Car Sharing Station Choice by using Interval Valued Neutrosophic WASPAS Method

Ahmed Abdelaziz, Alia N. Mahmoud Nova

Information Management School, Universidade Nova de Lisboa, 1070-312, Lisboa, Portugal

Emails: D20190535@novaims.unl.pt; M20190508@novaims.unl.pt

Abstract

Adding car-sharing to existing public transit options is a great idea. However, finding the right location for a car-sharing station is difficult. The car-sharing station choice has many conflicting criteria, so the multi-criteria decision-making idea is used to deal with various conflict criteria. The process of choosing a suitable car-sharing station is containing vague and imprecise information. So, the neutrosophic set (NS) is used to overcome this problem. This paper introduced a framework consisting of the weighted aggregated sum product assessment (WASPAS) method with the NS. The WASPAS is an MCDM method. The WASPAS is used to compute the importance of criteria and the importance of alternatives. The WASPAS is a hybrid with interval-valued neutrosophic sets (IVNS). The suggested framework is applied to select car-sharing stations. This paper can help decision-makers in selecting the location to install a car sharing station.

Keywords: WASPAS Method; Interval Valued Neutrosophic Set; Car Sharing; Site Selection; MCDM.

1. Introduction

The rise of car-sharing programs in recent years as a novel and more environmentally friendly mode of transportation has shifted the focus on personal mobility away from vehicle ownership and towards connectivity as a commodity. The principle behind car-sharing is straightforward: members take turns using a fleet of vehicles to travel. Although economic concerns led to the establishment of the initial public car-sharing service in 1948 in the Swiss city of Zurich, subsequent efforts to implement such a system were unsuccessful. Several effective car-sharing programs began in the 1980s, were consolidated in the early 1990s owing to a newfound awareness among residents, and had a true explosion due to the widespread adoption of ICT and mobile services in the 2000s[1], [2].

Individuals of the community may take advantage of this newfound freedom by utilizing car-sharing services to go to locations that are inconveniently located for them to reach by other means of transportation, such as public transportation, foot, or bicycle. By giving people in such areas even another means of mobility, it encourages and fosters multi-modal environments. From the perspective of creating an environmentally friendly city, car-sharing is a good idea since the cars employed by it are often fuel-efficient and have a favorable impact on lowering urban pollutants and traffic jams[3], [4].

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Daimler, BMW, and the FCA group, to name a few, have recently begun to take an active role in car-sharing services with the goal of expanding their reach in the marketplace. numerous major corporations are emerging on a global scale right now, like Zipcar and Car2Go[5]–[7].

So, the industry is expanding rapidly, and so is the need for improved knowledge of and command over the system. The reality is that car-sharing involves a wide range of stakeholders beyond only businesses, such as governments, cities, and businesses themselves[8], [9]. The connection with the present public transport structure and the regulations for letting various businesses clash in an identical urban area all add layers of complexity to an already complicated system because of the close connection among the actors and their effects on the leadership of a city. So, the car sharing is playing an important role for all produces[10], [11].

So, it is a challenge to build car sharing station and select the best location. The selection of car-sharing stations contains many criteria so, the concept of MCDM is introduced in this paper. The WASPAS method is used to give rank to various car-sharing stations[12]–[14].

This paper used the neutrosophic set to overcome the issue of uncertainty in the evaluation process. The NS is a generalization on a fuzzy set[15], [16]. It has three values truth, indeterminacy, and falsity membership degrees. This paper used the interval-valued neutrosophic set to build the decision matrix between criteria and alternatives[17]–[20].

2. Interval Valued Neutrosophic Set

This section displayed some interval valued neutrosophic operations[21], [22].

Multiplication, sum, and subtract of two IVNNs can be computed [23] as:

$$\lambda(x_n^*) = \begin{pmatrix} ([1-\inf t_n])^{\lambda}, 1-(1-\sup t_n)^{\lambda}, \\ \left[(\inf i_n)^{\lambda}, (\sup i_n)^{\lambda}\right], \\ \left[(\inf f_n)^{\lambda}, (\sup f_n)^{\lambda}\right] \end{pmatrix} \tag{1}$$

$$(x_n^*)^c = \begin{pmatrix} \left[(\inf f_n)^{\lambda}, (\sup f_n)^{\lambda}\right], \\ ([1-\inf i_n])^{\lambda}, 1-(1-\sup i_n)^{\lambda}, \\ \left[(\inf t_n)^{\lambda}, (\sup t_n)^{\lambda}\right] \end{pmatrix} \tag{2}$$

$$(x_{n1}^*) + (x_{n2}^*) = \begin{pmatrix} \begin{bmatrix} \inf t_{n1} + \inf t_{n2} - \inf t_{n1} \cdot \inf t_{n2}, \\ \sup t_{n1} + \sup t_{n2} - \sup t_{n1} \cdot \sup t_{n2} \end{bmatrix}, \\ [\inf i_{n1} \cdot \inf i_{n2}, \sup i_{n1} \cdot \sup i_{n2}], \\ [\inf f_{n1} \cdot \inf f_{n2}, \sup f_{n1} \cdot \sup f_{n2}] \end{pmatrix} \tag{3}$$

$$(x_n^*)^{\lambda} = \begin{pmatrix} \left[(\inf t_n)^{\lambda}, (\sup t_n)^{\lambda}\right], \\ ([1-\inf i_n])^{\lambda}, 1-(1-\sup i_n)^{\lambda}, \\ ([1-\inf f_n])^{\lambda}, 1-(1-\sup f_n)^{\lambda} \end{pmatrix} \tag{4}$$

$$(x_{n1}^*) \cdot (x_{n2}^*) = \begin{pmatrix} [(\inf t_{n1} \cdot \inf t_{n2}), \sup t_{n1} \cdot \sup t_{n2}], \\ \left(\begin{bmatrix} \inf i_{n1} + \inf i_{n2} - \inf i_{n1} \cdot \inf i_{n2}, \\ \sup i_{n1} + \sup i_{n2} - \sup i_{n1} \cdot \sup i_{n2} \end{bmatrix}\right), \\ \left(\begin{bmatrix} \inf f_{n1} + \inf f_{n2} - \inf f_{n1} \cdot \inf f_{n2}, \\ \sup f_{n1} + \sup f_{n2} - \sup f_{n1} \cdot \sup f_{n2} \end{bmatrix}\right) \end{pmatrix} \tag{5}$$

$$S(R_1) = \begin{bmatrix} \inf t_{n1} + 1 - \sup i_{n1} + 1 - \sup f_{n1}, \\ \sup t_{n1} + 1 - \inf i_{n1} + 1 - \inf f_{n1} \end{bmatrix} \tag{6}$$

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$$a(R_1) = \begin{bmatrix} \min\{\inf t_{n1} - \inf f_{n1}, \sup t_{n1} - \sup f_{n1}\}, \\ \max\{\inf t_{n1} - \inf f_{n1}, \sup t_{n1} - \sup f_{n1}\} \end{bmatrix} \quad (7)$$

$$c(R_1) = [\inf t_{n1}, \sup t_{n1}] \quad (8)$$

3. WASPAS Method for Car Sharing Stating Choice

The WASPAS system is built on two goals that together provide more confidence in the final verdict. The WASPAS technique also uses extremely little computing power, which is important for real-time uses[23]. Figure 1 shows the steps of the WASPAS method.

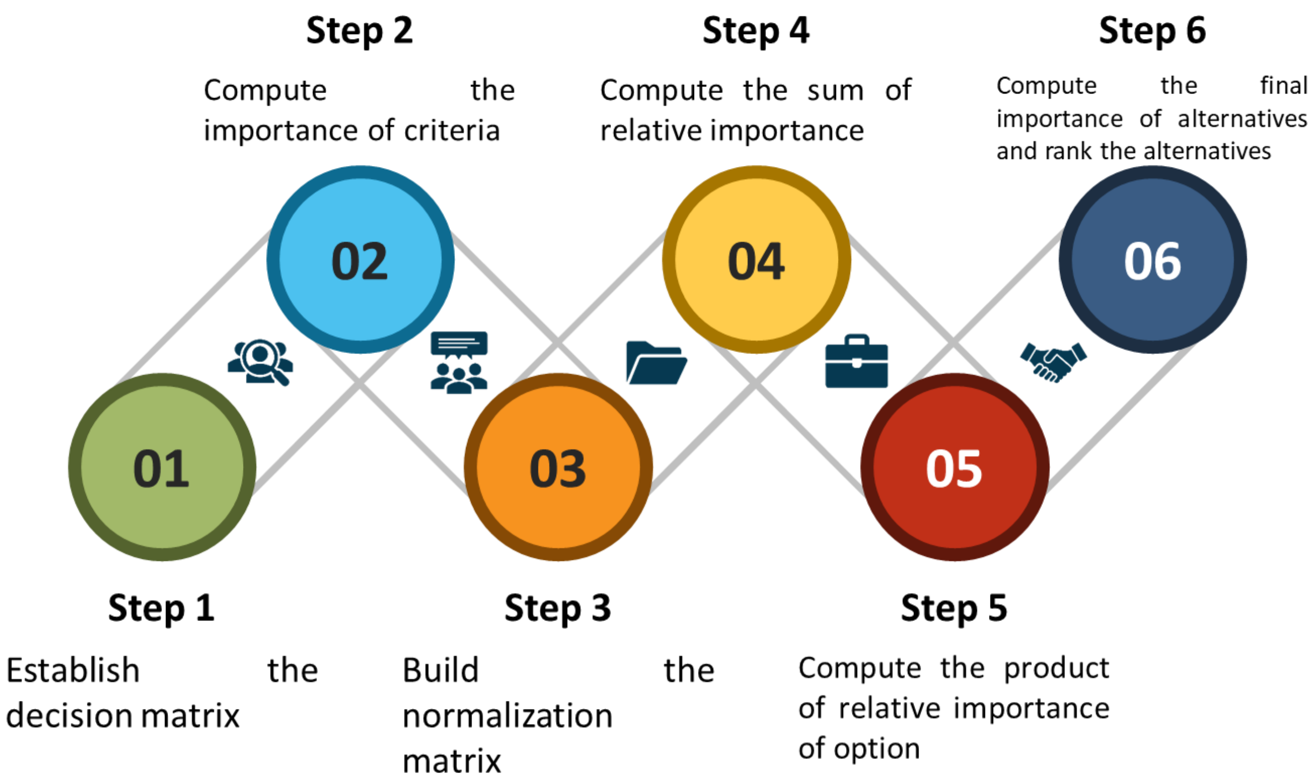

Figure 1: Steps of Interval valued neutrosophic WASPAS method

Step 1. Establish the decision matrix

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix} \quad (9)$$

Where X refers to the values of criteria and alternatives in decision matrix, n refers to the alternatives and m refers to the criteria.

Step 2. Compute the importance of criteria

Apply the average method by the WASPAS method to compute the weights of criteria.

Step 3. Build the normalization matrix

$$inf\ X_{ij}^{*} = \frac{inf\ x_{ij}}{\max_i x\sqrt{m}} \quad (10)$$

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$$sup\ X_{ij}^{*} = \frac{sup\ x_{ij}}{\max_{i} x\sqrt{m}} \tag{11}$$

Step 3.1. Apply the neutrosophication stage

The values of decision matrix are replaced by the interval valued neutrosophic numbers.

Step 4. Compute the sum of relative importance as:

$$R_j^{(1)} = \sum_{i=1}^{C_{max}} (x_n^*)_{ij} \cdot w_i + \left(\sum_{i=1}^{C_{min}} (x_n^*)_{ij} \cdot w_i\right)^c \tag{12}$$

$$\begin{pmatrix} w_i \ldots is\ a\ weight\ of\ criteria \\ i \ldots\ is\ the\ criteria \\ j \ldots is\ the\ alternative \\ C_{max} \ldots .is\ the\ positive\ criteria \\ C_{min} \ldots .is\ the\ cost\ criteria \\ (x_n^*)_{ij} \ldots interval\ valued\ neutrosophic\ number \end{pmatrix} \tag{13}$$

Step 5. Compute the product of relative importance of option

$$R_j^{(2)} = \prod_{i=1}^{c_{max}} (x_n^*)_{ij}^{w_i} \cdot \left(\prod_{i=1}^{c_{min}} (x_n^*)_{ij}^{w_i}\right)^c \tag{14}$$

Step 6. Final importance of alternatives can be computed as:

$$R_j = 0.5R_j^{(1)} + 0.5R_j^{(2)} \tag{15}$$

Step 7. Rank the options

4. Results

In this section, an illustrative example is provided for a choice car-sharing station to show the application of the interval-valued neutrosophic WASPAS. The suggested method is applied to selected criteria and selected locations. The selected criteria are gathered from previous studies in car sharing stating selection. This study used 12 criteria and 10 alternatives. All criteria are positive except three criteria include Investment cost, Construction cost, and Annual operation and maintenance cost. Figure 2 shows the 12 criteria used in this study.

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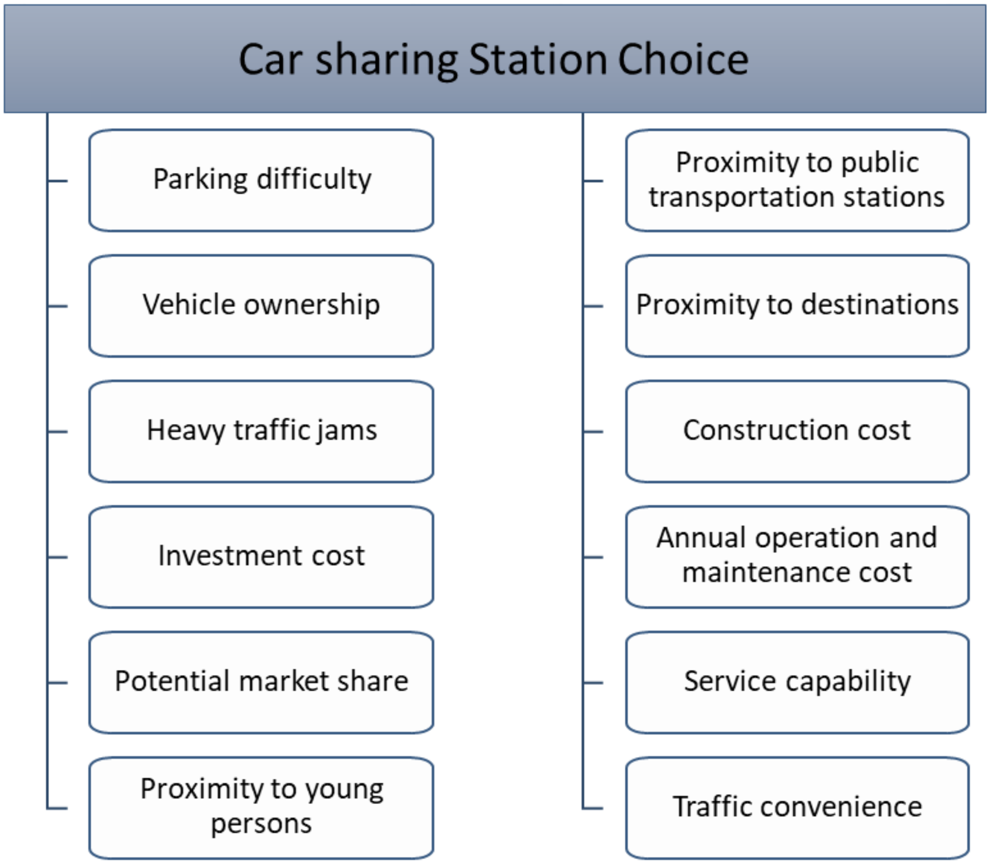

Figure 2: Car sharing station attributes.

The experts used the scale of IVNSs [23] to evaluate the criteria and alternatives via building the decision matrix by using Eq. (9). Then replace the opinions of experts by the IVNNs as shown in Table 1. Then compute the importance of attenuates by the average method as shown in Figure 3.

Table 1: Interval Valued Neutrosophic Numbers

	CSSC$_1$	CSSC$_2$	CSSC$_3$	CSSC$_4$	CSSC$_5$	CSSC$_6$	CSSC$_7$	CSSC$_8$	CSSC$_9$	CSSC$_{10}$	CSSC$_{11}$	CSSC$_{12}$
CSSA$_1$	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.275, 0.672, 0.622), (0.378, 0.775, 0.725)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.094, 0.887, 0.875), (0.125, 0.906, 0.906)]
CSSA$_2$	[(0.289,	[(0.139,	[(0.289,	[(0.289,	[(0.204,	[(0.223,	[(0.139,	[(0.139,	[(0.139,	[(0.223,	[(0.223,	[(0.094,

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	0.757, 0.707), (0.293, 0.761, 0.711)]	0.672, 0.622), (0.378, 0.881, 0.861)]	0.757, 0.707), (0.293, 0.761, 0.711)]	0.757, 0.707), (0.293, 0.761, 0.711)]	0.815, 0.765), (0.235, 0.846, 0.796)]	0.802, 0.752), (0.248, 0.827, 0.777)]	0.672, 0.622), (0.378, 0.881, 0.861)]	0.672, 0.622), (0.378, 0.881, 0.861)]	0.672, 0.622), (0.378, 0.881, 0.861)]	0.802, 0.752), (0.248, 0.827, 0.777)]	0.802, 0.752), (0.248, 0.827, 0.777)]	0.887, 0.875), (0.125, 0.906, 0.906)]
$CSSA_3$	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.094, 0.887, 0.875), (0.125, 0.906, 0.906)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.275, 0.672, 0.622), (0.378, 0.775, 0.725)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]
$CSSA_4$	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.094, 0.887, 0.875), (0.125, 0.906, 0.906)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]
$CSSA_5$	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.094, 0.887, 0.875), (0.125, 0.906, 0.906)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.275, 0.672, 0.622), (0.378, 0.775, 0.725)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]
$CSSA_6$	[(0.139, 0.672, 0.622), (0.378, 0.881	[(0.139, 0.672, 0.622), (0.378, 0.881	[(0.139, 0.672, 0.622), (0.378, 0.881	[(0.139, 0.672, 0.622), (0.378, 0.881	[(0.347, 0.672, 0.622), (0.378, 0.703	[(0.094, 0.887, 0.875), (0.125, 0.906	[(0.289, 0.757, 0.707), (0.293, 0.761	[(0.204, 0.815, 0.765), (0.235, 0.846	[(0.204, 0.815, 0.765), (0.235, 0.846	[(0.347, 0.672, 0.622), (0.378, 0.703,	[(0.139, 0.672, 0.622), (0.378, 0.881,	[(0.139, 0.672, 0.622), (0.378, 0.881,

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	, 0.861)]	, 0.861)]	, 0.861)]	, 0.861)]	, 0.653)]	, 0.906)]	, 0.711)]	, 0.796)]	, 0.796)]	0.653)]	0.861)]	0.861)]
$CSSA_{7}$	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]
$CSSA_{8}$	[(0.275, 0.672, 0.622), (0.378, 0.775, 0.725)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]
$CSSA_{9}$	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.094, 0.887, 0.875), (0.125, 0.906, 0.906)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]
$CSSA_{10}$	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.347, 0.672, 0.622), (0.378, 0.703, 0.653)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]	[(0.204, 0.815, 0.765), (0.235, 0.846, 0.796)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.289, 0.757, 0.707), (0.293, 0.761, 0.711)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.139, 0.672, 0.622), (0.378, 0.881, 0.861)]	[(0.223, 0.802, 0.752), (0.248, 0.827, 0.777)]

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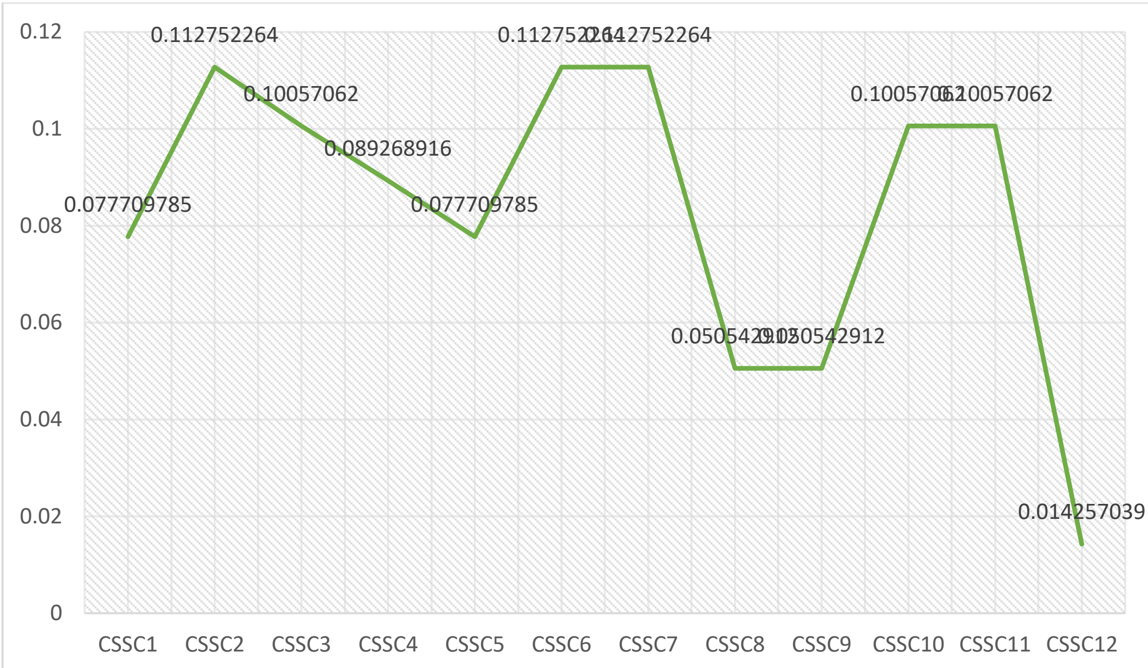

Figure 3: The importance of 12 factors.

Then normalize the decision matrix by using Eqs. (10 and 11) as shown in Table 2. Then compute the sum of relative importance by using Eqs. (12 and 13). Then compute the product of relative importance of option by using Eq. (14). Then compute the final importance according to alternatives as shown in Table 3. Table 3 shows the rank of alternatives.

Table 2: Normalization Interval Valued Neutrosophic Numbers

	CSSC$_1$	CSSC$_2$	CSSC$_3$	CSSC$_4$	CSSC$_5$	CSSC$_6$	CSSC$_7$	CSSC$_8$	CSSC$_9$	CSSC$_{10}$	CSSC$_{11}$	CSSC$_{12}$
CSSA$_1$	0.689208	1	0.891961	0.887624	0.689208	1	0.337864	0.448265	0.753715	0.378788	0.378788	0.126446
CSSA$_2$	0.891961	0.337864	0.891961	1	0.448265	0.689208	1	0.337864	1	0.490221	0.490221	0.126446
CSSA$_3$	0.448265	0.337864	0.126446	0.378788	0.337864	0.689208	0.753715	0.891961	0.426744	1	0.337864	0.337864
CSSA$_4$	1	0.126446	1	1	0.448265	0.337864	1	1	0.490221	1	0.337864	0.337864
CSSA$_5$	0.689208	0.126446	0.448265	1	0.791726	1	0.337864	0.337864	1	0.337864	1	0.337864
CSSA$_6$	0.337864	0.337864	0.337864	0.378788	1	0.126446	0.378788	0.448265	0.753715	0.337864	1	0.337864
CSSA$_7$	0.337864	0.337864	0.337864	0.378788	1	0.689208	0.753715	0.891961	0.378788	1	1	0.689208
CSSA$_8$	0.791726	0.689208	0.891961	0.502561	1	0.337864	1	0.337864	1	0.490221	0.337864	1
CSSA$_9$	1	0.126446	1	1	0.448265	0.337864	1	1	0.490221	1	0.337864	0.337864

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CSS A_{10}	0.337864	0.337864	0.337864	0.378788	1	0.689208	0.753715	0.891961	0.378788	1	1	0.689208

Table 3: The final importance of alternatives.

Alternatives	Importance
$CSSA_1$	0.645962
$CSSA_2$	0.648936
$CSSA_3$	0.477094
$CSSA_4$	0.617393
$CSSA_5$	0.564934
$CSSA_6$	0.429478
$CSSA_7$	0.614171
$CSSA_8$	0.63789
$CSSA_9$	0.617393
$CSSA_{10}$	0.614171

5. Conclusion

This paper introduced a framework for car-sharing station choice based on a set of criteria and alternatives. The criteria are gathered from multiple sources in the literature. Of the 12 criteria, 10 alternatives are selected. There are three criteria are negative criteria and nine criteria are positive criteria. This study introduced the WASPAS method. The WASPAS is an MCDM method. It is used to compute the importance of alternatives, then rank them. The concept of MCDM is used due to various criteria used. The interval-valued neutrosophic set is used in this paper to solve uncertainty. The IVNSs are a kind of neutrosophic set. The illustrative example is provided to show the robustness of the suggested method.

The results of this research may be used by companies who provide car-sharing services to either review their current prospective locations or to locate new ones. The location of car-sharing stations is determined by a variety of criteria that vary from city to city. The suggested approach is flexible enough to be adapted to the specific needs of other municipalities. To better represent the ambiguous and fuzzy information at play in choosing a site issue of car sharing stations, researchers may want to use innovative techniques such as probabilistic term sets and fuzzy sets in future work.

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