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Hazardous Materials Warehouse Selection as a Multiple Criteria Decision making Problem

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Abstract. Radioactive, toxic, smother, flammable, and explosive materials in solid, liquid or gas states which can negatively impact goods, organisms, and most importantly humans are called as "Hazardous Materials". Hazardous material transportation and storage carry risk factors in addition to their other types of transportation operations. Furthermore, selection of a suitable warehouse becomes a problematic issue in which multiple criteria are evaluated as paying attention to risky circumstances. In this context, hazardous material warehouse selection is considered as a multiple criteria decision problem in our study. In particularly, for the explosives storage among other hazardous materials, necessary criteria are determined according to expert's consultant. The determined criteria are weighted according to decision makers' consultancy and the alternatives are evaluated by fuzzy MULTIMOORA under uncertainty throughout the decision making process in the study.. The proposed approach is discussed on a case study.
Keywords. Fuzzy MULTIMOORA, Warehouse Selection, Hazardous Materials.
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1. Introduction

In addition to transportation of hazardous materials, other logistic operations including handling, storage and packaging carry importance. Hazardous materials, which can be found solid, liquid or gas states, may endanger environment and human safety aftermath of a negligence/accident during production, usage, handling, storage or transporting processes because of their natural conditions and have great risk to cause negative effects on environment and living organisms (Bali & Göztepe, 2014). Such risks as explosion, flaming, leaking and spreading the environment exist during hazardous material storage.

The logistic operations of hazardous materials of which warehouse selection has amplitude importance due to potential negative impacts over living organisms and the nature require great attention and serious trainings. United Nations divides hazardous chemicals into two groups as hazardous materials and articles and likewise categorized into totally 9 groups according to hazardous materials and articles characteristics in order to ease the hazardous material logistic processes. Internationally accepted order of hazardous materials could be presented as the following (IATA, 2013);

- Explosives,
- Gases,
- Flammable Liquids,

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- Flammable solids; Self-combustible materials; In contact with water emit flammable gases materials,
- Oxidizing substances and organic peroxides
- Toxic and Infectious Materials,
- Radioactive Materials,
- Corrosive Materials,
- Materials which may have other danger

The purpose of this classification is to accumulate the materials who have common dangerous characteristics so that suitable handling, storage, packaging and emergency intervention could be made.

In the research of hazardous material literature, it is observed that many studies generally focused on hazardous material transportation. On the other hand, this study in which the risks which may occur during hazardous material storage is taken into account offers an approach minimizing the risks over humankind and the nature. There are only very few studies focusing the suitable warehouse selection although there are many studies focusing various logistics operations and especially transportation issues. Necessary criteria for hazardous material warehouse selection are determined and the importance levels of the determined criteria are evaluated by decision maker group. A model is suggested in our study using fuzzy set theory since both criteria and decision makers group's evaluations carry uncertainty. Multiple Criteria Decision Making (MCDM) approach is utilized in order to determine the criteria and to order the alternatives because the decision making is hard since amplitude of determined criteria and alternatives. In this context, fuzzy MULTIMOORA approach which offers three different approaches for alternatives' comparison process is utilized as it was not utilized for warehouse selection studies in the literature before.

This study is composed of four sections. After the introduction section in which the purpose of this study is presented, in the second section necessary details are provided about criteria determination for hazardous material warehouse selection and about the methods which are used in the study. In the third section, obtained results are evaluated as applying a case study. Lastly, in the conclusion section a quick evaluation is provided.

2. Hazardous materials and warehouse selection

Warehouse selection is one of the most important and strategic decisions within the logistic system optimization. Being a long term decision, it is influenced by quantitative and qualitative factors. In addition to various studies about warehouse selection issue, MCDM approach is also utilized.

Korpela and Tuominen (1996) established a decision support system utilizing AHP approach as declaring that warehouse selection is an important process of logistics management. Chen (2009) utilized Focus center and AHP approach as stating that warehouse selection is an important strategic study. Demirel et al. (2010) emphasized that the land is important on warehouse selection. They considered the problem as a MCDM problem and solved it as utilizing ChoqueIntegral method which a fuzzy Integral method which is rooted from the uncertainty of some criteria for a real Turkish logistics company. Cost, structure, market, business characteristics and environment were considered as main criteria in the problem and four alternative lands are evaluated with the sub-criteria depending on the main criteria. Özcan et al. (2011) made comparison analysis related to the study in which MCDM methods utilized in warehouse selection problem. They crated comparisons as using TOPSS, ELECTRE and Grey theories in their studies. Garcia et al. (2014) utilized AHP technic in MCDM methods in order to determine the most appropriate site for agriculture-food warehouses. In the case study, they tried to determine a new banana warehouse site as analyzing the pre-determined six generic criteria including site, distance, cost, accessibility, site safety, company regional acceptance and its needs and at the result, the most convenient site is tried to determine among three sites. Erbaş et al (2014) stated that warehouse selection is made especially as determining the regions which would provide the company the maximum benefit and which may cause the minimum negative impacts to nature in case of an unexpected accident. Firstly, they tried to determine the necessary criteria for hazardous material warehouse selection and then they tried to determine the most convenient site as using the geographical information systems. Eroğlu et al (2014) tried to determine the necessary criteria for hazardous material warehouse selection and then aimed to specify the importance levels of the determined criteria with fuzzy AHP method. The researcher consulted the experts who work in various firms specializing the hazardous material storage and took their ideas with Delphi technic in criteria determination process.

Table 1. *Literature Research for Warehouse Selection*

Researcher	Subject
Korpel & Tuominen (1996)	Improving the Decision Support System with AHP Method in Warehouse Selection
Chen (2009)	Warehouse Selection with AHP and Focus Center
Demirel et al. (2010)	Multiple Criteria Warehouse Selection using ChoquetIntegral
Özcan et al. (2011)	Comparison Analysis of Multiple Criteria Decision Making Methodology and Warehouse Selection Application
Garcia et al. (2014)	AHP Method Based Evaluation for Agricultural Product Warehouse Selection
Erbaş et al. (2014)	Evaluation of Hazardous Material Warehouse Selection in terms of Geographical Information Systems
Eroğlu et al. (2014)	Determination of Necessary Criteria for Hazardous Material Warehouse Selection with Delphi Technic and Fuzzy AHP

2.1. Determination of Necessary Criteria for Warehouse Selection

Determination of the warehouse region for hazardous material, whose importance grows over the years, carries importance. Determination of the criteria in the hazardous material warehouse selection problem is the most important phases. There found very few studies which focus on the hazardous material warehouse selection and necessary criteria determination in the literature. Some criteria are determined after the literature research. The determined criteria are presented in the Table 2.

Table 2. *Determination of Necessary Criteria for Warehouse Selection*

Criteria	Value/ Cost	Resourse
Climate and Land Condition (C1); (Earthquake Zone, humidity, temperature differences, Precipitation Amount, Floor Condition)	Value (Maximization)	Hokkanen et al.(1999), Onut et al.(2011), Ömürbek et al. (2013), Taghizadeh (2011), Tang et al. (2013), Roh et al. (2013).
Legal and Political (C2); (Politics, Compliance ADR, Safety Management)	Value (Maximization)	Tzeng et al. (2002), Onut et al. (2011), Acar & Çakmak, (2013), Taghizadeh (2011), Eroğlu et al. (2014).
Costs (C3); (Plant installation costs, Labor, Transportation, Replenishment, Infrastructure and Superstructure Services)	Cost (Minimization)	Eroğlu et al. (2014), Demirel et al.(2010), Vlachopoulou, et al. (2001), Roh et al, (2013), Ersöz & Aktepe (2014), Özdağoğlu, (2011), Ömürbek et al.(2013).
Proximity (C4); (to market to customer)	Value (Maximization)	Demirel et al. (2010), Özcan et al. (2011), Cheng et al. (2002), Ömürbek et al. (2013).
Accessibility (C5); (Time, Distance)	Cost (Minimization)	Vlachopoulou, et al. (2001), Ömürbek et al. (2013), Demirel et al. (2010), Eroğlu et al. (2014), Taghizadeh (2011).
Distance (C6); (to lakes, to forest area, to rivers, to city, center to industry)	Value (Maximization)	Erbaş et al. (2014), Ömürbek et al. (2013), Acar & Çakmak, (2013), Demirel et al. (2010).

Population (C7); (Amount of population and the expected population density in the regions where the warehouse is planned to install)	Cost (Minimization)	Kahraman et al. (2003), Chang et al. (2008), Taghizadeh (2011), Tzenget al. (2002), Ömürbek et al. (2013).

2.2. Fuzzy MULTIMOORA Method

MOORA method from the multiple purposed optimization methods was introduced by Brauersa and Zavadskas (2006) and is mainly utilized for optimization of more than one target. Brauersa and Zavadskas (2010) strengthened MULTIMOORA as developing MOORA method. MULTIMOORA method is composed of three parts including Rate System, Reference Point and Complete Multiplicative Form. Each part carries the same level of importance. Being a quantitative method, MULTIMOORA tries to find the most convenient target as comparing the multiple targets to each other. There are many studies using this method which are presented in Table-3.

Table 3. *Studies Related to MULTIMOORA Method*

Researcher	Subject
Baležentis & Baležentis (2011)	An innovative Multi-Criteria Supplier Selection Based on Two-Tuple MULTIMOORA and Hybrid Data
Brauers & Zavadskas (2011)	MULTIMOORA Optimization Used to Decide on A Bank Loanto Buy Property
Baležentis et al. (2012)	Personnel Selection Basedon Computing with Wordsand Fuzzy MULTIMOORA
Önay & Çetin (2012)	Determination of Popularity of Touristic Destinations: İstanbul Case
Brauers et al. (2012)	Lithuanian Case Study of Masonry Buildings from The Soviet Period
Brauers et al. (2012a)	European Union Memberstates Preparing for Europe 2020. An Application of the Multimoora Method
Brauers & Zavadskas (2012)	Robustness of MULTIMOORA: A Method for Multi-Objective Optimization
Baležentiene et al. (2013)	Fuzzy Decision Support Methodology for Sustainable Energy Cropselection
Vatansever & Uluköy (2013)	Corporate Source Planning Determination using Fuzzy AHP and Fuzzy MOORA Methods: An Application in Procurement Sector

2.2.1. Fuzzy Ratio System

Ratio system established the decision system which is normalization of decision makers' evaluation.. Normalization is implemented by comparison of suitable values of fuzzy numbers (Liu & Liu, 2010). Assuming $i=1,2,\ldots,m$ is alternative numbers, $j=1,2,\ldots,n$ is criterion number and, $\tilde{X}_{ij}$ where i is alternative's performance evaluation value in terms of j criterion; normalization process is calculated by dividing each of the alternative's squareroot with criteria as shown in the Equation 1(Baležentis et al., 2012).

$$\tilde{X}_{ij}^{*} = \left(X_{ij1}^{*}, X_{ij2}^{*}, X_{ij3}^{*}\right) =$$
$$\begin{cases} X_{ij1}^{*} = X_{ij1}^{*} / \sqrt{\sum_{i=1}^{m}[(X_{ij1})^2 + (X_{ij2})^2 + (X_{ij3})^2]} \\ X_{ij2}^{*} = X_{ij2}^{*} / \sqrt{\sum_{i=1}^{m}[(X_{ij1})^2 + (X_{ij2})^2 + (X_{ij3})^2]} \\ X_{ij3}^{*} = X_{ij3}^{*} / \sqrt{\sum_{i=1}^{m}[(X_{ij1})^2 + (X_{ij2})^2 + (X_{ij3})^2]} \end{cases} \quad \forall i,j. \tag{1}$$

Following this normalization calculation, summary ratios should be calculated for each of the ith alternative. The calculation is determined through whether the purposes are value or cost criteria. Total cost criteria values are subtracted from the total value criteria values. Since the criteria are weighed, they are multiplied by the normalization values. Therefore, the calculation is conducted as shown in Equation

2 assuming that $j = 1, 2, \ldots, g$ are the purposes which will be maximised and $j = g+1, g+2, \ldots, n$ are the purposes which will be minimized. On the other hand .s_j represents the criteria weights.

$$\tilde{y}_i^* = \sum_{j=1}^{g} s_j X_{ij}^* - \sum_{j=g+1}^{n} s_j X_{ij,}^* \tag{2}$$

Defuzzificationcalculation of the obtained values are conducted through Equation 3.

$$\mathrm{BNP_i} = \frac{(y_{i3}^* - y_{i1}^*) + (y_{i2}^* - y_{i1}^*)}{3} + y_{i1}^* \tag{3}$$

Ordering is made as the highest value among the defuzzified numbers will be selected as the best alternative.

2.2.2. Fuzzy Reference Point System

Fuzzy reference point approach is depended on the fuzzy ratio system. For all purposes, maximum points are found if the problem is maximization, and minimum points and maximal purpose reference points $\tilde{r}$ values are found if the problem is minimization. The distance with $\tilde{X}_{ij}$ is found to the obtained points. Below stated Equation is utilized since criteria have weight coefficient.

$$d_i = si\left|\tilde{r} - \tilde{x}_{ij}\right| \tag{4}$$

Calculation is completed and written as matrix. The defuzzification calculation is repeated in this process. "Tchebycheff Min-Maks Metrik" is applied to the obtained matrix as shown in the Equation 5. Accordingly, the best alternative is determined.

$$\min_i \left(\max_j \mathrm{d}(\tilde{r}_j, \tilde{X}_{ij}) \right) \tag{5}$$

Ordering is made in accordance with the Equation 5.

2.2.3. Fuzzy Complete Multiplicative Form System

$$\breve{U}_1 = \frac{\breve{A}_i}{\breve{B}_i} \tag{6}$$

if the ith purpose is a maximization problem, Equation 7 is applied.

$$\breve{A}_i = (A_{i1}, A_{i2} A_{i3}) = \prod_{i=1}^{g} \tilde{X}_{ij}, \ \ i = 1,2, \ldots, m \tag{7}$$

if the purpose is a minimization problem, Equation 8 is applied.

$$\breve{B}_i = (B_{i1}, B_{i2}, B_{i3}) = \prod_{i=g+1}^{n} \tilde{X}_{ij}, \tag{8}$$

Then, the obtained matrix is defuzzified. Ordering is made as the highest value among the defuzzified numbers will be selected as the best alternative (Baležentis et al., 2012).

3. Case study

A new warehouse determination is demanded by a public institution located in Ankara since the current hazardous material storage warehouse is completed its economic life. The institution authorized four expert decision makers for determination of new hazardous material warehouse region. Four alternative sites are determined after the experts' researches. Experts gave attention for the alternatives to have distance of 90 km to Ankara. The pre-determined criteria for hazardous material warehouse determination are evaluated for each four alternatives.

Step 1: Assigning the decision makers group. The management board of the public institution established decision makers group for four experts and the mission to determine the most convenient site for hazardous material warehouse is assigned. The identification of four experts are provided in Table 4.

Table 4. *Experts Identification*

Experts	Age	Education Level	Experience
Expert 1	40	PhD	17
Expert 2	27	Master	6
Expert 3	38	Undergraduate	12
Expert 4	43	Undergraduate	19

Step 2: Determination of Alternatives and Necessary Criteria. Decision maker group determined four alternatives for hazardous material warehouse selection problem. Seven criteria are specified to solve the problem. Necessary explanations about criteria are provided in Table 2.

Step 3: Evaluation of criteria by decision makers group and establishing the criteria weight matrix. Decision makers evaluated the criteria as shown in Table 6 as using the verbal variables for qualitative evaluation in Table 5. Additionally, the triangle fuzzy numbers corresponding to verbal variables are provided in Table 7.

Table 5. *Verbal Variables for Qualitative Evaluation*

Verbal Variables	Fuzzy Numbers
Very Insignificant (VIT)/ Very Weak (VW)	(0.00, 0.00, 0.16)
Insignificant (IT)/ Weak (W)	(0.00, 0.16, 0.34)
Middle Insignificant (MIT)/ Middle Weak (MW)	(0.16, 0.34, 0.50)
Middle (M)	(0.34, 0.50, 0.66)
Middle Significant (MS)/ Middle Good (MG)	(0.50, 0.66, 0.84)
Significant (S)/ Good (G)	(0.66, 0.84, 1.00)
Very Significant (VS)/ Very Good (VG)	(0.84, 1.00, 1.00)

Table 6. *Evaluation of Alternatives with Verbal Symbols by Four Experts*

		C1	C2	C3	C4	C5	C6	C7
DM1	A1	M	MW	M	G	W	M	MW
	A2	MW	MG	W	G	MW	MW	W
	A3	MG	G	ÇW	M	MG	MG	MW
	A4	W	M	MW	MW	M	MG	MG
DM2	A1	G	M	MG	G	MW	MG	W
	A2	MG	G	M	G	M	M	MW
	A3	G	M	MW	M	MG	MG	M
	A4	M	M	M	M	G	M	M
DM3	A1	G	G	MG	MG	MW	MG	W
	A2	M	M	MW	ÇG	W	M	MW
	A3	G	MG	MW	MG	M	G	M
	A4	M	MG	M	M	MG	G	M
DM4	A1	MG	M	MG	G	MW	MG	M
	A2	MG	G	MW	G	M	G	MW
	A3	G	ÇG	MW	M	MG	M	M
	A4	M	MG	M	G	MG	M	MG

Table 7. *Evaluation of Alternatives with Fuzzy Numbers by Decision Makers*

		C1	C2	C3	C4	C5	C6	C7
DM 1	A1	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)	(0.34, 0.50, 0.66)	(0.66, 0.84, 1.00)	(0.00, 0.16, 0.34)	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)
	A2	(0.17, 0.33, 0.50)	(0.50, 0.66, 0.84)	(0.00, 0.16, 0.34)	(0.66, 0.84, 1.00)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.00, 0.16, 0.34)
	A3	(0.50, 0.66, 0.84)	(0.66, 0.84, 1.00)	(0.00, 0.00, 0.16)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)
	A4	(0.00, 0.16, 0.34)	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)	(0.17, 0.33, 0.50)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.50, 0.66, 0.84)
DM 2	A1	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.66, 0.84, 1.00)	(0.17, 0.33, 0.50)	(0.50, 0.66, 0.84)	(0.00, 0.16, 0.34)
	A2	(0.50, 0.66, 0.84)	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)
	A3	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)	(0.50, 0.66, 0.84)	(0.50, 0.66, 0.84)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)
	A4	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)
DM 3	A1	(0.63, 0.79, 0.92)	(0.66, 0.84, 1.00)	(0.50, 0.66, 0.84)	(0.50, 0.66, 0.84)	(0.17, 0.33, 0.50)	(0.50, 0.66, 0.84)	(0.00, 0.16, 0.34)
	A2	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)	(0.84, 1.00, 1.00)	(0.00, 0.16, 0.34)	(0.34, 0.50, 0.66)	(0.17, 0.33, 0.50)
	A3	(0.66, 0.84, 1.00)	(0.58, 0.75, 0.88)	(0.17, 0.33, 0.50)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)
	A4	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)
DM 4	A1	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.66, 0.84, 1.00)	(0.17, 0.33, 0.50)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)
	A2	(0.50, 0.66, 0.84)	(0.66, 0.84, 1.00)	(0.17, 0.33, 0.50)	(0.66, 0.84, 1.00)	(0.34, 0.50, 0.66)	(0.66, 0.84, 1.00)	(0.17, 0.33, 0.50)
	A3	(0.66, 0.84, 1.00)	(0.84, 1.00, 1.00)	(0.17, 0.33, 0.50)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)	(0.34, 0.50, 0.66)
	A4	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)	(0.66, 0.84, 1.00)	(0.50, 0.66, 0.84)	(0.34, 0.50, 0.66)	(0.50, 0.66, 0.84)

Common criterion weight matrix is established as equally weighting the evaluations done by each of the decision maker using verbal symbols mentioned in Table 5, and stated in Table 8.

Table 8. *Common Evaluation of Criteria by Decision Makers*

Criteria	Evaluation	Fuzzy Numbers
C1	G	(0.66, 0.84, 1.00)
C2	VG	(0.84, 1.00, 1.00)
C3	M	(0.34, 0.50, 0.66)
C4	MW	(0.16, 0.34, 0.50)
C5	MW	(0.16, 0.34, 0.50)
C6	MG	(0.50, 0.66, 0.84)
C7	G	(0.66, 0.84, 1.00)

Step 4: The averages of four decision makers' evaluations for each of the alternatives are provided in Table 9.

Table 9. *Average Evaluation for Each of the Alternative Warehouse*

	C1	C2	C3	C4	C5	C6	C7
A 1	(0.54, 0.71, 0.88)	(0.38, 0.55, 0.71)	(0.46, 0.62, 0.79)	(0.62, 0.80, 0.96)	(0.12, 0.30, 0.46)	(0.46, 0.62, 0.80)	(0.13, 0.29, 0.46)
A 2	(0.38, 0.54, 0.71)	(0.54, 0.71, 0.88)	(0.17, 0.34, 0.50)	(0.71, 0.88, 1.00)	(0.21, 0.38, 0.54)	(0.38, 0.55, 0.71)	(0.12, 0.30, 0.46)
A 3	(0.62, 0.80, 0.96)	(0.59, 0.75, 0.88)	(0.12, 0.26, 0.42)	(0.38, 0.54, 0.71)	(0.46, 0.62, 0.80)	(0.50, 0.67, 0.84)	(0.34, 0.50, 0.66)
A 4	(0.26, 0.42, 0.58)	(0.42, 0.58, 0.75)	(0.30, 0.46, 0.62)	(0.38, 0.55, 0.71)	(0.50, 0.67, 0.84)	(0.46, 0.63, 0.79)	(0.42, 0.58, 0.75)

Step 5: Normalized values are provided in Table 10 as the values in the Step 4 are normalized through Equation 1.

Table 10. *Normalized values*

	C1	C2	C3	C4	C5	C6	C7
A1	(0.24, 0.32, 0.39)	(0.16, 0.24, 0.31)	(0.29, 0.39, 0.50)	(0.25, 0.32, 0.39)	(0.07, 0.16, 0.25)	(0.21, 0.29, 0.36)	(0.08, 0.18, 0.29)
A2	(0.17, 0.24, 0.32)	(0.24, 0.31, 0.38)	(0.10, 0.21, 0.31)	(0.29, 0.36, 0.41)	(0.11, 0.20, 0.29)	(0.17, 0.25, 0.32)	(0.08, 0.19, 0.29)
A3	(0.28, 0.36, 0.43)	(0.26, 0.33, 0.38)	(0.08, 0.16, 0.26)	(0.15, 0.22, 0.29)	(0.25, 0.34, 0.43)	(0.23, 0.30, 0.38)	(0.21, 0.32, 0.42)
A4	(0.11, 0.19, 0.26)	(0.18, 0.25, 0.33)	(0.18, 0.29, 0.39)	(0.15, 0.22, 0.29)	(0.27, 0.36, 0.45)	(0.21, 0.29, 0.36)	(0.27, 0.37, 0.47)

Step 6: As multiplying the normalized values in Step 5 with criterion weights, weighted normalized values which are presented in Table 11 are obtained.

Table 11. *Weighted Normalized Values*

	C1	C2	C3	C4	C5	C6	C7
A1	(0.16, 0.27, 0.39)	(0.14, 0.24, 0.31)	(0.10, 0.19, 0.33)	(0.04, 0.11, 0.19)	(0.01, 0.05, 0.12)	(0.11, 0.19, 0.31)	(0.05, 0.15, 0.29)
A2	(0.11, 0.20, 0.32)	(0.20, 0.31, 0.38)	(0.04, 0.10, 0.21)	(0.05, 0.12, 0.20)	(0.02, 0.07, 0.15)	(0.09, 0.16, 0.27)	(0.05, 0.15, 0.29)
A3	(0.18, 0.30, 0.43)	(0.21, 0.33, 0.38)	(0.03, 0.08, 0.17)	(0.02, 0.07, 0.14)	(0.04, 0.11, 0.22)	(0.11, 0.20, 0.32)	(0.14, 0.27, 0.42)
A4	(0.08, 0.16, 0.26)	(0.15, 0.25, 0.33)	(0.06, 0.14, 0.26)	(0.02, 0.08, 0.14)	(0.04, 0.12, 0.23)	(0.11, 0.19, 0.30)	(0.18, 0.31, 0.47)
$\tilde{r}$	(0.18, 0.30, 0.43)	(0.21, 0.33, 0.38)	(0.03, 0.08, 0.17)	(0.05, 0.12, 0.20)	(0.01, 0.05, 0.12)	(0.11, 0.20, 0.32)	(0.05, 0.15, 0.29)
$\tilde{r} * s_i$	(0.12, 0.25, 0.43)	(0.18, 0.33, 0.38)	(0.01, 0.04, 0.11)	(0.01, 0.04, 0.10)	(0.00, 0.02, 0.06)	(0.06, 0.13, 0.27)	(0.03, 0.13, 0.29)

After finding the weighted normalized values, summary ratio calculation is made using Equation 2. Therefore, value and cost criteria are summed up within. As subtracting the total cost criteria from total value criteria, Table 12 is obtained.

Table 12. Fuzzy Ratio System

$\tilde{y}_i^*$	BNP_i	Ordering
(0.28, 0.40, 0.46)	0,3786	3
(0.34, 0.47, 0.53)	0,4448	1
(0.33, 0.44, 0.47)	0,4139	2
(0.08, 0.10, 0.08)	0,0842	4

Defuzzification calculation is completed for the obtained results as using Equation 3 and ordering is made as the highest value among the defuzzified numbers is determined as the best alternative.

Step 7: In this step which reference point approach is utilized, new matrix is obtained as giving attention to the purpose is either value or cost criteria, and subtracting $\left|(\tilde{r} * s_i) - \tilde{X}_{ij}\right|$ from weigthed normalized values and Table 13 is obtained.

Table 13. *Significance Co-efficiency Number for Reference Point System*

	C1	C2	C3	C4	C5	C6	C7
A1	(0.04, 0.02, 0.04)	(0.04, 0.09, 0.07)	(0.09, 0.15, 0.22)	(0.03, 0.07, 0.09)	(0.01, 0.04, 0.06)	(0.05, 0.05, 0.04)	(0.02, 0.02, 0.00)
A2	(0.01, 0.05, 0.11)	(0.02, 0.02, 0.00)	(0.03, 0.06, 0.09)	(0.04, 0.08, 0.10)	(0.02, 0.05, 0.08)	(0.03, 0.03, 0.00)	(0.02, 0.03, 0.00)
A3	(0.06, 0.05, 0.00)	(0.03, 0.00, 0.00)	(0.02, 0.04, 0.06)	(0.02, 0.03, 0.04)	(0.04, 0.10, 0.15)	(0.06, 0.07, 0.05)	(0.11, 0.14, 0.13)
A4	(0.05, 0.09, 0.17)	(0.03, 0.07, 0.05)	(0.05, 0.10, 0.14)	(0.02, 0.03, 0.04)	(0.04, 0.10, 0.16)	(0.05, 0.06, 0.03)	(0.14, 0.18, 0.18)

Defuzzification calculation is applied to the obtained matrix. Moreover, alternatives are prioritized as ordering the obtained numbers using Equation 5 and are presented in Table 14.

Table 14. *Defuzzification and Ordering for Reference Point System*

	C1	C2	C3	C4	C5	C6	C7	$\min_i \left(\max_j d(\tilde{r}_j, \tilde{X}_{ij}) \right)$	Ordering
A1	(0.031)	(0.069)	(0.153)	(0.065)	(0.036)	(0.046)	(0.015)	(0.153)	3
A2	(0.057)	(0.012)	(0.062)	(0.073)	(0.050)	(0.021)	(0.015)	(0.073)	1
A3	(0.037)	(0.011)	(0.038)	(0.031)	(0.096)	(0.059)	(0.124)	(0.124)	2
A4	(0.103)	(0.052)	(0.100)	(0.031)	(0.103)	(0.046)	(0.168)	(0.168)	4

Step 8: Complete multiplicative form is applied according to the purpose situation being whether value or cost criteria, using Equation 7 or Equation 8, Table 15 is obtained. As defuzzification calculation of the numbers in Table 15, the obtained numbers are descended.

Table 15. *Fuzzy Complete Multiplicative Form*

$\tilde{U}_i$	BNP_i	Ordering
(1.74602, 0.80155, 0.60151)	1,04969	2
(2.68587, 1.10601, 0.75792)	1,51660	1
(0.76596, 0.60377, 0.48807)	0,61927	3
(0.06221, 0.10301, 0.13411)	0,09978	4

Step 9: As comparing the orderings obtained on Ratio System, Reference Point System and Complete Multiplicative Form applications the final ordering is obtained using MULTIMOORA and presented in Table 16.

Table 16. *MULTIMOORA Analysis*

	Fuzzy Ratio System	Fuzzy Reference System	Fuzzy Complete Multiplicative Form	MULTİMOORA
A1	3	3	2	**3**
A2	1	1	1	**1**
A3	2	2	3	**2**
A4	4	4	4	**4**

It could be stated that second alternative is the most convenient alternative for hazardous material warehouse according to fuzzy MULTIMOORA method.

4. Conclusion and Suggestions

Hazardous material storage is an important subject for human and environmental aspects. Likewise, the most convenient site for hazardous material warehouse should be determined. In this study, fuzzy set theory based MCDM approach is presented in order to minimize the risks which may occur especially during the hazardous material storage processes. In our study, MULTIMOORA method is utilized in order to handle the group decision making using the fuzzy weighted average operator. Hazardous material warehouse selection problem during the group decision making process is discussed on the case study. A committee composing from four decision makers is established for the hazardous material warehouse which completed institution economical life. Four alternative sites are determined by the decision makers group. The determined four alternatives are evaluated using fuzzy verbal symbols according to seven criteria by decision makers group. MULTIMOORA method which utilizes Ratio system, reference system and Complete multiplicative form is used in order to make the comparisons of the alternatives. As a result, the second alternative is found as the most convenient site for hazardous material warehouse. New approaches could be suggested for warehouse selection as using other MCDM methods in the future studies of this approach which we designed for explosives materials storage.

MULTIMOORA technic through, which we used both quantitative and qualitative data in this study, could be utilized for other hazardous material warehouse selection problems in addition to explosive materials. Geographical information systems could be utilized for hazardous material warehouse selection problems in the future studies. On the other hand, transporting to demand points in addition to warehouse selection could be analyzed together.

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