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Research article

2-tuple linguistic Fermatean fuzzy MAGDM based on the WASPAS method for selection of solid waste disposal location

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Abstract: Manufacturing plants generate toxic waste that can be harmful to workers, the population and the atmosphere. Solid waste disposal location selection (SWDLS) for manufacturing plants is one of the fastest growing challenges in many countries. The weighted aggregated sum product assessment (WASPAS) is a unique combination of the weighted sum model and the weighted product model. The purpose of this research paper is to introduce a WASPAS method with a 2-tuple linguistic Fermatean fuzzy (2TLFF) set for the SWDLS problem by using the Hamacher aggregation operators. As it is based on simple and sound mathematics, being quite comprehensive in nature, it can be successfully applied to any decision-making problem. First, we briefly introduce the definition, operational laws and some aggregation operators of 2-tuple linguistic Fermatean fuzzy numbers. Thereafter, we extend the WASPAS model to the 2TLFF environment to build the 2TLFF-WASPAS model. Then, the calculation steps for the proposed WASPAS model are presented in a simplified form. Our proposed method, which is more reasonable and scientific in terms of considering the subjectivity of the decision maker's behaviors and the dominance of each alternative over others. Finally, a numerical example for SWDLS is proposed to illustrate the new method, and some comparisons are also conducted to further illustrate the advantages of the new method. The analysis shows that the results of the proposed method are stable and consistent with the results of some existing methods.

Keywords: 2-tuple linguistic model; Fermatean fuzzy sets; WASPAS; Hamacher aggregation operator

1. Introduction

Manchester has a rich industrial heritage, a very diverse economy and a center for cultural industries, retail, transport, logistics, finance and manufacturing. Manufacturing companies rely on efficient

and optimized production methods to create their products. But even the most efficient method of manufacturing plants inevitably generates some form of waste. The selection of the best place to dispose of the waste from manufacturing plants requires the need to first understand the type of waste. There are three main types of waste in manufacturing: solid waste, chemical waste and toxic waste. Solid waste includes paper, metal or carbon-based materials that are leftover after basic manufacturing processes have been completed. Some types of waste can be recycled and some cannot be recycled; the latter must be undergo proper disposal; otherwise, it will endanger the health of the workers. The second category is chemical waste, which includes the waste of residual chemicals. Some manufacturing processes may generate large amounts of chemical waste. Solid waste can be placed in the bin, but chemical waste should be handled in a specific way to prevent the dangerous effects of these chemicals. The third is toxic waste, which is a by-product of many manufacturing processes. We cannot reduce the toxicity of certain types of waste, but we should ensure that these toxic substances do not contaminate the surrounding environment. Some other types of waste are manufacturing waste, green waste, organic waste, metal and plastic waste, etc. Manufacturing waste includes dust, sand, broken glass, etc. Green garbage includes trees, leaves, grass, fruit, wood, etc. Organic waste includes food, leftover manure, straw, etc. Metal and plastic waste include bottle caps, batteries, etc. The form of waste that cannot be reused or recycled is often thrown into landfills. Landfills can be found all over the UK, in particular, Manchester has a lot of landfills. Some use the ”landfill” method, and some use the ”land-raising” method. Landfills are designed in such a way that the risk of contaminating the environment is minimized. They should be built away from industrial and residential areas. Although, landfills are a good source of waste disposal, but there are also some drawbacks. The main issues with landfills as follows:
1. toxins,
2. leachates,
3. greenhouse gases.

Electronic material when it becomes waste, contains toxic substances. These toxins leach into the soil and become hazardous. This leachate pollutes the groundwater and waterways. Landfills contain a lot of waste that can create leachates and become harmful to the environment. Some secondary side effects of landfills include the following:
1. nauseous odors,
2. unpleasant view,
3. rat and seagull infestations.

Even though it has a lot of disadvantages, it is still necessary because with increasing population waste is increasing day by day. Even with increasing recycling rates, it is still general waste which is to be disposed of in landfills. But there are a lot of problems with the current landfill system. Some of the issues with the current landfill system according to Doaemo et al. [1] are shown in Figure 1. Choosing the appropriate location for a landfill is very important because a wrong site selection causes a lot of health issues. The main objective of this research article is to propose the best method for the solid waste disposal location selection (SWDLS) problem of manufacturing plants in Manchester. The proposed methodology is based on the use of the weighted aggregated sum product assessment (WASPAS) method with 2-tuple linguistic Fermatean fuzzy sets (2TLFFSs). According to the ratings given by decision-makers (DMs), the simple multi-attribute rating technique (SMART) [2] is used to get the criteria weights. This method is also developed in many other fuzzy environments.

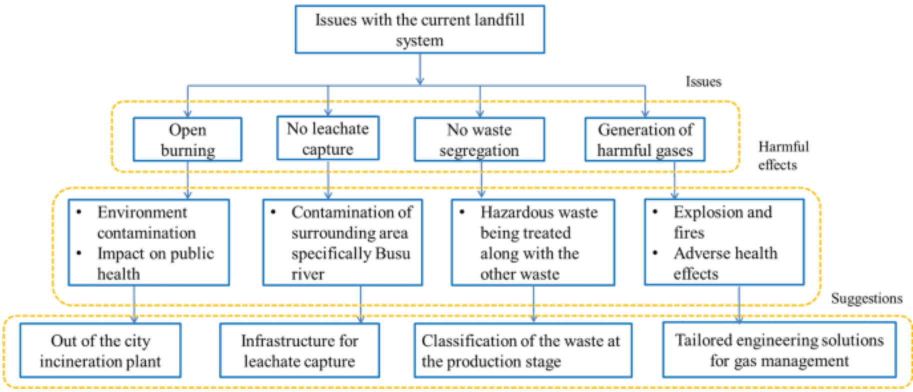

Figure 1. Issues with current landfills [1].

Zadeh [3] introduced the concept of fuzzy sets in 1965. The concept of an intuitionistic fuzzy set (IFS) was proposed by Atanassov [4] in 1986. Szmidt and Kacprzyk [5] introduced the medical applications of IFSs. Further, Yager [6] proposed the concept of a Pythagorean fuzzy set (PFS). PFS models are more powerful than IFS models in addressing real-world applications, but these collections have some limitations. Some applications may contain the decision maker's opinion as $(0.8, 0.9)$. In such cases, PFSs and IFSs failed to apply. To overcome the limitations of IFSs and PFSs, Senapati and Yager [7] introduced Fermatean fuzzy sets (FFSs). The FFSs are those sets in which the cube sum of the membership degree (MD) and non-MD is less than or equal to 1. Senapati and Yager introduced the solution of some multi-criteria decision-making (MCDM) problems based on FFSs [8,9]. The utilization of FFSs in MAGDM (multi-attribute group decision-making) approaches have been proposed in [10,11]. Liu et al. [12] proposed an MAGDM method with probabilistic linguistic information based on an adaptive consensus reaching model and evidential reasoning. Liu et al. [13] presented an opinion dynamics and minimum adjustment-driven consensus model for multi-criteria large-scale group decision making under a novel social trust propagation mechanism. Liu et al. [14] proposed MCDM with incomplete weights based on 2-D uncertain linguistic Choquet integral operators.

The 2-tuple linguistic representation model was first proposed by Herrera and Martinez [15, 16]. Several decision methods based on 2-tuple linguistic data have been presented. Fazi et al. [17] introduced worst-case methods and Hamacher aggregation operations for an intuitive 2-tuple linguistic set. Herrera and Herrera-Viedma [18] introduced the linguistic decision analysis procedure for solving decision problems with linguistic information. Recently, many applications for MAGDM issues have been developed [19, 20] Zavadskas et al. [21] introduced the WASPAS method to solve the MAGDM problem. It is a combination of two models i.e., the weighted aggregated sum model (WeSM) and weighted aggregated product model (WePM). WASPAS is more precise than the WePM and WeSM. Zavadskas et al. [22] considered the single-valued neurotrophic WASPAS and discussed its applications in alternative site construction. Mishra et al. [23] presented a hesitant fuzzy HF WASPAS and illustrated its application in green supplier selection. Schitea et al. [24] discussed intuitionistic fuzzy (IF) WASPAS-COPRAS (COmplex PRoportional ASsessment)-EDAS (Evaluation based on Distance from Average Solution) and its application in site selection. Mardani et al. [25] described HF-strengths, Weaknesses, Opportunities, and Threats (SWOT)-stepwise weight assessment ratio analysis (SWARA)-WASPAS and its application in the assessment of digital technologies intervention. Akram and Niaz [26] recently proposed a 2-tuple linguistic Fermatean fuzzy (2TLFF) decision-making method based on combined compromise solution with criteria importance through inter-criteria correlation for drip irrigation system analysis. Rani et al. [27] studied the IF type-2 WASPAS and its application in physician selection. The existing studies based on the WASPAS method are shown in Table 1.

Table 1. Some of the important studies on the WASPAS.

Authors	Year	Significance influence
Zavadskas et al. [21]	2012	Proposed optimization of WASPAS
Antucheviciene et al. [28]	2013	Introduced MCDM methods WASPAS and MULTIMOORA
Lashgari et al. [29]	2014	Determined outsourcing strategies using QSPM and WASPAS methods
Zavadskas et al. [30]	2014	Designed WASPAS with interval-valued IF numbers
Chakraborty and Saparauskas [31]	2014	Proposed WASPAS method in manufacturing decision making
Chakraborty et al. [32]	2015	Studied WASPAS method as a MCDM tool
Zavadskas et al. [22]	2015	Presented the single-valued neurotrophic WASPAS
Zavadskas et al. [33]	2015	Studied WASPAS method as an optimization tool
Karabasevic et al. [34]	2016	Proposed a personnel selection method based on SWARA and WASPAS
Zavadskas et al. [35]	2016	Presented a multi-attribute assessment using WASPAS
Mardani et al. [36]	2017	Described a systematic review of SWARA and WASPAS
Mardani et al. [25]	2017	Introduced HF-SWOT-SWARA-WASPAS
Bausys and Juodagalvien [37]	2017	Investigated garage location selection using WASPAS-SVNS method
Stanujki and Karabasevi [38]	2018	Designed extension of the WASPAS method with IF numbers
Turskis et al. [39]	2019	Presented an F-WASPAS-based approach
Mishra et al. [23]	2019	Proposed the HF WASPAS
Schitea et al. [24]	2019	Described IF-WASPAS-COPRAS-EDAS
Gundogdu and Kahraman [40]	2019	Introduced WASPAS with spherical fuzzy sets
Dehshiri and Aghaei [41]	2019	Examined fuzzy Delphi, SWARA and WASPAS
Rani and Mishra [42]	2020	Proposed q-rung orthopair WASPAS
Mohagheghi and Mousavi [43]	2020	Introduced IVPF D-WASPAS
Rani et al. [27]	2020	Presented IF type-2 WASPAS
Sergi and Ucal Sari [44]	2021	Examined digitalization using fuzzy Z-WASPAS and fuzzy Z-AHP
Rudnik et al. [45]	2021	Introduced the ordered fuzzy WASPAS method
Badalpur and Nurbakhsh [46]	2021	Presented the WASPAS method for risk qualitative analysis
Pamucar et al. [47]	2022	Designed fuzzy Hamacher WASPAS decision-making model
This study	2022	Proposes 2-tuple linguistic Fermatean fuzzy WASPAS

The selection of a suitable place for disposal of the solid waste of different industries is one of the important concerns for municipalities and manufacturers. Many researchers have solved the MAGDM problems related to waste disposal systems. Yazdani et al. [48] evaluated the best location for HCW (health care waste) disposal. Mishra et al. [49] proposed an entropy-based EDAS model to find out a health care waste disposal method using IFSs. Yahya et al. [50] evaluated the waste water treatment technologies using the technique for order of preference by similarity to an ideal solution (TOPSIS) method. Suntrayuth et al. [51] in 2020, based on an improved entropy-TOPSIS method, presented an evaluation method for industrial sewage treatment projects. Liu et al. [52] proposed a novel PFS combined compromise solution framework for the assessment of medical waste treatment technology in

2021. Mussa and Suryabhagavan [53] presented a solid waste dumping site selection using geographic information system based multi-criteria spatial modeling in 2021. Aslam et al. [54] provided the identification and ranking of landfill sites for municipal solid waste management in 2022. Bui et al. [55] presented opportunities and challenges for solid waste reuse and recycling in emerging economies in 2022.

In this study, we expand the WASPAS method with a 2-tuple linguistic Fermatean fuzzy set (2TLFFS) and apply an extended method to evaluate the best place to dispose of manufacturing solid waste. The MAGDM problem using the 2TLFF-WASPAS method has not been previously defined in any studies. The following are the motivations for this study:

1. As an improvement of 2-tuple linguistic PFS, the concept of 2TLFFSs has been proved to be a superior tool for modeling the imprecise and uncertain information that arises in practical applications. Combined with its unique benefits, this research focuses on the 2TLFFS environment.
2. In the conventional FFS, the MD and non-MD are determined by numerical values that fall within the range of [0, 1], whereas in the 2TLFFS, the degrees are determined by the 2-tuple linguistic model which is more useful for addressing those real-world MAGDM issues where experts communicate their opinions using linguistic labels.
3. The Hamacher t-conorm and t-norm are more comprehensive, complete and dynamic extensions of the algebraic and Einstein t-norm and t-conorm.
4. The decision-making potential, ease of use and attractiveness theories of the WASPAS approach are the main incentives to explore this approach in order to expand the literature on 2-tuple linguistic FFSs (2TFFSs).
5. The proposed operators are very general. They overcome the shortcomings and limitations of the current operators and provide outstanding service for 2TLFF information as well as 2-tuple linguistic IF (2TLIF) and 2-tuple linguistic Pythagorean fuzzy (2TLPF).
6. The proposed operators are more accurate when used to solve real-world MAGDM problems based on 2-tuple linguistic Pythagorean fuzzy (2TLFF) data because they can take correlated arguments into account.

The main contributions of this study are as follows:

1. An MAGDM method is proposed using the WASPAS method and 2-tuple linguistic Pythagorean fuzzy numbers (2TLFFN).
2. The ability of the proposed method to select the best site for disposing of manufacturing solid waste is proved.
3. An explanatory numerical example is presented to unfold the application of the proposed approach in real-life decision-making situations. The dominance and authenticity of the proposed approach is verified via comparative analysis.
4. The advantages of the proposed technique are thoroughly elaborated.

Remainder of the paper is subsequently arranged to achieve the goals of this study. Some basic concepts of 2-tuple language terminology and several Hamacher operators of 2TLFFSs and their important properties are defined in the Section 2. Section 3 details the complete procedure for extending the WASPAS method with 2TLFFNs. A numerical example of SWDLS is solved using 2TLFF Hamacher weighted average (2TLFFHWA) operator, 2TLFF Hamacher weighted geometric (2TLFFHWG) operator, WePM and WeSM in Section 4. Parametric analysis of the numerical examples is given in Section 5. In Section 6, comparative analysis with the combinative distance based assessment (CODAS) method for the 2TLPFHWA operator, generalized 2-tuple linguistic Pythagorean fuzzy weighted Heronian mean operator (G2TLPFWHMO) [56], 2-tuple linguistic Pythagorean fuzzy weighted geometric Heronian mean operator (2TLPFWGHMO) [56], dual generalized 2-tuple linguistic Pythagorean fuzzy weighted Bonferroni mean operator (DG2TLPFWBMO) [57], dual generalized 2-tuple linguistic Pythagorean fuzzy weighted geometric Bonferroni mean operator (DG2TLPFWGBMO) [57] is provided. In Section 8, we conclude the discussion and illustrate some future directions.

2. Preliminaries

Some basic definitions are reviewed in this section.

Definition 2.1. [16] Let there exist a linguistic term (LT) set $\dot{S} = \{\bar{s}_i \,|\, i = 0, 1, \ldots, t\}$, where $\bar{s}_i$ indicates a possible LT for a linguistic variable (LV). For instance, an LT set $\dot{S}$ having three terms can be described as follows:

$$\dot{S} \quad = \quad \{\bar{s}_0 = none, \bar{s}_1 = low, \bar{s}_2 = high\}.$$

If $\bar{s}_i, \bar{s}_k \in \dot{S}$, then the LT set has the following characteristics:

(i) $\bar{s}_i > \bar{s}_k$, iff $i > k$.

(ii) $\max(\bar{s}_i, \bar{s}_k) = \bar{s}_i$, iff $i \geq k$.

(iii) $\min(\bar{s}_i, \bar{s}_k) = \bar{s}_i$, iff $i \leq k$.

(iv) $\mathrm{Neg}(\bar{s}_i) = \bar{s}_k$ such that $k = t - i$.

Definition 2.2. [16] Let $\grave{\beta}$ be the outcome of an aggregation of the indices of a set of labels assessed in a LT set $\dot{S}$, i.e., the outcome of a symbolic aggregation operation, $i \in [0, t]$, where t is the cardinality of $\dot{S}$. Let $i = \mathrm{round}(\grave{\beta})$ and $\alpha = \grave{\beta} - i$ be two values such that $i \in [0, t]$ and $\alpha \in [-\frac{1}{2}, \frac{1}{2})$, then, α is called a symbolic translation.

Definition 2.3. [16] Let $\dot{S} = \{\bar{s}_i \mid i = 0, \ldots, t\}$ be a LT set and $i \in [0, t]$ be a number value representing the aggregation outcome of the linguistic symbol. Then the function Δ used to obtain the 2-tuple linguistic information equivalent to $\grave{\beta}$ is defined as

$$\Delta : [0, t] \to \dot{S} \times [-\frac{1}{2}, \frac{1}{2}),$$

$$\Delta(\grave{\beta}) = \begin{cases} \bar{s}_i, i = \mathrm{round}(\grave{\beta}), \\ \alpha = \grave{\beta} - i, \ \alpha \in [-\frac{1}{2}, \frac{1}{2}). \end{cases} \tag{2.1}$$

Definition 2.4. [16] Let $\dot{S} = \{\bar{s}_i | i = 0, \ldots, t\}$ be a LT set and $(\bar{s}_i, \alpha_i)$ be a 2-tuple, there exists a function Δ^{-1} that can restore the 2-tuple to its equivalent numerical value $\grave{\beta} \in [0, t] \subset R$, where

$$\begin{aligned} \Delta^{-1} &: \dot{S} \times [-\frac{1}{2}, \frac{1}{2}) \to [0, t], \\ \Delta^{-1}(\bar{s}_i, \alpha) &= i + \alpha = \grave{\beta}. \end{aligned} \tag{2.2}$$

Definition 2.5. [9] Let X be a fixed set. A FFS is an object having the form

$$F = \{(x, (\mu_F(x), \nu_F(x)))| \ x \in X\}, \tag{2.3}$$

where the function μ_F is from X to [0,1] specifying the MD, and ν_F is from X to [0,1] specifying the non-MD of an element $x \in X$ to F. For every $x \in X$, it satisfies $(\mu_F(x))^3 + (\nu_F(x))^3 \leq 1$.

Definition 2.6. [58] Let $\delta = \{\bar{s}_0, \bar{s}_1, \bar{s}_2, \ldots, \bar{s}_t\}$ be a LT set, having odd cardinality. If $\delta = \{(\bar{s}_\phi, \phi), (\bar{s}_\theta, \theta)\}$ is defined for $\bar{s}_\phi, \bar{s}_\theta \in \delta$ and $\theta, \phi \in [-0.5, 0.5)$, where $(\bar{s}_\phi, \phi)$ and $(\bar{s}_\theta, \theta)$ express the MD and non-MD by 2-tuple linguistic term sets. Then the 2TLFFS can be defined as follows:

$$P = [\langle x, \{(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)\}\rangle | \ x \in X],$$

where $(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)$ are 2-tuple linguistic terms such that $0 \leq \Delta^{-1}(\bar{s}_{\phi_j}, \phi_j) \leq t$,$0 \leq \Delta^{-1}(\bar{s}_{\theta_j}, \theta_j) \leq t$ and $0 \leq (\Delta^{-1}(\bar{s}_{\phi_j}, \phi_j))^3 + (\Delta^{-1}(\bar{s}_{\theta_j}, \theta_j))^3 \leq t^3$. In order to simplify computation, $\delta_j = \{(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)\}$, denote 2TLFFN.

Definition 2.7. [58] Let $\delta_1 = \{(\bar{s}_{\phi_1}, \phi_1), (\bar{s}_{\theta_1}, \theta_1)\}$ be a 2TLFFN in P. Then the score and accuracy functions for a 2TLFFN are defined as

$$\dot{S}(\delta_1) = \Delta\{\frac{t}{2}(1 + \{(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3\})\}, \tag{2.4}$$

$$H(\delta_1) = \Delta\{t((\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3 + (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3)\}. \tag{2.5}$$

Definition 2.8. [58] Let $\delta_1 = \{(\bar{s}_{\phi_1}, \phi_1), (\bar{s}_{\theta_1}, \theta_1)\}$ and $\delta_2 = \{(\bar{s}_{\phi_2}, \phi_2), (\bar{s}_{\theta_2}, \theta_2)\}$ be two 2TLFFNs and $\lambda > 0$ be real numbers, where $\bar{s}_{\phi_1}, \bar{s}_{\theta_1}, \bar{s}_{\phi_2}, \bar{s}_{\theta_2} \in \dot{S} = \{\bar{s}_\alpha | \bar{s}_0 \leq \bar{s}_\alpha \leq \bar{s}_t, \alpha \in [0, t]\}$. Then some basic operations on 2TLFFNs are defined as follows:

1. $\delta_1 \oplus \delta_2 = \Bigg\{\Delta\Bigg(t\sqrt[3]{(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3 + (\Delta^{-1}(\bar{s}_{\phi_2}, \phi_2)/t)^3 - (\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2}, \phi_2)t)^3}\Bigg),$
$\Delta\Bigg(t(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2}, \theta_2)/t)^3\Bigg)\Bigg\},$
2. $\delta_1 \otimes \delta_2 = \Bigg\{\Delta\Bigg(t(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2}, \phi_2)/t)^3\Bigg),$
$\Delta\Bigg(t\sqrt[3]{(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3 + (\Delta^{-1}(\bar{s}_{\theta_2}, \theta_2)/t)^3 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2}, \theta_2)/t)^3}\Bigg)\Bigg\},$
3. $\lambda\delta_1 = \Bigg\{\Delta\Bigg(t\sqrt[3]{(1 - (1 - (\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3)^\lambda)}\Bigg), \Delta\Bigg(t(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^{3\lambda}\Bigg)\Bigg\},$
4. ${\delta_1}^\lambda = \Bigg\{\Delta\Bigg(t(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1/t))^{3\lambda}\Bigg), \Delta\Bigg(t\sqrt[3]{(1 - (1 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3)^\lambda)}\Bigg)\Bigg\}.$

Definition 2.9. [59] Let $\delta_1 = \{(\bar{s}_{\phi_1}, \phi_1), (\bar{s}_{\theta_1}, \theta_1)\}$ and $\delta_2 = \{(\bar{s}_{\phi_2}, \phi_2), (\bar{s}_{\theta_2}, \theta_2)\}$ be two 2TLFFNs and $\gamma, \lambda > 0$ be real numbers, where $\bar{s}_{\phi_1}, \bar{s}_{\theta_1}, \bar{s}_{\phi_2}, \bar{s}_{\theta_2} \in \dot{S} = \{\bar{s}_\alpha | \bar{s}_0 \leq \bar{s}_\alpha \leq \bar{s}_t, \alpha \in [0, t]\}$. Then some basic Hamacher operations on 2TLFFNs are defined as follows:

1. $$\delta_1 \oplus \delta_2 = \Bigg\{\Delta\Bigg(t\sqrt[3]{\frac{(\Delta^{-1}(\bar{s}_{\phi_1},\phi_1)/t)^3+(\Delta^{-1}(\bar{s}_{\phi_2},\phi_2)/t)^3-(\Delta^{-1}(\bar{s}_{\phi_1},\phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2},\phi_2)/t)^3-(1-\gamma)(\Delta^{-1}(\bar{s}_{\phi_1},\phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2},\phi_2)/t)^3}{1-(1-\gamma)(\Delta^{-1}(\bar{s}_{\phi_1},\phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2},\phi_2)/t)^3}}\Bigg),$$
$$\Delta\Bigg(t\frac{(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2}, \theta_2)/t)^3}{\sqrt[3]{\gamma + (1-\gamma)(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3 + (\Delta^{-1}(\bar{s}_{\theta_2}, \theta_2)/t)^3 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2}, \theta_2)/t)^3}}\Bigg)\Bigg\},$$
2. $$\delta_1 \otimes \delta_2 = \Bigg\{\Delta\Bigg(t\frac{(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2}, \phi_2)/t)^3}{\sqrt[3]{\gamma + (1-\gamma)(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3 + (\Delta^{-1}(\bar{s}_{\phi_2}, \phi_2)/t)^3 - (\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3(\Delta^{-1}(\bar{s}_{\phi_2}, \phi_2)/t)^3}}\Bigg),$$
$$\Delta\Bigg(t\sqrt[3]{\frac{(\Delta^{-1}(\bar{s}_{\theta_1},\theta_1)/t)^3+(\Delta^{-1}(\bar{s}_{\theta_2},\theta_2)/t)^3-(\Delta^{-1}(\bar{s}_{\theta_1},\theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2},\theta_2)/t)^3-(1-\gamma)(\Delta^{-1}(\bar{s}_{\theta_1},\theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2},\theta_2)/t)^3}{1-(1-\gamma)(\Delta^{-1}(\bar{s}_{\theta_1},\theta_1)/t)^3(\Delta^{-1}(\bar{s}_{\theta_2},\theta_2)/t)^3}}\Bigg)\Bigg\},$$
3. $$\lambda\delta_1 = \Bigg\{\Delta\Bigg(t\sqrt[3]{\frac{(1 + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3)^\lambda - (1 - (\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3)^\lambda}{(1 + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3)^\lambda + (\gamma-1)(1 - (\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3\lambda}}\Bigg),$$
$$\Delta\Bigg(t\frac{\sqrt{\gamma}(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3\lambda}{\sqrt[3]{(1 + (\gamma - 1)(1 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3)^\lambda + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3\lambda}}\Bigg)\Bigg\},$$
4. $$\delta_1{}^\lambda = \Bigg\{\Delta\Bigg(t\frac{\sqrt{\gamma}(\frac{\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)}{t})^3\lambda}{\sqrt[3]{(1 + (\gamma - 1)(1 - (\phi^-1(\bar{s}_{\phi_1}, \phi_1)/t)^3)^\lambda + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\phi_1}, \phi_1)/t)^3\lambda}}\Bigg),$$
$$\Delta\Bigg(t\sqrt[3]{\frac{(1 + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3)^\lambda - (1 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3)^\lambda}{(1 + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3)^\lambda + (\gamma - 1)(1 - (\Delta^{-1}(\bar{s}_{\theta_1}, \theta_1)/t)^3\lambda}}\Bigg)\Bigg\}.$$

Definition 2.10. [59] Let $\delta_j = \{(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)\}$, $(1 \leq j \leq n)$ be a group of 2TLFFNs. Its weight vector (WV) is $u = (u_1, u_2, \ldots, u_n)^T$, satisfying $u_j \in [0, 1]$ and $\sum_{j=1}^n u = 1$. Then the 2TLFFHWA operator is given by

$$2TLFFHWA_u(\delta_1, \delta_2, \ldots, \delta_n) = \oplus_{j=1}^n(u_j\delta_j). \tag{2.6}$$

Proposition 2.1. [59] Let $\delta_j = \{(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)\}$, $(1 \leq j \leq n)$ be a group of 2TLFFNs. The result by the 2TLFFHWA operator is a 2TLFFN, where

$$2TLFFHWA_u(\delta_1, \delta_2, \ldots, \delta_n) = \oplus_{j=1}^n(u_j\delta_j)$$
$$= \Bigg\{\Delta\Bigg(t\sqrt[3]{\frac{\prod_{j=1}^n(1 + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\phi_j}, \phi_j)/t)^3)^{u_j} - \prod_{j=1}^n(1 - (\Delta^{-1}(\bar{s}_{\phi_j}, \phi_j)/t)^3)^{u_j}}{\prod_{j=1}^n(1 + (\gamma - 1)(\Delta^{-1}(\bar{s}_{\phi_j}, \phi_j)/t)^3)^{u_j} + (\gamma - 1)\prod_{j=1}^n(1 - (\Delta^{-1}(\bar{s}_{\phi_j}, \phi_j)/t)^3)^{u_j}}}\Bigg),$$
$$\Delta\Bigg(t\frac{\sqrt{\gamma}\prod_{j=1}^n(\Delta^{-1}(\bar{s}_{\theta_j}, \theta_j)/t)^{u_j}}{\sqrt[3]{\prod_{j=1}^n(1 + (\gamma - 1)(1 - (\Delta^{-1}(\bar{s}_{\theta_j}, \theta_j)/t)^3))^{u_j} + (\gamma - 1)\prod_{j=1}^n(\Delta^{-1}(\bar{s}_{\theta_j}, \theta_j)/t)^3u_j}}\Bigg)\Bigg\}.$$

Definition 2.11. [59] Let $\delta_j = \{(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)\}$, $(1 \leq j \leq n)$ be a group of 2TLFFNs with the WV $u = (u_1, u_2, \ldots, u_n)^T$, which satisfies $u_j \in [0, 1]$ and $\sum_{j=1}^n u = 1$. Then we can define the 2TLFFHWG operator as

$$2TLFFHWG_u(\delta_1, \delta_2, \ldots, \delta_n) = \otimes_{j=1}^n(\delta_j)^{u_j}.$$

Proposition 2.2. [59] Let $\delta_j = \{(\bar{s}_{\phi_j}, \phi_j), (\bar{s}_{\theta_j}, \theta_j)\}$, $(1 \leq j \leq n)$ be a group of 2TLFFNs. The outcome by the 2TLFFHWG operator is also a 2TLFFN, where

$$2TLFFHWG_u(\delta_1,\delta_2,\ldots,\delta_n)=\otimes_{j=1}^{n}(\delta_j)^{u_j}$$
$$=\left\{\Delta\left(t\frac{\sqrt{\gamma}\prod_{j=1}^{n}(\Delta^{-1}(\bar{s}_{\phi_j},\phi_j)/t)^{u_j}}{\sqrt[3]{\prod_{j=1}^{n}(1+(\gamma-1)(1-(\Delta^{-1}(\bar{s}_{\phi_j},\phi_j)/t)^3))^{u_j}+(\gamma-1)\prod_{j=1}^{n}(\Delta^{-1}(\bar{s}_{\phi_j},\phi_j)/t)^3u_j}}\right),\right.$$
$$\left.\Delta\left(t\sqrt[3]{\frac{\prod_{j=1}^{n}(1+(\gamma-1)(\Delta^{-1}(\bar{s}_{\theta_j},\theta_j)/t)^3)^{u_j}-\prod_{j=1}^{n}(1-(\Delta^{-1}(\bar{s}_{\theta_j},\theta_j)/t)^3)^{u_j}}{\prod_{j=1}^{n}(1+(\gamma-1)(\Delta^{-1}(\bar{s}_{\theta_j},\theta_j)/t)^3)^{u_j}+(\gamma-1)\prod_{j=1}^{n}(1-(\Delta^{-1}(\bar{s}_{\theta_j},\theta_j)/t)^3)^{u_j}}}\right)\right\}.$$

3. Extended WASPAS method with 2-tuple linguistic Fermatean fuzzy numbers

The WASPAS method is an MAGDM method which is used in a lot of MAGDM problems. WASPAS method is a combination of the WeSM and WePM [21]. We are going to propose an effective method based on the 2TLFFHWA operator and WASPAS to select the best disposal location for solid waste of manufacturing plants. The 2TLFFHWA and 2TLFFHWG operators mentioned in Propositions 2.1 and 2.2, respectively have been used to enhance the WASPAS method. A flowchart of the proposed WASPAS method using 2TLFFNs is shown in Figure 2. The following substitutions are used for alternatives, criteria and DMs, i.e., p stands for alternative, q stands for criteria and r for DM. Following are the steps used in our proposed method.

1. We choose a number of DMs who have a complete mastery over the topic.
2. In this step, the DMs define a set of alternatives. The selected DMs list the alternatives that are essential for the evaluation process after fully understanding the problem.
3. Define a set of attributes. The selected DMs list the alternatives that are essential for evaluation process. These attributes are defined with the help of previous studies on the particular subject.
4. In this step, the DM uses the SMART method [60] to determine the weight of each attribute. In this method, the DM is asked to assign 10 points to the least important criterion/criteria. The sum of the points for each criterion is calculated. The final criteria weights are determined by normalization of the sum of points.
5. Define the LTs and corresponding 2TLFFNs. These linguistic terms and corresponding 2TLFFNs are defined by the DMs.
6. Obtain the judgment of the DMs on each attribute in the form of linguistic terms.
7. Convert the linguistic matrices into assessing matrices (AsMs).
8. In this step, the DM can evaluate alternatives using the 2TLFFHWAO and 2TLFFHWGO, i.e., the ith alternative is evaluated by the kth DM on the basis of the jth criteria.

$$Q_{ij}=\left(\Delta\left(t\sqrt[3]{1-\prod_{k=1}^{q}(1-(\Delta^{-1}(\bar{s}_{\phi_{ij}^k},\phi_{ij}^k)/t)^3)^{\omega_k}}\right),\Delta\left(t\prod_{k=1}^{q}(\Delta^{-1}(\bar{s}_{\theta_{ij}^k},\theta_{ij}^k)/t)^{\omega_k}\right)\right), \tag{3.1}$$

$$Q_{ij}=\left(\Delta\left(t\prod_{k=1}^{m}(\Delta^{-1}(\bar{s}_{\theta_{ij}^k},\theta_{ij}^k)/t)^{\omega_j}\right),\Delta\left(t\sqrt[3]{1-\prod_{k=1}^{m}(1-(\Delta^{-1}(\bar{s}_{\phi_{ij}^k},\phi_{ij}^k)/t)^3)^{\omega_j}}\right)\right). \tag{3.2}$$

9. In this step, if the criterion is a beneficial criterion (BeC), then it does not change, but if it is a non-beneficial criterion (NoC), we take the complement as defined in this Equation 3.3.

$$Com(Q_{ij})=\{(\bar{s}_\theta,\theta),(\bar{s}_\phi,\phi)\}. \tag{3.3}$$

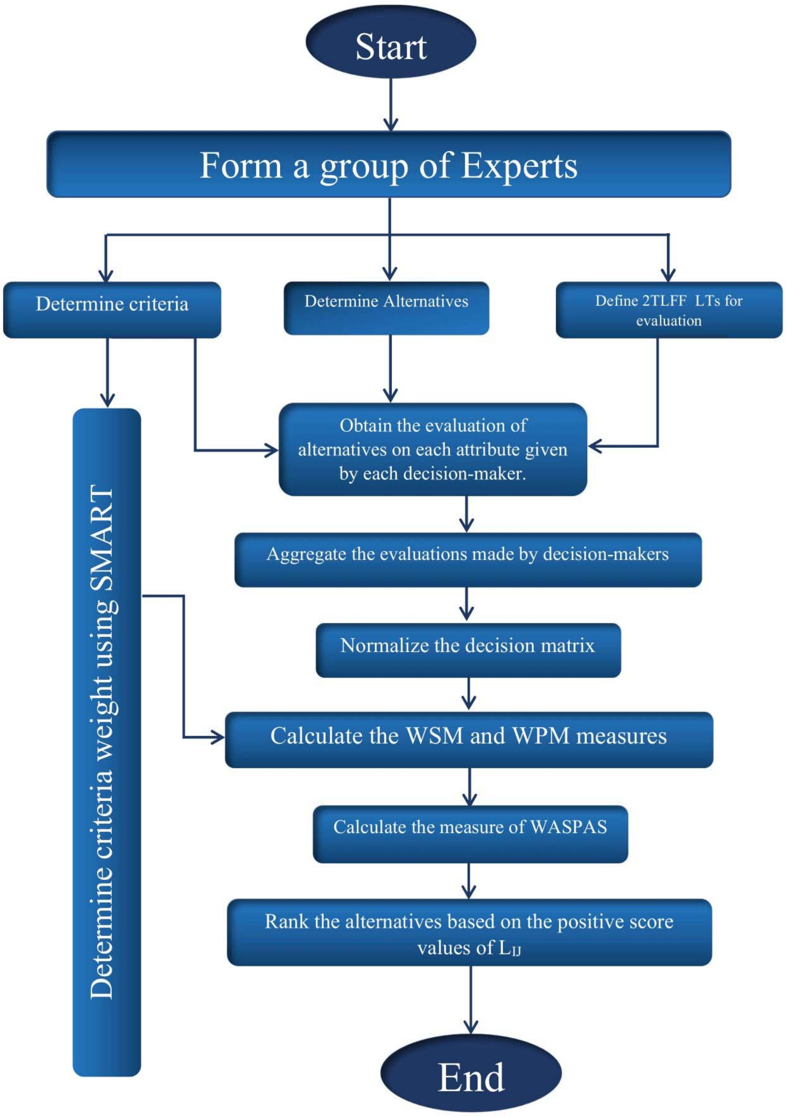

Figure 2. Extended WASPAS method using 2TLFFNs.

The normalized decision matrix can be calculated as

$$L_{ij}^{k}=\{(\bar{s}_{\phi_{ij}^{k}},\phi_{ij}^{k}),(\bar{s}_{\theta_{ij}^{k}},\theta_{ij}^{k})\} \quad = \begin{cases} Q_{ij} & if\ j\in BeC, \\ Com(Q_{ij}) & if\ j\in NoC. \end{cases} \tag{3.4}$$

10. We calculate the WeSM and WePM measures by using Propositions 2.1 and 2.2 (using $\gamma = 1$).

$$\begin{aligned} L_{ij}^{s} &= 2TLFFHWA(\delta_{ij}^{1},\delta_{ij}^{2},\ldots,\delta_{ij}^{m}) \\ &= \bigoplus_{k=1}^{m}(\omega_j\otimes L_{ij}^{k}) \\ &= \left(\Delta\left(t\sqrt[3]{1-\prod_{k=1}^{m}(1-(\Delta^{-1}(\bar{s}_{\phi_{ij}^{k}},\phi_{ij}^{k})/t)^{3})^{\omega_k}}\right),\Delta\left(t\prod_{k=1}^{m}(\Delta^{-1}(\bar{s}_{\theta_{ij}^{k}},\theta_{ij}^{k})/t)^{\omega_j}\right)\right), \\ L_{ij}^{p} &= 2TLFFHWG(\delta_{ij}^{1},\delta_{ij}^{2},\ldots,\delta_{ij}^{m}) \\ &= \bigotimes_{k=1}^{m}(\omega_j\otimes L_{ij}^{k}) \end{aligned}$$

$$= \left(\Delta\left(t\prod_{k=1}^{m}(\Delta^{-1}(\bar{s}_{\theta_{ij}^{k}}, \theta_{ij}^{k})/t)^{\omega_j}\right), \Delta\left(t\sqrt[3]{1-\prod_{k=1}^{m}(1-(\Delta^{-1}(\bar{s}_{\phi_{ij}^{k}}, \phi_{ij}^{k})/t)^3)^{\omega_j}}\right)\right).$$

Now calculate the measure of WASPAS by using Equation 3.5.

$$L_{ij} = \tau L_{ij}^{s} \oplus (1-\tau) L_{ij}^{p}. \tag{3.5}$$

11. Calculate the ranking of the alternatives using the formula given below, where $\dot{S}^{p}(\delta_1)$ represents the positive score function and $\dot{S}(\delta_1)$ represents the score function.

$$\dot{S}^{p}(\delta_1) = 1 + \dot{S}(\delta_1). \tag{3.6}$$

4. Application

In this section, we extend the WASPAS method with the 2TLFFHWA operator, 2TLFFHWG operator, WeSM and WePM under the 2TLFF environment.

Example 4.1 (SWDLS problem). In many cities of the United Kingdom, manufacturing companies are trendy and a key concern. Manchester is a city of the UK with a lot of cultures. There are many public and private manufacturing companies in Manchester. These manufacturing plants produce a lot of solid waste and pollution. Solid waste can cause various diseases in humansuch as bacillary dysentery, amoebic dysentery, cholera, jaundice, gastero, enteric diseases, endemic typhus, salmonellosis, trichinosis, diarrhea, plague, etc. Nowadays, disposal of this type of waste is a big issue. Consequently, finding the best place to dispose of such waste is an essential job of manufacturing organizations. We have used three main manufacturing companies of Manchester namely, Manchester manufacturing group, Automation technology and Iceland manufacturing limited to choose the best location for disposal of their solid waste. The waste management procedures of the above-mentioned manufacturing plants were monitored and we collected the information about collection, storage and disposal of their solid waste. The total waste bags produced were recorded. The weights of each waste bag were also recorded from each company. Although these companies have proper disposal system, due to continued enlargement and increasing product demand of these companies, the administration is supposed to build a proper waste disposal location. The aim of this research article is to introduce MAGDM methodology to select the best location for the disposal of waste.

We have selected the attributes and alternatives on the basis of the DM's opinion, research articles, case studies, etc. A flowchart of the application using the WASPAS method is shown in Figure 3.

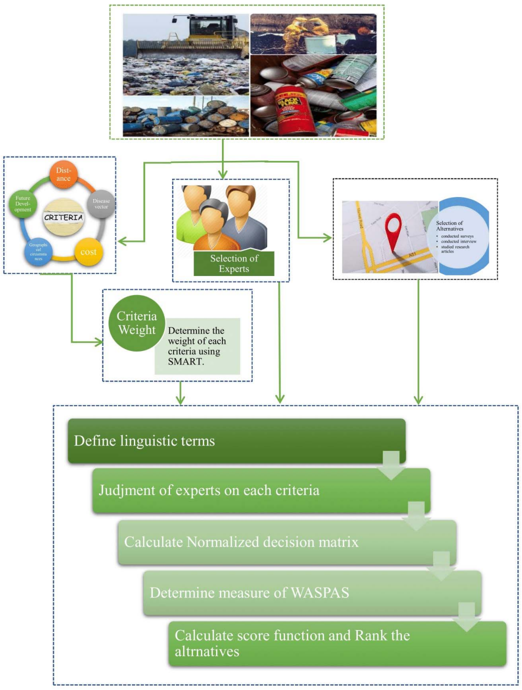

Figure 3. Solid waste disposal location selection using the WASPAS method.

A. Solution of SWDLS problem using the extended WASPAS method with the 2TLFFHWAO

We solve the SWDLS problem by using the extended WASPAS measure with the 2TLFFHWGO which is defined in 2.1.

1. We have selected three DMs (E_1, E_2 and E_3). The first DM is the plant manager, second is the factory engineer and third is the production manager. The collective opinions of all these DMs were used in decision-making. The WV of DMs the (0.2, 0.5, 0.3).
2. The DMs thoroughly studied and checked out the history of methods to dispose waste. On the basis of their study and after screening the list of possible landfill locations, they obtained a set of 4 alternatives (W_1 to W_4). The following four alternatives have been selected as listed in Table 2.

Table 2. Selected alternatives.

Alternatives	Site name
Astley sand and aggregated limited (W_1)	Morleys quarry
Augean north limited (W_2)	Marks Quarry Landfill site
Augean west limited (W_3)	Port Clarence non-hazardous landfill site
Augean south limited (W_4)	East Northants resource management facility

3. For defining the criteria and the DMs studied research articles, literature and conducted surveys. Following five attributes have been selected as listed in Table 3.
4. To calculate criteria weights, we used the SMART method [60]. The results are recorded in Table 4.
5. Now we define LT for the 2TLFFNs which are given in Table 5.

Table 3. Selected attributes.

Attribute	Type	Definition
Distance (T_1)	benefit	Distance from populated areas
Disease vector (T_2)	cost	Breeding of vectors in (e.g., rats, mosquitos) in landfill
Cost (T_3)	Cost	Land price, transportation cost and employee salary
Future development (T_4)	Benefit	possibility of development of land in future
Geographical circumstances (T_5)	Benefit	study of natural features of Earth's surface

Table 4. Determination of attribute weights by using SMART.

Attribute	Type	E_1	E_2	E_3	Sum	w_j
Distance (T_1)	benefit	80	70	85	235	0.23
Disease vector (T_2)	cost	40	30	60	130	0.13
Cost (T_3)	cost	90	90	80	260	0.26
Future development (T_4)	benefit	70	60	50	180	0.18
Geographical circumstances (T_5)	benefit	65	50	85	200	0.20

Table 5. Linguistic variables and their 2TLFFNs.

LV	2TLFFNs
Very low ($\ddot{VL}$)	$\{(\bar{s}_0, 0), (\bar{s}_6, 0)\}$
Low ($\ddot{L}$)	$\{(\bar{s}_1, 0), (\bar{s}_5, 0)\}$
Medium Low ($\ddot{ML}$)	$\{(\bar{s}_2, 0), (\bar{s}_4, 0)\}$
Medium ($\ddot{M}$)	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$
Medium High ($\ddot{MH}$)	$\{(\bar{s}_4, 0), (\bar{s}_2, 0)\}$
High ($\ddot{H}$)	$\{(\bar{s}_5, 0), (\bar{s}_1, 0)\}$
Very High ($\ddot{VH}$)	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$

6. Each DM judges the alternatives on each criteria. The results are given in Table 6.

Table 6. Judgment of sites by DMs.

DMs	Sites	T_1	T_2	T_3	T_4	T_5
E_1	W_1	$\ddot{H}$	$\ddot{H}$	$\ddot{L}$	$\ddot{L}$	$\ddot{MH}$
	W_2	$\ddot{M}$	$\ddot{ML}$	$\ddot{MH}$	$\ddot{L}$	$\ddot{ML}$
	W_3	$\ddot{L}$	$\ddot{H}$	$\ddot{H}$	$\ddot{M}$	$\ddot{VH}$
	W_4	$\ddot{L}$	$\ddot{MH}$	$\ddot{M}$	$\ddot{H}$	$\ddot{L}$
E_2	W_1	$\ddot{H}$	$\ddot{H}$	$\ddot{L}$	$\ddot{M}$	$\ddot{M}$
	W_2	$\ddot{M}$	$\ddot{M}$	$\ddot{MH}$	$\ddot{H}$	$\ddot{H}$
	W_3	$\ddot{VH}$	$\ddot{H}$	$\ddot{MH}$	$\ddot{M}$	$\ddot{VH}$
	W_4	$\ddot{L}$	$\ddot{L}$	$\ddot{M}$	$\ddot{MH}$	$\ddot{L}$
E_3	W_1	$\ddot{H}$	$\ddot{VH}$	$\ddot{H}$	$\ddot{MH}$	$\ddot{MH}$
	W_2	$\ddot{M}$	$\ddot{L}$	$\ddot{L}$	$\ddot{L}$	$\ddot{ML}$
	W_3	$\ddot{H}$	$\ddot{H}$	$\ddot{H}$	$\ddot{M}$	$\ddot{MH}$
	W_4	$\ddot{H}$	$\ddot{H}$	$\ddot{M}$	$\ddot{H}$	$\ddot{H}$

7. We convert the LAM given in Table 6 into AsMs. The outcomes are given in Table 7.

Table 7. AsMs by DMs.

DMs	Sites	T_1	T_2	T_3	T_4	T_5
E_1	W_1	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$
	W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_2,0),(\bar{s}_4,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_2,0),(\bar{s}_4,0)\}$
	W_3	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
	W_4	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$
E_2	W_1	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$
	W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$
	W_3	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
	W_4	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_0,0),(\bar{s}_6,0)\}$
E_3	W_1	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$
	W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_2,0),(\bar{s}_4,0)\}$
	W_3	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$
	W_4	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$

8. The AsMs were aggregated based on Equation 3.1. Then we obtained Q_{ij}. The results are recorded in Table 8.

Table 8. Aggregated AsMs.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_4,-0.33),(\bar{s}_3,0.5)\}$	$\{(\bar{s}_3,0.25),(\bar{s}_3,-0.05)\}$	$\{(\bar{s}_4,-0.40),(\bar{s}_2,0.44)\}$
W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_2,0.5),(\bar{s}_4,-0.29)\}$	$\{(\bar{s}_4,-0.38),(\bar{s}_3,-0.63)\}$	$\{(\bar{s}_4,0.23),(\bar{s}_2,0.44)\}$	$\{(\bar{s}_4,0.28),(\bar{s}_2,0)\}$
W_3	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,-0.38),(\bar{s}_1,0.41)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
W_4	$\{(\bar{s}_4,-0.33),(\bar{s}_3,0.50)\}$	$\{(\bar{s}_4,-0.06),(\bar{s}_3,-0.43)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,-0.38),(\bar{s}_1,0.41)\}$	$\{(\bar{s}_4,-0.32),(\bar{s}_3,0.37)\}$

9. The calculated results of the normalized decision matrix using Equation 3.4 are given in Table 9.

Table 9. Normalized decision matrices.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_0,0),(\bar{s}_6,0)\}$	$\{(\bar{s}_3,0.5),(\bar{s}_4,-0.33)\}$	$\{(\bar{s}_3,0.25),(\bar{s}_3,-0.05)\}$	$\{(\bar{s}_4,-0.40),(\bar{s}_2,0.44)\}$
W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,-0.29),(\bar{s}_2,0.5)\}$	$\{(\bar{s}_3,-0.63),(\bar{s}_4,-0.38)\}$	$\{(\bar{s}_4,0.23),(\bar{s}_2,0.44)\}$	$\{(\bar{s}_4,0.28),(\bar{s}_2,0)\}$
W_3	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0.41),(\bar{s}_5,-0.38)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
W_4	$\{(\bar{s}_4,-0.33),(\bar{s}_3,0.50)\}$	$\{(\bar{s}_3,-0.43),(\bar{s}_4,-0.06)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,-0.38),(\bar{s}_1,0.41)\}$	$\{(\bar{s}_4,-0.32),(\bar{s}_3,0.37)\}$

10. The calculated result of the WeSM, WePM and WASPAS measures by using the following equations and results are recorded in Table 10. $L^s_{ij} = 2TLFFHWA(\delta^1_{ij}, \delta^2_{ij}, \ldots, \delta^m_{ij})$

$$= \bigoplus_{k=1}^m (\omega_j \otimes L^k_{ij})$$

$$= \left(\Delta\left(t\sqrt[3]{1-\prod_{k=1}^m (1-(\Delta^{-1}(\bar{s}_{\phi^k_{ij}}, \phi^k_{ij})/t)^3)^{\omega_k}}\right), \Delta\left(t\prod_{k=1}^m (\Delta^{-1}(\bar{s}_{\theta^k_{ij}}, \theta^k_{ij})/t)^{\omega_j}\right)\right),$$

$$L^p_{ij} = 2TLFFHWG(\delta^1_{ij}, \delta^2_{ij}, \ldots, \delta^m_{ij})$$

$$= \bigotimes_{k=1}^m (\omega_j \otimes L^k_{ij})$$

$$= \left(\Delta\left(t\prod_{k=1}^m (\Delta^{-1}(\bar{s}_{\theta^k_{ij}}, \theta^k_{ij})/t)^{\omega_j}\right), \Delta\left(t\sqrt[3]{1-\prod_{k=1}^m (1-(\Delta^{-1}(\bar{s}_{\phi^k_{ij}}, \phi^k_{ij})/t)^3)^{\omega_j}}\right)\right).$$

Table 10. Measures of WASPAS for 2TLFFNs

Sites	L^s_{ij}	L^p_{ij}	L_{ij}
W_1	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_4, 0.26), (\bar{s}_3, -0.30)\}$	$\{(\bar{s}_6, 0), (\bar{s}_0, 0.01)\}$
W_2	$\{(\bar{s}_4, -0.28), (\bar{s}_3, -0.35)\}$	$\{(\bar{s}_4, -0.48), (\bar{s}_3, -0.18)\}$	$\{(\bar{s}_4, -0.37), (\bar{s}_0, 0.01)\}$
W_3	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_5, -0.16), (\bar{s}_2, -0.18)\}$	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$
W_4	$\{(\bar{s}_4, -0.18), (\bar{s}_3, -0.32)\}$	$\{(\bar{s}_4, -0.33), (\bar{s}_3, 0.03)\}$	$\{(\bar{s}_3, -0.25), (\bar{s}_0, 0.05)\}$

11. The calculated results of the score function of L_{ij} based on Definition 2.7 and the ranking of locations are given in Table 11.

Table 11. Results for score function and final ranking.

Sites	$\dot{S}(L_{ij})$	Ranking
W_1	5.999	2
W_2	1.3208	4
W_3	6	1
W_4	1.45859	3

From Table 11, we can deduce that $W_3 > W_1 > W_4 > W_2$. Thus, W_3 is the best location to dispose of the solid waste.

B. Solution of SWDLS problem using the extended WASPAS method with the 2TLFFHWGO

We solved the SWDLS problem by the extended WASPAS measure with the 2TLFFHWGO which is defined in 2.2.

1. The AsMs were aggregated based on Equation 3.2. The results are recorded in Table 12.

Table 12. Aggregated AsMs.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_5, 0.47), (\bar{s}_1, -0.20)\}$	$\{(\bar{s}_5, 0.28), (\bar{s}_1, -0.11)\}$	$\{(\bar{s}_2, -0.38), (\bar{s}_5, -0.38)\}$	$\{(\bar{s}_3, -0.37), (\bar{s}_4, -0.36)\}$	$\{(\bar{s}_3, 0.46), (\bar{s}_3, -0.39)\}$
W_2	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$	$\{(\bar{s}_2, -0.01), (\bar{s}_4, 0.13)\}$	$\{(\bar{s}_3, -0.36), (\bar{s}_4, -0.22)\}$	$\{(\bar{s}_2, 0.23), (\bar{s}_4, 0.23)\}$	$\{(\bar{s}_3, 0.16), (\bar{s}_3, 0.27)\}$
W_3	$\{(\bar{s}_4, -0.04), (\bar{s}_3, 0.25)\}$	$\{(\bar{s}_5, 0), (\bar{s}_1, 0)\}$	$\{(\bar{s}_4, 0.47), (\bar{s}_2, -0.34)\}$	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$	$\{(\bar{s}_5, 0.31), (\bar{s}_1, 0.34)\}$
W_4	$\{(\bar{s}_2, -0.38), (\bar{s}_5, -0.39)\}$	$\{(\bar{s}_2, 0.13), (\bar{s}_4, 0.25)\}$	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$	$\{(\bar{s}_4, 0.47), (\bar{s}_2, -0.34)\}$	$\{(\bar{s}_2, -0.38), (\bar{s}_5, -0.38)\}$

2. The calculated results of the normalized decision matrix are given in Table 13.

Table 13. Aggregated AsMs

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_5, 0.47), (\bar{s}_1, -0.20)\}$	$\{(\bar{s}_1, -0.11), (\bar{s}_5, 0.28)\}$	$\{(\bar{s}_5, -0.38), (\bar{s}_2, -0.38)\}$	$\{(\bar{s}_3, -0.37), (\bar{s}_4, -0.36)\}$	$\{(\bar{s}_3, 0.46), (\bar{s}_3, -0.39)\}$
W_2	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$	$\{(\bar{s}_4, 0.13), (\bar{s}_2, -0.01)\}$	$\{(\bar{s}_4, -0.22), (\bar{s}_3, -0.36)\}$	$\{(\bar{s}_2, 0.23), (\bar{s}_4, 0.23)\}$	$\{(\bar{s}_3, 0.16), (\bar{s}_3, 0.27)\}$
W_3	$\{(\bar{s}_4, -0.04), (\bar{s}_3, 0.25)\}$	$\{(\bar{s}_1, 0), (\bar{s}_5, 0)\}$	$\{(\bar{s}_2, -0.34), (\bar{s}_4, 0.47)\}$	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$	$\{(\bar{s}_5, 0.31), (\bar{s}_1, 0.34)\}$
W_4	$\{(\bar{s}_2, -0.38), (\bar{s}_5, -0.39)\}$	$\{(\bar{s}_4, 0.25), (\bar{s}_2, 0.13)\}$	$\{(\bar{s}_3, 0), (\bar{s}_3, 0)\}$	$\{(\bar{s}_4, 0.47), (\bar{s}_2, -0.34)\}$	$\{(\bar{s}_2, -0.38), (\bar{s}_5, -0.39)\}$

3. We calculated the WeSM, WePM and WASPAS measures by the Definition 2.9 with $\gamma = 1$. The results are recorded in Table 14.
4. The calculated results of the score function of L_{ij} using Definition 2.7 and the ranking of locations are given in Table 15. From Table 15, we conclude that $W_3 > W_1 > W_4 > W_2$. Thus, W_3 is the best location to dispose of the solid waste of manufacturing plants.

Table 14. Results of WASPAS for 2TLFFNs.

Sites	L_{ij}^s	L_{ij}^p	L_{ij}
W_1	$\{(\bar{s}_4, -0.29), (\bar{s}_0, 0.28)\}$	$\{(\bar{s}_3, -0.45), (\bar{s}_0, 0.44)\}$	$\{(\bar{s}_4, -0.01), (\bar{s}_0, 0.021)\}$
W_2	$\{(\bar{s}_2, 0.19), (\bar{s}_0, 0.40)\}$	$\{(\bar{s}_2, 0.1), (\bar{s}_0, 0.48)\}$	$\{(\bar{s}_3, -0.31), (\bar{s}_0, 0.03)\}$
W_3	$\{(\bar{s}_4, -0.2), (\bar{s}_0, 0.106)\}$	$\{(\bar{s}_3.0.49), (\bar{s}_0, 0.26)\}$	$\{(\bar{s}_4, 0.43), (\bar{s}_0, 0.004)\}$
W_4	$\{(\bar{s}_2, 0.47), (\bar{s}_1, 0)\}$	$\{(\bar{s}_2, -0.12), (\bar{s}_1, 0)\}$	$\{(\bar{s}_3, -0.22), (\bar{s}_0, 0.16)\}$

Table 15. Results of score function and final ranking.

Sites	$\dot{S}(L_{ij})$	Ranking
W_1	1.7757	2
W_2	0.53986	4
W_3	2.41718	1
W_4	0.59495	3

C. Solution of SWDLS problem using the extended WeSM with the 2TLFFNs

We solved the SWDLS problem by the extended WeSM measure with 2TLFFNs. In the WeSM, we put $\tau = 1$ in Equation 3.5. The results obtained are shown in Tables 16 and 17.

Table 16. Results of WASPAS for 2TLFFNs.

Sites	L_{ij}^s	L_{ij}^p	L_{ij}
W_1	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_4, 0.26), (\bar{s}_3, -0.30)\}$	$\{(\bar{s}_6, 0), (\bar{s}_0, 0.01)\}$
W_2	$\{(\bar{s}_4, -0.28), (\bar{s}_3, -0.35)\}$	$\{(\bar{s}_4, -0.48), (\bar{s}_3, -0.18)\}$	$\{(\bar{s}_4, -0.28), (\bar{s}_3, -0.35)\}$
W_3	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_5, -0.16), (\bar{s}_2, -0.18)\}$	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$
W_4	$\{(\bar{s}_4, -0.18), (\bar{s}_3, -0.32)\}$	$\{(\bar{s}_4, -0.33), (\bar{s}_3, 0.03)\}$	$\{(\bar{s}_4, -0.18), (\bar{s}_3, -0.32)\}$

Table 17. Results of score function and final ranking.

Sites	$\dot{S}(L_{ij})$	Ranking
W_1	6	1
W_2	0.9161	3
W_3	6	1
W_4	0.9885	2

From Table 17, we conclude that $W_3 = W_1 > W_4 > W_2$. Thus, W_3 and W_1 are the best locations to dispose of the solid waste of manufacturing plants.

D. Solution of SWDLS problem using the extended WePM with the 2TLFFNs

Now we solve the SWDLS problem by the extended WePM with 2TLFFNs. In the WePM, we put $\tau = 0$ in Equation 3.5. The results obtained are shown in Tables 18 and 19.

From Table 19, we can infer that $W_3 > W_1 > W_4 > W_2$. Thus, W_3 is the best location to dispose of the solid waste of manufacturing plants.

Table 18. The measure of WASPAS for 2TLFFNs.

Sites	L_{ij}^{s}	L_{ij}^{p}	L_{ij}
W_1	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_4, 0.26), (\bar{s}_3, -0.30)\}$	$\{(\bar{s}_4, 0.26), (\bar{s}_3, -0.30)\}$
W_2	$\{(\bar{s}_4, -0.28), (\bar{s}_3, -0.35)\}$	$\{(\bar{s}_4, -0.48), (\bar{s}_3, -0.18)\}$	$\{(\bar{s}_4, -0.48), (\bar{s}_3, -0.18)\}$
W_3	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_5, -0.16), (\bar{s}_2, -0.18)\}$	$\{(\bar{s}_5, -0.16), (\bar{s}_2, -0.18)\}$
W_4	$\{(\bar{s}_4, -0.18), (\bar{s}_3, -0.32)\}$	$\{(\bar{s}_5, -0.16), (\bar{s}_2, -0.18)\}$	$\{(\bar{s}_5, -0.16), (\bar{s}_2, -0.18)\}$

Table 19. The results of score function and final ranking.

Sites	$\dot{S}(L_{ij})$	Ranking
W_1	1.6181	2
W_2	0.58762	4
W_3	2.96668	1
W_4	0.59008	3

5. Parametric analysis

The parameter γ is used in our research study to explain the interdependency between distinct quantifiable attributes. Various numerical values of the parameter γ illustrate the various decision-making possibilities and circumstances. We assigned numerical values from 1 to 6 to γ the results are shown in Tables 20 and 21. The scoring values of each selected alternative varied depending on the crisp value of the parameter, but the derived results are roughly the same. When we allocated distinguishable numerical values to the parameter γ, the best alternative is O_3 for the SWDLS problem solved with the extended 2TLFF-WASPAS method using two different operators, i.e., the 2TLFFHWA operator and 2TLFFHWG operator. We can also summarize from the appraisal scoring results as shown in Tables 20 and 21 that the 2TLFFHWA and 2TLFFHWG operators proposed in this research study are the best approaches to summarize aggregated 2TLFF information. A graph of the ranking

Table 20. Score functions and ranking results for SWDLS with the 2TLFFHWAO.

Parameter	$\dot{S}(W_1)$	$\dot{S}(W_2)$	$\dot{S}(W_3)$	$\dot{S}(W_4)$	Ranking
$\gamma = 1$	$(\bar{s}_6, -0.0001)$	$(\bar{s}_4, -0.29)$	$(\bar{s}_6, 0)$	$(\bar{s}_4, -0.34)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 2$	$(\bar{s}_6, -0.00001)$	$(\bar{s}_4, -0.30)$	$(\bar{s}_6, 0)$	$(\bar{s}_3, 0.34)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 3$	$(\bar{s}_6, -0.00001)$	$(\bar{s}_4, -0.31)$	$(\bar{s}_6, 0)$	$(\bar{s}_3, 0.41)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 4$	$(\bar{s}_6, -0.000001)$	$(\bar{s}_3, 0.32)$	$(\bar{s}_6, 0)$	$(\bar{s}_3, 0.33)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 5$	$(\bar{s}_6, -0.000001)$	$(\bar{s}_3, 0.33)$	$(\bar{s}_6, 0)$	$(\bar{s}_3, 0.33)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 6$	$(\bar{s}_6, -0.000001)$	$(\bar{s}_3, 0.34)$	$(\bar{s}_6, 0)$	$(\bar{s}_3, 0.33)$	$W_3 > W_1 > W_2 > W_4$

results of SWDLS by the 2TLFFHWAO using different values of γ is shown in Figure 4.

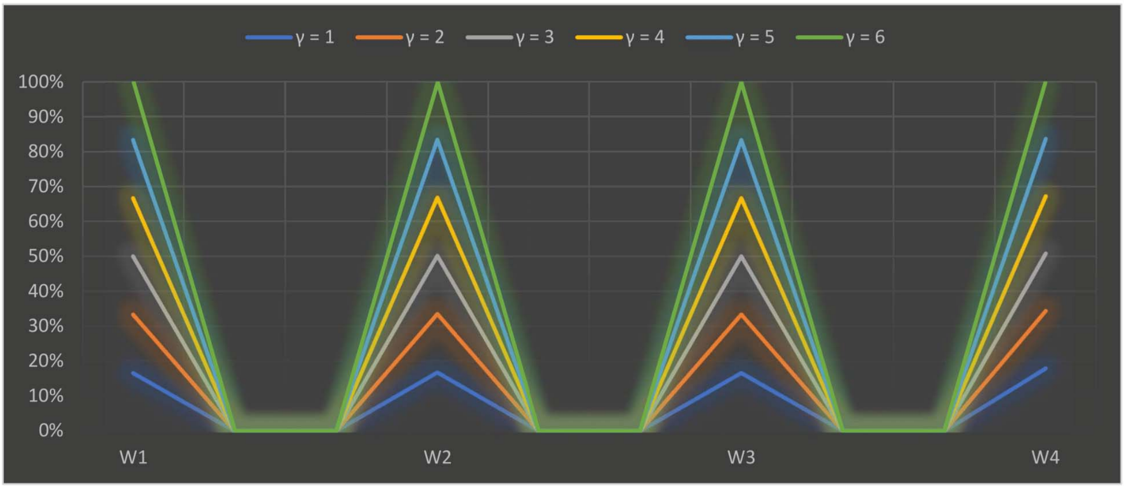

Figure 4. Ranking results of SWDLS by 2TLFFHWAO using $\gamma = 1, 2, 3, 4, 5, 6$.

Table 21. Score functions and ranking results with the 2TLFFHWGO.

Parameter	$\dot{S}(W_1)$	$\dot{S}(W_2)$	$\dot{S}(W_3)$	$\dot{S}(W_4)$	Ranking
$\gamma = 1$	$(\bar{s}_2, 0.25)$	$(\bar{s}_2, 0.12)$	$(\bar{s}_3, -0.08)$	$(\bar{s}_2, -0.13)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 2$	$(\bar{s}_2, 0.32)$	$(\bar{s}_2, 0.15)$	$(\bar{s}_3, -0.17)$	$(\bar{s}_2, -0.06)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 3$	$(\bar{s}_2, 0.37)$	$(\bar{s}_2, 0.17)$	$(\bar{s}_3, -0.19)$	$(\bar{s}_2, -0.04)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 4$	$(\bar{s}_2, 0.40)$	$(\bar{s}_2, 0.18)$	$(\bar{s}_3, -0.19)$	$(\bar{s}_2, 0)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 5$	$(\bar{s}_2, 0.43)$	$(\bar{s}_2, 0.19)$	$(\bar{s}_3, -0.19)$	$(\bar{s}_2, 0.03)$	$W_3 > W_1 > W_2 > W_4$
$\gamma = 6$	$(\bar{s}_2, 0.45)$	$(\bar{s}_2, 0.19)$	$(\bar{s}_3, -0.19)$	$(\bar{s}_2, 0.05)$	$W_3 > W_1 > W_2 > W_4$

A graph of the ranking results of SWDLS by the 2TLFFHWGO using different values of γ is shown in Figure 5.

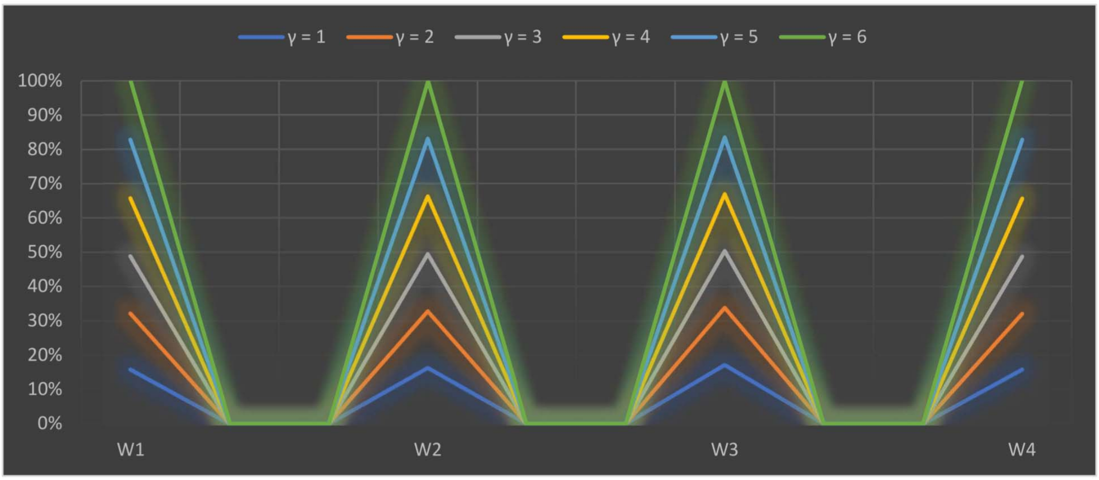

Figure 5. Ranking results for SWDLS with the 2TLFFHWGO using $\gamma = 1, 2, 3, 4, 5, 6$.

6. Comparative analysis

We solved the problem of SWDLS using the CODAS method for 2TLPFNs [61].

1. We converted the linguistic assessing matrices which are given in Table 6, into assessing matrices. The outcomes are given in Tables 22, 23 and 24.

Table 22. AsMs by E_1.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$
W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_2,0),(\bar{s}_4,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_2,0),(\bar{s}_4,0)\}$
W_3	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
W_4	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$

Table 23. AsMs by E_2.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$
W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$
W_3	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
W_4	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_0,0),(\bar{s}_6,0)\}$

Table 24. AsMs by E_3.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$
W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_1,0),(\bar{s}_5,0)\}$	$\{(\bar{s}_2,0),(\bar{s}_4,0)\}$
W_3	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0)\}$
W_4	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$

2. The calculated results of the collective 2TLPF matrices are given in Table 25.

Table 25. Collective 2TLPF matrices.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_3,0.28),(\bar{s}_3,0.5)\}$	$\{(\bar{s}_3,0.16),(\bar{s}_3,-0.05)\}$	$\{(\bar{s}_4,-0.42),(\bar{s}_2,0.44)\}$
W_2	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_2,0.4),(\bar{s}_4,-0.29)\}$	$\{(\bar{s}_4,-0.49),(\bar{s}_3,-0.36)\}$	$\{(\bar{s}_4,0),(\bar{s}_2,0.44)\}$	$\{(\bar{s}_4,0.15),(\bar{s}_2,0)\}$
W_3	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$	$\{(\bar{s}_5,0),(\bar{s}_1,0)\}$	$\{(\bar{s}_5,-0.39),(\bar{s}_1,0.41)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_6,0),(\bar{s}_0,0)\}$
W_4	$\{(\bar{s}_3,0.28),(\bar{s}_3,0.50)\}$	$\{(\bar{s}_4,-0.27),(\bar{s}_3,-0.43)\}$	$\{(\bar{s}_3,0),(\bar{s}_3,0)\}$	$\{(\bar{s}_5,-0.39),(\bar{s}_1,0.41)\}$	$\{(\bar{s}_3,0.30),(\bar{s}_3,0.37)\}$

3. The results for 2TLPF weighted matrices are given in Table 26.
4. The calculated results for the negative ideal solution are given in Table 27.

5. Calculations of Euclidean distance (UD_i) and Hamming distance (AD_i) are given below:

$$UD_1 = 1.72967, UD_2 = 0.34654, UD_3 = 2.01339, UD_4 = 0.26798,$$
$$AD_1 = 1.73838, AD_2 = 0.35433, AD_3 = 2.03841, AD_4 = 0.2744.$$

Table 26. Collective weighted 2TLPF matrices.

Sites	T_1	T_2	T_3	T_4	T_5
W_1	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_2, -0.32), (\bar{s}_5, 0.21)\}$	$\{(\bar{s}_2, -0.38), (\bar{s}_5, 0.27)\}$	$\{(\bar{s}_2, -0.15), (\bar{s}_5, 0.01)\}$
W_2	$\{(\bar{s}_2, -0.48), (\bar{s}_5, 0.11)\}$	$\{(\bar{s}_1, 0.19), (\bar{s}_6, -0.36)\}$	$\{(\bar{s}_2, -0.18), (\bar{s}_5, -0.15)\}$	$\{(\bar{s}_2, 0.14), (\bar{s}_5, 0.1)\}$	$\{(\bar{s}_2, 0.23), (\bar{s}_5, -0.18)\}$
W_3	$\{(\bar{s}_6, 0), (\bar{s}_0, 0)\}$	$\{(\bar{s}_3, -0.06), (\bar{s}_5, -0.24)\}$	$\{(\bar{s}_3, -0.43), (\bar{s}_4, 0.12)\}$	$\{(\bar{s}_2, -0.48), (\bar{s}_5, 0.29)\}$	$\{(\bar{s}_6, 0), (\bar{s}_0)\}$
W_4	$\{(\bar{s}_2, -0.31), (\bar{s}_5, 0.30)\}$	$\{(\bar{s}_2, 0.05), (\bar{s}_5, 0.37)\}$	$\{(\bar{s}_2, -0.48), (\bar{s}_5, 0.01)\}$	$\{(\bar{s}_3, -0.42), (\bar{s}_5, -0.37)\}$	$\{(\bar{s}_2, -0.30), (\bar{s}_5, 0.34)\}$

Table 27. Negative ideal solution with 2TLPFNs.

T_1	T_2	T_3	T_4	T_5
$\{(\bar{s}_2, -0.31), (\bar{s}_5, 0.30)\}$	$\{(\bar{s}_1, 0.19), (\bar{s}_6, -0.36)\}$	$\{(\bar{s}_2, -0.32), (\bar{s}_5, 0.21)\}$	$\{(\bar{s}_2, -0.48), (\bar{s}_5, 0.29)\}$	$\{(\bar{s}_2, -0.30), (\bar{s}_5, 0.34)\}$

6. The results for the Relative assessment matrix are shown in Table 28.

Table 28. Relative assessment matrix.

	T_1	T_2	T_3	T_4
W_1	0	3.2974	-0.1986	3.60157
W_2	0.49488	0	1.0358	0.244875
W_3	0.36884	4.47397	0	4.82431
W_4	0.67819	-0.07227	1.3335	0

7. The average results are given below:

$$AW_1 = 6.70044, AW_2 = 1.75629, AW_3 = 9.66712, AW_4 = 1.93942,$$

8. The ranking order is

$$W_3 > W_1 > W_4 > W_2. \tag{6.1}$$

and W_3 is the best among four alternatives.

We have solved a problem of SWDLS for manufacturing plants in Manchester. For this purpose, we have used the extended 2TLFF-WASPAS method with Hamacher aggregation operators. We have solved the SWDLS problem by using the WASPAS method with the 2TLFFHWA operator and 2TLFFHWG operator. Also, we have solved the SWDLS problem using the extended-WeSM measure and extended-WePM measure. To check the feasibility of our proposed method, we have compared the SWDLS problem with the operators including G2TLPFWHMO [56], 2TLPFWGHMO, DG2TLPFWBMO [57] and DG2TLPFWGBMO. We have also compared it with the CODAS method [61] for 2TLPFNs. From the above analysis, we have the same best landfill location, i.e., W_3. The comparative analysis shows that the proposed WASPAS method yields valid results. Neither 2TLISs nor 2TLPFSs can handle the situation when the sum of squares of the 2-tuple linguistic MD and non-MD exceeds 1. Hence, it is necessary to develop a new model in this case. Also the proposed 2TLFF-WASPAS method is superior to the existing CODAS method [61], because the existing CODAS method [61] can only be used for 2TLPF data whereas the proposed method can be used for both

Table 29. Comparative analysis.

Methods	Ranking	Optimal Alternative
WASPAS method with 2TLFFHWA operator	$W_3 > W_1 > W_4 > W_2$	W_3
WASPAS method with 2TLFFHWG operator	$W_3 > W_1 > W_4 > W_2$	W_3
WeSM method with 2TLFFHWA operator	$W_3 = W_1 > W_4 > W_2$	W_3 and W_1
WePM method with 2TLFFHWA operator	$W_3 > W_1 > W_4 > W_2$	W_3
CODAS method with 2TLPFNs [61]	$W_3 > W_1 > W_4 > W_2$	W_3
G2TLPFWHMO [56]	$W_3 > W_1 > W_4 > W_2$	W_3
2TLPFWGHMO [56]	$W_3 > W_1 > W_4 > W_2$	W_3
DG2TLPFWBMO [57]	$W_3 > W_1 > W_4 > W_2$	W_3
DG2TLPFWGBMO [57]	$W_3 > W_1 > W_4 > W_2$	W_3

2TLPF data and 2TLFF data. The combined ranking of all above-mentioned applications is shown in Table 29. A graph of the ranking of all above-mentioned methods is shown in Figure 6.

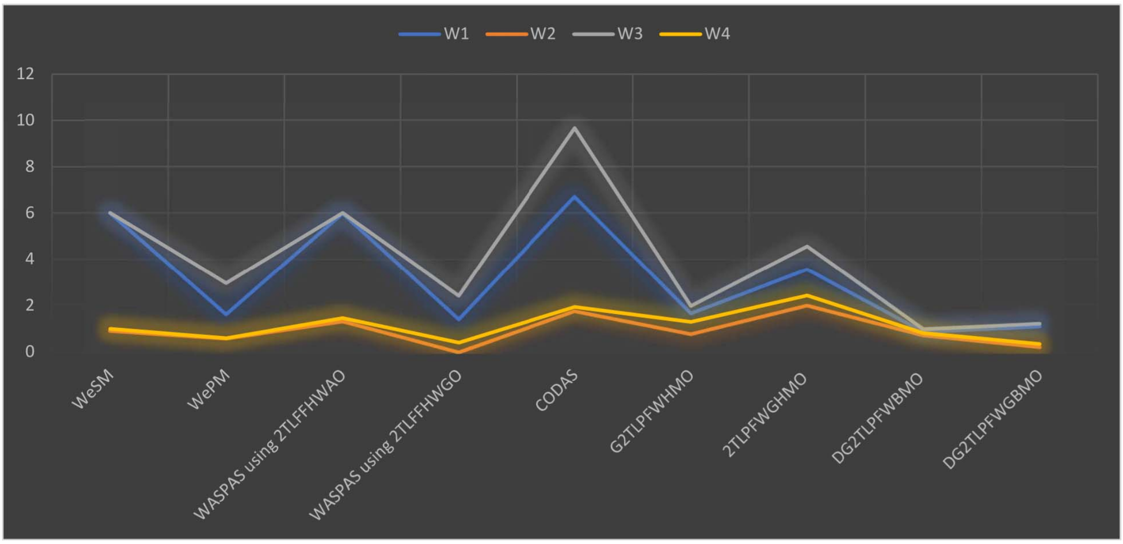

Figure 6. Comparative analysis.

7. Discussion

MAGDM methods have been widely used in the field of SWDLS problems. This study is the first to take into account the MAGDM of SWDLS in the context of 2TLFFSs. Many MAGDM techniques, though, which are used for evaluation with many criteria, have not yet been modified for this setting. One of the effective MAGDM techniques is the WASPAS approach, which has been used to solve numerous MAGDM issues in the real world. In this paper, a novel integrated strategy based on the WASPAS method is put forth to address MAGDM issues with 2TLFFNs. The principles and arithmetic operations of 2TFFSs have been applied in this technique to adapt the WASPAS method to 2TLFF information, and various modifications have been made in the process. In this work, we modified the

WePM and WeSM processes, and we suggested an expanded WASPAS that can tackle MAGDM issues in such a scenario. Additionally, the SMART technique has been applied to get more accurate criteria weights using data with 2TLFFSs as a defining characteristic. One of the main issues with the decision-making process is the calculation of criteria weights. The proposed approach has been validated using a SWDLS example. To do this, the findings of the suggested strategy were compared to those of several other methods, and a sensitivity analysis was carried out by altering a method parameter. The analysis' findings indicate that the integrated strategy that has been suggested is valid for evaluating SWDLS and may work well for many other MAGDM issues.

1. The WASPAS method selects the option with the greatest utility, whereas previous methods prefer alternatives that are close to the ideal solution.
2. WASPAS is a combination of the WeSM and WePM and its accuracy is more consistent than the WePM and WeSM.
3. In the proposed 2TLFF-WASPAS, the standard weights are computed based on the SMART method [60], while in the CODAS method [61], Deng et al. [57] and Wei et al. [56], assuming standard weights, this leaves no room for dealing with ambiguity.
4. The advantages of the proposed WASPAS method include its efficiency of use in MCDM problems, the flexibility of using a FFS and 2-tuple LTs to define the information expressed by the DM and its applicability to various decision-making problems.

8. Conclusions

The WASPAS method is important among the available methods because of its ability to improve ranking accuracy. The 2TLFFS is a new generalization of the 2TLPFS and 2TLIFS, as it can handle more general cases than the 2TLPFS and 2TLIFS. In this research study, we have selected the best sites for manufacturing industrial solid waste in Manchester to dispose of. We have solved the SWDLS problem using the WASPAS method of the 2TLFFHWA operator. Furthermore, we have solved it using the WASPAS method for the 2TLFFHWG operator, WePM measurement and WeSM measurements. We also conducted a comparative study with existing methods [61] and operators, namely the G2TLPFWHMO [56], 2TLPFWGHMO [56] and DG2TLPFWBMO [57] DG2TLPFWGBMO [57] to show the applicability of its integrity.

Various MAGDM applications in other industries, i.e., agriculture, healthcare, etc., can be handled using the proposed technique. Certain new methods, such as double normalization-based multiple aggregation, gained and lost dominance score, ORESE, and measurement of alternatives and ranking according to the compromise solution in the fuzzy context of FFS and the 2TLFF can be used for future development. These methods can be used to solve SWDLS problems in different regions. Furthermore, the proposed 2TLFF-WASPAS method could be coupled with some other subjective criteria weighting methods such as analytic hierarchy process, Best Worst Method and analytic network process. Finally, the proposed method can be used to solve other emerging MAGDM problems.

The proposed method is based on FFS theory, which is a generalization of the PFS and IFS theories. Therefore, there are currently no significant limitations in the application of the proposed approach. The only real limitation that is observed is the selection of attributes. Only five attributes were selected, although many other factors, such as groundwater depth, proximity to surface water, elevation, land slope, soil permeability, soil stability, flooding susceptibility, lithology and stratification, faults, land use type, nearby settlements and urbanization, proximity to cultural and protected sites, wind direction, roads, railroads, proximity to building materials, pipelines, powerlines and proximity to airports are considered while selecting a disposal site. These factors can be considered in future studies.

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Conflict of interest

The authors declare no conflict of interest.

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