Applied Energy 311 (2022) 118680

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects

Gang Kou [a,*], Serhat Yüksel [b], Hasan Dinçer [b]

[a] School of Business Administration, Faculty of Business Administration, Southwestern University of Finance and Economics, Chengdu 611130, China
[b] The School of Business, İstanbul Medipol University, Turkey

HIGHLIGHTS

- This study illustrates causal relationships of innovative strategies for solar energy projects.
- An extension of group decision-making and spherical fuzzy numbers is proposed.
- Dynamicity is the most critical TRIZ-based factor.
- Composite materials have an important impact in this scenario.
- Solar panels should be designed to receive sunlight at different times vertically.

ARTICLE INFO

Keywords:
Carbon Emission
Electric Vehicles
Solar Energy
TRIZ
Incomplete Preferences
Consensus
Spherical Fuzzy DEMATEL

ABSTRACT

The transportation sector is also of great importance in terms of carbon emission problem. Significant amount of carbon dioxide is emitted into the atmosphere due to the use of fossil fuels in transport vehicles. Electric vehicles play a key role to overcome this problem. However, high cost is an important handicap in choosing electric vehicles, especially in road transport. Therefore, electric vehicles charged with solar energy can also contribute significantly to the solution of this problem. In this study, it is aimed to generate inventive problem-solving map of innovative carbon emission reduction strategies for transportation investment projects. Hence, this study illustrates causal relationships of innovative strategies for solar energy projects. Therefore, the influencing and influenced items can be defined. An extension of group decision-making (GDM) and spherical fuzzy numbers is proposed regarding solar energy projects. These principles are weighted by spherical fuzzy methodology. The main contribution of this study is to present significant strategies to increase the effectiveness of the solar energy investment projects with a novel hybrid decision-making methodology. Therefore, the analysis results have a positive contribution to the solution of carbon emission problem in the transportation industry. The findings explain that dynamicity is the most critical TRIZ-based factor that improves the effectiveness of solar energy projects because it has the greatest weight (0.267). Composite materials have an important impact in this scenario with the weight of 0.255. It is recommended that solar panels should be designed so that they can receive sunlight at different times vertically. Flexible structured solar panels should be considered that can change position according to the angle of the sun during the day. Thus, more electrical energy can be obtained.

1. Introduction

Carbon emission, in its most general definition, means the release of carbon gas into the atmosphere. It is possible to talk about many serious disadvantages of carbon gas. High carbon emissions increase acid rain. This situation threatens the health of living things. On the other hand, carbon emission also accelerates the global warming process. As a result, many problems such as hunger and famine occur. One of the most important causes of global warming is the use of fossil fuels [92]. In addition to this, uncontrolled population growth, increase in global energy demand and decrease in green areas are other important issues that cause carbon emissions. The use of renewable energy significantly helps to reduce the carbon emission problem.

The transportation sector is also of great importance in terms of

* Corresponding author.
E-mail addresses: kougang@swufe.edu.cn (G. Kou), serhatyuksel@medipol.edu.tr (S. Yüksel), hdincer@medipol.edu.tr (H. Dinçer).

https://doi.org/10.1016/j.apenergy.2022.118680
Received 16 October 2021; Received in revised form 7 December 2021; Accepted 5 February 2022
Available online 14 February 2022

carbon emission problem. As a result of the use of fossil fuels in transport vehicles, very significant amounts of carbon gas are emitted into the atmosphere [97]. Therefore, important actions must be taken in order to minimize carbon emissions in the transportation sector [48]. In this context, electric vehicles can be preferred, especially in road transport. Thanks to these vehicles that are more sensitive to the environment, it is possible to reduce the aforementioned problem [55]. On the other hand, the most important disadvantage of electric vehicles is their high costs. This is one of the most important handicaps in choosing electric vehicles, especially in road transport. Therefore, there is a need for actions that will contribute to the reduction of costs in the use of electric vehicles [37]. Electric vehicles charged with solar energy can also contribute significantly to the solution of this problem. Especially with the help of the technological improvements, there is a significant decrease in the cost of solar energy projects [58,42]. This situation has a powerful impact to overcome high-cost problem of these projects [50,104].

Solar energy refers to the energy that emanates from the conversion of hydrogen to helium and propagated in space as light. Solar panels are used to generate electricity from solar energy [44]. Initially in this process, photons from the sun are held on the panels. When these photons fall on the solar cells that are located on the panels, a voltage arises between the upper layer of the panel and the lower layer. Thus, a current flowing through the system to which the panel is connected can be obtained [71,24,12]. Solar energy is generally used where it is produced [2]. However, solar energy also has disadvantages [87,105]. Since solar radiation is less during the night and winter months, electricity must be stored [63,6]. High costs of solar power plants are accepted as an important disadvantage. This situation leads to hesitation among investors for solar energy projects [102].

It is very difficult to identify which issue should be given priority to increase the effectiveness of these projects. To address this issue, a specific evaluation should be conducted with an effective methodology. The TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch) technique has been preferred in the literature to find effective strategies [51]. More than 3 million patents around the world were examined, and it was realized that the ideas taken into consideration in solving the problems are actually formed by repeating similar themes [34]. In this framework, first, the problems in patent examinations are analyzed, and 39 engineering parameters that affect the performance of a product are determined. Subsequently, these parameters are evaluated in a 39X39 matrix, named as contradiction matrix [80]. In this matrix, the left side expresses the improvement of these parameters, while the worsening of these parameters is taken into account on the right. For these combinations, a strategy (or strategies) is defined out of 40 different innovative TRIZ solutions [45].

In this study, it is aimed to generate inventive problem-solving map of innovative carbon emission reduction strategies for transportation investment projects. For this purpose, causal relationships of innovative strategies are identified for solar energy projects. Therefore, the influencing and influenced items can be defined. The main reason is that electric vehicles charged with solar energy can also contribute significantly to the solution of carbon emission problem in the transportation industry. In this context, a novel model is generated to identify key strategies regarding solar energy projects. Fuzzy preferences are computed in the first stage. Within this context, principles are defined by considering the TRIZ technique. Later, preferences are generated regarding the principles by considering GDM. The factors are weighted with the spherical fuzzy decision-making trial and evaluation laboratory (DEMATEL).

This proposed model has some novelties. Firstly, the analysis results have a positive contribution to the solution of carbon emission problem in the transportation industry. The transportation sector has high impact on this problem mainly because of using fossil fuels in the transport vehicles. Therefore, electric vehicles are taken into consideration in this industry to handle this problem. Nevertheless, the main barrier in this process is the high cost. Electric vehicles can be charged with solar energy. Due to this situation, the analysis results of this study show the important issues to increase the effectiveness of solar energy projects. In the literature, there are limited studies that focused on the solar energy investments to overcome this problem for the transportation industry. Hence, it has a positive contribution to minimize carbon emission problem in this industry. In other words, the analysis results increase the performance of the solar energy projects that can be considered in the electric vehicles. This situation helps to handle carbon emission problem more effectively.

Moreover, a detailed criteria list is created in this study for the effectiveness of solar energy investment projects that can be accepted as a key novelty of this study. While generating these factors, lots of different studies in the literature are evaluated. These items can also be taken into consideration for other renewable energy important projects, such as wind and geothermal. Another important novelty of this model is considering TRIZ technique while defining the principles. This approach provides specific innovative solutions according to the type of the problems [8]. This situation prevents wasting time in this process [4]. In other words, the solutions can be defined more effectively and appropriately. Hence, it can be possible for the companies to increase their competitive powers by considering this technique [43]. Moreover, the criteria list proposed in this study has a leading effect for both researchers and investors. While considering these factors, solar energy investors can sole many problems more efficiently.

In addition to this issue, another significant novelty of this study is considering the incomplete preferences (IP) methodology to examine the evaluations of the decision makers [86;46]. Because all decision makers may not have opinions to evaluate some criteria, this missing information can be populated with the help of this method [29]. Therefore, more effective evaluations can be conducted [66]. Furthermore, considering GDM to calculate the fuzzy preferences is another novelty of this proposed model. Decision makers may have some opposite opinions with respect to some principles [103,21]. This situation decreases the effectiveness of the decision-making process. Thus, by considering this methodology, this issue can be minimized [93].

Spherical fuzzy numbers include membership, non-membership, and hesitancy [30;38]. Because of this situation, it can be said that more reliable results can be achieved in comparison with classical fuzzy sets [101]. Finally, making calculations with the DEMATEL approach is another advantage of this evaluation. There are many different MCDM models in the literature to weight different criteria. However, DEMATEL has some superiorities to other alternatives. For example, an impact-relation map can also be generated by the DEMATEL model [26]. Thus, causality analysis can be performed [100,15]. In other words, the influencing and influenced items can be defined. Therefore, more specific recommendations can be generated to solve the problem.

The rest of the manuscript is organized as follows. Literature review is taken place in the second part. The third part includes necessary information about the methodology. Analysis results are given in the fourth section. The final section includes the conclusion and discussion.

2. Literature review

In this section, relevant studies in the literature regarding solar energy projects are briefly reviewed. In this framework, some researchers have highlighted the importance of using quality materials [81]. By considering quality materials in the generation of these projects, the loss of energy can be minimized. Fontaine [27] made an evaluation regarding the sustainability of solar energy. For this purpose, the resource construction processes of local photovoltaic projects in France were examined. The quality of the materials is very significant for the sustainability of the solar energy project. Schindler et al. [77], Andreani et al. [9], and Wilkins et al. [90] also focused on this situation in different solar energy construction projects to understand the main indicators to improve the performance. They concluded material quality can significantly improve the performance of these investments.

Some studies have identified that effective cost evaluation plays a very crucial role. Solar energy projects have high initial costs, and this situation is accepted as the most significant disadvantage of these investments. Due to this issue, effective cost management techniques should be implemented in the constructions of these projects [47]. Imam and Ayadi [36] recommended that governments must provide cost incentives. In this context, feed-in tariffs can be the most effective financial support mechanism. Additionally, the authors also claimed that low-interest loans should be provided to solar energy investors. This increases the financial flexibility of investors. Corona et al. [19] and Raza et al. [73] suggested that necessary importance should be given to technological improvement in this area so that high-cost problems can be handled more easily.

Some researchers have argued that solar energy projects should be reliable. In other words, the performance of these projects should not be questionable. Solar energy investments are complex projects with detailed processes. Therefore, for this complex system to work effectively, the construction must be established effectively. In this way, both investors and customers will be able to use the facility confidently. Ramírez-Del-Barrio et al. [72] evaluated solar energy projects in Chile to provide the energy demand with the productive process. They reached a conclusion that there should be a high level of community involvement in order to increase the effectiveness of these projects. It can also be possible to increase the reliability. Assaf and Shabani [11] proposed a novel hybrid renewable energy alternative with the combination of solar and hydrogen. They discussed that for the success of these projects, full reliability of the constructions is a crucial factor. Additionally, Cheng et al. [17] tried to analyze solar energy projects by considering the renewal point technique and the Semi–Markov processes theory. They also underlined the significance of the reliability for the effectiveness of these projects.

Furthermore, solar energy projects should be user-friendly so that efficiency can be improved. Solar energy projects include very complex processes. Because of this issue, in the construction process, the steps are designed effectively. Meyer et al. [60] focused on the details of the mechanisms in solar panels and discussed that necessary implementations should be made for the easy usage of these projects. Savvides et al. [76] and Achuthan et al. [1] made an evaluation for the construction of solar energy projects and underlined the importance of similar issues. Some studies have also stated the importance of repairability (Sing et al., 2018). In other words, any problems in these panels should be easily repaired in a very short time. The main reason is that a long duration of repair reduces the efficiency of the process [98].

In addition, adoptability factor is also important in this regard. In solar energy markets, there are rapid developments in technology that have a positive contribution to the cost reduction of these projects [16,52,58]. Hence, solar energy projects should be designed effectively so that they can easily adapt to these developments. Shao et al. [78] performed a study to understand innovative and sustainable construction methods for solar energy projects. Rural areas in western China were analyzed in their study. They determined that traditional models may not be helpful. The main reason is that technology is rapidly increasing in this area. Therefore, solar energy projects should be designed so that they can adopt to changes in this area. High amount of electricity can have a positive influence on the income of the projects [13]. Owing to this condition, in the construction process of these projects, necessary importance should be given to increase the capacity [65]. In this way, effectiveness of these projects can be increased [39].

We identified certain important issues through our literature review. There is a significant number of studies on solar energy projects. In these studies, some factors that affect the efficiency of these structures are emphasized. There is a need for a study that presents more specific suggestions to increase the effectiveness of projects. Therefore, a new model is proposed in this manuscript to increase the efficiency of solar energy investments.

3. Methodology

This part gives information about the approaches used in the evaluation. In this study, an integrated methodology including the incomplete preferences, group decision making with consensus, Spherical fuzzy sets, and DEMATEL is proposed to evaluate the complex decision-making approach for the solar energy-based transportation investment projects. In some cases, the decision makers may not provide the relevant linguistic evaluations for each criterion and decision matrix because of the missing data and the experiences of the experts. So, the incomplete preferences can be completed methodologically by using the remaining evaluations properly [7,33]. Again, the consistency of the decision makers is one of the most important issues in the fuzzy decision-making approach [18;67]. The most appropriate evaluation and preference relations can be set with the consensus in group decision making process by using the feedback mechanism. [32,33]. Another important issue is to define the right member and non-membership degrees to evaluate the fuzzy-based complex decision-making models. Spherical fuzzy sets and DEMATEL are among the most prominent techniques to illustrate the impact-relation maps of the criteria with hesitancy degrees of the fuzzy preferences [31;53,94]. The methodology and the computation procedures of the integrated approach are given respectively in the following sub-sections.

3.1. IP in Decision-Making

A preference relation can be shown as $P = \left(p_{ij}\right)$, $p_{ij} = (x_i, x_j)$, $\forall i, j \in \{1, \cdots, n\}$. It is a $n \times n$ matrix and $p_{ij} \in S$. The linguistic term set is given as $S = \{S_0, S_1, \cdots, S_{g-1}, S_g\}$; g represents the number of linguistic preferences [95]. In the evaluation process, experts sometimes may not have necessary opinion to define the linguistic priorities for x_i over x_j. In this scenario, IPs can be taken into consideration to complete these missing values [57]. Regarding the estimation of linguistic preference ep_{ik} $(i \neq k)$, the Eqs. (1)–(4) are presented. In this process, an iterative estimation procedure is implemented. With the help of this issue, incomplete values can be estimated [74,62].

$$(ep_{ik})^{j1} = \Delta\left(\Delta^{-1}(p_{ij}) + \Delta^{-1}(p_{jk}) - \Delta^{-1}(S_{g/2})\right), \tag{1}$$

$$(ep_{ik})^{j2} = \Delta\left(\Delta^{-1}(p_{jk}) - \Delta^{-1}(p_{ji}) + \Delta^{-1}(S_{g/2})\right), \tag{2}$$

$$(ep_{ik})^{j3} = \Delta\left(\Delta^{-1}(p_{ij}) + \Delta^{-1}(p_{kj}) - \Delta^{-1}(S_{g/2})\right), \tag{3}$$

$$ep_{ik} = \Delta\left(\frac{1}{3}\left(\Delta^{-1}\left(ep_{ik}{}^{1}\right) + \Delta^{-1}\left(ep_{ik}{}^{2}\right) + \Delta^{-1}\left(ep_{ik}{}^{3}\right)\right)\right). \tag{4}$$

3.2. GDM with consensus

The lack of consensus among experts is a limitation in GDM. There is a possibility for experts to make different evaluations for a subject. This situation creates a problem for the performance of this process [49]. Group decision-making processes can be implemented with consensus to handle this complexity. In this process, the feedback mechanism is applied [96]. Eq. (5) gives information about the preference matrix [84].

$$P = (P_{ik}) and P_{ik} = \mu_p(x_i, x_k), (\forall i, k \in \{1, \cdots, n\}) \tag{5}$$

Where, P represents fuzzy preference relations, and $\mu_p : X \times X \rightarrow [0, 1]$ is the membership function.

Additionally, corresponding fuzzy preferences among the criteria (CP) can be calculated as in Eq. (6) so that the consistency levels of factors can be identified [83].

$$CP_{ik} = \frac{\sum_{j=1;i\neq k\neq j}^{n}(CP_{ik})^{j1} + \cdots + (CP_{ik})^{j(n-1)}}{(n-1)*(n-2)} \quad (6)$$

Eqs. (7) and (8) show the consistency level (CL).

$$CL_{ik} = 1 - \left(\frac{2*|CP_{ik} - P_{ik}|}{(n-1)}\right) \quad (7)$$

$$CL_i = \frac{\sum_{k=1;i\neq k}^{n}(CL_{ik} + CL_{ki})}{2(n-1)} \quad (8)$$

The global consistency level (GCL) is defined by using Eq. (9) [91].

$$GCL = \frac{\sum_{i=1}^{n} CL_i}{n} \quad (9)$$

Next, the similarity matrixes and results are identified by formulas (10) and (11). In these equations, ϕ indicates the aggregation function. e_h and e_l represent the decision makers, $(h < l)$, $\forall h, l = 1, \cdots, m$.

$$SM_{ik}^{hl} = 1 - \left|P_{ik}^{h} - P_{ik}^{l}\right| \quad (10)$$

$$SM_{ik} = \phi\left(SM_{ik}^{hl}\right) \quad (11)$$

Global consensus degrees (CR) are calculated by Eq. (12).

$$CR = \frac{\sum_{i=1}^{n}\frac{\sum_{k=1;k\neq i}^{n}(SM_{ik}+SM_{ki})}{2(n-1)}}{n} \quad (12)$$

Eq. (13) helps calculate the consensual degrees [23].

$$Z_{ik}^{h} = (1-\delta)*CL_{ik}^{h} + \delta*\left(\frac{\sum_{l=h+1}^{n} SM_{ik}^{hl} + \sum_{l=1}^{h-1} SM_{ik}^{lh}}{n-1}\right) \quad (13)$$

In this equation,δ refers to the parameter, and it can be between 0 and 1. When it is greater than 0.5, it means that more importance is given to the consensus. This value is defined as 0.75. P_{ik}^{c} explains "collective fuzzy preference relations" as in Eqs. (14)–(16). σ indicates a permutation of $\{1, \cdots, m\}$, $Z_{ik}^{\sigma(h)} \geq Z_{ik}^{\sigma(h+1)}$, $\forall h = 1, \cdots, m-1$. $\langle Z_{ik}^{\sigma(h)}, P_{\sigma(i)}\rangle$ explains a two-tuple with $Z_{ik}^{\sigma(h)}$ as the hth largest value in $\{Z_{ik}^{1}, \cdots, Z_{ik}^{m}\}$ [91].

$$A_S \oplus B_S = \left\{\left(\mu_{A_S}^2 + \mu_{B_S}^2 - \mu_{A_S}^2\mu_{B_S}^2\right)^{\frac{1}{2}}, v_{A_S}v_{B_S}, \left(\left(1-\mu_{B_S}^2\right)\pi_{A_S}^2 + \left(1-\mu_{A_S}^2\right)\pi_{B_S}^2 - \pi_{A_S}^2\pi_{B_S}^2\right)^{\frac{1}{2}}\right\} \quad (25)$$

$$P_{ik}^{c} = \Phi w\left(\langle Z_{ik}^{1}, P_{ik}^{1}\rangle, \cdots, \langle Z_{ik}^{m}, P_{ik}^{m}\rangle\right) = \sum_{h=1}^{m} w_h * P_{ik}^{\sigma(h)} \quad (14)$$

$$w_h = Q(h/n) - Q(h-1)/n \quad (15)$$

$$(r) = \begin{cases} 0 if r < a \\ \frac{r-a}{b-a} if a \leq r \leq b \\ 1 if r > a \end{cases} \quad (16)$$

The details of the proximity levels (PP_{ik}^{h}) and the relation (Pr^{h}) can be demonstrated by formulas (17) and (18) [83].

$$PP_{ik}^{h} = 1 - \left|P_{ik}^{h} - P_{ik}^{c}\right| \quad (17)$$

$$Pr^{h} = \frac{\sum_{i=1}^{n}\frac{\sum_{k=1;k\neq i}^{n}(PP_{ik}^{h}+PP_{ki}^{h})}{2(n-1)}}{n} \quad (18)$$

The consensus control level (CCL) is calculated with Eq. (19).

$$CCL = (1-\delta)*GCL + \delta*CR \quad (19)$$

CCL can be used to identify the final consensus result, which is compared to the critical value of 0.85. Feedback implementation is used to make necessary revisions. Several rounds are applied to reach this objective while changing the preference relations. EXPCH, ALT, and APS are calculated with the help of Eqs. (20)–(22) [84].

$$EXPCH = \left\{h \middle| (1-\delta)*CL^{h} + \delta*Pr^{h} < \gamma\right\} \quad (20)$$

$$ALT = \left\{(h,i) \middle| e_h \in EXPCH \wedge (1-\delta)*CL_i^{h} + \delta*\frac{\sum_{k=1;k\neq i}^{n}(PP_{ik}^{h} + PP_{ki}^{h})}{2(n-1)} < \gamma\right\} \quad (21)$$

$$APS = \left\{(h,i,k) \middle| (h,i) \in ALT \wedge (1-\delta)*CL_{ik}^{h} + \delta*PP_{ik}^{h} < \gamma\right\} \quad (22)$$

3.3. Spherical fuzzy sets

The increasing complexity of the problems aimed to be solved by decision-making methods has led to the need to enhance the methodologies that are used [101]. Spherical fuzzy sets are one of the important techniques for this purpose. The hesitancy degree is considered in this process (Gündoğdu and Kahraman, 2020); μ, ν, and π represent the parameters [53]. Spherical fuzzy sets are denoted as A_S and the details are given in Eqs. (23) and (24).

$$A_S = \left\{\left\langle u, \left(\mu_{A_S}(u), v_{A_S}(u), \pi_{A_S}(u)\right) | u \in U\right\rangle\right\} \quad (23)$$

$$0 \leq \mu_{A_S}^2(u) + v_{A_S}^2(u) + \pi_{A_S}^2(u) \leq 1, \forall_u \in U \quad (24)$$

Different degrees of spherical fuzzy sets are illustrated in Fig. 1 [89].

$A_S = (\mu_{A_S}, v_{A_S}, \pi_{A_S})$ and $B_S = (\mu_{B_S}, v_{B_S}, \pi_{B_S})$ show spherical fuzzy sets from two universes of X_1 and X_2. Eqs. (25)–(28) explain the details of the calculation process.

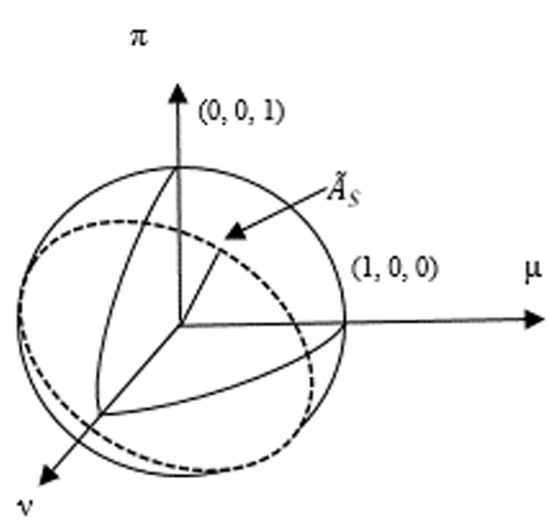

Fig. 1. Spherical Fuzzy Sets.

$$A_S \otimes B_S = \left\{ \left(\mu_{A_S}\mu_{B_S}, (v_{A_S}^2 + v_{B_S}^2 - v_{A_S}^2 v_{B_S}^2 \right)^{\frac{1}{2}}, \left(\left(1 - v_{B_S}^2\right)\pi_{A_S}^2 + \left(1 - v_{A_S}^2\right)\pi_{B_S}^2 - \pi_{A_S}^2\pi_{B_S}^2 \right)^{\frac{1}{2}} \right\} A_S \otimes B_S = \left\{ \left(\mu_{A_S}\mu_{B_S}, (v_{A_S}^2 + v_{B_S}^2 - v_{A_S}^2 v_{B_S}^2 \right)^{\frac{1}{2}}, \left(\left(1 - v_{B_S}^2\right)\pi_{A_S}^2 + \left(1 - v_{A_S}^2\right)\pi_{B_S}^2 - \pi_{A_S}^2\pi_{B_S}^2 \right)^{\frac{1}{2}} \right\} \quad (26)$$

$$\lambda^* A_S = \left\{ \left(1 - \left(1 - \mu_{A_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}, v_{A_S}^{\lambda}, \left(\left(1 - \mu_{A_S}^2\right)^{\lambda} - \left(1 - \mu_{A_S}^2 - \pi_{A_S}^2\right)^{\lambda} \right)^{\frac{1}{2}} \right\}, \lambda > 0 \quad (27)$$

$$A_S^{\lambda} = \left\{ \mu_{A_S}^{\lambda}, \left(1 - \left(1 - v_{A_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}, \left(\left(1 - v_{A_S}^2\right)^{\lambda} - \left(1 - v_{A_S}^2 - \pi_{A_S}^2\right)^{\lambda} \right)^{\frac{1}{2}} \right\}, \lambda > 0 \quad (28)$$

The aggregated values are identified by considering the spherical weighted arithmetic mean (SWAM) number as in formula (29) [40].

$$SWAM_w\left(A_{S1}, .., A_{Sn}\right) = w_1 A_{S1} + \cdots + w_n A_{Sn} = \left\{ \left[1 - \prod_{i=1}^{n}\left(1 - \mu_{A_{Si}}^2\right)^{w_i}\right]^{\frac{1}{2}}, \prod_{i=1}^{n} v_{A_{Si}}^{w_i}, \left[\prod_{i=1}^{n}\left(1 - \mu_{A_{Si}}^2\right)^{w_i} - \prod_{i=1}^{n}\left(1 - \mu_{A_{Si}}^2 - \pi_{A_{Si}}^2\right)^{w_i}\right]^{\frac{1}{2}} \right\} \quad (29)$$

There is a wide literature regarding Spherical fuzzy sets. For instance, Yuan et al. [99] focused on the key indicators of the green nuclear energy investments. In this context, different factors are evaluated by considering Spherical fuzzy DEMATEL methodology. In addition to this study, Liu et al. [50] tried to examine occupational health and safety risk assessment with the help of Spherical fuzzy TODIM. Moreover, Menekşe and Akdağ [56] used Spherical fuzzy ELECTRE technique to evaluate internal audit planning. Furthermore, Olugu et al. [64] integrated spherical fuzzy Delphi and TOPSIS techniques with the aim of defining significant indicators for sustainable maintenance management in the oil and gas industry. Additionally, Sharaf et al. [79] considered spherical fuzzy TODIM approach for green occupational health and safety equipment supplier selection. Also, Doğan [22] used spherical fuzzy AHP regarding process mining technology selection.

3.4. Dematel

DEMATEL is mainly applied to find the importance levels of the criteria. The main advantage is the generation of the impact relation map [95,82]. By expert evaluations, the direct relation matrix (A) is generated. The details are given by Eq. (30). a_{ij} gives information about the impact of item i on factor j [35,41].

$$A = \begin{bmatrix} 0 & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & 0 & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & 0 & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & 0 \end{bmatrix} \quad (30)$$

This matrix is normalized by using Eqs. (31) and (32) [88].

$$B = \frac{A}{max_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \quad (31)$$

$$0 \le b_{ij} \le 1 \quad (32)$$

The total relation matrix (C) can be constructed by the normalized matrix (B) and the identity matrix (I) as in Eq. (33) [75]

$$C = B(I - B)^{-1} \quad (33)$$

D and E are determined by formulas (34) and (35). They represent the sum of the rows and columns. In these equations, e_{ij} represents the elements of the total relation matrix [69].

$$D = \left[\sum_{j=1}^{n} e_{ij}\right]_{nx1} \quad (34)$$

$$E = \left[\sum_{i=1}^{n} e_{ij}\right]_{1xn} \quad (35)$$

Finally, the weights of the factors are calculated by considering the value of D + E. The value of D-E is considered to evaluate the causal relationship between the items. The threshold value (α) is calculated with Eq. (36) [100].

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left[e_{ij}\right]}{N} \quad (36)$$

3.5. Proposed model of this study

The details of this model are shown in Fig. 2.

Criteria are selected based on TRIZ principles. This technique gives an opportunity to reach the appropriate results in a quick manner [85,68,25]. Furthermore, IP methodology is considered to analyze the experts' evaluations. For some subjects, all experts may not have necessary opinions to evaluate some criteria [14,74,95]. The main advantage of this methodology is that this missing information in this process can be completed. In addition, considering GDM to calculate the fuzzy preferences also provides some advantages. Regarding some factors, experts may have the opposite opinions [96]. This situation creates some problems in this process [49]. The effectiveness of this process can be improved by consensus methodology [103,93]. Because spherical fuzzy sets include membership, non-membership, and hesitancy, it can be possible to reach more reliable results [5,3,70]. For instance, the impact-relation map can be created with this methodology so that cause-effect relationships can be examined [102,95,15].

4. Details of the analysis

The computation stages are detailed in the following subsections.

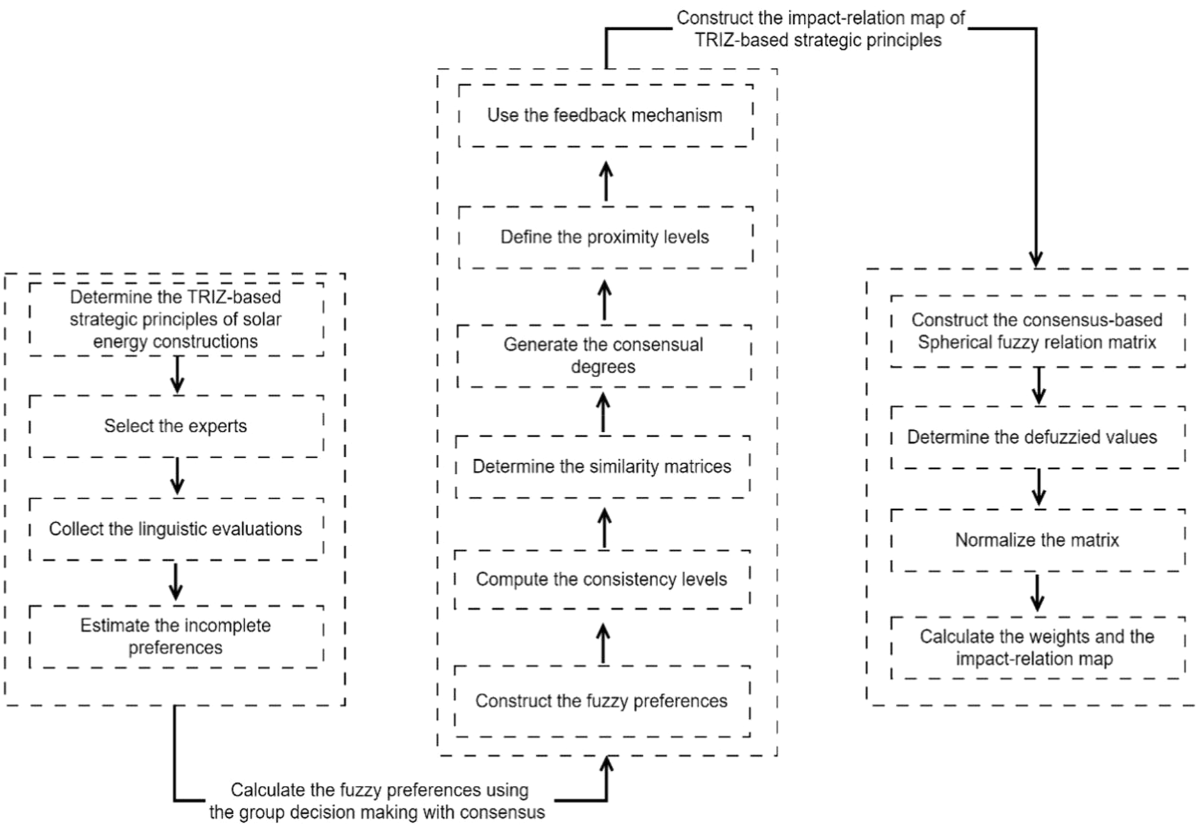

Fig. 2. Algorithm of the proposed model.

Table 1
Selected Characteristics.

Characteristics	Supported Literature
Loss of energy (FR 1)	Fontaine [27],Imam and Ayadi [36]
Reliability (FR 2)	Ramírez-Del-Barrio et al. [72],Assaf and Shabani [11]
Convenience of Use (FR 3)	Savvides et al. [76]
Repairability (FR 4)	Yang et al. (2019)
Adaptability (FR 5)	Shao et al. [78]
Capacity (FR 6)	Jin et al. [40]

4.1. Computation of the IPs

With respect to the carbon emission problem, the transportation sector plays a key role. The main reason is that using fossil fuels in transport vehicles leads to significant amount of carbon dioxide emission. In order to solve this problem, electric vehicles can be taken into consideration. Nevertheless, high cost is a crucial barrier in choosing electric vehicles, especially in road transport. Owing to this situation, electric vehicles charged with solar energy can also contribute significantly to the solution of this problem. Parallel to this issue, this study illustrates causal relationships of innovative strategies for solar energy projects. The first step identifies the important factors for solar energy projects. These items are defined based on the TRIZ technique. These characteristics are explained in Table 1.

There are six important factors for solar energy projects. First, loss of energy has a key importance in this regard. The design of solar energy projects should minimize the loss. Additionally, these projects should be reliable. In other words, the performance of these projects should not be questionable. The projects should be user friendly so that efficiency can be increased. Repairability is another crucial item that affects the performance of solar energy investments. In case of a possible problem in these projects, it is very important that this issue can be easily repaired. Otherwise, investors may have to bear very high costs. Long duration of repair also reduces the efficiency of the process. Adaptability is also an essential issue in this context. Rapid developments are occurring in technologies for solar energy projects. These new developments contribute significantly to the reduction of the costs in these projects. Therefore, the solar energy projects should be able to be easily adapted to these developments. Finally, solar energy projects should generate a high amount of electricity, as high capacity contributes positively to the performance of these projects.

The second step is related to the appointment of the decision makers for collecting the evaluations. For this purpose, four different decision makers are selected to evaluate the factors. These people have at least 17 years of experience. They are experts on the subjects of solar energy, strategy development, technology, construction, and manufacturing. These people are top managers in large-scale solar energy companies. Hence, it can be understood that these people have sufficient knowledge to evaluate the significant indicators of solar energy projects. After selecting the characteristics of solar energy projects, the characteristics are evaluated by the expert team. In this process, 40 different TRIZ principles are considered, which are explained in the appendix part. These six factors are compared to each other in this evaluation so that the contradiction matrix (CM) can be generated as in Table 2.

Table 2 shows the comparison of six different factors. The left side of this table gives information about the improvement of the factors. The right side explains the worsening characteristics. Within this framework, experts provide TRIZ-based solutions while comparing the six different factors with each other. As a result, four different TRIZ-based strategies are created; the details are given in Table 3.

Table 4 defines four different TRIZ-based principles for the performance of solar energy projects. First, prior counteraction gives information about periodically testing the counteraction of panels to avoid breakdown. Second, dynamicity explains the changes of the location or angle to attain optimal performance of sunlight. Periodic action includes

Table 2
CM.

	Worsening Items						
Improving Items	Characteristics	FR 1	FR 2	FR 3	FR 4	FR 5	FR 6
	FR 1	–	19	9,15	15	40	
	FR 2	9	–	9,15,19	15	19	40
	FR 3	9	15	–	9	19	
	FR 4	19,40	15	15,19	–		
	FR 5	9	15	19	40	–	
	FR 6		9,15,19	19	40	15,19	–

Table 3
TRIZ-based strategic principles.

Number ofStrategies	Selected Strategies (SGs)	Supported Literature
9	Prior Counteraction (SG1)	Andreani et al. [9],Wilkins et al. [90]
15	Dynamicity (SG2)	Corona et al. [19],Raza et al. [73]
19	Periodic Action (SG3)	Savvides et al. [76],Achuthan et al. [1]
40	Composite Materials (SG4)	Chen et al. [15]

the identification of the best frequency of maintenance for solar projects. Composite materials refers to deciding the most appropriate cell material alternatives for solar modules. The third step of this stage includes the collection of the linguistic preferences for these principles. Seven different linguistic scales are used. Later, the decision makers evaluate these factors. Some DMs cannot provide evaluations of the comparison of some criteria. Because of this situation, IP methodology is used to complete them. Within this scope, Eqs. (1)–(4) are used. For decision maker 1, ep_{12} and ep_{21} are missing. With the help of this methodology, first, ep_{12} is estimated. The iteration is detailed by Eqs. (37)–(40).

$$(ep_{12})^{31} = \Delta\left(\Delta^{-1}(sg_{13})+\Delta^{-1}(sg_{32}) - \Delta^{-1}(S_3)\right) = 5(\mathrm{VH}) \tag{37}$$

$$(ep_{12})^{32} = \Delta\left(\Delta^{-1}(sg_{32})-\Delta^{-1}(sg_{31}) + \Delta^{-1}(S_3)\right) = 3(\mathrm{M}) \tag{38}$$

$$(ep_{12})^{33} = \Delta\left(\Delta^{-1}(sg_{13})+\Delta^{-1}(sg_{23}) - \Delta^{-1}(S_3)\right) = 4(\mathrm{H}) \tag{39}$$

$$ep_{12} = \Delta\left(\frac{1}{3}\left(\Delta^{-1}\left(ep_{12}{}^{1}\right) + \Delta^{-1}\left(ep_{12}{}^{2}\right) + \Delta^{-1}\left(ep_{12}{}^{3}\right)\right)\right) = 4(\mathrm{H}) \tag{40}$$

Regarding ep_{21}, the details of the iteration are given in Eqs. (41)–(44).

$$(ep_{21})^{31} = \Delta\left(\Delta^{-1}(sg_{23})+\Delta^{-1}(sg_{31}) - \Delta^{-1}(S_3)\right) = 4(\mathrm{H}) \tag{41}$$

$$(ep_{21})^{32} = \Delta\left(\Delta^{-1}(sg_{31})-\Delta^{-1}(sg_{32}) + \Delta^{-1}(S_3)\right) = 3(\mathrm{M}) \tag{42}$$

$$(ep_{21})^{33} = \Delta\left(\Delta^{-1}(sg_{23})+\Delta^{-1}(sg_{13}) - \Delta^{-1}(S_3)\right) = 2(\mathrm{S}) \tag{43}$$

$$ep_{21} = \Delta\left(\frac{1}{3}\left(\Delta^{-1}\left(ep_{21}{}^{1}\right) + \Delta^{-1}\left(ep_{21}{}^{2}\right) + \Delta^{-1}\left(ep_{21}{}^{3}\right)\right)\right) = 3(\mathrm{M}) \tag{44}$$

For decision maker 3, the missing values are ep_{32} and ep_{41}. First, the iteration of ep_{32} is shown by Eqs. (45)–(48).

$$(ep_{32})^{41} = 5(\mathrm{VH}) \tag{45}$$

$$(ep_{32})^{42} = 4(\mathrm{H}) \tag{46}$$

$$(ep_{32})^{43} = 3(\mathrm{M}) \tag{47}$$

$$ep_{32} = 4(\mathrm{H}) \tag{48}$$

The iteration of ep_{41} is identified by considering Eqs. (49)–(52).

$$(ep_{41})^{31} = 2(\mathrm{S}) \tag{49}$$

$$(ep_{41})^{32} = 1(\mathrm{W}) \tag{50}$$

$$(ep_{41})^{33} = 3(\mathrm{M}) \tag{51}$$

$$ep_{41} = 2(\mathrm{S}) \tag{52}$$

The missing values of decision maker 4 are ep_{12}, ep_{21}, ep_{23}, and ep_{32}. The first iteration is related to ep_{23} and ep_{32} and explained in Eqs. (53)–(60).

$$(ep_{23})^{41} = 3(\mathrm{M}) \tag{53}$$

$$(ep_{23})^{42} = 4(\mathrm{H}) \tag{54}$$

$$(ep_{23})^{43} = 2(\mathrm{S}) \tag{55}$$

$$ep_{23} = 3(\mathrm{M}) \tag{56}$$

$$(ep_{32})^{41} = 3(\mathrm{M}) \tag{57}$$

$$(ep_{32})^{42} = 2(\mathrm{S}) \tag{58}$$

$$(ep_{32})^{43} = 4(\mathrm{H}) \tag{59}$$

$$ep_{32} = 3(\mathrm{M}) \tag{60}$$

Table 4
Completed linguistic evaluations of decision makers.

Decision Maker 1					Decision Maker 2				
Principles	**SG1**	**SG2**	**SG3**	**SG4**	**Principles**	**SG1**	**SG2**	**SG3**	**SG4**
SG1		H	H	M	SG1		S	S	H
SG2	M		M	H	SG2	S		M	H
SG3	H	H		H	SG3	W	VH		M
SG4	M	S	M		SG4	W	VH	VH	
Decision Maker 3					**Decision Maker 4**				
Principles	**SG1**	**SG2**	**SG3**	**SG4**	**Principles**	**SG1**	**SG2**	**SG3**	**SG4**
SG1		VH	M	M	SG1		M	M	M
SG2	M		M	H	SG2	M		M	M
SG3	S	H		H	SG3	M	M		H
SG4	S	H	M		SG4	M	S	M	

Finally, Eqs. (61)–(68) state the details of the iteration regarding ep_{12} and ep_{21}.

$$(ep_{12})^{31} = 3(\mathrm{M}) \quad (61)$$

$$(ep_{12})^{32} = 3(\mathrm{M}) \quad (62)$$

$$(ep_{12})^{33} = 3(\mathrm{M}) \quad (63)$$

$$ep_{12} = 3(\mathrm{M}) \quad (64)$$

$$(ep_{21})^{31} = 3(\mathrm{M}) \quad (65)$$

$$(ep_{21})^{32} = 3(\mathrm{M}) \quad (66)$$

$$(ep_{21})^{33} = 3(\mathrm{M}) \quad (67)$$

$$ep_{21} = 3(\mathrm{M}) \quad (68)$$

With the help of these iterations, the missing values can be estimated. Linguistic scales are listed as no influence (N), weak influence (W), somewhat influence (S), medium influence (M), high influence (H), very high influence (VH), extremely influence (E). The completed linguistic evaluations of the decision makers are given in Table 4.

4.2. Defining the fuzzy preferences using group decision making with consensus

Fuzzy preferences are constructed for the principles by using Eq. (5). In the second step, the consistency levels of the principles are calculated by considering Eqs. (7) and (8). The results are presented in Table 5.

By using Eq. (9), GCL is calculated as 0.89. In the third step, similarity matrixes (SMs) are defined for each decision maker. In this framework, Eqs. (10) and (11) are taken into consideration (Table 6).

After that, the collective similarity matrix (CSM) is generated by formula (12). As a result, CR is calculated as 0.83. The results are presented in Table 7.

In the fourth step, the consensual degrees are identified. Within this framework, formula (13) is used. Table 8 provides the results.

Next, the collective fuzzy preference relations (FPRs) are calculated with Eqs. (14)–(16). Table 9 explains the details.

Proximity levels (PLs) are calculated by Eqs. (17) and (18). Table 10 presents the results.

CCL is computed as 0.84, which is lower than 0.85. Hence, in the sixth step, the feedback mechanism is used. FPRs for the second round are given in Table 11.

CCL is defined as 0.83. Since it is lower than 0.85, the next round is applied. The details are given in Table 12.

CCL is calculated as 0.87, which is higher than 0.85. Thus, consensus can be obtained.

4.3. Illustrating causal relationships

First, the spherical fuzzy relation matrix is constructed in this stage. The normalized values are obtained with the boundaries of $0 \leq \mu_p^2(u) + \nu_p^2(u) + \pi_p^2(u) \leq 1$ for different degrees. Second, the defuzzified values are defined as in Table 13.

Third, this matrix is normalized by Eqs. (31) and (32). The values are stated in Table 14.

Finally, the weights of the factors are identified as in Table 15. For this purpose, Eqs. (33)–(35) are used.

The table shows that dynamicity (SG2) is the most critical principle that affects the effectiveness of solar energy projects. Composite materials (SG4) also play an important role. Prior counteraction (SG1) and periodic action (SG3) have the lowest weights. Causal relationship is identified by considering the threshold value (α) detailed in Eq. (36). The details are shown in Fig. 3.

Fig. 3 shows that prior counteraction (Principle 1) has an impact on the other three principles. Periodic action (Principle 3) is the most influenced principle. Another important point is that dynamicity (Principle 2) and composite materials (Principle 4) mutually affect each other. Moreover, these two principles affect periodic action (Principle 3) and are affected by prior counteraction (Principle 1).

5. Conclusion and discussion

In this study, we aimed to derive innovative strategies to increase the performance of solar energy projects. Dynamicity is the most significant factor that improves the effectiveness of these projects. Composite materials also have an important impact on this situation. It is recommended that solar panels be positioned so that they can receive sunlight at different times vertically. The solar panel can operate at the highest efficiency when it is fully directed to the sun. However, it is still debated in which direction and at what degree angle the solar panel should be positioned. In this framework, it is seen that different variations are made by companies. This situation shows that there is no consensus on this issue. The sun is at different positions in different time zones throughout the year. The sun is also constantly shifting during the day. Therefore, the angle of the solar panel is of vital importance to make the most of the sunlight. In today's applications, it is aimed to obtain maximum efficiency from the sun by calculating the most optimal angle of inclination. While looking at the results of the study, it should be aimed to create flexible structured solar panels that can change position according to the angle of the sun during the day. It will be possible to position it at a right angle to the sun, which is constantly changing during this day. This will contribute to generating more electrical energy.

Merin et al. [59] presented a study for wind and solar hybrid power systems. They reached the conclusion that to increase the effectiveness of these projects, it is necessary to make maximum use of sunlight. In this context, it is necessary to pay particular attention to this issue during the construction process of these projects. Similar to this study,

Table 5
Experts' Consistency Levels.

DM1 (CL^1:0.90)					**DM2 (CL^2:0.78)**				
CL^1	**SG1**	**SG2**	**SG3**	**SG4**	**CL^2**	**SG1**	**SG2**	**SG3**	**SG4**
SG1	–	0.87	0.87	0.82	SG1	–	0.62	0.76	0.80
SG2	0.93	–	0.96	0.87	SG2	0.91	–	0.93	0.84
SG3	0.93	0.91	–	1.00	SG3	0.82	0.67	–	0.89
SG4	0.91	0.80	0.93	–	SG4	0.67	0.78	0.64	–
DM3 (CL^3:0.91)					**DM4 (CL^4:0.95)**				
CL^3	**SG1**	**SG2**	**SG3**	**SG4**	**CL^4**	**SG1**	**SG2**	**SG3**	**SG4**
SG1	–	0.84	0.93	0.82	SG1	–	0.96	0.98	0.93
SG2	0.91	–	0.98	0.87	SG2	0.98	–	1.00	0.96
SG3	0.87	0.98	–	0.91	SG3	0.96	1.00	–	0.89
SG4	0.96	0.93	0.98	–	SG4	0.93	0.89	0.96	–

Table 6
SMs.

DM1-DM3 SM[13]	SG1	SG2	SG3	SG4	DM1-DM4 SM[14]	SG1	SG2	SG3	SG4
SG1		0.80	0.80	1.00	SG1		0.80	0.80	1.00
SG2	1.00		1.00	1.00	SG2	1.00		1.00	0.80
SG3	0.60	1.00		1.00	SG3	0.80	0.80		1.00
SG4	0.80	0.60	1.00		SG4	1.00	1.00	1.00	
DM2-DM3 SM[23]	SG1	SG2	SG3	SG4	DM2-DM4 SM[24]	SG1	SG2	SG3	SG4
SG1		0.40	0.80	0.80	SG1		0.80	0.80	0.80
SG2	0.80		1.00	1.00	SG2	0.80		1.00	0.80
SG3	0.80	0.80		0.80	SG3	0.60	0.60		0.80
SG4	0.80	0.80	0.60		SG4	0.60	0.40	0.60	

Table 7
CSM.

SM	P1	P2	P3	P4
P1		0.70	0.80	0.90
P2	0.90		1.00	0.90
P3	0.70	0.80		0.90
P4	0.80	0.70	0.80	

Asim et al. [10] focused on the efficiency enhancement of solar panels by considering the photodiode. They identified that more energy generation is possible with the help of solar tracking. This situation can be very helpful for the solar panels to maintain a perpendicular profile to the rays of the sun. Gangwar et al. [28] investigated performance assessment of solar power systems. For this purpose, they conducted an analysis by considering the Fibonacci number and Golden Ratio. They determined that each solar panel connected in solar trees should be in a different direction so that maximum amount of sunlight can be received throughout the day.

Another important point is that composite materials should be preferred in solar energy projects. It is important to use safe and durable goods. Composite materials refer to robust and light materials, and these materials are also resistant to heat and fire. In addition, it is considered an important advantage that these materials do not rust. These products should be preferred in the installation of solar panels. These considerations will increase the effectiveness of solar energy investments. Therefore, development of technological infrastructure is very important. In order to achieve this goal, research and development studies should be increased. In this way, it will be possible to determine which new and quality materials should be used in solar panels, which can have a significant contribution in minimizing the costs of these projects. Some researchers in the literature have discussed the importance of considering composite materials for the construction of solar panels. For example, Mirzaev et al. [61], Das et al. [20], and Mehdi et al. [54] evaluated the performance of solar panels. Different cases were taken into consideration to identify the significant issues that affect the performance of these projects. They underlined the importance of using composite materials for the construction of solar panel systems. These materials can help minimize the cost of these projects so that effectiveness can be increased.

Transportation sector has an increasing impact on the carbon emission problem because of using fossil fuels in transport vehicles. Electric vehicles can be taken into consideration in order to solve this problem. However, high cost is a crucial barrier in choosing electric vehicles, especially in road transport. Owing to this situation, electric vehicles charged with solar energy can also contribute significantly to the solution of this problem. In this context, the analysis results presented in this study pave the ways to increase efficiency and effectiveness of the solar energy investment projects. While improving solar energy projects, electric vehicles charged with solar energy can be increased. With the help of this situation, it can be possible for transportation sector to have a positive influence on the environment. Liu et al. [106] and Anser et al. [107] also identified that carbon emission problem should be reduced for the long-term improvement of the economies. Additionally, Wang et al. [108], Yin et al. [109] and Simionescu et al. [110] also discussed that technological improvements play a key role for the effectiveness of the investments.

The main limitation of this study is that it focuses only on solar energy projects. Further studies are recommended for other renewable energy alternatives. For example, a new study can be conducted to evaluate these factors for wind turbines. These studies can provide solutions to investors to minimize their costs and use their budget effectively and eventually have more environment friendly energy usage and decreasing carbon emission. This study did not include a case study. Therefore, industrial applications were not proposed. On the other hand,

Table 9
Collective FPRs.

Pc	SG1	SG2	SG3	SG4
SG1		0.72	0.80	0.89
SG2	0.91		0.99	0.90
SG3	0.71	0.83		0.92
SG4	0.80	0.69	0.83	

Table 8
Consensual Degrees.

DM1					DM2				
Z1	SG1	SG2	SG3	SG4	Z2	SG1	SG2	SG3	SG4
SG1		0.77	0.77	0.91	SG1		0.61	0.74	0.80
SG2	0.93		0.99	0.92	SG2	0.83		0.98	0.91
SG3	0.68	0.88		0.95	SG3	0.66	0.72		0.82
SG4	0.83	0.70	0.88		SG4	0.67	0.59	0.61	
DM3					DM4				
Z3	SG1	SG2	SG3	SG4	Z4	SG1	SG2	SG3	SG4
SG1		0.66	0.88	0.91	SG1		0.79	0.89	0.93
SG2	0.93		0.99	0.92	SG2	0.94		1.00	0.84
SG3	0.77	0.89		0.93	SG3	0.79	0.80		0.92
SG4	0.84	0.73	0.89		SG4	0.83	0.72	0.89	

Table 10
PLs.

DM1 (Pr^1 : 0.75)					DM2 (Pr^2 : 0.63)				
PP[1]	**SG1**	**SG2**	**SG3**	**SG4**	**PP[2]**	**SG1**	**SG2**	**SG3**	**SG4**
SG1		0.98	0.90	0.61	SG1		0.58	0.50	0.81
SG2	0.59		0.51	0.80	SG2	0.39		0.51	0.80
SG3	0.99	0.87		0.78	SG3	0.39	0.93		0.58
SG4	0.70	0.61	0.67		SG4	0.30	0.79	0.93	
DM3 (Pr^3 : 0.70)					**DM4** (Pr^4 : 0.67)				
PP[3]	**SG1**	**SG2**	**SG3**	**SG4**	**PP[4]**	**SG1**	**SG2**	**SG3**	**SG4**
SG1		0.82	0.70	0.61	SG1		0.78	0.70	0.61
SG2	0.59		0.51	0.80	SG2	0.59		0.51	0.60
SG3	0.59	0.87		0.78	SG3	0.79	0.67		0.78
SG4	0.50	0.99	0.67		SG4	0.70	0.61	0.67	

Table 11
FPRs of the second round.

DM1					DM2				
P[1]	**SG1**	**SG2**	**SG3**	**SG4**	**P[2]**	**SG1**	**SG2**	**SG3**	**SG4**
SG1	–	0.70	0.70	0.50	SG1	–	0.76	0.76	0.70
SG2	0.83	–	0.88	0.70	SG2	0.30	–	0.50	0.70
SG3	0.70	0.70	–	0.70	SG3	0.10	0.90	–	0.50
SG4	0.50	0.66	0.72	–	SG4	0.10	0.90	0.90	–
DM3					**DM4**				
P[3]	**SG1**	**SG2**	**SG3**	**SG4**	**P[4]**	**SG1**	**SG2**	**SG3**	**SG4**
SG1	–	0.90	0.50	0.86	SG1	–	0.50	0.50	0.50
SG2	0.50	–	0.50	0.70	SG2	0.82	–	0.87	0.82
SG3	0.65	0.70	–	0.70	SG3	0.50	0.50	–	0.70
SG4	0.30	0.70	0.50	–	SG4	0.50	0.63	0.73	–

Table 12
FPRs for the third round (consensus-based fuzzy preference relations).

DM1					DM2				
P[1]	**SG1**	**SG2**	**SG3**	**SG4**	**P[2]**	**SG1**	**SG2**	**SG3**	**SG4**
SG1	–	0.70	0.70	0.78	SG1	–	0.76	0.76	0.70
SG2	0.83	–	0.88	0.70	SG2	0.30	–	0.50	0.70
SG3	0.70	0.70	–	0.70	SG3	0.10	0.90	–	0.50
SG4	0.50	0.66	0.72	–	SG4	0.71	0.90	0.90	–
DM3					**DM4**				
P[3]	**SG1**	**SG2**	**SG3**	**SG4**	**P[4]**	**SG1**	**SG2**	**SG3**	**SG4**
SG1	–	0.90	0.50	0.86	SG1	–	0.73	0.80	0.77
SG2	0.50	–	0.50	0.70	SG2	0.82	–	0.87	0.82
SG3	0.65	0.70	–	0.70	SG3	0.50	0.50	–	0.70
SG4	0.72	0.70	0.72	–	SG4	0.50	0.63	0.73	–

Table 13
Defuzzified relation matrix.

Principles	SG1	SG2	SG3	SG4
SG1	0.000	0.380	0.278	0.377
SG2	0.234	0.000	0.314	0.312
SG3	0.140	0.306	0.000	0.221
SG4	0.181	0.324	0.373	0.000

Table 14
Normalized relation matrix.

Principles	SG1	SG2	SG3	SG4
SG1	0.000	0.367	0.268	0.364
SG2	0.226	0.000	0.303	0.302
SG3	0.136	0.295	0.000	0.214
SG4	0.175	0.313	0.360	0.000

for the future studies, different methodologies can be taken into consideration. For instance, researchers can use Pythagorean fuzzy sets in the analysis process. This situation provides an opportunity to make comparative evaluation. Similarly, interval type-2 and q-rang Orthopair fuzzy sets can also be considered to handle uncertainty more effectively.

CRediT authorship contribution statement

Gang Kou: Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Writing – original draft. **Serhat Yüksel:** Investigation, Methodology, Project administration, Writing – review & editing. **Hasan Dinçer:** Conceptualization, Formal analysis, Validation, Project administration, Resources, Software, Writing – review & editing.

Table 15
Weights.

Principles	SG1	SG2	SG3	SG4	D	E	D + E	D-E	Weights
SG1	0.800	1.545	1.470	1.436	5.251	3.168	8.419	2.083	0.236
SG2	0.863	1.085	1.305	1.222	4.475	5.062	9.537	-0.586	0.267
SG3	0.676	1.108	0.871	0.980	3.635	4.985	8.621	−1.350	0.242
SG4	0.829	1.323	1.340	0.987	4.479	4.625	9.104	-0.147	0.255

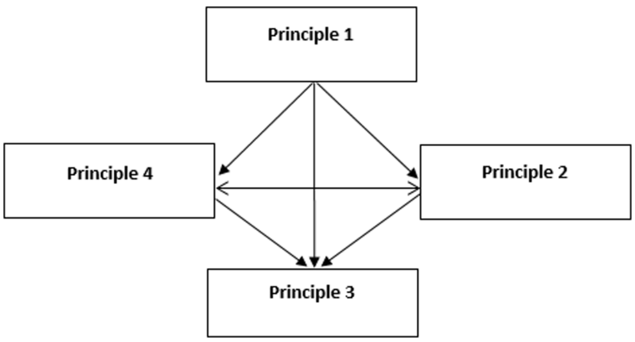

Fig. 3. Causal Relationships.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This paper was partially supported by grants from the National Natural Science Foundation of China (#71910107002 and #71725001), State key R & D Program of China(#2020YFC0832702) and Major project of the National Social Science Foundation of China (#19ZDA092).

References

[1] Achuthan K, Freeman JD, Nedungadi P, Mohankumar U, Varghese A, Vasanthakumari AM, et al. Remote triggered dual-axis solar irradiance measurement system. IEEE Trans Ind Appl 2020;56(2):1742–51.
[2] Ahangar N, Mehrpooya M. Thermaly integrated five-step ZnSI thermochemical cycle hydrogen production process using solar energy. Energy Convers Manage 2020;222:113243. https://doi.org/10.1016/j.enconman.2020.113243.
[3] Akram M, Saleem D, Al-Hawary T. Spherical Fuzzy Graphs with Application to Decision-Making. Math Comput Applications 2020;25(1):8.
[4] Al-Betar MA, Alomari OA, Abu-Romman SM. A TRIZ-inspired bat algorithm for gene selection in cancer classification. Genomics 2020;112(1):114–26.
[5] Ali Z, Mahmood T, Yang MS. Complex T-spherical fuzzy aggregation operators with application to multi-attribute decision making. Symmetry 2020;12(8):1311.
[6] Alirahmi SM, Rahmani Dabbagh S, Ahmadi P, Wongwises S. Multi-objective design optimization of a multi-generation energy system based on geothermal and solar energy. Energy Convers Manage 2020;205:112426. https://doi.org/10.1016/j.enconman.2019.112426.
[7] Alonso S, Cabrerizo FJ, Chiclana F, Herrera F, Herrera-Viedma E. Group decision making with incomplete fuzzy linguistic preference relations. Int J Intell Syst 2009;24(2):201–22.
[8] Al'tshuller GS. The innovation algorithm: TRIZ, systematic innovation and technical creativity. Technical innovation center Inc.; 1999.
[9] Andreani LC, Bozzola A, Kowalczewski P, Liscidini M, Redorici L. Silicon solar cells: toward the efficiency limits. Adv Phys: X 2019;4(1):1548305.
[10] Asim M, Khan MS, Ahmad J, Umar T, Riyaz A. Efficiency Enhancement of Solar Panel Using Photodiode. In: Energy Systems, Drives and Automations. Singapore: Springer; 2020. p. 215–23.
[11] Assaf J, Shabani B. A novel hybrid renewable solar energy solution for continuous heat and power supply to standalone-alone applications with ultimate reliability and cost effectiveness. Renew Energy 2019;138:509–20.
[12] Boretti A. Production of hydrogen for export from wind and solar energy, natural gas, and coal in Australia. Int J Hydrogen Energy 2020;45(7):3899–904.
[13] Buonomano A, Calise F, d'Accadia MD, Vicidomini M. A hybrid renewable system based on wind and solar energy coupled with an electrical storage: Dynamic simulation and economic assessment. Energy 2018;155:174–89.
[14] Cabrerizo FJ, Martínez MÁ, López-Gijón J, Cascón-Katchadourian J, Herrera-Viedma E. Group decision making and soft consensus: Analyzing citation classics by means of H-Classics. Procedia Comput Sci 2019;162:251–9.
[15] Chen Y, Liu Y, Liu J, Luo Xi, Wang D, Wang Y, et al. Design and adaptability of photovoltaic air conditioning system based on office buildings. Sol Energy 2020;202:17–24.
[16] Chen Z, Lu M, Ming X, Zhang X, Zhou T. Explore and evaluate innovative value propositions for smart product service system: A novel graphics-based rough-fuzzy DEMATEL method. J Cleaner Prod 2020;243:118672. https://doi.org/10.1016/j.jclepro.2019.118672.
[17] Cheng J, Tang Y, Yu M. The reliability of solar energy generating system with inverters in series under common cause failure. Appl Math Model 2019;68:509–22.
[18] Chiclana F, Mata F, Martinez L, Herrera-viedma E, Alonso S. Integration of a consistency control module within a consensus model. Int J Uncertainty Fuzziness Knowledge Based Syst 2008;16(supp01):35–53.
[19] Corona B, Cerrajero E, López D, San Miguel G. Full environmental life cycle cost analysis of concentrating solar power technology: Contribution of externalities to overall energy costs. Sol Energy 2016;135:758–68.
[20] Das J, Sahu PP, Deb P. H2 evolution through solar guided water splitting using Fe based composite electrode. Mater Today: Proc 2020.
[21] Dinçer H, Yüksel S, Korsakienė R, Raišienė AG, Bilan Y. IT2 hybrid decision-making approach to performance measurement of internationalized firms in the baltic states. Sustainability 2019;11(1):296.
[22] Dogan O. Process mining technology selection with spherical fuzzy AHP and sensitivity analysis. Expert Syst Appl 2021;178:114999. https://doi.org/10.1016/j.eswa.2021.114999.
[23] Dong Y, Zha Q, Zhang H, Herrera F. Consensus reaching and strategic manipulation in group decision making with trust relationships. IEEE Trans Syst Man Cybern Syst 2020.
[24] Dupont E, Koppelaar R, Jeanmart H. Global available solar energy under physical and energy return on investment constraints. Appl Energy 2020;257:113968. https://doi.org/10.1016/j.apenergy.2019.113968.
[25] Ekmekci I, Nebati EE. Triz Methodology and Applications. Procedia Comput Sci 2019;158:303–15.
[26] Farooque M, Jain V, Zhang A, Li Z. Fuzzy DEMATEL analysis of barriers to Blockchain-based life cycle assessment in China. Comput Ind Eng 2020;147:106684. https://doi.org/10.1016/j.cie.2020.106684.
[27] Fontaine A. Debating the sustainability of solar energy: Examining resource construction processes for local photovoltaic projects in France. Energy Res Social Sci 2020;69:101725. https://doi.org/10.1016/j.erss.2020.101725.
[28] Gangwar P, Singh R, Tripathi RP, Singh AK. Effective solar power harnessing using a few novel solar tree designs and their performance assessment. Energy Sources Part A 2019;41(15):1828–37.
[29] Gao J, Xu Z, Liang Z, Liao H. Expected consistency-based emergency decision making with incomplete probabilistic linguistic preference relations. Knowl-Based Syst 2019;176:15–28.
[30] Kutlu Gündoğdu F, Kahraman C. A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets. Eng Appl Artif Intell 2019;85:307–23.
[31] Kutlu Gündoğdu F, Kahraman C. A novel spherical fuzzy QFD method and its application to the linear delta robot technology development. Eng Appl Artif Intell 2020;87:103348. https://doi.org/10.1016/j.engappai.2019.103348.
[32] Herrera F, Herrera-Viedma E, Verdegay JL. Choice processes for non-homogeneous group decision making in linguistic setting. Fuzzy Sets Syst. 1998;94(3):287–308.
[33] Herrera-Viedma E, Alonso S, Chiclana F, Herrera F. A consensus model for group decision making with incomplete fuzzy preference relations. IEEE Trans Fuzzy Syst 2007;15(5):863–77.
[34] Hoch N, Brad S. In: October). Managing AI Technologies in Earthwork Construction: A TRIZ-Based Innovation Approach. Cham: Springer; 2020. p. 3–14.
[35] Hu KH, Hsu MF, Chen FH, Liu MZ. Identifying the key factors of subsidiary supervision and management using an innovative hybrid architecture in a big data environment. Financial Innovation 2021;7(1):1–27.
[36] Imam R, Ayadi O. Powering electric tower cranes by solar energy for sustainable construction. Int J Construct Manage 2020:1–11.
[37] Irfan M, Ahmad M. Relating consumers' information and willingness to buy electric vehicles: Does personality matter? Transport Res Part D: Transport Environ 2021;100:103049.
[38] Jin H, Ashraf S, Abdullah S, Qiyas M, Bano M, Zeng S. Linguistic spherical fuzzy aggregation operators and their applications in multi-attribute decision making problems. Mathematics 2019;7(5):413.

[39] Jin Y, Ashraf S, Abdullah S. Spherical fuzzy logarithmic aggregation operators based on entropy and their application in decision support systems. Entropy 2019;21(7):628.
[40] Jin Z, Chen S, Zhang Y, Wang Y, Zhang X, Liu Y. Construction of hierarchical hetero-structured TiO2 photoanodes for dye-sensitized solar energy conversion: Case study of anatase nanobranches on rutile nanorod arrays. Chem Phys 2019;522:129–33.
[41] Kou G, Akdeniz ÖO, Dinçer H, Yüksel S. Fintech investments in European banks: a hybrid IT2 fuzzy multidimensional decision-making approach. Financial Innovation 2021;7(1):1–28.
[42] Kösedağlı BY, Kışla GH, Çatık AN. The time-varying effects of oil prices on oil–gas stock returns of the fragile five countries. Financial Innovation 2021;7(1):1–22.
[43] Lee TR, Sinnarong N, Hsu YH, Lan HY, Yeh CH, Hilletofth P. The sequence of strategies when establishing Taiwanese restaurant in Thailand. Eur Bus Rev 2020.
[44] Li Y-X, Wu Z-X, Dinçer H, Kalkavan H, Yüksel S. Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling. Energy Rep 2021;7:95–108.
[45] Liskiewicz TW, Kubiak KJ, Mann DL, Mathia TG. Analysis of surface roughness morphology with TRIZ methodology in automotive electrical contacts: Design against third body fretting-corrosion. Tribol Int 2020;143:106019. https://doi.org/10.1016/j.triboint.2019.106019.
[46] Liu H, Ma Y, Jiang Le. Managing incomplete preferences and consistency improvement in hesitant fuzzy linguistic preference relations with applications in group decision making. Information Fusion 2019;51:19–29.
[47] Liu J, Zhang Z, Yan L, Wen F. Forecasting the volatility of EUA futures with economic policy uncertainty using the GARCH-MIDAS model. Financial Innovation 2021;7(1):1–19.
[48] Liu R, Zhu Y-J, Chen Y, Liu H-C. Occupational health and safety risk assessment using an integrated TODIM-PROMETHEE model under linguistic spherical fuzzy environment. Int J Intell Syst 2021;36(11):6814–36.
[49] Liu X, Xu Y, Herrera F. Consensus model for large-scale group decision making based on fuzzy preference relation with self-confidence: Detecting and managing overconfidence behaviors. Information Fusion 2019;52:245–56.
[50] Liu Y, Wang Y, Lyu Pu, Hu S, Yang L, Gao G. Rethinking the carbon dioxide emissions of road sector: Integrating advanced vehicle technologies and construction supply chains mitigation options under decarbonization plans. J Cleaner Prod 2021;321:128769. https://doi.org/10.1016/j.jclepro.2021.128769.
[51] Liu Z, Feng J, Wang J. Resource-Constrained Innovation Method for Sustainability: Application of Morphological Analysis and TRIZ Inventive Principles. Sustainability 2020;12(3):917.
[52] Luo Y, Zhang L, Liu Z, Yu J, Xu X, Su X. Towards net zero energy building: The application potential and adaptability of photovoltaic-thermoelectric-battery wall system. Appl Energy 2020;258:114066. https://doi.org/10.1016/j.apenergy.2019.114066.
[53] Mathew M, Chakrabortty RK, Ryan MJ. A novel approach integrating AHP and TOPSIS under spherical fuzzy sets for advanced manufacturing system selection. Eng Appl Artif Intell 2020;96:103988. https://doi.org/10.1016/j.engappai.2020.103988.
[54] Mehdi G, Ali N, Hussain S, Zaidi AA, Shah AH, Azeem MM. In: January). Design and Fabrication of Automatic Single Axis Solar Tracker for Solar Panel. IEEE; 2019. p. 1–4.
[55] Mena RM, dos Santos ML, Saidel MA. SWOT Matrix and Strategies for Battery Electric Vehicles Adoption in Brazil. J Control Automation Electrical Syst 2021:1–11.
[56] Menekşe A, Akdağ HC. Internal audit planning using spherical fuzzy ELECTRE. Appl Soft Comput 2021;108155.
[57] Meng F, Tang J, Cabrerizo FJ, Herrera-Viedma E. A rational and consensual method for group decision making with interval-valued intuitionistic multiplicative preference relations. Eng Appl Artif Intell 2020;90:103514. https://doi.org/10.1016/j.engappai.2020.103514.
[58] Meng Y, Wu H, Zhao W, Chen W, Dinçer H, Yüksel S. A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. Financial Innovation 2021;7(1):1–34.
[59] Merin JV, Reyes RC, Sevilla RV, Caballero JMF, Cuesta TR, Paredes RJM, Tandog GO. Automated Greenhouse Vertical Farming With Wind and Solar Hybrid Power System. In: 2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM) (pp. 1-6). IEEE.
[60] Meyer TH, Chesnokov GA, Ackermann L. Cobalta-Electrocatalyzed C− H Activation in Biomass-Derived Glycerol: Powered by Renewable Wind and Solar Energy. ChemSusChem 2020;13(4):668–71.
[61] Mirzaev MA, Smirnov IG, Dyshekov AI, Slavkina VE, Shereuzhev MA, Aliev SA. Design of the solar panel frame of the spacecraft by 3D printing with composite materials. MS&E 2020;747(1):012009. https://doi.org/10.1088/1757-899X/747/1/012009.
[62] Misyurin SY, Nelyubin AP, Potapov MA. Designing Robotic Groups Under Incomplete Information About the Dominance of Many Goals. In: Advanced Technologies in Robotics and Intelligent Systems. Cham: Springer; 2020. p. 267–73.
[63] Mohammadnia A, Rezania A, Ziapour BM, Sedaghati F, Rosendahl L. Hybrid energy harvesting system to maximize power generation from solar energy. Energy Convers Manage 2020;205:112352. https://doi.org/10.1016/j.enconman.2019.112352.
[64] Olugu EU, Mammedov YD, Young JCE, Yeap PS. Integrating spherical fuzzy Delphi and TOPSIS technique to identify indicators for sustainable maintenance management in the Oil and Gas industry. J King Saud Univ-Eng Sci 2021. https://doi.org/10.1016/j.jksues.2021.11.003.
[65] Pantsyr Y, Garasymchuk I, Hutsol T, Gordiychuk I. Energy parameters' calculation of a hybrid heat supply system for a private house in the conditions of western part of Ukraine. In: Renewable Energy Sources: Engineering, Technology, Innovation. Cham: Springer; 2018. p. 765–80.
[66] Pelissari R, Oliveira MC, Ben Amor S, Abackerli AJ. A new FlowSort-based method to deal with information imperfections in sorting decision-making problems. Eur J Oper Res 2019;276(1):235–46.
[67] Perez IJ, Cabrerizo FJ, Alonso S, Herrera-Viedma E. A new consensus model for group decision making problems with non-homogeneous experts. IEEE Trans Syst Man Cybern: Syst 2014;44(4):494–8.
[68] Phillips I, Kenley CR. July). An SSM-TRIZ Methodology for Business Problem Structuring. In INCOSE International Symposium 2019;29(1):406–20.
[69] Qiu D, Dinçer H, Yüksel S, Ubay GG. Multi-Faceted Analysis of Systematic Risk-Based Wind Energy Investment Decisions in E7 Economies Using Modified Hybrid Modeling with IT2 Fuzzy Sets. Energies 2020;13(6):1423.
[70] Quek SG, Selvachandran G, Munir M, Mahmood T, Ullah K, Son LH, et al. Multi-attribute multi-perception decision-making based on generalized T-spherical fuzzy weighted aggregation operators on neutrosophic sets. Mathematics 2019;7(9):78.
[71] Rabaia MKH, Abdelkareem MA, Sayed ET, Elsaid K, Chae KJ, Wilberforce T, et al. Environmental impacts of solar energy systems: A review. Sci Total Environ 2020;754:141989.
[72] Ramírez-Del-Barrio P, Valencia F, Marconi-Vargas A, Polanco-Lobos I, Mendoza-Araya P. In: March). An alpaca fiber processing solution based on Solar energy for an isolated location in Chile following a co-construction approach. IEEE; 2017. p. 130–6.
[73] Raza A, Malik TN, Khan MFN, Ali S. Energy management in residential buildings using energy hub approach. Build. Simul. 2020;13(2):363–86.
[74] Ren P, Hao Z, Wang X, Zeng XJ, Xu Z. Decision-Making Models Based on Incomplete Hesitant Fuzzy Linguistic Preference Relation With Application to Site Selection of Hydropower Stations. IEEE Trans Eng Manage 2020.
[75] Rostamnezhad M, Nasirzadeh F, Khanzadi M, Jarban MJ, Ghayoumian M. Modeling social sustainability in construction projects by integrating system dynamics and fuzzy-DEMATEL method: a case study of highway project. ECAM 2020;27(7):1595–618.
[76] Savvides A, Vassiliades C, Michael A, Kalogirou S. Siting and building-massing considerations for the urban integration of active solar energy systems. Renew Energy 2019;135:963–74.
[77] Schindler F, Michl B, Krenckel P, Riepe S, Benick J, Müller R, et al. Optimized multicrystalline silicon for solar cells enabling conversion efficiencies of 22%. Sol Energy Mater Sol Cells 2017;171:180–6.
[78] Shao J, Chen H, Zhu T. Solar energy block-based residential construction for rural areas in the West of China. Sustainability 2016;8(4):362.
[79] Sharaf IM, Khalil E-H. A spherical fuzzy TODIM approach for green occupational health and safety equipment supplier selection. Int J Manage Sci Eng Manage 2021;16(1):1–13.
[80] Shibata M, Takahashi M. A study on technology visualization analysis method using patent classifier. Electron Commun Jpn 2020;140(10):1127–33.
[81] Singh SC, Li H, Yao C, Zhan Z, Yu W, Yu Z, et al. Structural and compositional control in copper selenide nanocrystals for light-induced self-repairable electrodes. Nano Energy 2018;51:774–85.
[82] Suzan V, Yavuzer H. A Fuzzy Dematel Method To Evaluate The Most Common Diseases In Internal Medicine. Int J Fuzzy Syst 2020;22(7):2385–95.
[83] Tang M, Zhou X, Liao H, Xu J, Fujita H, Herrera F. Ordinal consensus measure with objective threshold for heterogeneous large-scale group decision making. Knowl-Based Syst 2019;180:62–74.
[84] Tian Z-P, Nie R-X, Wang J-Q. Social network analysis-based consensus-supporting framework for large-scale group decision-making with incomplete interval type-2 fuzzy information. Inf Sci 2019;502:446–71.
[85] Tsai ZL, Shu KM, Kang JY, Lin YC. In: October). Design of two-way transmission mechanism of bicycle using TRIZ theory. IEEE; 2019. p. 380–3.
[86] Ureña R, Kou G, Wu J, Chiclana F, Herrera-Viedma E. Dealing with incomplete information in linguistic group decision making by means of Interval Type-2 Fuzzy Sets. Int J Intell Syst 2019;34(6):1261–80.
[87] Vaka M, Walvekar R, Rasheed AK, Khalid M. A review on Malaysia's solar energy pathway towards carbon-neutral Malaysia beyond Covid'19 pandemic. J Cleaner Prod 2020;273:122834. https://doi.org/10.1016/j.jclepro.2020.122834.
[88] Wang C, Zhou H, Dincer H, Yuksel S, Ubay GG, Uluer GS. Analysis of electricity pricing in emerging economies with hybrid multi-criteria decision-making technique based on interval-valued intuitionistic hesitant fuzzy sets. IEEE Access 2020;8:190882–96.
[89] Wei G, Wang J, Lu M, Wu J, Wei C. Similarity measures of spherical fuzzy sets based on cosine function and their applications. IEEE Access 2019;7:159069–80.
[90] Wilkins MM, Dumitrescu EC, Krich JJ. In: June). Minimum material quality threshold for intermediate band solar cells using a multi-band device simulator with fully coupled optics. IEEE; 2019. p. 2126–9.
[91] Wu P, Zhu J, Zhou L, Chen H. Local feedback mechanism based on consistency-derived for consensus building in group decision making with hesitant fuzzy linguistic preference relations. Comput Ind Eng 2019;137:106001. https://doi.org/10.1016/j.cie.2019.106001.

[92] Xia Q, Tian G, Wu Z. Examining embodied carbon emission flow relationships among different industrial sectors in China. Sustainable Production and Consumption; 2021.
[93] Xiao J, Wang X, Zhang H. Managing personalized individual semantics and consensus in linguistic distribution large-scale group decision making. Information Fusion 2020;53:20–34.
[94] Xie W, Xu Z, Ren Z, Herrera-Viedma E. A new multi-criteria decision model based on incomplete dual probabilistic linguistic preference relations. Appl Soft Comput 2020;91:106237. https://doi.org/10.1016/j.asoc.2020.106237.
[95] Xie Y, Peng Y, Yuksel S, Dincer H, Uluer GS, Caglayan C, et al. Consensus-Based Public Acceptance and Mapping of Nuclear Energy Investments Using Spherical and Pythagorean Fuzzy Group Decision Making Approaches. IEEE Access 2020;8:206248–63.
[96] Xu W, Chen X, Dong Y, Chiclana F. Impact of decision rules and non-cooperative behaviors on minimum consensus cost in group decision making. Group Decis Negot 2020:1–22.
[97] Xu Y, Liang J, Cheng B, He W, Shu J, Li K, et al. In: August). Research on the impact of re-electrication in the transportation sector on carbon emission and pollutant emission in Yunnan province. IEEE; 2021. p. 407–12.
[98] Yang Z, Xue X, Dai J-G, Li Y, Qin J, Feng Ya, et al. Study of a super-non-wetting self-cleaning solar reflective blue-grey paint coating with luminescence. Sol Energy Mater Sol Cells 2018;176:69–80.
[99] Yuan G, Xie F, Dinçer H, Yüksel S. The theory of inventive problem solving (TRIZ)-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach. Int J Energy Res 2021.
[100] Yuan J, Zhang ZM, Yuksel S, Dincer H. Evaluating recognitive balanced scorecard-based quality improvement strategies of energy investments with the integrated hesitant 2-tuple interval-valued pythagorean fuzzy decision-making approach to QFD. IEEE Access 2020;8:171112–28.
[101] Zeng S, Hussain A, Mahmood T, Irfan Ali M, Ashraf S, Munir M. Covering-based spherical fuzzy rough set model hybrid with TOPSIS for multi-attribute decision-making. Symmetry 2019;11(4):547.
[102] Zhang G, Zhou S, Xia X, Yuksel S, Bas H, Dincer H. Strategic Mapping of Youth Unemployment With Interval-Valued Intuitionistic Hesitant Fuzzy DEMATEL Based on 2-Tuple Linguistic Values. IEEE Access 2020;8:25706–21.
[103] Zhang H, Kou G, Peng Yi. Soft consensus cost models for group decision making and economic interpretations. Eur J Oper Res 2019;277(3):964–80.
[104] Zhang X, Lu F, Tao R, Wang S. The time-varying causal relationship between the Bitcoin market and internet attention. Financial Innovation 2021;7(1):1–19.
[105] Zhong J, Hu X, Yuksel S, Dincer H, Ubay GG. Analyzing the investments strategies for renewable energies based on multi-criteria decision model. IEEE Access 2020;8:118818–40.
[106] Liu W, Sun Y, Yüksel S, Dinçer H. Consensus-based multidimensional due diligence of fintech-enhanced green energy investment projects. Financial Innovation 2021;7(1):1–31.
[107] Anser MK, Khan MA, Zaman K, Nassani AA, Askar SE, Abro MMQ, Kabbani A. Financial development during COVID-19 pandemic: the role of coronavirus testing and functional labs. Financial Innovation 2021;7(1):1–13.
[108] Wang T, Zuo H, Wu CH, Hu B. Combined soft measurement on key indicator parameters of new competitive advantages for China's export. Financial Innovation 2021;7(1):1–24.
[109] Yin X, Meng Z, Yi X, Wang Y, Hua X. Are "Internet+" tactics the key to poverty alleviation in China's rural ethnic minority areas? Empirical evidence from Sichuan Province. Financial Innovation 2021;7(1):1–19.
[110] Simionescu LN, Gherghina ŞC, Tawil H, Sheikha Z. Does board gender diversity affect firm performance? Empirical evidence from Standard & Poor's 500 Information Technology Sector. Financial Innovation 2021;7(1):1–45.