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SELECTION OF FORKLIFT UNIT FOR TRANSPORT HANDLING USING INTEGRATED MCDM UNDER NEUTROSOPHIC ENVIRONMENT

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Abstract. *In material handling, warehousing, manufacturing and construction applications, forklifts are vital equipment, which are used to engage, lift and move palletized items. So, selection of the most appropriate forklift is an essential task for transportation of materials in warehouses for optimal use of the equipment. The present treatise introduces a well-known multi-criteria decision making (MCDM) technique, namely fully consistent method (FUCOM) under neutrosophic environment (NE) to model and solve the problem of selecting the best forklift for warehouse. In this regard, the linguistic assessments of the criteria have been represented in terms of single valued triangular neutrosophic numbers (SVTNNs). A novel triangular neutrosphic score function and ranking function are also proposed. To calculate criteria weights, a novel SVTN linear programming problem (SVTNLPP) has been developed. The alternatives have been ranked through multi-objective optimization on the basis of ratio analysis (MOORA). The robustness, consistency and reliability of the proposed integrated method have been checked through comparative and sensitivity analyses. This study makes a significant contribution by developing an original integrated model which provides warehousing system managers a quantifiable analysis, based on which they may make future decisions in order to improve the overall efficiency of the organization in transport handling*.

Key words: *Multi-Criteria Decision Making, Fully Consistent Method, Neutrosophic Set, Forklift, Warehouse, MOORA*

1. INTRODUCTION

A forklift is a compact industrial vehicle with a power-operated forked platform connected to the front that can be lifted and lowered to lift or move freight. Forklifts are one of the most commonly used pieces of material handling equipment. Despite the

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emergence of a significant number of automated solutions on the market, demand for traditional and electric forklifts is expected to remain stable. Forklifts fulfill the demands of a variety of businesses, including warehouses and other big storage facilities and are thus widely utilized for carrying materials and commodities across the industry. Forklifts can securely carry goods that people cannot, making them essential on every job site, when one needs to transport huge loads in a warehouse or on a construction site. Special attention should be paid to storage systems, cost optimization and the enhancement of all aspects that affect efficiency and contribute to the smooth operation of logistics subsystems in the logistics sector. The issue of analyzing and selecting the most appropriate forklift in real-time industrial practice is a complex decision-making problem that should be formulated through an efficient analytical model. The efficiency of forklifts is critical to the success of any company. Every day, forklifts are employed and no logistical procedures would be possible without them. As a result, it was determined to assess their efficiency, which will aid in the process optimization in this logistics subsystem. So selection of an optimal forklift for warehouse is an imperative issue. As the productivity of the forklift has an indirect impact on the productivity of logistics centers, so it is legitimate to consider the process of selecting forklifts as part of the machine tool selection (MTS) [1], which can be viewed as MCDM technique. When selecting the most appropriate future machines, researchers apply a variety of decision-making processes. Few of the influential factors related to forklift selection process for warehouse are its manufacturing cost, manufacturing time, load capacity, working time, lift height, etc. Thus considering these parameters as selection criteria of forklift for warehouse, the problem of selecting the best forklift unit for warehouse can be modeled in terms of MCDM problem.

MCDM is a powerful technique that includes individual decision-makers' value judgments to assist them and get the best option. Decision makers use MCDM strategies to organize and synthesize the data they have gathered so they may feel confident and at ease with their choices [2,3,4]. The purpose of decision making techniques is to figure out and visualize the influence of an attribute on a choice. It is obvious that the impact of all criteria cannot be equal in every decision-making challenge. In comparison to another procedure that offers virtually differentiable values to indicate parameter significance, the approach that can considerably demonstrate the difference in importance for the selected parameter with regard to the decision objective is preferable. So, selection of a MCDM technique [5] to resolve any decision making problem is very vital to get satisfactory solution. As a pair wise comparison (PWC) method, the FUCOM reduces a large number of PWCs from similar and popular approaches such as the AHP and the BWM. For example, for n criteria, AHP [6,7] needs n(n-1)/2 pair wise comparison and BWM needs (2n - 3) pair wise comparisons; whereas FUCOM needs only (n -1) pair wise comparison resulting it a less time-consuming technique compared to those of AHP and BWM. The following are the primary advantages of FUCOM over conventional MCDM methods: (i) a substantially lower number of paired comparisons, (ii) a dependable PWC of the associated criteria, and (iii) the determination of dependable values for criteria weight coefficients, all of which help to reasonable judgment [8]. Badi and Kridish [9] suggested an integrated framework of FUCOM and CODAS method to select the best dumping of solid waste site for landfill in the Misuratacity, Libya. Yazdani et al. [10] proposed the FUCOM and the CoCoSo in the rough set setting to find the logistics center location in

Spain. Ramezanzade et al. [11] proposed a hybridized decision-making technique consisting of AHP, BWM and FUCOM for selecting the superior hybrid renewable energy arrangement for supplying power in government organizations. Feizi et al. [12] proposed two hybrid MCDMs, viz., FUCOM-MOORA and FUCOM-MOOSRA and applied those to solve the problem of mineral potential mapping in green field. Ong et al. [13] created the FUCOM-VIKOR hybrid technique to incorporate the positive attributes as well as negative attributes of the alternatives of corresponding criteria. Yousefi et al. [14] developed a combined method using Z-number theoretic CoCoSo and FUCOM to study failure modes and effects analysis. Further, they applied their model in an industry of automotive parts. Das and Sarkar [15] proposed FUCOM-ISOCOV, a hybrid technique for determining performance scores of various materials while taking into account value restrictions in order to pick the optimum materials for four different applications. Durmić et al. [16] used combined FUCOM - Rough SAW approach for supplier selection in order to achieve sustainability, taking into account all aspects: economic, social and environmental criteria. Badi et al. [17] used FUCOM-MARCOS to evaluate and prioritize aspects of green innovation, taking into account sustainability performance indicators.

However, the bulk of MCDM approaches deal with discrete options that are defined by a set of criteria that may be determined using cardinal or ordinal data. Furthermore, the data might be exact or ambiguous, confusing or partial. In practical MCDM contexts, fuzzy set theory and its expansions have shown to be effective tools for dealing with ambiguous and unclear data. In the context of decision theory, there are numerous multi-criteria decision making (MCDM) strategies [18,19,20] that can aid in the resolution of machine tool selection difficulties under uncertainty. In 2011, Taha and Rostam [21] used the fuzzy AHP, MOORA and an artificial neural network to develop a DSS for machine tool selection in a flexible manufacturing cell. For rating machine tool alternatives, Ayag and Gurcan [22] suggested a fuzzy MCDM model based on the modified TOPSIS and fuzzy ANP. Li et al. [23] proposed a MTS model using fuzzy DEMATEL, entropy weighing and VIKOR. In their study of Maclaurian Symmetric Mean using interval valued picture fuzzy (IVPF) sets, Ashraf et al. [24] addressed how to use IVPF data to determine the best employee benefit plan. Riaz et al. [25] introduced some picture fuzzy aggregation operators to select third party logistic provider using MCDM. In order to choose a student's career, Sahu et al. [26] used a hybridized distance measure in a picture-fuzzy environment, where the assessing information about the student, subject, and student's attributes is provided in picture-fuzzy numbers. For weighing and supplier evaluation with regard to information system performance and environmental consequences, Kazemitash et al. [27] employed the rough best worst technique. Additionally, a case study was carried out for the supplier selection of a biofuel firm, and the outcomes suggest the efficacy of the method in tactical performance evaluation. Sharma et al. [28] carried out a case study on accommodation providing hotels by developing a strategy to increase their profit margins by welcoming more and more tourists using the Dominance Based Rough Set Theory (DRST) on the data gathered for the variables like location, facility, value for money, etc.

Although fuzzy set theory is effective at dealing with issues about ambiguities or partial presence of members of a particular set, it cannot account for all of the ambiguity that arises in real-world situations, such as difficulties requiring imperfect knowledge. To overcome this challenge, Atanassov [29] devised an extension, known as intuitionistic fuzzy sets (IFS), where the idea of a non-membership degree of each element was introduced in addition with the membership grade. The notion of IFS is preferable when the information provided is inadequate to determine imprecision using traditional fuzzy sets. The degree of non-membership function in a fuzzy set is always equal to one less than the degree of membership. However, this is not always the case in the real world. For instance, if everyone in an area wants to elect one leader, the degree of membership will fall between 0 and 1 for those who will vote, but it will not be equal to one minus the membership value for those who will not vote. This is due to the possibility that a small number of members will cast illegal votes or abstain altogether. So to deal with such situation, the concepts of membership and non-membership have been further generalized by Smarandache [30] and Neutrosophic sets (NSs) have been introduced for dealing with incomplete, abstruse and contradictory data that can be found in numerous real-world scenarios. He proposed the membership functions for truth, indeterminacy, and falsity, where the sum of these three membership values is unbounded. NSs are advantageous to deal with quantitative data. Karamaşa et al. [31] used Neutrosophic AHP for selecting the right logistic service provider. Yazdani et al. [32] used CRITIC - CoCoSo under Interval Valued Fuzzy Neutrosophic environment for evaluation and selection of suppliers for a dairy company in Iran.

1.1 Research Gap

One of the helpful pieces of machinery for lifting and transferring palletized things is the forklift. Finding a suitable forklift unit for transport handling in a warehouse is therefore crucial. To the best of our knowledge, there isn't much research in the literature where the development of FUCOM under NE and consideration of the best forklift for a warehouse have been made. These research gaps have motivated us to introduce FUCOM under NE to model and solve the problem of optimal forklift selection for warehouse.

1.2 Motivation

The motivation of the present research is two-fold.

- First of all, a forklift is one of the most frequently used material handling instruments and is particularly helpful for industrial storage. Therefore, choosing a suitable forklift for transport handling is necessary for business houses for optimal service of the forklifts.
- Secondly, one of the most widely used MCDM strategies, FUCOM, is quite helpful in resolving practical decision-making issues. Therefore, it makes sense to develop such a consistent MCDM technique under NE to address problems in real life.

1.3 Novelty

The fact that Neutrosophic Numbers (NNs) demonstrate a broad model function for truth, indeterminacy and falsity memberships, with the sum falling between (0 -,1+), makes them useful for addressing a variety of real-world decision-making problems (DMPs). As a result, NNs are more able to handle a range of ambiguities that arise in DMPs than other existing fuzzy numbers, such as intuitionistic and Pythagorean fuzzy numbers. On the other hand, forklifts are a very valuable piece of equipment for transport handling in warehouses, thus choosing the right forklift unit is a crucial task. So, in this paper, SVTNNs are used as uncertain data to select the optimal forklift for a warehouse. The novelty of the present study is twofold:

- Firstly, the problem of optimal forklift selection for a warehouse has been considered under NE and solved using the proposed integrated MCDM approach.
- Secondly, FUCOM has been introduced under NE by defining a new score and ranking function for SVTNNs, through which the linguistic assessments of the decision makers are addressed.

1.4 Contribution

The main contributions of the proposed research are given below:

- By introducing a novel scoring and ranking function of SVTNNs to determine criteria weights, a novel SVTNFUCOM has been developed.
- An optimal forklift selection problem for warehouse operation is modeled and solved using the proposed SVTNFUCOM and the alternatives are ranked using MOORA.
- Various comparative and sensitivity analyses have been carried out to check the robustness, reliability and consistency of the proposed integrated approach.

The rest of the paper is laid out as given below: Section 2 includes a brief literature review on forklift for transport handling. Preliminaries on NNs are covered in Section 3. SVTNLPP and SVTNFUCOM with the suggested score and accuracy function have been presented in Section 4. The application of the proposed approach in forklift selection presented in Section 5 demonstrates the efficacy of projected integrated MCDM technique. The findings are discussed in detail in Section 6 and compared with other MCDMs together with SA. Section 7 concludes by summarizing the proposed technique, addressing limitations and suggesting the future study direction.

2. Literature Review

A large number of modern studies are there in literature, where MCDM techniques are used to solve the problems of transport handling. Forklift is one of the useful equipment for lifting and moving palletized items. Pallet load handling in warehouses, which includes receiving, transport, disposal and loading and unloading of items, are almost impossible without the employment of appropriate forklift trucks [33]. Some of the popular types of forklift are warehouse forklift, side loader forklift, counterbalance forklift, heavy-duty forklift, rough terrain forklift, pallet jack forklift etc. However, the technical and operational characteristics of forklifts are largely determined by factors, such as the type of load, the type and size of the warehouse designed to handle these loads, and most importantly, the warehouse managers' ability to obtain optimal handling equipment that meets their requirements. According to a study conducted by the research firm Research and Markets, the forklift market will reach 2.2 million units in 2023, with a compound annual growth rate (CAGR) of nearly 9% [34]. According to Prnewsire [35], the forklift market is expected to rise at a 7.8% annual rate, from 2 billion in 2020 to 2.9 billion in 2035. The rising use of new technologies in the process of boosting the productivity of resources owned by businesses is the key element driving the market's dynamic growth. While the retail industry, particularly e-commerce, is driving the forklift business, the rise of automated guided vehicles is posing a significant challenge to the market. The widespread usage of forklifts is in numerous areas, such as transportation and logistics accounts for the high growth rate of this equipment. Mešić et al. [36] used an integrated CRITIC- MARCOS mode to compare and rank the Western Balkan countries' Logistics Performance Index (Bosnia and Herzegovina, North Macedonia, Albania, Serbia, and Montenegro), which was calculated by the World Bank for 2018. As the problem of forklift selection is also under the category of MTS, so various researchers modeled this problem as MCDM problem and solved it using various integrated MCDM techniques. During the literature survey, it has been noticed that a very few researches have concentrated on selection of optimal forklift unit for warehousing, especially using MCDM technique. In this section, a brief literature on forklift for transport handling has been discussed.

Ombale et al. [37] designed and developed forklift which will lift the load and then transfer the load from one place to another place. Gawade et al. [38] designed electrically powered forklift for material handling in industrial warehouses and workshops. Chen et al. [39] presented the power system structure of electric forklift and the battery–super capacitor hybrid energy management method of electric forklift truck. Conte et al. [40] theoretically and experimentally evaluated the effective technical and economical benefits of newly commercialized electric forklift by means of a conventional electric forklift. Barrois et al. [41] presented a combination of Fuzzy Analytic Hierarchy Process and Fuzzy Decision Making Trial and Evaluation Laboratory to select the most suitable supplier of forklift filters.

In 2011, Alberti et al. [1] developed a Decision Support System (DSS) for selecting the best milling machine tool using an artificial neural network. Atanasković et al. [42] applied Delphy method for selection of forklift unit for warehouse. Pamucar and Ćirović [43] used DEMATEL-MABAC model in the process of making investment decisions on the acquisition of forklifts in logistics centers. Prusa et al. [44] used TOPSIS method to select forklift truck for logistic company. Fazlollahtabar et al. [45] used FUCOM-WASPAS model to select side-loading forklift for warehouse. Mahmutagić et al. [46] proposed an integrated forklift selection model using Data Envelopment Analysis (DEA), FUCOM) and Measurement Alternatives and Ranking According to the Compromise Solution (MARCOS) methods. In [47], authors used an integrated CRITIC-MARCOS approach for forklift selection in the warehousing system.

3. PRELIMINARIES

Smarandache [30] introduced neutrosophic sets (NSs), a combination of fuzzy sets (FSs) and IFSs. They are characterized by truth (T), indeterminacy (I) and a falsity (F) membership function (MF) and they are a useful tool for dealing with incomplete, ambiguous and inconsistent information in the actual world (F). Indeterminacy may be simply defined and truth, indeterminacy and falsity MFs are all independent, making this theory extremely helpful in a variety of applications. Different significant concepts regarding NSs are discussed in this section.

3.1 Definition (Neutrosophic Sets)

A Neutrosophic Sets (NS) [48] N in X , the universe of discourse is characterized by a truth, indeterminacy and falsity MFs T_N, I_N and F_N, respectively; where T_N, I_N and F_N are mappings from X to [0,1] denoted by N = {< x, (T_N, I_N, F_N >}, where x belongs to X, T_N, I_N, F_N belongs to (0^-, 1^+) and $T_N + I_N + F_N$ belongs to [0^-, 1^+].

3.2 Definition (Single-valued Neutrosophic Sets)

Let X be the universe with generic elements in ϑ denoted by x. A single valued NS S^N (SVNS) is characterized by truth MF, T_S^N (x), an indeterminacy MF, I_S^N (x) and a falsity MF, F_S^N (x) and is defined as

$$S^N = \left\{ \langle x : T_S^N(x), I_S^N(x), F_S^N(x) \rangle : x \in \vartheta \right\}$$

3.3 Definition (Single-Valued Triangular Neutrosophic Number)

A single valued triangular neutrosophic number (SVTNN) A = <(a,b,c): T_A,I_A, F_A> is a NS on the set of real number R , whose truth, indeterminacy and a falsity MFs are as follows:

$$T_A(x) = \begin{Bmatrix} \frac{(x-a)T_A}{b-a}, a \le x \le b \\ T_A, x = b \\ \frac{(c-x)T_A}{c-b}, b \le x \le c \\ 0, otherwise \end{Bmatrix}, I_A(x) = \begin{Bmatrix} \frac{(b-x+I_A(x-a))}{b-a}, a \le x \le b \\ I_A, x = b \\ \frac{(x-b+I_A(c-x))}{c-b}, b \le x \le c \\ 1, otherwise \end{Bmatrix}, F_A(x) = \begin{Bmatrix} \frac{(b-x+F_A(x-a))}{b-a}, a \le x \le b \\ F_A, x = b \\ \frac{(x-b+I_A(c-x))}{c-b}, b \le x \le c \\ 1, otherwise \end{Bmatrix}$$

where T_A, I_A, F_A belongs to [0,1]; a, b, c belongs to R; x belongs to X.

3.4 Definition (Operations on Single-Valued Triangular Neutrosophic Numbers)

Let A = < *(a, b, c):* T_A, I_A, F_A>, A_1 = < (a_1, b_1, c_1): T_1^A, I_1^A, F_1^A > and A_2 = < (a_2, b_2, c_2): T_2^A, I_2^A, F_2^A > be three SVTNNs. The operations for SVTNNs are defined as follows:

a. $$A_1 \oplus A_2 = \langle (a_1 + a_2, b_1 + b_2, c_1 + c_2), \min(T_1^A, T_2^A), \max(I_1^A, I_2^A), \max(F_1^A, F_2^A) \rangle \quad (1)$$

b. $$A_1 \otimes A_2 = \langle (a_1 a_2, b_1 b_2, c_1 c_2), \min(T_1^A, T_2^A), \max(I_1^A, I_2^A), \max(F_1^A, F_2^A) \rangle \quad (2)$$

c. $$\mu A = \langle (\mu a, \mu b, \mu c) : T_A, I_A, F_A \rangle, \mu > 0 \quad (3)$$

3.5 Definition (Score and Accuracy Function of SVTNN)

Let A = < *(a, b, c):* T_A, I_A, F_A> be a SVTNN, then score and accuracy function of A is defined as follows:

a. $$s(A)=\frac{(a+2b+c)(2+T_A-I_A-F_A)}{12} \quad (4)$$

b. $$a(A)=\frac{(a+2b+c)(2+T_A-I_A-F_A)}{12} \quad (5)$$

3.6 Ranking of Single-Valued Triangular Neutrosophic Number

Let $A_1 = < (a_1, b_1, c_1): T_1^A, I_1^A, F_1^A >$ and $A_2 = < (a_2, b_2, c_2): T_2^A, I_2^A, F_2^A >$ be two SVTNNs. The ranking of the SVTNNs is defined as follows:

a. If $s(A_1) < s(A_2)$, then $A_1 < A_2$.
b. If $s(A_1) = s(A_2)$ and if
  i. $a(A_1) < a(A_2)$, then $A_1 < A_2$
  ii. $a(A_1) > a(A_2)$, then $A_1 > A_2$

Neutrosophic Sets (NS) N in X , the universe of discourse is characterized by a truth, indeterminacy and falsity MFs T_N, I_N and F_N, respectively; where T_N, I_N and F_N are mappings from X to [0,1] denoted by N = {< x, (T_N, I_N, F_N >}, where x belongs to X, T_N, I_N, F_N belongs to (0^-, 1^+) and $T_N + I_N + F_N$ belongs to [0^-, 1^+].

3.7 Multi-Objective Optimization Method Based on Ratio Analysis

The multi-objective optimization method based on ratio analysis (MOORA) was presented by Brauers and Zavadskas [49,50]. A set of weighted targeting criteria can be incorporated into mineral potential maps using this technique. In the first stage, positive and negative signs are employed to separate targeting criteria. A set of criteria with a positive sign indicates that higher values should take precedence. Negative criteria, on the other hand, prioritize lower-valued items. Here MOORA was applied to rank alternatives. The following is an explanation of the MOORA method:

Step 1: First create the matrix below, where m and n represent the number of unit cells in the area and the number of targeting criteria, respectively [50]

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (6)$$

Step 2: Normalize each x_{ij} in the above matrix to x^*_{ij}, with values ranging from [0, 1] for individual targeting criterion, using the following equation:

$$x^*_{ij}=\frac{x_{ij}}{(\sum_{i=1}^{m} x_{ij}^2)^{\frac{1}{2}}},\ j=1,2,...,n \quad (7)$$

Step 3: Determine the following optimization function to evaluate the possible values allocated to individual unit cells y_i:

$$y_i = \sum_{j=1}^{g} w_j x_{ij}^* - \sum_{j=g+1}^{n} w_j x_{ij}^* \tag{8}$$

where g and w_j respectively denote the number of beneficial criteria and the weight allocated to the j^{th} criterion. Here rest of the criteria is considered to be non-beneficial criteria.

Step 4: Finally rank alternatives as per values of y_i in ascending order.

4. Proposed Method

In this section, we have introduced FUCOM under NE for the selection of optimal forklift for warehouse, by representing the linguistic assessment of decision-maker (DM) by SVTNNs. To calculate criteria weights, we have used FUCOM and the alternatives are ranked through MOORA. To describe the proposed method, let us first discuss some newly introduced concepts as follows:

4.1 Single Valued Triangular Neutrosophic Score and Accuracy Function

Let $A = \langle (a, b, c): T_A, I_A, F_A \rangle$ be a SVTNN. The main aim of the score function is to convert the SVTNN to a crisp number. The mean of the TNN is $(x + y + z)/3$. The score value of MF is $(2 + T_A - I_A - F_A)/3$. Thus the proposed score function is defined as

$$s(A) = \frac{(x+y+z)(2+T_A - I_A - F_A)}{9} \tag{9}$$

Also the accuracy function is defined as

$$a(A) = \frac{(x+y+z)(2+T_A - F_A)}{9} \tag{10}$$

4.2 Properties of Score Function

Some of the properties of the proposed score function of SVTNN are given below:

i. If $T_A = 1, I_A = 0$ and $F_A = 0$, then $s(A) = 1$.

ii. If $T_A = 0, I_A = 1$ and $F_A = 1$, then $s(A) = 0$.

iii. Both score and accuracy functions of SVTNN are real numbers.

4.3 Ranking of SVTNNs in respect of proposed score and accuracy functions

Suppose $A_1 = \langle (a_1, b_1, c_1): T_1^A, I_1^A, F_1^A \rangle$ and $A_2 = \langle (a_2, b_2, c_2): T_2^A, I_2^A, F_2^A \rangle$ be two SVTNNs. The ranking of the SVTNNs is defined as follows:

a. If $s(A_1) < s(A_2)$, then $A_1 < A_2$

b. $s(A_1) = s(A_2)$ and if

   i. $a(A_1) > a(A_2)$, then $A_1 > A_2$

   ii. $a(A_1) < a(A_2)$, then $A_1 < A_2$

   iii. $a(A_1) = a(A_2)$, then $A_1 = A_2$

4.4 Ranking Function of SVTNN

Let $A = < (a, b, c): T_A, I_A, F_A>$ be a SVTNN. The ranking function of the SVTNN is defines as:

$$R(A) = \frac{(x+y+z)(2+\min T_A - \max I_A - \max F_A)}{9} \tag{11}$$

4.5 Single Value Triangular Neutrosophic Linear Programming Problem (SVTNLPP)

Let us take the general form of the proposed SVTNLPP involving m constraints with n unknowns, where all coefficients and resources are represented by SVTNNs as follows:

$$\begin{aligned} &\max \ (\min) \ c^T x; \\ &\text{Subject to} \quad Ax \le b; x \ge 0 \end{aligned} \tag{12}$$

where c, A and b be the matrices of dimensions n, m×n and m respectively. They are represented by SVTNNs as follows:

Let $c = < (c_1, c_2, c_3): T_c, I_c, F_c>$ be the cost vector; $A = < (a, b, c): T_A, I_A, F_A>$ be the coefficient matrix and $b = <(b_1, b_2, b_3): T_b, I_b, F_b>$ be the vector of resources. Thus the proposed SVTNLPP has become

$$\begin{aligned} &\max \ (\min) \ < (c_1, c_2, c_3): T_c, I_c, F_c > T_x \\ &\text{Subject to} \quad < (a, b, c): T_A, I_A, F_A > x \ \le < (b_1, b_2, b_3): T_b, I_b, F_b >; \ x \ge 0 \end{aligned} \tag{13}$$

The proposed algorithm to solve system (13) is as follows:

Step 1: Let us first consider system given by Eq. (12).

Step 2: To convert the SVTNLPP to crisp LPP, use Eq. (11) and system given by Eq. (13) will then become

$$\begin{aligned} &\max \ (\min) \ R\,(< (c_1, c_2, c_3): T_c, I_c, F_c > T)\, x \\ &\text{Subject to} \quad R\,(< (a, b, c): T_A, I_A, F_A >)\, x \ \le \ R\,(< (b_1, b_2, b_3): T_b, I_b, F_b >); \ x \ge 0 \end{aligned} \tag{14}$$

Step 3: As system (14) is a crisp LPP, use LINGO 19.0 software to solve system (14) to obtain optimal solution of the proposed SVTNLPP.

4.6 Proposed Single Valued Triangular Neutrosophic FUCOM (SVTNFUCOM)

In this subsection, the procedure of the proposed SVTNFUCOM is presented to obtain the criteria weights of any MCDM problem.

Suppose there are m alternatives A_i, $i = 1, 2, \dots, m$; n criteria $C_j, j = 1, 2, \dots, n$ and w_j be the weight of the j^{th} criterion. Algorithm of the proposed SVTNFUCOM is discussed below:

Step 1: First, rank the criteria in order of priority among the predefined set of evaluation criteria C_j, $j = 1, 2, \dots, n$, starting with the criterion that is predicted to have the highest weight:

$$C_{j(1)}, C_{j(2)}, ..., C_{j(r)}) \tag{15}$$

where r denotes the rank of each criterion. If there is more than one criterion having same rank, the sign of '='is used in place of '>' between them in Eq. (15).

Step 2: Compare these criteria by determining the comparative priority (CP) $\phi_{k/k+1}$, $k = 1, 2, ..., n$ of each criterion. Thus the CP vector is determined as

$$\phi = (\phi_{1/2}, \phi_{2/3}, ..., \phi_{k/(k+1)}) \tag{16}$$

where $\phi_{k/k+1}$ denotes priority of the criterion of the $C_{j(k)}$ rank to the criterion of the $C_{j(k+1)}$ rank.

Step 3: Next calculate the final values of the weight vector $(w_1, w_2, ..., w_n)^T$, where $w_j = <(a_j, b_j, c_j): T_w, I_w, F_w) >, j = 1, 2, ..., n$ of the evaluation criteria satisfying following two conditions:

$$\begin{aligned} &\text{i. } \frac{w_k}{w_{k+1}} = \phi_{k/k+1} \\ &\text{ii. } \phi_{k/(k+1)} \otimes \phi_{k+1/k+2} = \phi_{k/k+2} \\ &\text{that is, } \frac{w_k}{w_{k+1}} \otimes \frac{w_{k+1}}{w_{k+2}} = \frac{w_k}{w_{k+2}} \end{aligned} \tag{17}$$

Thus the weight coefficients must satisfy the condition

$$\frac{w_k}{w_{k+2}} = \phi_{k/k+2} \tag{18}$$

The minimum deviation of full consistency (DFC) $\chi = \langle (a,b,c): T_\chi, I_\chi, F_\chi \rangle$ is satisfied only if transitivity is satisfied, i.e. when the conditions of $\frac{w_k}{w_{k+1}} = \phi_{k/k+1}$, $\frac{w_{k+1}}{w_{k+2}} = \phi_{k+1/k+2}$ and $\frac{w_k}{w_{k+2}} = \phi_{k/(k+1)} \otimes \phi_{k+1/k+2}$ are met so that the requirement for maximum consistency is fulfilled, i.e. DFC is $\chi = 0$ for the obtained values of the weight vector. In order for the conditions to be met, it is necessary that the values of the weight vector $(w_1, w_2, ..., w_n)^T$ meet the condition of $\left| \frac{w_k}{w_{k+1}} - \phi_{k/k+1} \right| < \chi$ and $\left| \frac{w_k}{w_{k+2}} - \phi_{k/(k+1)} \otimes \phi_{k+1/k+2} \right| < \chi$, with the minimization of the value χ. The condition for maximum consistency is met in this way.

The final model for finding the final weight vector of the criterion can be defined as below based on the following settings:

$$\min \chi$$

$$\text{Subject to } \left| \frac{w_{j(k)}}{w_{j(k+1)}} - \phi_{k/k+1} \right| < \chi, \forall j; \left| \frac{w_{j(k)}}{w_{j(k+2)}} - \phi_{k/(k+1)} \otimes \phi_{k+1/k+2} \right| < \chi, \forall j; \sum_{j=1}^{n} w_j = 1, \forall j; w_j \geq 0, \forall j \tag{19}$$

Step 4: Rewrite system (19) as

$$
\begin{aligned}
&\min\ \langle (a,b,c):T_\chi, I_\chi, F_\chi \rangle \\
&\text{Subject to} \\
&\left| \frac{\langle (a_{j(k)}, b_{j(k)}, c_{j(k)}) : T_{j(k)}, I_{j(k)}, F_{j(k)} \rangle}{\langle (a_{j(k+1)}, b_{j(k+1)}, c_{j(k+1)}) : T_{j(k+1)}, I_{j(k+1)}, F_{j(k+1)} \rangle} - \phi_{k/k+1} \right| < \langle (a,b,c):T_\chi, I_\chi, F_\chi \rangle, \forall j \\
&\left| \frac{\langle (a_{j(k)}, b_{j(k)}, c_{j(k)}) : T_{j(k)}, I_{j(k)}, F_{j(k)} \rangle}{\langle (a_{j(k+2)}, b_{j(k+2)}, c_{j(k+2)}) : T_{j(k+2)}, I_{j(k+2)}, F_{j(k+2)} \rangle} - \phi_{k/(k+1)} \otimes \phi_{k+1/k+2} \right| < \langle (a,b,c):T_\chi, I_\chi, F_\chi \rangle, \forall j \\
&\sum_{j=1}^{n} \langle (a_j, b_j, c_j) : T_w, I_w, F_w \rangle = \langle (1,1,1):1,0,0 \rangle, \forall j \\
&\langle (a_j, b_j, c_j) : T_w, I_w, F_w \rangle \geq \langle (0,0,0):0,1,1 \rangle, \forall j
\end{aligned} \tag{20}
$$

Step 5: Convert the SVTNLPP to crisp LPP using Eq. (11) in system (20) as follows:

$$
\begin{aligned}
&\min\ R(\langle (a,b,c):T_\chi, I_\chi, F_\chi \rangle) \\
&\text{Subject to} \\
&R(\left| \frac{\langle (a_{j(k)}, b_{j(k)}, c_{j(k)}) : T_{j(k)}, I_{j(k)}, F_{j(k)} \rangle}{\langle (a_{j(k+1)}, b_{j(k+1)}, c_{j(k+1)}) : T_{j(k+1)}, I_{j(k+1)}, F_{j(k+1)} \rangle} - \phi_{k/k+1} \right|) < R(\langle (a,b,c):T_\chi, I_\chi, F_\chi \rangle), \forall j \\
&R(\left| \frac{\langle (a_{j(k)}, b_{j(k)}, c_{j(k)}) : T_{j(k)}, I_{j(k)}, F_{j(k)} \rangle}{\langle (a_{j(k+2)}, b_{j(k+2)}, c_{j(k+2)}) : T_{j(k+2)}, I_{j(k+2)}, F_{j(k+2)} \rangle} - \phi_{k/(k+1)} \otimes \phi_{k+1/k+2} \right|) < R(\langle (a,b,c):T_\chi, I_\chi, F_\chi \rangle), \forall j \\
&\sum_{j=1}^{n} R(\langle (a_j, b_j, c_j) : T_w, I_w, F_{wj} \rangle) = R(\langle (1,1,1):1,0,0 \rangle), \forall j \\
&R(\langle (a_j, b_j, c_j) : T_w, I_w, F_{wj} \rangle) \geq R(\langle (0,0,0):0,1,1 \rangle), \forall j
\end{aligned} \tag{21}
$$

Solve the crisp LPP (21) using LINGO 19.0 software to get the final weight vector $(w_1, w_2, \ldots, w_n)^T$.

5. Application of the Proposed Integrated Model in Forklift Selection for Warehouse

Transportation is an extension of the manufacturing process and one of the most significant aspects of firm logistics management. Transport is required to carry raw and supporting materials to their processing locations, as well as to move commodities within the manufacturing process, so that finished or semi-finished products can be transported to market using various modes of transportation. The forklift is one of the most commonly used modes of delivery for commodities in the actual manufacturing process. The results of the research can be applied in the real-world when choosing the best forklift unit for a warehouse operation with the help of a case study. The process of selecting the best transport/handling unit (forklift) is part of the investment decision-making process. The criteria for selecting the best transport handling forklifts have been identified and illustrated in Table 1.

The Euro-Roal company possesses a number of forklifts that are more than 20 years old and ten (10) alternatives (side-loading forklifts), viz. Forklift 1 to Forklift 10 will be investigated to improve and refine their fleet [45]. Ten (10) different alternatives are assessed with the purpose of putting the study to the test, with the best option being chosen for the investor based on the criteria. Forklift models of ten distinct manufacturers have chosen and studied. All of the chosen forklift models meet the standards for warehouse operating based on their basic characteristics. One of them will be selected as a Euro-Roal candidate.

Table 1 Description of evaluation criteria

Sl. No.	Criteria	Description
Cr1	Purchase cost	On the market, forklift prices vary depending on the manufacturer. The purchase price should not be important for the buyer when making an investment decision, but it does have a substantial impact on the final decision. Once the essential parameters are completed in an ad hoc approach, the purchase price is frequently a deciding factor.
Cr2	Age	A forklift's manufacturing period is defined by its age or year of manufacture. Recently made Forklifts have superior specifications and alternatives for customizing them to meet individual needs.
Cr3	Working time	When choosing a forklift, one of the most crucial factors to consider is the forklift's utilization time. The lower the number of hours a forklift is used, the less likely it is to break down.
Cr4	Maximum load capacity	The maximum load capacity of a forklift is a metric that measures how much weight a forklift can lift in kg.
Cr5	Maximum lift height	The maximum lift height is a criterion that describes how high a forklift can raise anything.
Cr6	Environmental factors	Environmental impact of forklift operating.
Cr7	Supply of spare parts	Some representatives functioning in the Republic of Serbia's market do not have in stock all necessary spare parts that are subject to frequent replacements and their delivery takes weeks, leading the means to be fixed for a long time.

According to Petrović et al. [51], determination of the significance of criteria is one of the most crucial steps in the DMP. The decision-maker employed a 9-level set of linguistic factors listed in Table 2 to score the alternatives and criteria.

At first, SVTNFUCOM has been applied to find weights of the criteria for selecting the optimal forklift based on the linguistic assessments of expert. The linguistic assessments have been considered as SVTNNs. Then out of 10 forklifts, the best one has been selected using MOORA [52]. The algorithm of the proposed method to select optimal forklift for warehouse has been discussed below:

5.1 Algorithm

Step 1: The evaluation criteria are ranked as: Cr3 > Cr2 > Cr4 = Cr5 > Cr1 > Cr7 > Cr6.

Table 2 9-level scale to rate criteria and alternatives

Extreme Low	Very Low	Low	Moderate Low	Moderate	Moderate High	High	Very High	Extreme High
EL	VL	L	ML	M	MH	H	VH	EH

Step 2: Perform a PWC of the ranked criteria with respect to the first ranked criterion Cr1, based on 9-level scale depicted in Table 3. Thus the significances of criteria are obtained for all criteria ranked in Step 1.

Step 3: Following Step 3 of the proposed SVTNFUCOM, the SVTNLPP is formulated as follows:

$$\min \chi$$

$$\begin{aligned}
&\text{Subject to } \left|\frac{w_3}{w_2} - \langle(1,2,3):(.9,.1,.1)\rangle\right| < \chi; \left|\frac{w_2}{w_4} - \langle(2,1.5,1.33):(.89,.11,0)\rangle\right| < \chi; \\
&\left|\frac{w_4}{w_5} - \langle(1,1,1):(1,0,0)\rangle\right| < \chi; \left|\frac{w_5}{w_1} - \langle(2,1.67,1.5):(.75,.125,.22)\rangle\right| < \chi; \\
&\left|\frac{w_1}{w_7} - \langle(1.25,1.2,1.17):(.83,.14,.14)\rangle\right| < \chi; \left|\frac{w_7}{w_6} - \langle(1.4,1.33,1.28):(.8,0,.14)\rangle\right| < \chi; \\
&\left|\frac{w_3}{w_4} - \langle(2,3,4):(.89,.11,.1)\rangle\right| < \chi; \left|\frac{w_2}{w_5} - \langle(2,1.5,1.33):(.89,.11,0)\rangle\right| < \chi; \\
&\left|\frac{w_4}{w_1} - \langle(2,1.67,1.5):(.75,.125,.22)\rangle\right| < \chi; \left|\frac{w_5}{w_7} - \langle(2.5,2.004,1.76):(.75,.14,.22)\rangle\right| < \chi; \\
&\left|\frac{w_1}{w_6} - \langle(1.75,1.596,1.5):(.8,.14,.14)\rangle\right| < \chi; \sum_{j=1}^{7} w_i = \langle(1,1,1):1,0,0\rangle, \forall j; w_i \geq \langle(0,0,0):0,1,1\rangle, \forall j
\end{aligned} \tag{22}$$

Step 4: Using Eq. (11) in system (22), SVTNLPP has been converted into crisp LPP as follows:

$$\min R(\chi)$$

$$\begin{aligned}
&\text{Subject to } R(\left|\frac{w_3}{w_2} - \langle(1,2,3):(.9,.1,.1)\rangle\right|) < R(\chi); R(\left|\frac{w_2}{w_4} - \langle(2,1.5,1.33):(.89,.11,0)\rangle\right|) < R(\chi); \\
&R(\left|\frac{w_4}{w_5} - \langle(1,1,1):(1,0,0)\rangle\right|) < R(\chi); R(\left|\frac{w_5}{w_1} - \langle(2,1.67,1.5):(.75,.125,.22)\rangle\right|) < R(\chi); \\
&R(\left|\frac{w_1}{w_7} - \langle(1.25,1.2,1.17):(.83,.14,.14)\rangle\right|) < R(\chi); R(\left|\frac{w_7}{w_6} - \langle(1.4,1.33,1.28):(.8,0,.14)\rangle\right|) < R(\chi) \\
&R(\left|\frac{w_3}{w_4} - \langle(2,3,4):(.89,.11,.1)\rangle\right|) < R(\chi); R(\left|\frac{w_2}{w_5} - \langle(2,1.5,1.33):(.89,.11,0)\rangle\right|) < R(\chi) \\
&R(\left|\frac{w_4}{w_1} - \langle(2,1.67,1.5):(.75,.125,.22)\rangle\right|) < R(\chi); R(\left|\frac{w_5}{w_7} - \langle(2.5,2.004,1.76):(.75,.14,.22)\rangle\right|) < R(\chi); \\
&R(\left|\frac{w_1}{w_6} - \langle(1.75,1.596,1.5):(.8,.14,.14)\rangle\right|) < R(\chi); \sum_{j=1}^{7} w_i = 1, \forall j; w_i \geq 0, \forall j
\end{aligned} \tag{23}$$

Solving system of system (23) using LINGO 19.0 version, the final weight vector of the criteria is obtained as follows:

w_1 = 0.09, w_2 = 0.18, w_3 = 0.33, w_4 = 0.13, w_5 = 0.13, w_6 = 0.06, w_7 = 0.08 and the DFC is $\chi \approx 0.04$.

Step 5: The initial decision matrix (IDM) is furnished in Table 3 as follows:

Table 3 Initial decision matrix

Alternatives	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7
FL1	7.95	10	5012	4000	5400	5	7.67
FL2	12.9	10	7140	3000	3500	7	7.67
FL3	17.8	9	6500	5000	4500	7	5
FL4	19.3	19	4312	3000	6000	3	3.67
FL5	1.87	18	12000	3000	4000	5	3
FL6	3.4	7	4800	4000	4000	7.67	9
FL7	8.093	25	12000	4000	5900	3	5
FL8	29.8	11	3720	3000	5100	9	9
FL9	13.75	17	15350	4500	4800	3	5
FL10	18.297	13	6122	3000	4000	5	7

Step 6: In the present case study, as Cr1, Cr2 and Cr3 are non-beneficiary criteria and Cr4, Cr5, Cr6 and Cr7 are beneficiary criteria, so to make all the criteria of the same type, the IDM has been normalized by using Eq. (7). The normalized decision matrix (NDM) is presented in Table 4.

Table 4 Normalized decision matrix

Alternatives	Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7
FL1	0.135573	0.212286	0.18488	0.340195	0.356438	0.271231	0.371557
FL2	0.219987	0.212286	0.263377	0.255146	0.231024	0.379724	0.371557
FL3	0.303548	0.2	0.239769	0.425243	0.297031	0.379724	0.242215
FL4	0.329127	0.403343	0.159059	0.255146	0.396042	0.162739	0.177786
FL5	0.185369	0.382115	0.44265	0.255146	0.264028	0.271231	0.145329
FL6	0.518418	0.1486	0.17706	0.340195	0.264028	0.416069	0.435987
FL7	0.138012	0.530715	0.44265	0.340195	0.389441	0.162739	0.242215
FL8	0.508186	0.233515	0.137221	0.255146	0.336635	0.488216	0.435987
FL9	0.234482	0.360886	0.566223	0.382719	0.316833	0.162739	0.242215
FL10	0.312023	0.275972	0.225825	0.255146	0.264028	0.271231	0.339101

Step 7: Finally, using Eq. (8) the values of y_i and the ranking of alternatives are determined and furnished in Table 5**.**

Table 5 Ranking of alternatives

Forklifts	y_i	Ranking
FL1	0.025137	1
FL2	-0.02921	6
FL3	-0.00639	4
FL4	-0.04607	7
FL5	-0.13615	9
FL6	-0.00532	3
FL7	-0.08772	8
FL8	0.016455	2
FL9	-0.15283	10
FL10	-0.02357	5

6. Results and Discussion

According to the findings of this study, FL1 is identified as the optimal choice for warehouse. FL8, FL6, FL3, FL10, FL2, FL4, FL7, FL5 and FL9 have been ranked as 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, 9th and 10th position respectively. The performance of the alternatives through the proposed approach is shown in Fig. 1. From Table 5, it could be observed that the values of y_i are lying in between –1 and +1, that is a variation is found in the values.

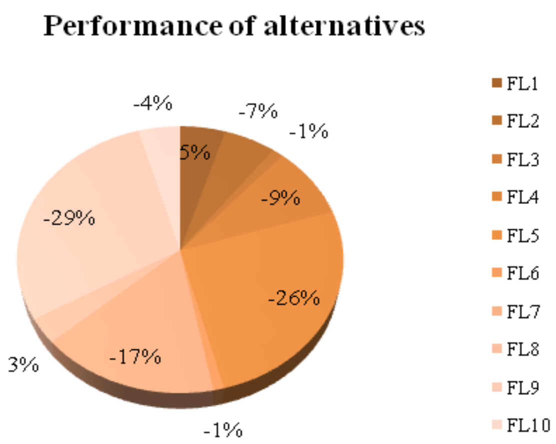

Fig. 1 Performance of alternatives through proposed integrated approach

To check the consistency of the proposed technique, a comparison has been carried in subsection 6.1 between the results obtained by the proposed method and other well-known MCDM techniques.

6.1 Comparison

The results obtained through proposed integrated approach are compared with other well-known MCDM techniques, viz. Technique for the Order of Prioritization by Similarity to Ideal Solution (TOPSIS), Weighted Aggregated Sum Product Assessment (WASPAS), Complex Proportional Assessment (COPRAS), Additive Ratio Analysis (ARAS), Multi-Attributive Border Approximation area Comparison (MABAC), Combined Compromise Solution (CoCoSo), Weighted Sum Model (WSM) and Weighted Product Model (WPM). The rank of alternatives obtained through all the methods are furnished in Table 6.

The comparison shows that all the methods, except WSM and ARAS, have identified FL1 as the best alternative for warehouse. WSM and ARAS have identified FL8 as the best choice of forklift. A small violation could be observed in the ranking order of the comparatively lower ranked alternatives. This has been occurred as a result of the diverse methods considered for ranking the alternatives. Fig. 2 shows the comparison of scores of the alternatives obtained through TOPSIS, WASPAS, COPRAS, ARAS, WSM, WPM, MABAC, CoCoSo and the proposed approach.

Table 6 Comparison between different ranking methods

Ranking methods	**Ranking orders of alternatives**
TOPSIS	FL1 > FL8 > FL6 > FL3 > FL10 > FL4 > FL2 > FL5 > FL7 > FL9
WASPAS	FL1 > FL8 > FL6 > FL3 > FL4 > FL2 > FL10 > FL7 > FL9 > FL5
COPRAS	FL1 > FL6 > FL8 > FL3 > FL2 > FL10 > FL4 > FL5 > FL7 > FL9
WSM	FL8 > FL1 > FL6 > FL3 > FL4 > FL2 > FL10 > FL7 > FL9 > FL5
WPM	FL1 > FL8 > FL6 > FL3 > FL2 > FL4 > FL10 > FL7> FL5 > FL9
ARAS	FL8 > FL6 > FL1 > FL3 > FL4 > FL2 > FL10 > FL7 > FL9 > FL5
MABAC	FL1 > FL3 > FL6 > FL8 > FL4 > FL2 > FL10 > FL7 > FL9 > FL5
CoCoSo	FL1 > FL3 > FL6 > FL8 > FL10 > FL2 > FL4 > FL7 > FL9 > FL5
Integrated approach	FL1 > FL8 > FL6 > FL3 > FL10 > FL2 > FL4> FL7> FL5 > FL9

As there is a variation in the ranking order of the alternatives for different MCDM approaches, so to check the correlation between the other MCDM techniques with that of the proposed one, Spearman’s rank correlation coefficients have been determined as follows:

6.2 Spearman's rank correlation coefficient

Spearman's rank correlation coefficient is a measure which indicates how much the MCDM techniques are correlated to each other. It lies between -1 to +1. It the correlation coefficient between the methods is +1 or nearer to +1, they are said to be strongly correlated. In this study, the correlation coefficients between the proposed method and the other existing MCDM techniques have been calculated and presented in Table 7.

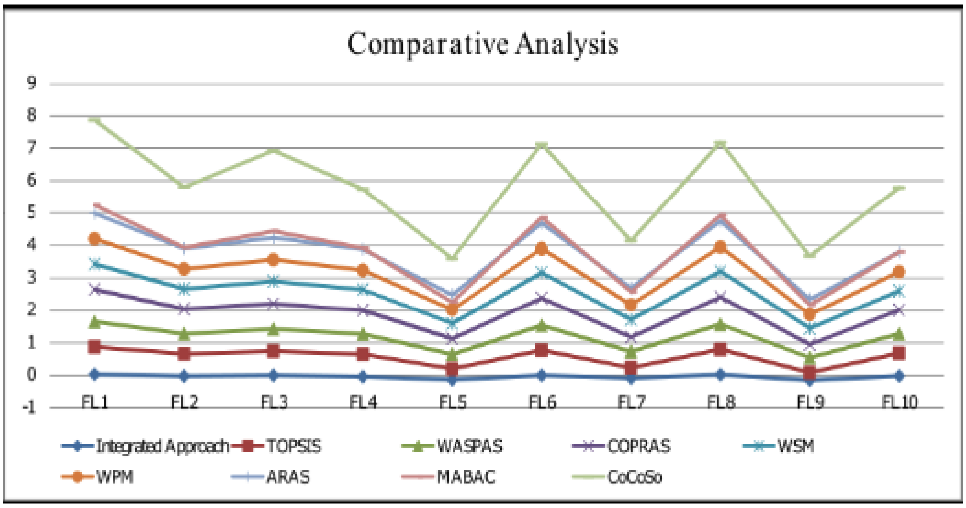

Fig. 2 Comparison between proposed approach and other MCDM methods

From the table, it could be observed that the correlation coefficients between the proposed integrated approach with other existing methods are nearer to +1, which indicates the strong correlation between the MCDMs with the proposed one. Thus it could be concluded that the proposed method is consistent and comparable with other MCDMs. For further validation of statistical consistency of the rankings obtained through the proposed integrated approach, WS coefficient between the proposed method with TOPSIS, WASPAS, COPRAS, WSM, WPM, ARAS, MABAC and CoCoSo have been calculated and obtained as (0.998, 0.984, 0.941, 0.898, 0.983, 0.824, 0.901, 0.916). From the results it is clear that the proposed method is strongly correlated with the other existing MCDM techniques.

6.3 Sensitivity Analysis

The weight coefficients of the criterion, or the proportional priority assigned to specific criteria, have a significant impact on the outcome of MCDM method. Because the final selections can alter when the weight coefficients of the criteria change even little, the results of MCDM approaches should be accompanied with a study of their sensitivity to these changes. In decision making problems, the purpose of sensitivity analysis (SA) is to see how the weights of criteria affect the outcome. Based on different scenarios revealed during the study, it may result in a shift in alternative precedence. It can be concluded that the obtained findings are sensitive or resilient if the achieved order of ranking changes when the importance of criterion is modified. In instances when it's difficult to determine the relative relevance of multiple aspects, SA can help decision-makers. Swapping the weights of one criterion with another is done to examine if switching the weights causes the order of precedence of alternatives to change.

Table 7 Spearman's rank correlation coefficient

	Integrated approach	TOPSIS	WASPAS	COPRAS	WSM	WPM	ARAS	MABAC	CoCoSo
Integrated approach	1	0.975	0.95	0.958	0.933	0.983	0.9	0.883	0.917
TOPSIS	-	1	0.942	0.967	0.925	0.975	0.892	0.875	0.875
WASPAS	-	-	1	0.892	0.983	0.967	0.95	0.933	0.9
COPRAS	-	-	-	1	0.858	0.958	0.84	0.858	0.892
WSM	-	-	-	-	1	0.95	0.98	0.883	0.85
WPM	-	-	-	-	-	1	0.917	0.9	0.9
ARAS	-	-	-	-	-	-	1	0.85	0.817
MABAC	-	-	-	-	-	-	-	1	0.967
CoCoSo	-	-	-	-	-	-	-	-	1

To check robustness of the proposed method, a sensitivity analysis (SA) is presented by varying the weights obtained for each criterion. In Table 8, the different cases of varying the weights and their impacts on the ranking of alternatives are shown.

From Table 8, it could be observed that FL1 is the optimal alternative for warehouse for any choice of weights for criteria. Also FL8 has obtained the second position in each of the cases; a little change could be observed in the ranking of lower ranked alternatives. So this SA verified the robustness and consistency of the proposed integrated approach. Fig. 3 shows SA for the variation in weights of criteria.

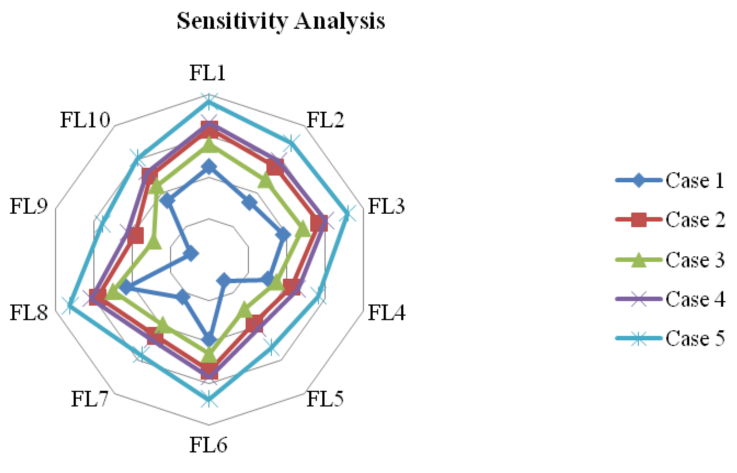

Fig. 3 Sensitivity Analysis

6.4 Managerial Inference

An effective approach for selecting the best forklift for a warehouse has been established in the suggested application. Managers of related businesses can use the proposed framework to choose which forklift is best for their warehouse. This will result in significant resource and expense savings, as well as in transportation implications. All of the criteria listed will assist firms in dealing with a variety of issues and improving their attempts to find user-friendly forklifts for transportation. Furthermore, the method of forklift selection criteria using industry expert responses and literature is a significant benefit of this suggested endeavor. Managers will be able to test the observation stability using the implemented sensitivity analysis.

The suggested model has a flaw in that subsystems linked with the criteria are not taken into account when minimizing complexity. So as future endeavor, the sub criteria may also be taken into consideration for the said purpose.

Table 8 Sensitivity Analysis

Cases	Variation in weights		Ranking of alternatives
Case 1	Weights obtained through proposed method		FL1 > FL8 > FL6 >FL3 > FL10 > FL2 > FL4 > FL7 > FL5 > FL9
Case 2	Assigning equal weights to each criterion		FL1 > FL8 > FL3 >FL2 > FL6 > FL10 > FL7 > FL4 > FL9 > FL5
Case 3	50% weights assigned to non-beneficial criteria	50% weights assigned to beneficial criteria	FL1 > FL8 > FL3 >FL2 > FL6 > FL10 > FL7 > FL4 > FL5 > FL9
Case 4	40% weights assigned to non-beneficial criteria	60% weights assigned to beneficial criteria	FL1 > FL8 > FL3 >FL2 > FL6 > FL10 > FL7 > FL4 > FL9 > FL5
Case 5	30% weights assigned to non-beneficial criteria	70% weights assigned to beneficial criteria	FL1 > FL8 > FL3 >FL2 > FL6 > FL10 > FL7 > FL4 > FL9 > FL5

7. CONCLUSION

In this research, FUCOM has been introduced under NE. The linguistic assessments of the experts have been considered as SVTNNs and the criteria weights are calculated using the proposed novel SVTNFUCOM. To do so, a novel SVTNLPP and a new score function have been introduced. The alternatives are ranked using MOORA. To validate the applicability of the proposed technique, it was used to choose transport and handling methods in a warehouse system. The study was carried out in a company that primarily trades and distributes aluminum profiles. The proposed method has identified FL1 as the optimal forklift for warehouse. The model in use allows for objective consideration of input parameters that influence the final decision. The comparison, which entails use of another eight popular MCDM approaches, demonstrates consistency of previously obtained results if the model is consistently applied across all conceivable versions. To check the robustness of the proposed method, a SA is presented by varying the weights of the beneficiary and non-beneficiary criteria. From SA also, it is seen that FL1 is the optimal choice for handling and transport in a warehouse.

The unique contribution of the present study is the introduction of FUCOM method under NE to model and solve the problem of forklift selection for transport handling. The key advantage of the proposed integrated strategy is that it allows warehousing system managers to make more decisions in order to improve the overall efficiency of the warehousing systems. It is feasible to readily estimate the efficiency of both forklifts and other equipment by using this model, and to pay greater attention to identify and monitor input and output characteristics by using this model. In light of the findings, warehousing system managers must conduct adequate monitoring of all forklift activities and rationalize all superfluous forklift movements and operations.

However, the suggested methodology has certain drawbacks, especially based on the assessment of single decision expert, final decision on forklift selection has been taken. In future, we shall collect several assessments from different domain experts, so that the problem of optimal forklift selection for warehouse can be modeled as a MCGDM problem and based on the aggregated assessments of experts, final decision can be made. In this regard various aggregation operators under NE can be taken into consideration.

From the foregoing, we may conclude that the warehousing systems of companies are extremely complicated, with several potential for cost reductions and opportunities to improve all activities and procedures inside it.

Future study might concentrate on ensuring that inefficient forklifts can be reusable. In this regard, to identify some recycling techniques for the damaged forklifts can also be taken into consideration, concerning circular economy. The construction of a model for estimating the efficiency of operating the selected side-loading forklift is also a future research topic related to this study. In this regard, other generalizations of fuzzy sets may also be applied to this problem. Moreover, while considering the problem as MCGDM, various aggregation operators under various fuzzy environments can be considered.

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