267)	(1.400,2.467,4.467)	(1.400,3.000,5.000)	(1.133,2.067,4.067)	(1.267,2.600,4.600)	(1.400,2.600,4.600)
A_2	(2.067,3.933,5.933)	(1.800,3.400,5.400)	(1.400,2.467,4.467)	(1.400,3.133,5.133)	(1.133,2.067,4.067)	(1.267,2.600,4.600)	(1.400,2.600,4.600)	(1.400,2.600,4.600)	(1.267,2.867,4.867)
A_3	(1.933,3.533,5.533)	(2.333,4.067,6.067)	(2.200,3.533,5.400)	(2.067,3.667,5.667)	(2.200,3.667,5.667)	(1.933,3.667,5.533)	(1.533,3.000,5.000)	(2.067,3.000,4.867)	(1.800,2.733,4.600)
A_4	(3.800,5.800,7.800)	(3.667,5.667,7.533)	(3.667,5.400,7.267)	(3.133,4.867,6.733)	(2.733,4.600,6.600)	(2.733,4.600,6.600)	(2.867,4.200,6.200)	(2.200,4.067,6.067)	(2.200,3.667,5.667)
A_5	(5.000,7.000,8.733)	(4.733,6.733,8.333)	(4.333,6.333,8.067)	(4.333,6.333,8.067)	(4.600,6.600,8.467)	(4.067,6.067,7.800)	(3.133,5.000,7.000)	(3.133,5.000,7.000)	(3.267,5.267,7.133)
A_6	(4.200,6.200,7.933)	(4.733,6.733,8.333)	(4.333,6.333,8.200)	(4.600,6.600,8.333)	(4.467,6.467,8.200)	(3.933,5.933,7.667)	(3.800,5.667,7.533)	(4.067,5.933,7.800)	(4.067,6.067,7.933)
A_7	(2.333,4.333,6.333)	(2.600,4.333,6.200)	(2.467,4.067,5.933)	(2.600,4.600,6.467)	(2.067,3.800,5.800)	(2.200,3.933,5.933)	(2.200,3.667,5.667)	(1.667,3.133,5.133)	(2.333,3.933,5.933)
A_8	(5.267,7.267,8.733)	(4.467,6.467,8.333)	(5.400,7.400,8.600)	(4.067,6.067,8.067)	(4.733,6.733,8.600)	(4.600,6.600,8.333)	(4.867,6.867,8.600)	(4.333,6.333,8.200)	(5.000,7.000,8.733)
A_9	(5.533,7.533,8.467)	(5.667,7.667,8.733)	(5.400,7.400,8.600)	(5.533,7.533,8.467)	(5.800,7.800,8.733)	(5.133,7.133,8.600)	(5.533,7.533,8.467)	(5.800,7.800,8.733)	(5.000,7.000,8.333)

A_{10}	(4.600,6.600,8.467)	(3.933, 5.933,7.933)	(4.600, 6.600,8.467)	(4.200, 6.200,8.067)	(4.200, 6.200,7.933)	(4.333, 6.333,8.333)	(4.600, 6.600,8.333)	(4.333, 6.333,8.333)	(5.133, 7.133,8.867)

Table IX. Normalized Fuzzy Decision Matrix

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	(0.160,0.328,0.557)	(0.145, 0.282,0.512)	(0.147, 0.287,0.519)	(0.213, 0.386,0.622)	(0.160, 0.282,0.512)	(0.163, 0.349,0.581)	(0.132, 0.240,0.473)	(0.145, 0.298,0.527)	(0.158, 0.293,0.519)
A_2	(0.237,0.450,0.679)	(0.206, 0.389,0.618)	(0.163, 0.287,0.519)	(0.165, 0.370,0.606)	(0.130, 0.237,0.466)	(0.147, 0.302,0.535)	(0.163, 0.302,0.535)	(0.160, 0.298,0.527)	(0.143, 0.323,0.549)
A_3	(0.221,0.405,0.634)	(0.267, 0.466,0.695)	(0.256, 0.411,0.628)	(0.244, 0.433,0.669)	(0.252, 0.420,0.649)	(0.225, 0.426,0.643)	(0.178, 0.349,0.581)	(0.237, 0.344,0.557)	(0.203, 0.308,0.519)
A_4	(0.435,0.664,0.893)	(0.420, 0.649,0.863)	(0.426, 0.628,0.845)	(0.370, 0.575,0.795)	(0.313, 0.527,0.756)	(0.318, 0.535,0.767)	(0.333, 0.488,0.721)	(0.252, 0.466,0.695)	(0.248, 0.414,0.639)
A_5	(0.573,0.802,1.000)	(0.542, 0.771,0.954)	(0.504, 0.736,0.938)	(0.512, 0.748,0.953)	(0.527, 0.756,0.970)	(0.473, 0.705,0.907)	(0.364, 0.581,0.814)	(0.359, 0.573,0.802)	(0.368, 0.594,0.804)
A_6	(0.481,0.710,0.908)	(0.542, 0.771,0.954)	(0.504, 0.736,0.953)	(0.543, 0.779,0.984)	(0.512, 0.741,0.939)	(0.457, 0.690,0.892)	(0.442, 0.659,0.876)	(0.466, 0.679,0.893)	(0.459, 0.684,0.895)
A_7	(0.267,0.496,0.725)	(0.298, 0.496,0.710)	(0.287, 0.473,0.690)	(0.307, 0.543,0.764)	(0.237, 0.435,0.664)	(0.256, 0.457,0.690)	(0.256, 0.426,0.659)	(0.191, 0.359,0.588)	(0.263, 0.444,0.669)
A_8	(0.603,0.832,1.000)	(0.512, 0.741,0.954)	(0.628, 0.860,1.000)	(0.480, 0.717,0.953)	(0.542, 0.771,0.985)	(0.535, 0.767,0.969)	(0.566, 0.798,1.000)	(0.496, 0.725,0.939)	(0.564, 0.789,0.985)

A_9	(0.63 4,0.8 63,0. 970)	(0.649, 0.878,1 .000)	(0.628, 0.860,1 .000)	(0.653, 0.890,1 .000)	(0.664, 0.893,1 .000)	(0.597, 0.829,1 .000)	(0.643, 0.876,0 .985)	(0.664, 0.893,1 .000)	(0.564, 0.789,0 .940)
A_{10}	(0.52 7,0.7 56,0. 970)	(0.450, 0.679,0 .908)	(0.535, 0.767,0 .985)	(0.496, 0.732,0 .953)	(0.481, 0.710,0 .908)	(0.504, 0.736,0 .969)	(0.535, 0.767,0 .969)	(0.496, 0.725,0 .954)	(0.579, 0.804,1 .000)

Table X. Weighted Normalized Fuzzy Decision Matrix

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	0.48) 1,2.0 .78,5 (016	,0.145) 1.223,3 (581.	,0.442) 1.893,4 (675.	,0.213) 1.416,4 (354.	,0.160) 1.525,4 (604.	,0.163) 1.790,5 (233.	,0.132) 1.106,4 (256.	,0.435) 1.965,4 (741.	,0.158) 1.387,4 (669.
A_2	0.71) 0,2.8 .51,6 (114	,0.206) 1.686,4 (328.	,0.488) 1.893,4 (675.	,0.165) 1.358,4 (244.	,0.130) 1.278,4 (191.	,0.147) 1.551,4 (814.	,0.163) 1.391,4 (814.	,0.481) 1.965,4 (741.	,0.143) 1.529,4 (940.
A_3	0.66) 4,2.5 .61,5 (702	,0.267) 2.017,4 (863.	,0.767) 2.711,5 (651.	,0.244) 1.589,4 (685.	,0.252) 2.267,5 (840.	,0.225) 2.187,5 (790.	,0.178) 1.605,5 (233.	,0.710) 2.267,5 (016.	,0.203) 1.458,4 (669.
A_4	1.30) 5,4.2 .04,8 (038	,0.420) 2.810,6 (038.	,1.279) 4.144,7 (605.	,0.370) 2.110,5 (566.	,0.313) 2.844,6 (802.	,0.318) 2.744,6 (907.	,0.333) 2.247,6 (488.	,0.756) 3.074,6 (252.	,0.248) 1.956,5 (752.
A_5	1.71) 8,5.0 .74,9 (000	,0.542) 3.338,6 (679.	,1.512) 4.860,8 (442.	,0.512) 2.745,6 (669.	,0.527) 4.081,8 (726.	,0.473) 3.619,8 (163.	,0.364) 2.674,7 (326.	,1.076) 3.779,7 (214.	,0.368) 2.810,7 (240.
A_6	1.44) 3,4.4 .94,8 (176	,0.542) 3.338,6 (679.	,1.512) 4.860,8 (581.	,0.543) 2.861,6 (889.	,0.512) 3.999,8 (451.	,0.457) 3.539,8 (024.	,0.442) 3.031,7 (883.	,1.397) 4.484,8 (038.	,0.459) 3.236,8 (052.
A_7	0.80) 1,3.1 .41,6 (527	,0.298) 2.148,4 (970.	,0.861) 3.121,6 (209.	,0.307) 1.994,5 (347.	,0.237) 2.350,5 (977.	,0.256) 2.346,6 (209.	,0.256) 1.961,5 (931.	,0.573) 2.368,5 (290.	,0.263) 2.098,6 (022.

A$_8$	1.80) 9,5.2 .67,9 (000	,0.512) 3.206,6 (679.	,1.884) 5.679,9 (000.	,0.480) 2.630,6 (669.	,0.542) 4.163,8 (863.	,0.535) 3.937,8 (721.	,0.566) 3.673,9 (000.	,1.488) 4.786,8 (451.	,0.564) 3.734,8 (864.
A$_9$	1.90) 1,5.4 .60,8 (726	,0.649) 3.801,7 (000.	,1.884) 5.679,9 (000.	,0.653) 3.265,7 (000.	,0.664) 4.823,9 (000.	,0.597) 4.255,9 (000.	,0.643) 4.029,8 (861.	,1.992) 5.895,9 (000.	,0.564) 3.734,8 (458.
A$_{10}$	1.58) 0,4.7 .84,8 (726	,0.450) 2.942,6 (359.	,1.605) 5.065,8 (861.	,0.496) 2.687,6 (669.	,0.481) 3.834,8 (176.	,0.504) 3.778,8 (721.	,0.535) 3.530,8 (721.	,1.488) 4.786,8 (588.	,0.579) 3.805,9 (000.

Table XI. Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS)

	Positive ideal (FPIS)	**Negative ideal (FNIS)**
C$_1$	(1.901,5.460,9.000)	(0.481,2.078,5.016)
C$_2$	(0.649,3.801,7.000)	(0.145,1.223,3.581)
C$_3$	(1.884,5.679,9.000)	(0.442,1.893,4.675)
C$_4$	(0.653,3.265,7.000)	(0.165,1.358,4.244)
C$_5$	(0.664,4.823,9.000)	(0.130,1.278,4.191)
C$_6$	(0.597,4.255,9.000)	(0.147,1.551,4.814)
C$_7$	(0.643,4.029,9.000)	(0.132,1.106,4.256)
C$_8$	(1.992,5.895,9.000)	(0.435,1.965,4.741)
C$_9$	(0.579,3.805,9.000)	(0.143,1.387,4.669)

Table XII. Distance from each key deriver to FPIS and FNIS

	Distance from positive ideal (d_i^*)	**Distance from negative ideal (d_i^-)**
A$_1$	26.286	0.642
A$_2$	25.083	1.888
A$_3$	21.81	5.178
A$_4$	13.662	13.37
A$_5$	6.74	20.477
A$_6$	5.774	21.394

A_7	18.504	8.457
A_8	2.66	24.693
A_9	0.554	26.443
A_{10}	4.036	23.317

Table XIII. Computation of Closeness Coefficient (CC_i) for each driver and rank determination

Alternatives / KSFs	d_i^*	d_i^-	$d_i^* + d_i^-$	$CC_i = ((d_i^-)/(d_i^* + d_i^-))$	Rank
A_1	26.286	0.642	26.928	0.024	10
A_2	25.083	1.888	26.971	0.07	9
A_3	21.81	5.178	26.988	0.192	8
A_4	13.662	13.37	27.032	0.495	6
A_5	6.74	20.477	27.217	0.752	5
A_6	5.774	21.394	27.168	0.787	4
A_7	18.504	8.457	26.961	0.314	7
A_8	2.66	24.693	27.353	0.903	2
A_9	0.554	26.443	26.997	0.979	1
A_{10}	4.036	23.317	27.353	0.852	3

Table XIV. Sensitivity Analysis

	SCENARIO									**Ranking for each scenario**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
	C_1= (7,9,9), and others (1,1,3)	**C_2= (7,9,9), and others (1,1,3)**	**C_3= (7,9,9), and others (1,1,3)**	**C_4= (7,9,9), and others (1,1,3)**	**C_5= (7,9,9), and others (1,1,3)**	**C_6= (7,9,9), and others (1,1,3)**	**C_7= (7,9,9), and others (1,1,3)**	**C_8= (7,9,9), and others (1,1,3)**	**C_9= (7,9,9), and others (1,1,3)**	
A1	0.019000	0.018000	0.019000	0.035000	0.040000	0.041000	0.018000	0.018000	0.023000	10
A2	0.115000	0.103000	0.056000	0.053000	0.050000	0.053000	0.080000	0.056000	0.067000	9
A3	0.185000	0.231000	0.205000	0.183000	0.225000	0.205000	0.189000	0.172000	0.163000	8
A4	0.543000	0.539000	0.535000	0.481000	0.485000	0.488000	0.476000	0.439000	0.434000	6
A5	0.802000	0.784000	0.773000	0.760000	0.777000	0.766000	0.697000	0.680000	0.715000	4

A6	0.781000	0.810267	0.800000	0.803000	0.794000	0.784000	0.762000	0.760000	0.792000	5
A7	0.319000	0.333000	0.323000	0.325000	0.315000	0.314000	0.314000	0.258000	0.315000	7
A8	0.920000	0.871000	0.936000	0.849000	0.882000	0.903000	0.902000	0.856000	0.926000	2
A9	0.975000	0.985000	0.984000	0.984000	0.985000	0.984000	0.980000	0.985000	0.965000	1
A10	0.851000	0.810297	0.861000	0.825000	0.822000	0.858000	0.857000	0.826000	0.903000	3

Figures

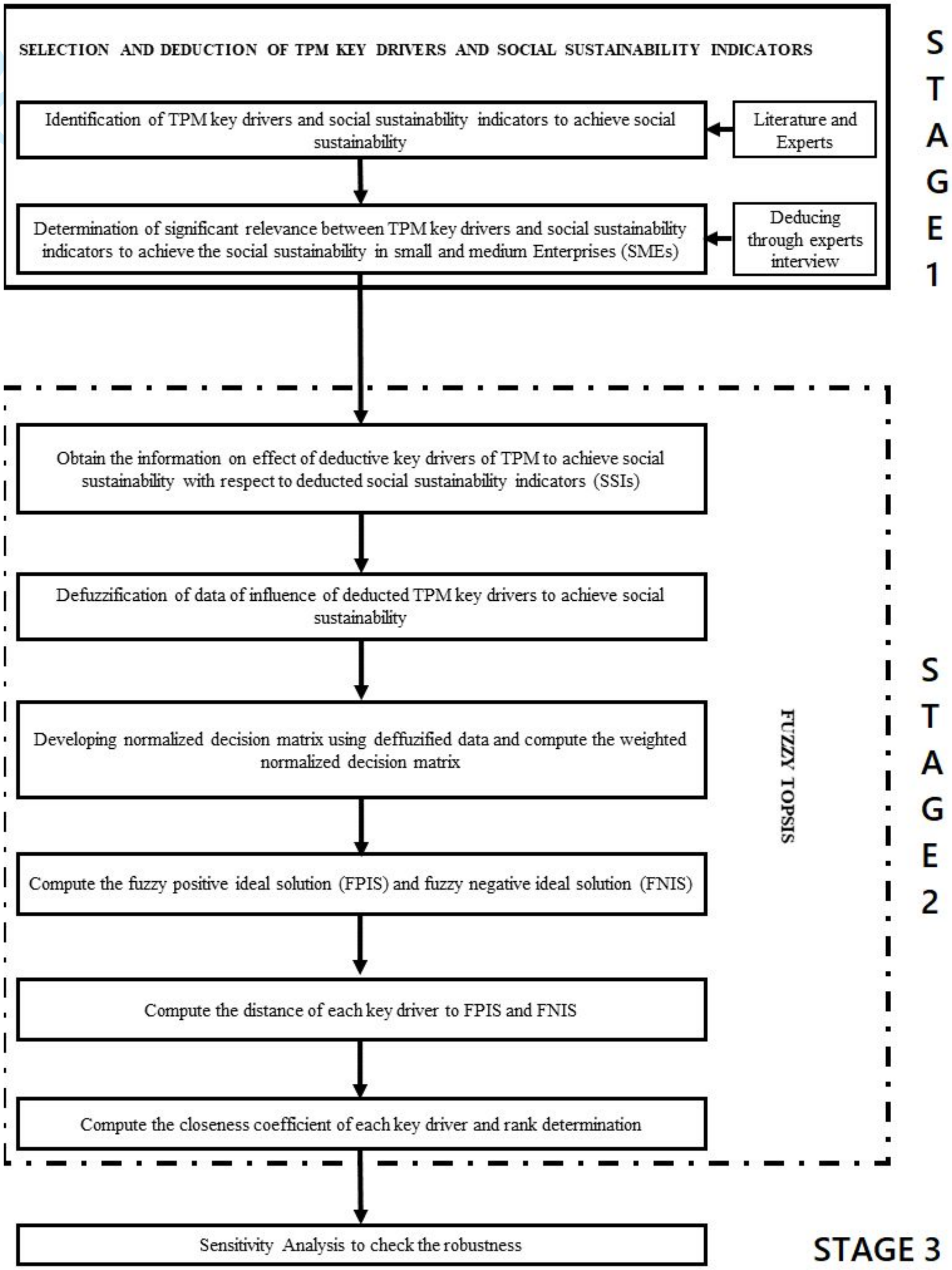

Figure 1. Research Methodology

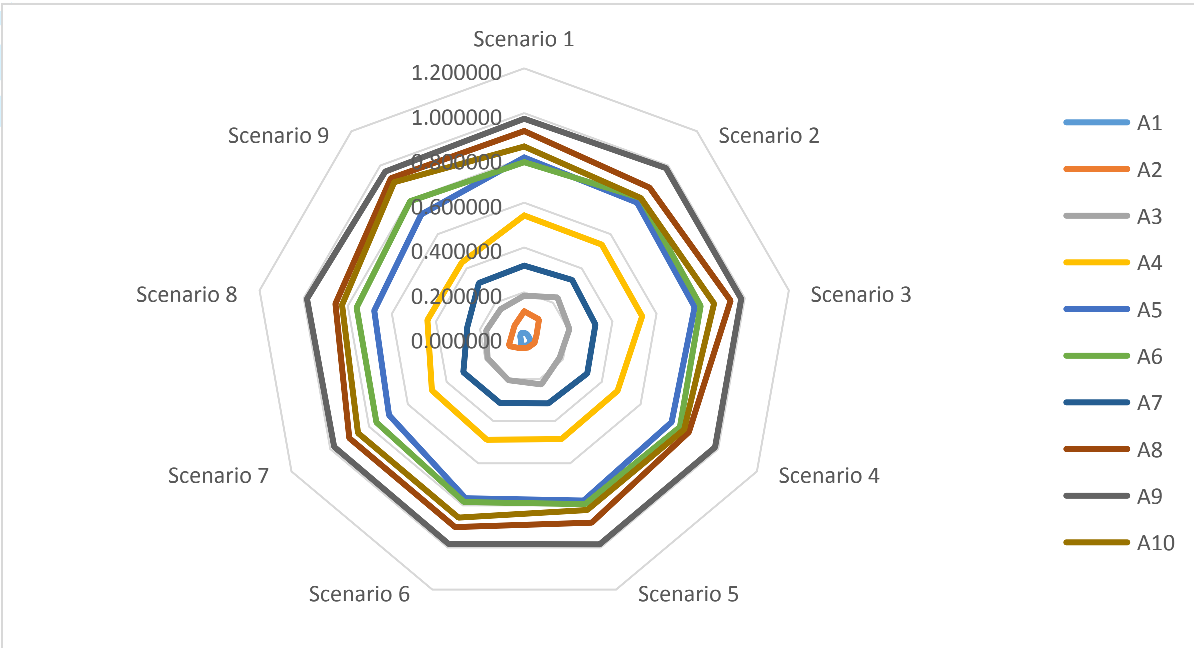

Figure 2. Radar diagram of sensitivity analysis

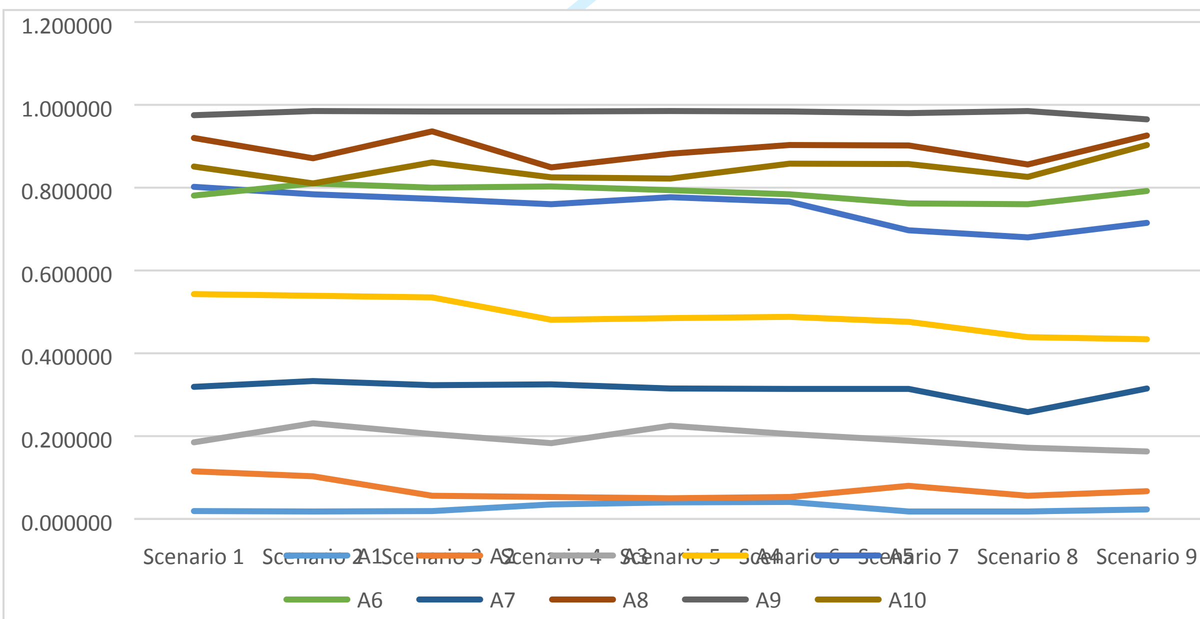

Figure 3. Behaviour of various alternatives in different scenarios

Tables

Table I. KSFs of TPM

S.No.	KSFs	Citation
1.	Effective equipment utilization **(A_1)**	Jain *et al.*, 2015; Tortorella *et al.*, 2021; Vilarinho *et al.*, 2018; Wickramasinghe & Perera, 2016
2.	Quality improvement **(A_2)**	Nallusamy & Majumdar, 2017; Sabry Shaaban and H. Awni, 2014
3.	Preventive Breakdown **(A_3)**	Yücenur & Şenol, 2021; Wickramasinghe & Perera, 2016; Vukadinov *et al.*, 2018
4.	Teamwork motivation **(A_4)**	Shinde *et al.*, 2017; Santandreu-Mascarell *et al.*, 2013; Baird *et al.*, 2011; Piechnicki *et al.*, 2015
5.	Effective workplace management **(A_5)**	Gupta & Jain, 2015
6.	Employee engagement and effective communication **(A_6)**	Singh and Gurtu, 2021; Agustiady & Cudney, 2018; Wickramasinghe & Perera, 2016; Turanoglu Bekar *et al.*, 2016; Piechnicki *et al.*, 2015; Panneerselvam, 2012; Sahoo & Yadav, 2018; Hooi & Leong, 2017; Attri *et al.*, 2013; Bakri *et al.*, 2018
7.	Training and education **(A_7)**	Singh and Gurtu, 2021; Panneerselvam, 2012; Piechnicki *et al.*, 2015; Hooi & Leong, 2017; Vukadinov *et al.*, 2018; Attri *et al.*, 2013; Bakri *et al.*, 2018; Gupta *et al.*, 2015
8.	Organizational culture **(A_8)**	Singh and Gurtu, 2021; Wickramasinghe & Perera, 2016; Prajogo & McDermott, 2011; Attri *et al.*, 2013; Shaaban & Awni, 2014; Piechnicki *et al.*, 2015; Gupta *et al.*, 2015; Sabry Shaaban and H. Awni, 2014
9.	Health and Safety of employee with safer working environment **(A_9)**	Jasiulewicz-Kaczmarek, 2014; Jain *et al.*, 2014; Vukadinov *et al.*, 2018; Jasiulewicz-Kaczmarek, 2014; Jain *et al.*, 2017
10.	Top management commitment **(A_{10})**	Singh and Gurtu, 2021; Wickramasinghe & Perera, 2016; Díaz-Reza *et al.*, 2018; Shinde *et al.*, 2017; Shavarini *et al.*, 2013; Hooi & Leong, 2017; Attri *et al.*, 2013; Shaaban & Awni, 2014; Panneerselvam, 2012; Jain *et al.*, 2017; Bakri *et al.*, 2018; Piechnicki *et al.*, 2015; Gupta *et al.*, 2015; Sabry Shaaban and H. Awni, 2014
11.	Costs Minimization **(A_{11})**	Yücenur & Şenol, 2021; Hooi & Leong, 2017; Vukadinov *et al.*, 2018
12.	Maximize resource utilization **(A_{12})**	Tortorella *et al.*, 2021; Vilarinho *et al.*, 2018

Table II. Social Sustainability Indicators

S.No.	**Indicators of Social Sustainability**	**Citation**
1.	Health and safety of employee **(C_1)**	Radjiyev *et al.*, 2015; Ocampo, 2015; Hassan *et al.*, 2015; Hsu *et al.*, 2017
2.	Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) **(C_2)**	Zarte *et al.*, 2019; Latif *et al.*, 2017; Hassan *et al.*, 2015; Lin *et al.*, 2019
3.	Quality of life **(C_3)**	Hassan *et al.*, 2015; Hojnik *et al.*, 2020
4.	Stakeholder participation and satisfaction **(C_4)**	Hristov and Chirico, 2019
5.	Improved Working Environment **(C_5)**	Lin *et al.*, 2019
6.	Appropriate/Fair Workload distribution for the Operator **(C_6)**	Lin *et al.*, 2019
7.	Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**	Zarte *et al.*, 2019; Lin *et al.*, 2019; Hsu *et al.*, 2017; Latif *et al.*, 2017
8.	Minimize the repetition of Work **(C_8)**	Latif *et al.*, 2017
9.	Achieve operators wellbeing and job satisfaction **(C_9)**	Lin *et al.*, 2019; Ocampo, 2015
10.	Employee overall growth **(C_{10})**	Hojnik *et al.*, 2020
11.	Reduce employee turnover Ratio **(C_{11})**	Hojnik *et al.*, 2020

Table III. Experts Summary

Characteristics		**Number of Experts response**	**Percentage of experts response**
Age	25- 40 years	4	26.67%
	41- 60 years	11	73.33%
Education	Graduation	3	20%
	Post-Graduation	12	80%
Experience	10- 20 years	5	33.33%
	More than 20 years	10	66.67%
Level of	Middle Management	6	40%

management	Upper Management	9	60%

Table IV. Deduction summary for TPM KSFs in SMEs

Alternatives / KSFs	**Relevant to Small and Medium Enterprises (SMEs)**				
	Experts with "Yes" Response	**Percentage of "Yes" Response (%)**	**Experts with "No" Response**	**Percentage of "No" Response (%)**	**Total number of Response**
Effective equipment utilization **(A_1)**	12	80	3	20	15
Quality improvement **(A_2)**	12	80	3	20	15
Preventive Breakdown **(A_3)**	11	73.33	4	26.67	15
Team work motivation **(A_4)**	11	73.33	4	26.67	15
Effective workplace management **(A_5)**	12	80	3	20	15
Employee engagement and effective communication **(A_6)**	11	73.33	4	26.67	15
Training and education **(A_7)**	12	80	3	20	15
Organizational culture **(A_8)**	13	86.67	2	13.33	15
Health and Safety of employee with safer working environment **(A_9)**	15	100	-	-	15
Top management commitment **(A_{10})**	14	93.33	1	6.67	15
Costs Minimization **(A_{11})**	2	13.33	13	86.67	15
Maximize resource utilization **(A_{12})**	3	20	12	80	15

Table V. Deduction summary for Social Sustainability Indicators (SSIs) in SMEs

Criteria/ SSIs	**Relevant to Small and Medium Enterprises (SMEs)**

	Experts with "Yes" Response	Percentage of "Yes" Response (%)	Experts with "No" Response	Percentage of "No" Response (%)	Total number of Response
Health and safety of employee **(C_1)**	15	100	-	-	15
Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) **(C_2)**	14	93.33	1	6.67	15
Quality of life **(C_3)**	12	80	3	20	15
Stakeholder participation and satisfaction **(C_4)**	13	86.67	2	13.33	15
Improved Working Environment **(C_5)**	12	80	3	20	15
Appropriate/Fair Workload distribution for the Operator **(C_6)**	11	73.33	4	26.67	15
Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**	11	73.33	4	26.67	15
Minimize the repetition of Work **(C_8)**	11	73.33	4	26.67	15
Achieve operators wellbeing and job satisfaction **(C_9)**	12	80	3	20	15
Employee overall growth **(C_{10})**	3	20	12	80	15
Reduce employee turnover Ratio **(C_{11})**	2	13.33	13	86.67	15

Table VI. Interpretation of linguistic scale and TFN

Scale	**Scores**	**Triangular Fuzzy Number (TFN)**
Very Poor Effect (VPE)	1	(1,1,3)
Poor Effect (PE)	2	(1,3,5)
Medium Effect (ME)	3	(3,5,7)
High Effect (HE)	4	(5,7,9)
Very High Effect (VHE)	5	(7,9,9)

Table VII. Aggregate fuzzy weight allocation for various SSIs (criteria)

Criterion	Criterion type	Aggregate Fuzzy Weight (W_j)
C_1	Benefit	(3.000,6.330,9.000)
C_2	Benefit	(1.000,4.330,7.000)
C_3	Benefit	(3.000,6.600,9.000)
C_4	Benefit	(1.000,3.670,7.000)
C_5	Benefit	(1.000,5.400,9.000)
C_6	Benefit	(1.000,5.130,9.000)
C_7	Benefit	(1.000,4.600,9.000)
C_8	Benefit	(3.000,6.600,9.000)
C_9	Benefit	(1.000,4.730,9.000)

Table VIII. Combined Decision Matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	(1.400,2.867,4.867)	(1.267, 2.467,4.467)	(1.267, 2.467,4.467)	(1.800, 3.267,5.267)	(1.400, 2.467,4.467)	(1.400, 3.000,5.000)	(1.133, 2.067,4.067)	(1.267, 2.600,4.600)	(1.400, 2.600,4.600)
A_2	(2.067,3.933,5.933)	(1.800, 3.400,5.400)	(1.400, 2.467,4.467)	(1.400, 3.133,5.133)	(1.133, 2.067,4.067)	(1.267, 2.600,4.600)	(1.400, 2.600,4.600)	(1.400, 2.600,4.600)	(1.267, 2.867,4.867)
A_3	(1.933,3.533,5.533)	(2.333, 4.067,6.067)	(2.200, 3.533,5.400)	(2.067, 3.667,5.667)	(2.200, 3.667,5.667)	(1.933, 3.667,5.533)	(1.533, 3.000,5.000)	(2.067, 3.000,4.867)	(1.800, 2.733,4.600)
A_4	(3.800,5.800,7.800)	(3.667, 5.667,7.533)	(3.667, 5.400,7.267)	(3.133, 4.867,6.733)	(2.733, 4.600,6.600)	(2.733, 4.600,6.600)	(2.867, 4.200,6.200)	(2.200, 4.067,6.067)	(2.200, 3.667,5.667)
A_5	(5.000,7.0	(4.733, 6.733,8.333)	(4.333, 6.333,8.067)	(4.333, 6.333,8.067)	(4.600, 6.600,8.467)	(4.067, 6.067,7.800)	(3.133, 5.000,7.000)	(3.133, 5.000,7.000)	(3.267, 5.267,7.133)

	00,8.733)								
A_6	(4.200,6.200,7.933)	(4.733,6.733,8.333)	(4.333,6.333,8.200)	(4.600,6.600,8.333)	(4.467,6.467,8.200)	(3.933,5.933,7.667)	(3.800,5.667,7.533)	(4.067,5.933,7.800)	(4.067,6.067,7.933)
A_7	(2.333,4.333,6.333)	(2.600,4.333,6.200)	(2.467,4.067,5.933)	(2.600,4.600,6.467)	(2.067,3.800,5.800)	(2.200,3.933,5.933)	(2.200,3.667,5.667)	(1.667,3.133,5.133)	(2.333,3.933,5.933)
A_8	(5.267,7.267,8.733)	(4.467,6.467,8.333)	(5.400,7.400,8.600)	(4.067,6.067,8.067)	(4.733,6.733,8.600)	(4.600,6.600,8.333)	(4.867,6.867,8.600)	(4.333,6.333,8.200)	(5.000,7.000,8.733)
A_9	(5.533,7.533,8.467)	(5.667,7.667,8.733)	(5.400,7.400,8.600)	(5.533,7.533,8.467)	(5.800,7.800,8.733)	(5.133,7.133,8.600)	(5.533,7.533,8.467)	(5.800,7.800,8.733)	(5.000,7.000,8.333)
A_{10}	(4.600,6.600,8.467)	(3.933,5.933,7.933)	(4.600,6.600,8.467)	(4.200,6.200,8.067)	(4.200,6.200,7.933)	(4.333,6.333,8.333)	(4.600,6.600,8.333)	(4.333,6.333,8.333)	(5.133,7.133,8.867)

Table IX. Normalized Fuzzy Decision Matrix

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	(0.160,0.328,0.557)	(0.145,0.282,0.512)	(0.147,0.287,0.519)	(0.213,0.386,0.622)	(0.160,0.282,0.512)	(0.163,0.349,0.581)	(0.132,0.240,0.473)	(0.145,0.298,0.527)	(0.158,0.293,0.519)
A_2	(0.237,0.450,0.679)	(0.206,0.389,0.618)	(0.163,0.287,0.519)	(0.165,0.370,0.606)	(0.130,0.237,0.466)	(0.147,0.302,0.535)	(0.163,0.302,0.535)	(0.160,0.298,0.527)	(0.143,0.323,0.549)
A_3	(0.221,0.405,0.634)	(0.267,0.466,0.695)	(0.256,0.411,0.628)	(0.244,0.433,0.669)	(0.252,0.420,0.649)	(0.225,0.426,0.643)	(0.178,0.349,0.581)	(0.237,0.344,0.557)	(0.203,0.308,0.519)

A_4	(0.435,0.664,0.893)	(0.420, 0.649,0.863)	(0.426, 0.628,0.845)	(0.370, 0.575,0.795)	(0.313, 0.527,0.756)	(0.318, 0.535,0.767)	(0.333, 0.488,0.721)	(0.252, 0.466,0.695)	(0.248, 0.414,0.639)
A_5	(0.573,0.802,1.000)	(0.542, 0.771,0.954)	(0.504, 0.736,0.938)	(0.512, 0.748,0.953)	(0.527, 0.756,0.970)	(0.473, 0.705,0.907)	(0.364, 0.581,0.814)	(0.359, 0.573,0.802)	(0.368, 0.594,0.804)
A_6	(0.481,0.710,0.908)	(0.542, 0.771,0.954)	(0.504, 0.736,0.953)	(0.543, 0.779,0.984)	(0.512, 0.741,0.939)	(0.457, 0.690,0.892)	(0.442, 0.659,0.876)	(0.466, 0.679,0.893)	(0.459, 0.684,0.895)
A_7	(0.267,0.496,0.725)	(0.298, 0.496,0.710)	(0.287, 0.473,0.690)	(0.307, 0.543,0.764)	(0.237, 0.435,0.664)	(0.256, 0.457,0.690)	(0.256, 0.426,0.659)	(0.191, 0.359,0.588)	(0.263, 0.444,0.669)
A_8	(0.603,0.832,1.000)	(0.512, 0.741,0.954)	(0.628, 0.860,1.000)	(0.480, 0.717,0.953)	(0.542, 0.771,0.985)	(0.535, 0.767,0.969)	(0.566, 0.798,1.000)	(0.496, 0.725,0.939)	(0.564, 0.789,0.985)
A_9	(0.634,0.863,0.970)	(0.649, 0.878,1.000)	(0.628, 0.860,1.000)	(0.653, 0.890,1.000)	(0.664, 0.893,1.000)	(0.597, 0.829,1.000)	(0.643, 0.876,0.985)	(0.664, 0.893,1.000)	(0.564, 0.789,0.940)
A_{10}	(0.527,0.756,0.970)	(0.450, 0.679,0.908)	(0.535, 0.767,0.985)	(0.496, 0.732,0.953)	(0.481, 0.710,0.908)	(0.504, 0.736,0.969)	(0.535, 0.767,0.969)	(0.496, 0.725,0.954)	(0.579, 0.804,1.000)

Table X. Weighted Normalized Fuzzy Decision Matrix

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	0.48) 1,2.0 .78,5 (016	,0.145) .1.223,3 (581	,0.442) .1.893,4 (675	,0.213) .1.416,4 (354	,0.160) .1.525,4 (604	,0.163) .1.790,5 (233	,0.132) .1.106,4 (256	,0.435) .1.965,4 (741	,0.158) .1.387,4 (669
A_2	0.71) 0,2.8	,0.206) .1.686,4 (328	,0.488) .1.893,4 (675	,0.165) .1.358,4 (244	,0.130) .1.278,4 (191	,0.147) .1.551,4 (814	,0.163) .1.391,4 (814	,0.481) .1.965,4 (741	,0.143) .1.529,4 (940

	.51,6 (114								
A_3	0.66) 4,2.5 .61,5 (702	,0.267) .2.017,4 (863	,0.767) .2.711,5 (651	,0.244) .1.589,4 (685	,0.252) .2.267,5 (840	,0.225) .2.187,5 (790	,0.178) .1.605,5 (233	,0.710) .2.267,5 (016	,0.203) .1.458,4 (669
A_4	1.30) 5,4.2 .04,8 (038	,0.420) .2.810,6 (038	,1.279) .4.144,7 (605	,0.370) .2.110,5 (566	,0.313) .2.844,6 (802	,0.318) .2.744,6 (907	,0.333) .2.247,6 (488	,0.756) .3.074,6 (252	,0.248) .1.956,5 (752
A_5	1.71) 8,5.0 .74,9 (000	,0.542) .3.338,6 (679	,1.512) .4.860,8 (442	,0.512) .2.745,6 (669	,0.527) .4.081,8 (726	,0.473) .3.619,8 (163	,0.364) .2.674,7 (326	,1.076) .3.779,7 (214	,0.368) .2.810,7 (240
A_6	1.44) 3,4.4 .94,8 (176	,0.542) .3.338,6 (679	,1.512) .4.860,8 (581	,0.543) .2.861,6 (889	,0.512) .3.999,8 (451	,0.457) .3.539,8 (024	,0.442) .3.031,7 (883	,1.397) .4.484,8 (038	,0.459) .3.236,8 (052
A_7	0.80) 1,3.1 .41,6 (527	,0.298) .2.148,4 (970	,0.861) .3.121,6 (209	,0.307) .1.994,5 (347	,0.237) .2.350,5 (977	,0.256) .2.346,6 (209	,0.256) .1.961,5 (931	,0.573) .2.368,5 (290	,0.263) .2.098,6 (022
A_8	1.80) 9,5.2 .67,9 (000	,0.512) .3.206,6 (679	,1.884) .5.679,9 (000	,0.480) .2.630,6 (669	,0.542) .4.163,8 (863	,0.535) .3.937,8 (721	,0.566) .3.673,9 (000	,1.488) .4.786,8 (451	,0.564) .3.734,8 (864
A_9	1.90) 1,5.4 .60,8 (726	,0.649) .3.801,7 (000	,1.884) .5.679,9 (000	,0.653) .3.265,7 (000	,0.664) .4.823,9 (000	,0.597) .4.255,9 (000	,0.643) .4.029,8 (861	,1.992) .5.895,9 (000	,0.564) .3.734,8 (458
A_{10}	1.58) 0,4.7 .84,8 (726	,0.450) .2.942,6 (359	,1.605) .5.065,8 (861	,0.496) .2.687,6 (669	,0.481) .3.834,8 (176	,0.504) .3.778,8 (721	,0.535) .3.530,8 (721	,1.488) .4.786,8 (588	,0.579) .3.805,9 (000

Table XI. Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS)

	Positive ideal (FPIS)	**Negative ideal (FNIS)**

C_1	(1.901,5.460,9.000)	(0.481,2.078,5.016)
C_2	(0.649,3.801,7.000)	(0.145,1.223,3.581)
C_3	(1.884,5.679,9.000)	(0.442,1.893,4.675)
C_4	(0.653,3.265,7.000)	(0.165,1.358,4.244)
C_5	(0.664,4.823,9.000)	(0.130,1.278,4.191)
C_6	(0.597,4.255,9.000)	(0.147,1.551,4.814)
C_7	(0.643,4.029,9.000)	(0.132,1.106,4.256)
C_8	(1.992,5.895,9.000)	(0.435,1.965,4.741)
C_9	(0.579,3.805,9.000)	(0.143,1.387,4.669)

Table XII. Distance from each key deriver to FPIS and FNIS

	Distance from positive ideal (d_i^*)	**Distance from negative ideal (d_i^-)**
A_1	26.286	0.642
A_2	25.083	1.888
A_3	21.81	5.178
A_4	13.662	13.37
A_5	6.74	20.477
A_6	5.774	21.394
A_7	18.504	8.457
A_8	2.66	24.693
A_9	0.554	26.443
A_{10}	4.036	23.317

Table XIII. Computation of Closeness Coefficient (CC_i) for each driver and rank determination

Alternatives/ KSFs	**d_i^***	**d_i^-**	**$d_i^* + d_i^-$**	**$CC_i = ((d_i^-)/(d_i^* + d_i^-))$**	**Rank**
A_1	26.286	0.642	26.928	0.024	10

A_2	25.083	1.888	26.971	0.07	9
A_3	21.81	5.178	26.988	0.192	8
A_4	13.662	13.37	27.032	0.495	6
A_5	6.74	20.477	27.217	0.752	5
A_6	5.774	21.394	27.168	0.787	4
A_7	18.504	8.457	26.961	0.314	7
A_8	2.66	24.693	27.353	0.903	2
A_9	0.554	26.443	26.997	0.979	1
A_{10}	4.036	23.317	27.353	0.852	3

Table XIV. Sensitivity Analysis

	SCENARIO									**Ranking for each scenario**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
	C_1=(7,9,9), and others (1,1,3)	**C_2=(7,9,9), and others (1,1,3)**	**C_3=(7,9,9), and others (1,1,3)**	**C_4=(7,9,9), and others (1,1,3)**	**C_5=(7,9,9), and others (1,1,3)**	**C_6=(7,9,9), and others (1,1,3)**	**C_7=(7,9,9), and others (1,1,3)**	**C_8=(7,9,9), and others (1,1,3)**	**C_9=(7,9,9), and others (1,1,3)**	
A1	0.019000	0.018000	0.019000	0.035000	0.040000	0.041000	0.018000	0.018000	0.023000	10
A2	0.115000	0.103000	0.056000	0.053000	0.050000	0.053000	0.080000	0.056000	0.067000	9
A3	0.185000	0.231000	0.205000	0.183000	0.225000	0.205000	0.189000	0.172000	0.163000	8
A4	0.543000	0.539000	0.535000	0.481000	0.485000	0.488000	0.476000	0.439000	0.434000	6
A5	0.802000	0.784000	0.773000	0.760000	0.777000	0.766000	0.697000	0.680000	0.715000	4
A6	0.781000	0.810267	0.800000	0.803000	0.794000	0.784000	0.762000	0.760000	0.792000	5
A7	0.319000	0.333000	0.323000	0.325000	0.315000	0.314000	0.314000	0.258000	0.315000	7
A8	0.920000	0.871000	0.936000	0.849000	0.882000	0.903000	0.902000	0.856000	0.926000	2
A9	0.975000	0.985000	0.984000	0.984000	0.985000	0.984000	0.980000	0.985000	0.965000	1
A10	0.851000	0.810297	0.861000	0.825000	0.822000	0.858000	0.857000	0.826000	0.903000	3

Appendices 1

Questionnaire for the experts: -

Objective- The effect of the pressing global need to deliver sustainable outcomes is now being felt by Small and Medium Size Enterprises (SMEs), and key success factors (KSFs) of Total Productive Maintenance (TPM) have played a significant role in achieving environmental and economic sustainability. Therefore, this questionnaire aims to identify and prioritize the most influential TPM KSFs for achieving social sustainability (SS) in manufacturing SMEs. We have given the list of different TPM KSFs and SS indicators from the academic literature. Further, the survey will be conducted in two parts. In the first part, we will deduce the number of TPM KSFs and SS indicators to offer more concise research. In the second part, we will prioritize the important TPM KSFs based on their influence on different SS indicators with the help of experts.

The first part of the research (deducing approach): -

We have described selected TPM KSFs and SS indicators, which have been selected from past studies. For the given objective, you (experts) must select the most relevant TPM KSFs and SS indicators from Table A and Table B.

Table A. KSFs of TPM

Alternatives / KSFs	**Relevant to Small and Medium Enterprises (SMEs)**	
	"Yes"	**"No"**
Effective equipment utilization **(A_1)**		
Quality improvement **(A_2)**		
Preventive Breakdown **(A_3)**		
Team work motivation **(A_4)**		
Effective workplace management **(A_5)**		
Employee engagement and effective communication **(A_6)**		
Training and education **(A_7)**		
Organizational culture **(A_8)**		
Health and Safety of employee with safer working environment **(A_9)**		
Top management commitment **(A_{10})**		
Costs Minimization **(A_{11})**		

Maximize resource utilization **(A_{12})**		

Table B. Social Sustainability Indicators

Criteria/ SSIs	**Relevant to Small and Medium Enterprises (SMEs)**	
	"Yes"	**"No"**
Health and safety of employee **(C_1)**		
Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) **(C_2)**		
Quality of life **(C_3)**		
Stakeholder participation and satisfaction **(C_4)**		
Improved Working Environment **(C_5)**		
Appropriate/Fair Workload distribution for the Operator **(C_6)**		
Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**		
Minimize the repetition of Work **(C_8)**		
Achieve operators wellbeing and job satisfaction **(C_9)**		
Employee overall growth **(C_{10})**		
Reduce employee turnover Ratio **(C_{11})**		

After completing the first part, we finalized the KSFs and indicators. Then we contacted again with experts for conducting the second part of the research.

The second part of the research (Fuzzy TOPSIS approach): -

Based on the above objective, you (experts) must prioritize the most influential TPM KSFs according to their impact on different SS indicators. A fuzzy linguistic scale will be used to measure the influence of TPM KSFs on various SSIs. The linguistic scale and its interpretation in triangular fuzzy numbers are presented in Table C. For example, if one expert thinks that alternative A1 has a high effect (HE) on criteria C3, he/ she will score 4 in his questionnaire, and that response will be interpreted in TFN as (5,7,9). Tables D and E represent the final TPM KSFs and SS indicators selected for further study. Further, Table F represents the response sheet for each expert.

Table C. Interpretation of linguistic scale and TFN

Scale	**Scores**	**Triangular Fuzzy Number (TFN)**
Very Poor Effect (VPE)	1	(1,1,3)
Poor Effect (PE)	2	(1,3,5)
Medium Effect (ME)	3	(3,5,7)

High Effect (HE)	4	(5,7,9)
Very High Effect (VHE)	5	(7,9,9)

Table D. Finalized TPM KSFs

S.No.	Alternatives / KSFs
1	Effective equipment utilization **(A_1)**
2	Quality improvement **(A_2)**
3	Preventive Breakdown **(A_3)**
4	Team work motivation **(A_4)**
5	Effective workplace management **(A_5)**
6	Employee engagement and effective communication **(A_6)**
7	Training and education **(A_7)**
8	Organizational culture **(A_8)**
9	Health and Safety of employee with safer working environment **(A_9)**
10.	Top management commitment **(A_{10})**

Table E. Finalized SS indicators

S.No.	Alternatives / KSFs
1	Health and safety of employee **(C_1)**
2	Minimize/eliminate various hazards (chemical, physical, biological, and ergonomic hazards) **(C_2)**
3	Quality of life **(C_3)**
4	Stakeholder participation and satisfaction **(C_4)**
5	Improved Working Environment **(C_5)**
6	Appropriate/Fair Workload distribution for the Operator **(C_6)**
7	Reduce accidents and work-related psycho-social risks in the workstation **(C_7)**
8	Minimize the repetition of Work **(C_8)**
9	Achieve operators wellbeing and job satisfaction **(C_9)**

Table F. TPM KSFs influence on different SS indicators

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1									
A_2									
A_3									
A_4									
A_5									
A_6									
A_7									
A_8									
A_9									
A_{10}									

Finally, Tables G1-G15 show the response of each expert for prioritizing the TPM KSFs based on their influence on different SS indicators.

Table G1. Response of expert 1

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	1	2	3	3	3	3	2	2	1
A_2	3	3	3	2	1	1	1	1	2
A_3	4	4	4	3	4	5	4	5	5
A_4	3	4	5	3	3	3	4	3	3
A_5	4	4	3	3	3	5	2	1	2
A_6	4	4	4	4	3	4	4	3	4
A_7	3	2	3	3	1	2	4	3	3
A_8	4	3	3	3	4	2	3	4	4
A_9	5	4	3	5	4	4	4	5	4
A_{10}	4	3	4	5	5	3	4	4	4

Table G2. Response of expert 2

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	1	1	2	2	2	2	1	1	2
A_2	3	2	1	3	2	1	2	2	3
A_3	2	2	1	2	3	2	2	1	2
A_4	4	3	3	4	2	1	4	2	2
A_5	4	4	4	3	4	3	3	3	3
A_6	3	4	3	3	4	3	2	3	4
A_7	2	1	2	2	2	1	2	1	1
A_8	4	5	4	4	3	4	4	3	5
A_9	5	5	5	5	5	4	5	4	5
A_{10}	5	3	3	3	5	4	4	4	4

Table G3. Response of expert 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	3	2	1	1	1	2	1	1	1
A_2	2	3	1	2	3	1	2	2	2
A_3	3	3	3	3	2	1	2	1	1
A_4	3	4	4	3	2	2	1	2	1
A_5	5	4	4	4	5	3	3	3	4
A_6	4	4	4	4	3	3	4	4	4
A_7	4	3	4	3	2	2	2	1	2
A_8	5	4	4	4	4	4	5	4	4

A_9	5	5	5	5	5	5	5	5	5
A_{10}	4	4	4	3	4	4	4	3	4

Table G4. Response of expert 4

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	3	2	2	2	2	2	1	2	2
A_2	2	2	2	1	1	1	1	2	2
A_3	2	3	1	2	1	2	2	1	1
A_4	4	3	2	4	4	3	4	3	4
A_5	4	4	4	4	3	4	3	4	3
A_6	5	4	4	3	3	3	3	4	5
A_7	4	5	5	5	4	3	3	3	3
A_8	3	3	5	4	4	4	4	4	4
A_9	4	5	4	4	3	4	4	3	4
A_{10}	4	4	4	4	3	3	3	4	4

Table G5. Response of expert 5

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	2	2	2	3	2	1	2	2	1
A_2	1	1	1	2	1	2	1	1	2
A_3	2	3	1	2	1	2	2	2	2
A_4	3	4	3	3	3	4	2	4	3
A_5	3	3	3	4	4	3	4	4	4
A_6	4	5	4	4	4	5	4	3	3
A_7	4	3	3	3	3	4	2	2	2
A_8	5	4	5	4	4	3	3	3	4
A_9	5	5	5	4	5	5	5	5	5
A_{10}	4	3	3	3	3	4	5	4	4

Table G6. Response of expert 6

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	2	2	3	2	3	3	3	2	3
A_2	3	3	3	2	1	2	1	3	2
A_3	1	1	1	2	1	2	1	3	3
A_4	4	3	1	2	3	2	4	3	3
A_5	3	4	4	4	4	3	4	3	4
A_6	4	5	3	4	5	4	4	5	4
A_7	3	3	3	2	2	1	2	2	3
A_8	4	3	3	3	4	3	4	3	3
A_9	3	5	5	5	4	5	3	5	5
A_{10}	4	4	4	3	4	4	3	3	4

Table G7. Response of expert 7

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	3	4	2	4	1	2	2	1	1
A_2	2	3	1	2	1	2	1	1	2
A_3	2	2	3	3	3	2	3	3	3
A_4	3	2	2	1	3	4	2	3	3
A_5	4	5	3	3	4	4	4	4	3
A_6	3	3	4	4	4	3	3	4	4
A_7	2	3	3	3	2	2	4	2	2
A_8	4	4	4	4	4	4	4	4	4
A_9	5	5	4	5	4	3	3	4	5
A_{10}	4	3	3	3	3	3	4	3	4

Table G8. Response of expert 8

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	2	1	1	2	1	2	2	2	2
A_2	3	2	1	2	2	1	2	1	2
A_3	2	2	2	2	2	2	1	1	1
A_4	4	4	4	3	3	2	1	2	3
A_5	5	4	4	5	4	5	4	3	3
A_6	4	4	3	3	3	3	4	4	4
A_7	2	3	3	3	3	3	4	4	3
A_8	5	4	4	4	4	5	4	4	4
A_9	5	4	4	5	5	5	5	5	4
A_{10}	3	4	3	3	3	4	5	4	5

Table G9. Response of expert 9

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	2	1	2	1	1	2	2	1	2
A_2	2	3	2	1	2	2	1	1	1
A_3	3	4	5	4	4	3	2	4	2
A_4	4	3	4	5	4	4	1	2	1
A_5	4	3	5	4	4	3	4	4	5
A_6	4	4	5	4	4	3	4	4	3
A_7	3	3	3	2	1	3	2	1	4
A_8	4	3	3	4	3	4	3	3	3
A_9	4	5	4	4	5	4	4	5	4
A_{10}	4	3	4	4	4	3	4	4	4

Table G10. Response of expert 10

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	2	2	1	3	2	2	1	2	1
A_2	3	2	1	4	2	3	2	1	2
A_3	4	3	2	3	3	2	1	1	1
A_4	4	2	1	4	3	2	1	1	2
A_5	4	5	3	3	3	3	2	3	4
A_6	3	3	2	2	4	2	4	4	2
A_7	2	2	2	3	4	2	1	3	2
A_8	3	3	4	3	4	4	4	4	4
A_9	5	4	5	5	5	4	5	5	5
A_{10}	3	4	4	4	3	4	4	4	4

Table G11. Response of expert 11

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	1	2	1	2	1	1	1	2	2
A_2	3	2	1	2	1	2	3	2	1
A_3	2	1	1	1	1	2	1	1	1
A_4	3	5	4	1	2	3	4	2	1
A_5	4	3	5	3	3	4	3	3	2
A_6	2	3	4	5	2	3	2	4	4
A_7	2	3	1	4	2	3	1	2	3
A_8	5	4	5	3	3	5	4	4	4
A_9	4	5	4	5	4	4	5	5	4
A_{10}	3	4	5	4	3	3	3	3	4

Table G12. Response of expert 12

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	2	2	2	2	1	2	1	2	3
A_2	3	3	3	2	1	2	3	3	3
A_3	3	3	3	3	3	3	2	1	1
A_4	3	3	3	4	3	4	3	4	2
A_5	4	3	3	3	4	4	3	3	3
A_6	5	5	4	4	4	3	4	3	3
A_7	2	3	2	3	3	3	2	1	1
A_8	4	4	4	4	5	4	4	3	4
A_9	5	4	5	4	5	5	5	4	4
A_{10}	3	3	4	4	3	4	4	4	5

Table G13. Response of expert 13

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
A_1	1	1	1	1	1	1	1	1	1
A_2	2	2	2	2	2	2	2	2	2

A_3	2	3	2	3	3	3	3	3	3
A_4	3	3	4	3	3	4	4	3	3
A_5	4	4	3	4	4	3	2	2	2
A_6	3	3	4	4	4	4	2	1	2
A_7	3	2	1	2	2	3	4	2	1
A_8	4	4	5	3	4	3	4	4	5
A_9	5	4	5	4	3	4	3	4	3
A_{10}	4	3	4	3	4	4	3	4	4

Table G14. Response of expert 14

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	2	1	2	3	2	3	2	3	3
A_2	2	1	2	2	2	3	2	3	2
A_3	1	2	2	1	2	1	2	1	1
A_4	2	3	4	2	1	2	3	2	1
A_5	4	3	3	3	4	3	1	2	2
A_6	3	4	4	5	5	5	1	2	3
A_7	2	1	1	2	3	2	1	2	4
A_8	4	4	5	3	4	4	5	5	4
A_9	5	4	5	5	5	4	5	4	5
A_{10}	4	4	4	4	3	4	4	3	3

Table G15. Response of expert 15

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	2	1	1	1	3	2	1	3	2
A_2	3	1	2	2	1	2	3	2	1
A_3	1	2	3	1	2	3	2	2	1
A_4	4	4	4	2	3	2	1	2	3
A_5	4	5	4	5	4	3	3	3	3
A_6	3	3	3	4	4	4	5	4	4
A_7	2	3	2	2	2	3	1	2	3
A_8	4	4	5	3	4	4	4	3	4
A_9	5	5	5	5	5	5	5	5	5
A_{10}	4	3	4	4	4	4	3	4	4

Appendices 2

Sensitivity Analysis for Scenario 1-

Criterion	**Weight**
C_1	(7.000,9.000,9.000)
C_2	(1.000,1.000,3.000)
C_3	(1.000,1.000,3.000)
C_4	(1.000,1.000,3.000)
C_5	(1.000,1.000,3.000)
C_6	(1.000,1.000,3.000)
C_7	(1.000,1.000,3.000)
C_8	(1.000,1.000,3.000)
C_9	(1.000,1.000,3.000)

SCALE				
Score	**Linguistic terms**	**Low**	**Medium**	**Upper**
1	Very low	1	1	3
2	Low	1	3	5
3	Medium	3	5	7
4	High	5	7	9
5	Very high	7	9	9

Decision matrix									
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	(1.400, 2.867,4.867)	(1.267, 2.467,4.467)	(1.267, 2.467,4.467)	(1.800, 3.267,5.267)	(1.400, 2.467,4.467)	(1.400, 3.000,5.000)	(1.133, 2.067,4.067)	(1.267, 2.600,4.600)	(1.400, 2.600,4.600)
A_2	(2.067, 3.933,5.933)	(1.800, 3.400,5.400)	(1.400, 2.467,4.467)	(1.400, 3.133,5.133)	(1.133, 2.067,4.067)	(1.267, 2.600,4.600)	(1.400, 2.600,4.600)	(1.400, 2.600,4.600)	(1.267, 2.867,4.867)
A_3	(1.933, 3.533,5.533)	(2.333, 4.067,6.067)	(2.200, 3.533,5.400)	(2.067, 3.667,5.667)	(2.200, 3.667,5.667)	(1.933, 3.667,5.533)	(1.533, 3.000,5.000)	(2.067, 3.000,4.867)	(1.800, 2.733,4.600)
A_4	(3.800, 5.800,7.800)	(3.667, 5.667,7.533)	(3.667, 5.400,7.267)	(3.133, 4.867,6.733)	(2.733, 4.600,6.600)	(2.733, 4.600,6.600)	(2.867, 4.200,6.200)	(2.200, 4.067,6.067)	(2.200, 3.667,5.667)
A_5	(5.000, 7.000,8.733)	(4.733, 6.733,8.333)	(4.333, 6.333,8.067)	(4.333, 6.333,8.067)	(4.600, 6.600,8.467)	(4.067, 6.067,7.800)	(3.133, 5.000,7.000)	(3.133, 5.000,7.000)	(3.267, 5.267,7.133)
A_6	(4.200, 6.200,7.933)	(4.733, 6.733,8.333)	(4.333, 6.333,8.200)	(4.600, 6.600,8.333)	(4.467, 6.467,8.200)	(3.933, 5.933,7.667)	(3.800, 5.667,7.533)	(4.067, 5.933,7.800)	(4.067, 6.067,7.933)
A_7	(2.333, 4.333,6.333)	(2.600, 4.333,6.200)	(2.467, 4.067,5.933)	(2.600, 4.600,6.467)	(2.067, 3.800,5.800)	(2.200, 3.933,5.933)	(2.200, 3.667,5.667)	(1.667, 3.133,5.133)	(2.333, 3.933,5.933)

A_8	(5.267, 7.267,8.733)	(4.467, 6.467,8.333)	(5.400, 7.400,8.600)	(4.067, 6.067,8.067)	(4.733, 6.733,8.600)	(4.600, 6.600,8.333)	(4.867, 6.867,8.600)	(4.333, 6.333,8.200)	(5.000, 7.000,8.733)
A_9	(5.533, 7.533,8.467)	(5.667, 7.667,8.733)	(5.400, 7.400,8.600)	(5.533, 7.533,8.467)	(5.800, 7.800,8.733)	(5.133, 7.133,8.600)	(5.533, 7.533,8.467)	(5.800, 7.800,8.733)	(5.000, 7.000,8.333)
A_{10}	(4.600, 6.600,8.467)	(3.933, 5.933,7.933)	(4.600, 6.600,8.467)	(4.200, 6.200,8.067)	(4.200, 6.200,7.933)	(4.333, 6.333,8.333)	(4.600, 6.600,8.333)	(4.333, 6.333,8.333)	(5.133, 7.133,8.867)

Normalized decision matrix									
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	(0.160,0.328,0.557)	(0.145,0.282,0.512)	(0.147,0.287,0.519)	(0.213,0.386,0.622)	(0.160,0.282,0.512)	(0.163,0.349,0.581)	(0.132,0.240,0.473)	(0.145,0.298,0.527)	(0.158,0.293,0.519)
A_2	(0.237,0.450,0.679)	(0.206,0.389,0.618)	(0.163,0.287,0.519)	(0.165,0.370,0.606)	(0.130,0.237,0.466)	(0.147,0.302,0.535)	(0.163,0.302,0.535)	(0.160,0.298,0.527)	(0.143,0.323,0.549)
A_3	(0.221,0.405,0.634)	(0.267,0.466,0.695)	(0.256,0.411,0.628)	(0.244,0.433,0.669)	(0.252,0.420,0.649)	(0.225,0.426,0.643)	(0.178,0.349,0.581)	(0.237,0.344,0.557)	(0.203,0.308,0.519)
A_4	(0.435,0.664,0.893)	(0.420,0.649,0.863)	(0.426,0.628,0.845)	(0.370,0.575,0.795)	(0.313,0.527,0.756)	(0.318,0.535,0.767)	(0.333,0.488,0.721)	(0.252,0.466,0.695)	(0.248,0.414,0.639)
A_5	(0.573,0.802,1.000)	(0.542,0.771,0.954)	(0.504,0.736,0.938)	(0.512,0.748,0.953)	(0.527,0.756,0.970)	(0.473,0.705,0.907)	(0.364,0.581,0.814)	(0.359,0.573,0.802)	(0.368,0.594,0.804)
A_6	(0.481,0.710,0.908)	(0.542,0.771,0.954)	(0.504,0.736,0.953)	(0.543,0.779,0.984)	(0.512,0.741,0.939)	(0.457,0.690,0.892)	(0.442,0.659,0.876)	(0.466,0.679,0.893)	(0.459,0.684,0.895)
A_7	(0.267,0.496,0.725)	(0.298,0.496,0.710)	(0.287,0.473,0.690)	(0.307,0.543,0.764)	(0.237,0.435,0.664)	(0.256,0.457,0.690)	(0.256,0.426,0.659)	(0.191,0.359,0.588)	(0.263,0.444,0.669)
A_8	(0.603,0.832,1.000)	(0.512,0.741,0.954)	(0.628,0.860,1.000)	(0.480,0.717,0.953)	(0.542,0.771,0.985)	(0.535,0.767,0.969)	(0.566,0.798,1.000)	(0.496,0.725,0.939)	(0.564,0.789,0.985)
A_9	(0.634,0.863,0.970)	(0.649,0.878,1.000)	(0.628,0.860,1.000)	(0.653,0.890,1.000)	(0.664,0.893,1.000)	(0.597,0.829,1.000)	(0.643,0.876,0.985)	(0.664,0.893,1.000)	(0.564,0.789,0.940)
A_{10}	(0.527,0.756,0.970)	(0.450,0.679,0.908)	(0.535,0.767,0.985)	(0.496,0.732,0.953)	(0.481,0.710,0.908)	(0.504,0.736,0.969)	(0.535,0.767,0.969)	(0.496,0.725,0.954)	(0.579,0.804,1.000)

Weighted normalized decision matrix									
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**
A_1	(1.122,2.955,5.016)	(0.145,0.282,1.535)	(0.147,0.287,1.558)	(0.213,0.386,1.866)	(0.160,0.282,1.535)	(0.163,0.349,1.744)	(0.132,0.240,1.419)	(0.145,0.298,1.580)	(0.158,0.293,1.556)
A_2	(1.657,4.053,6.114)	(0.206,0.389,1.855)	(0.163,0.287,1.558)	(0.165,0.370,1.819)	(0.130,0.237,1.397)	(0.147,0.302,1.605)	(0.163,0.302,1.605)	(0.160,0.298,1.580)	(0.143,0.323,1.647)

A_3	(1.549,3.641,5.702)	(0.267,0.466,2.084)	(0.256,0.411,1.884)	(0.244,0.433,2.008)	(0.252,0.420,1.947)	(0.225,0.426,1.930)	(0.178,0.349,1.744)	(0.237,0.344,1.672)	(0.203,0.308,1.556)
A_4	(3.046,5.977,8.038)	(0.420,0.649,2.588)	(0.426,0.628,2.535)	(0.370,0.575,2.386)	(0.313,0.527,2.267)	(0.318,0.535,2.302)	(0.333,0.488,2.163)	(0.252,0.466,2.084)	(0.248,0.414,1.917)
A_5	(4.008,7.214,9.000)	(0.542,0.771,2.863)	(0.504,0.736,2.814)	(0.512,0.748,2.858)	(0.527,0.756,2.909)	(0.473,0.705,2.721)	(0.364,0.581,2.442)	(0.359,0.573,2.405)	(0.368,0.594,2.413)
A_6	(3.367,6.390,8.176)	(0.542,0.771,2.863)	(0.504,0.736,2.860)	(0.543,0.779,2.953)	(0.512,0.741,2.817)	(0.457,0.690,2.675)	(0.442,0.659,2.628)	(0.466,0.679,2.679)	(0.459,0.684,2.684)
A_7	(1.870,4.465,6.527)	(0.298,0.496,2.130)	(0.287,0.473,2.070)	(0.307,0.543,2.291)	(0.237,0.435,1.992)	(0.256,0.457,2.070)	(0.256,0.426,1.977)	(0.191,0.359,1.763)	(0.263,0.444,2.007)
A_8	(4.222,7.489,9.000)	(0.512,0.741,2.863)	(0.628,0.860,3.000)	(0.480,0.717,2.858)	(0.542,0.771,2.954)	(0.535,0.767,2.907)	(0.566,0.798,3.000)	(0.496,0.725,2.817)	(0.564,0.789,2.955)
A_9	(4.435,7.763,8.726)	(0.649,0.878,3.000)	(0.628,0.860,3.000)	(0.653,0.890,3.000)	(0.664,0.893,3.000)	(0.597,0.829,3.000)	(0.643,0.876,2.954)	(0.664,0.893,3.000)	(0.564,0.789,2.819)
A_{10}	(3.687,6.802,8.726)	(0.450,0.679,2.725)	(0.535,0.767,2.954)	(0.496,0.732,2.858)	(0.481,0.710,2.725)	(0.504,0.736,2.907)	(0.535,0.767,2.907)	(0.496,0.725,2.863)	(0.579,0.804,3.000)

	Positive ideal (FPIS)	**Negative ideal (FNIS)**
C_1	(4.435,7.763,9.000)	(1.122,2.955,5.016)
C_2	(0.649,0.878,3.000)	(0.145,0.282,1.535)
C_3	(0.628,0.860,3.000)	(0.147,0.287,1.558)
C_4	(0.653,0.890,3.000)	(0.165,0.370,1.819)
C_5	(0.664,0.893,3.000)	(0.130,0.237,1.397)
C_6	(0.597,0.829,3.000)	(0.147,0.302,1.605)
C_7	(0.643,0.876,3.000)	(0.132,0.240,1.419)
C_8	(0.664,0.893,3.000)	(0.145,0.298,1.580)
C_9	(0.579,0.804,3.000)	(0.143,0.293,1.556)

	Distance from positive ideal (d_i^*)	**Distance from negative ideal (d_i^-)**
A_1	11.398	0.219
A_2	10.309	1.334
A_3	9.501	2.151
A_4	5.339	6.34

A_5	2.33	9.427
A_6	2.568	9.137
A_7	7.94	3.711
A_8	0.944	10.834
A_9	0.29	11.395
A_{10}	1.754	10.037

Alternatives / KSFs	d_i^*	d_i^-	$d_i^* + d_i^-$	$CC_i = ((d_i^-)/(d_i^* + d_i^-))$	Rank
A_1	11.398	0.219	11.617	0.019	10
A_2	10.309	1.334	11.643	0.115	9
A_3	9.501	2.151	11.652	0.185	8
A_4	5.339	6.34	11.679	0.543	6
A_5	2.33	9.427	11.757	0.802	4
A_6	2.568	9.137	11.705	0.781	5
A_7	7.94	3.711	11.651	0.319	7
A_8	0.944	10.834	11.778	0.92	2
A_9	0.29	11.395	11.685	0.975	1
A_{10}	1.754	10.037	11.791	0.851	3