



Enhance the Performance of Bus Rapid Transit (BRT) through the Evaluation of Alternatives under an Integrated MCDM Neutrosophic Environment

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Abstract

As a method of transportation, the bus rapid transit system (BRT), also known as BRT, has a greater occupancy rate and is better suited for travelling over longer distances. Evaluating the performance of potential alternatives is necessary because of concerns over sustainability and the need to improve BRT's performance to increase customer satisfaction. On the other hand, criteria that are predicated on the fundamental idea of the emission performance of BRT call for ambiguous or indeterminate expert evaluations to be addressed using single-valued neutrosophic sets (SVNSs). An integrated paradigm for making decisions based on several factors is shown here. To evaluate and rank the solutions, we used a measurement of the different options available and ranked them with the Neutrosophic MARCOS method.

Keywords: Bus rapid transit system; MCDM; Neutrosophic Sets; MARCOS;

1. Introduction

To beat the excessive traffic that plagues towns all over the world, public transit, and notably bus lanes, have proven to be the most effective and basic solutions. People, particularly in major cities, are persuaded to spend on public transportation systems so that they may better the prospects for the future. Even though it has produced considerable results, there is no assurance that the system will be successfully improved even if there are additional options. As a result, determining whether or not the investment will be successful in shifting the population's preference away from driving their private vehicles remains a difficulty [1], [2].

BRT systems are a component of the answer to the ongoing consequences of global urban growth in the majority of countries, but most notably in the metropolitan regions of the developing world. Before the implementation of BRT, the provision of public transportation services was commonly described by the hegemony of irregular contractors. These technicians ran cars and vans that were confidentially controlled but were perfectly organized at the route level through alliances. Before the implementation of BRT, this pattern was common [3]. Even though there are issues with security, reliability, and congestion, the overwhelming majority of individuals who are travelling depend on these resources to go about. According to studies carried out on the installation of a large number of BRT projects throughout the globe, BRT systems have certain challenges in the implementation that, if not managed effectively and early on, might result in results that are less than acceptable [4]–[6].

When BRT systems are put into place, it is usually necessary to make the shift from an unorganized public transportation sector to a system that is governed and controlled [7]. This is often a prerequisite for the successful deployment of BRT systems. It is necessary to coordinate not only the operations of the several entities engaged

in the planning, budgeting, and operation of the multiple elements of the public transportation system but also the actions of those entities. In addition to this, there is sometimes the necessity to carry out novel features that no business has ever attempted before[8], [9].

The various degrees of experience levels, individual perspectives of the decision-makers, and the complexity of the situation may all contribute to the generation of inaccurate or ambiguous information when it comes to the outcomes of the choices. In situations like this, theories like fuzzy sets (FSs), intuitionistic fuzzy sets (IFSs), and neutrosophic sets (NSs) are used to handle the ambiguities that are present throughout the process of decision-making. In this work, we make use of single-valued neutrosophic sets, also known as SVNSs. These sets are a subset of neutrosophic sets (NS) that were established by Wang et al. and are based on the core principle of aggregating a lot of inputs from many decision-makers into a single value. Because it also handles indeterminacies and irregularities, SVNSs have gained a large amount of importance in the process of addressing real-time problems[10]–[14].

Recent research conducted by Stevi et al. resulted in the development of an innovative decision-making algorithm dubbed the MARCOS technique, which was used to choose the most preferred supplier. The MARCOS technique is superior to other approaches because it takes into account both the ideal and anti-ideal solution as well as the utility function of the options. As a result, it can generate a solid and believable decision utility value of the option. Because of its superiority in dealing with choice dilemmas, the MARCOS approach and uncertain tools have been the subject of a significant amount of study that has been completed.

The goal of this paper assesses the strategies to improve the performance of BRT by the neutrosophic MARCOS method.

The rest of this paper is organized as: section 2 presented the literature review. Section 3 presented the methodology. Section 4 presented the results. Finally, the conclusion is presented in section 5.

2. Literature Review

Bouraima et al. [15]determined the obstacles that stand in the way of a successful deployment and operation of the BRT system, and they suggested the approach that would be most effective in overcoming those obstacles. They spoke on the difficulty of defining the obstacles, the weights of those problems, and the techniques that should be used. They were able to calculate the weights of the criterion by using the SWARA. In this manner, the strategy that ought to be adopted for the BRT system to have a successful installation and operation may be defined.

Mavi et al. [16] analyzed and improved the performance of a BRT line in Tehran so that it would be comparable to BRT line 1. They designed and simulated four distinct realistic situations using the actual data collected from BRT line 1, and they did this using the data. In each of these cases, the goal is to reduce the amount of time passengers have to wait, and thus increase the level of pleasure they get from the public transportation system. To evaluate different scenarios from a sustainability point of view, seventeen of the most relevant characteristics were identified. They established a taxonomy of criteria to analyze and choose the various modes of transportation, as well as the grey SWARA approach for balancing the assessment variables. The situations were ranked using grey COPRAS, which was applied. According to the findings, the most ideal option is supplementing the BRT line with regular bus service. They showed the substantial influence that urban public transportation, namely BRT, plays in reducing traffic congestion.

Nassereddine and Eskandari [17]came up with an innovative way for evaluating the level of consumer satisfaction with the urban transportation system in Tehran by combining survey research, statistical analysis, and several other approaches to decision-making based on multiple factors. They used an integrated innovative MCDM technique that was based on DELPHI, GAHP, and PROMETHEE to analyze and improve the level of customer satisfaction in Tehran's public transit systems. The suggested strategy, which makes use of the benefits offered by DELPHI, GAHP, and PROMETHEE, offers directions for investment activities, and it is possible to enhance the less favored means of public transportation to further boost levels of customer satisfaction. The integrated strategy that was provided may be used to solve difficult decision-making issues to cope with unclear, uncertain, and subjective data as well as hazy information.

For material selection, Haq et al. [18] utilized the neutrosophic MARCOS approach. By using an original framework, they planned to solve the environmental difficulties that were associated with the choice of materials for the construction. When the objective criterion weights have been determined using MEREC in an SVN environment, the alternatives are ranked using MARCOS. SVNSs are used to compile the thoughts of three separate specialists, which are afterward deneutrosophized to arrive at clear-cut values for use in the formation of the choice matrix. The framework's usefulness is illustrated by applying it to a real-time engineering challenge involving a lightweight aircraft wing spar. This demonstrates how the framework may be used.

Rong et al. [19] developed a hybrid evaluation method by combining regret theory, the MARCOS approach, and the Heronian mean operator inside an SVN environment. This was done to deal with the assessment difficulty that pharmaceutical firms have while dealing with uncertainty. Since it takes into account aspects such as uncertainty, the psychological influence of experts, and intrinsic significance throughout the evaluation process, the suggested assessment framework has the potential to provide decision results for experts that are more rational and trustworthy.

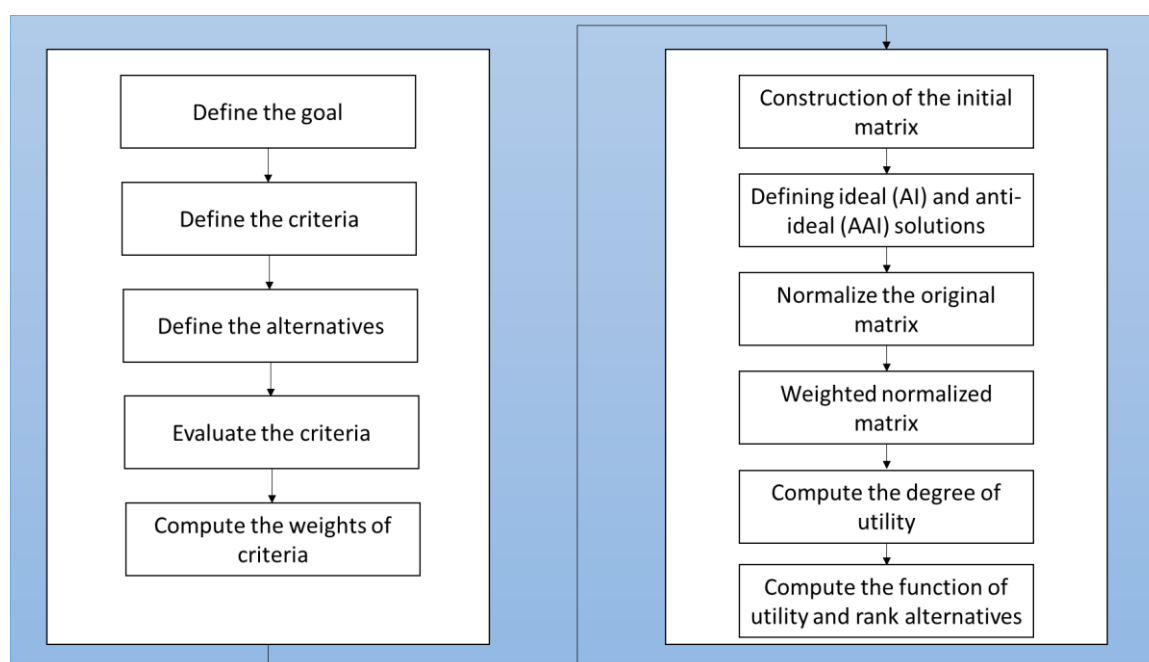


Figure 1: The steps of the proposed method.

3. Methodology

A comprehensive neutrosophic MARCOS approach is offered in the study as a means of evaluating the significance of criteria and ranking the effectiveness of BRT based on the significance of the criteria[20]–[24]. A representation of the integrated technique may be seen in figure 1.

Recent work by Stevi and colleagues has resulted in the development of a new technique known as MARCOS. This approach seeks to solve problems by analyzing the interrelationships between various reference values and potential solutions. The MARCOS methodology is applied in a wide variety of contexts, including the evaluation of software projects, the analysis of the performance of COVID-19 in insurance companies, the evaluation of the performance of railways, and the evaluation of environmentally responsible road transport depending on transportation fuels.

1. The construction of the initial matrix
2. The creation of an expanded original matrix by defining ideal (AI) and anti-ideal (AAI) solutions depending on the kind of criteria that is being considered.

$$Y = \begin{pmatrix} & BRTC_1 & BRTC_2 & \dots & BRTC_n \\ AAI & \begin{bmatrix} BRTaa_1 & \dots & BRTaa_n \\ BRT_{11} & \dots & BRT_{1n} \\ \vdots & \ddots & \vdots \\ BRT_{m1} & \dots & BRT_{mn} \\ BRT_{ai1} & \dots & BRT_{ain} \end{bmatrix} & & & \end{pmatrix} \quad (1)$$

$AAI = \min_i y_{ij}$ beneficial criteria

$AAI = \max_i y_{ij}$ cost criteria

$AI = \max_i y_{ij}$ beneficial criteria

$AI = \min_i y_{ij}$ cost criteria

3. Normalize the original matrix

$$Nor = \frac{y_{ai}}{y_{ij}} \text{ cost criteria} \quad (2)$$

$$Nor = \frac{y_{ij}}{y_{ai}} \text{ beneficial criteria} \quad (3)$$

4. Weighted normalized matrix

Multiply the weights of criteria by the normalization matrix.

5. Compute the degree of utility

$$U_i = \sum_{i=1}^n WNor \quad (4)$$

$$D^- = \frac{U_i}{U_{aai}} \quad (5)$$

$$D^+ = \frac{U_i}{U_{ai}} \quad (6)$$

6. Compute the function of the utility

$$f(D_i^-) = \frac{D_i^+}{D_i^+ + D_i^-} \quad (7)$$

$$f(D_i^+) = \frac{D_i^-}{D_i^+ + D_i^-} \quad (8)$$

7. Rank the options

4. Results

In the section, a real-world example of the prioritizing performance of the BRT system in Egypt is shown. The authors have identified four criteria (economic, social, security, and risk) that might arise from their assessment of the relevant literature, reports, government documents, and the views of subject matter experts. The data gathering was performed using a linguistic scale and was based on a hierarchical structure; as a result, all criteria were translated into benefits throughout the process of computation. The specialists who contributed to the data collection were three in number.

First, compute the weights of four criteria. Let experts evaluate the criteria then compute the weights of criteria as shown in figure 2.

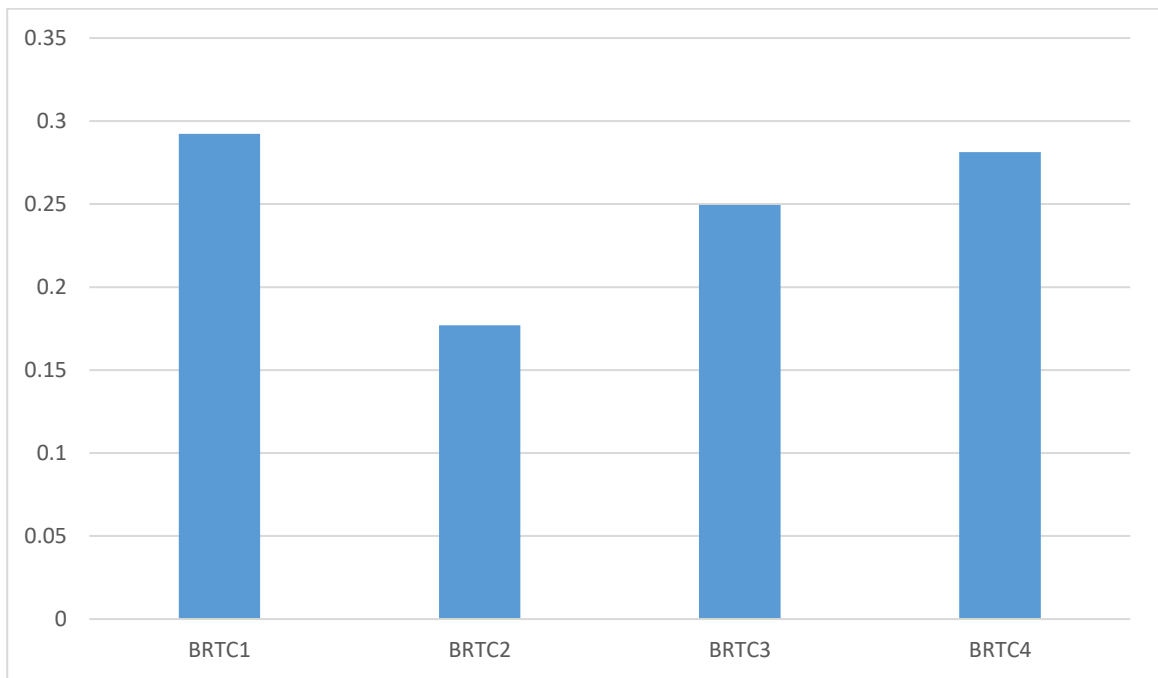


Figure 2: The weights of four criteria in the performance of BRT.

Then let experts evaluate the criteria and alternatives. There are four criteria and five alternatives. Tables 1-3 show the decision matrix. Then compute the normalization matrix as shown in table 4. Then compute the weighed normalized decision matrix. Then use Equations. (4-6) to compute the utility degree. Then compute the function of utility using Equations. (7,8). Then rank the alternatives. Figure 3 shows the rank of alternatives.

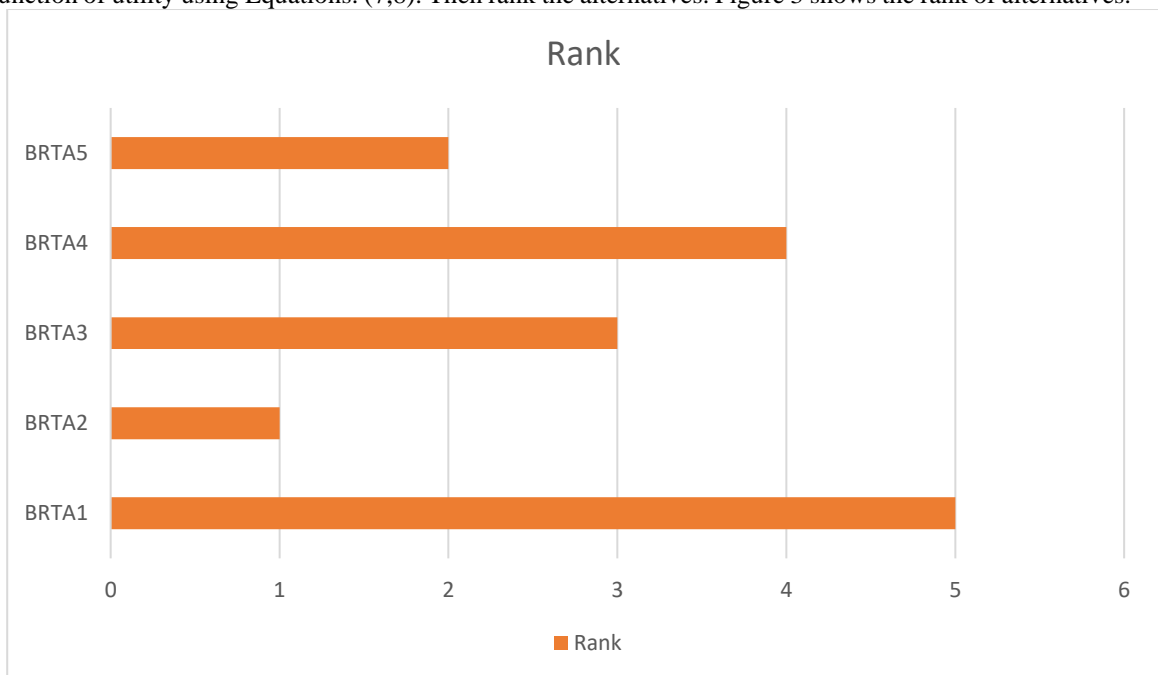


Figure 3: The rank of alternatives.

Table 1: The weight of the first expert to criteria and alternatives.

	BRTC ₁	BRTC ₂	BRTC ₃	BRTC ₄
BRTA ₁	(0.90, 0.10, 0.10)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)
BRTA ₂	(0.80, 0.15, 0.20)	(0.40, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.70, 0.25, 0.30)
BRTA ₃	(0.90, 0.10, 0.10)	(0.40, 0.65, 0.60)	(0.70, 0.25, 0.30)	(0.90, 0.10, 0.10)

BRTA ₄	(0.70, 0.25, 0.30)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)
BRTA ₅	(0.90, 0.10, 0.10)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)

Table 2: The weight of the second expert to criteria and alternatives.

	BRTC ₁	BRTC ₂	BRTC ₃	BRTC ₄
BRTA ₁	(0.30, 0.75, 0.70)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.30, 0.75, 0.70)
BRTA ₂	(0.80, 0.15, 0.20)	(0.40, 0.65, 0.60)	(0.30, 0.75, 0.70)	(0.70, 0.25, 0.30)
BRTA ₃	(0.30, 0.75, 0.70)	(0.30, 0.75, 0.70)	(0.70, 0.25, 0.30)	(0.90, 0.10, 0.10)
BRTA ₄	(0.70, 0.25, 0.30)	(0.30, 0.75, 0.70)	(0.80, 0.15, 0.20)	(0.30, 0.75, 0.70)
BRTA ₅	(0.30, 0.75, 0.70)	(0.30, 0.75, 0.70)	(0.60, 0.35, 0.40)	(0.30, 0.75, 0.70)

Table 3: The weight of the third expert to criteria and alternatives.

	BRTC ₁	BRTC ₂	BRTC ₃	BRTC ₄
BRTA ₁	(0.20, 0.85, 0.80)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.20, 0.85, 0.80)
BRTA ₂	(0.20, 0.85, 0.80)	(0.40, 0.65, 0.60)	(0.30, 0.75, 0.70)	(0.70, 0.25, 0.30)
BRTA ₃	(0.30, 0.75, 0.70)	(0.20, 0.85, 0.80)	(0.20, 0.85, 0.80)	(0.90, 0.10, 0.10)
BRTA ₄	(0.20, 0.85, 0.80)	(0.90, 0.10, 0.10)	(0.90, 0.10, 0.10)	(0.30, 0.75, 0.70)
BRTA ₅	(0.30, 0.75, 0.70)	(0.30, 0.75, 0.70)	(0.20, 0.85, 0.80)	(0.30, 0.75, 0.70)

Table 4: The normalization of criteria and alternatives.

	BRTC ₁	BRTC ₂	BRTC ₃	BRTC ₄
BRTA ₁	1.3293	2.8824	1.3059	1.0649
BRTA ₂	1	1.3529	1.0353	1.6753
BRTA ₃	1.2386	1	1.1412	2.1039
BRTA ₄	1.1237	2.1176	1.7882	1
BRTA ₅	1.2386	1.6275	1	1.1429

5. Conclusions

BRT systems provide several economic and social benefits, which include more trustworthy services, cars with higher capacities, and more reasonable costs. These advantages, together with other benefits of BRT systems, convinced policymakers to invest in the construction of BRT networks in several cities around the country. The purpose of this research was to analyze and perfect a BRT so that its overall performance may be enhanced. To achieve this goal, four distinct practical situations were outlined, and five possible solutions were subjected to discussion. A hybrid evaluation framework that integrates the MARCOS approach into the SVNS environment has been built to evaluate the performance of BRT in the presence of uncertainty in this study. By taking into account all of the potential sources of uncertainty, the suggested evaluation framework has the potential to help experts arrive at decisions that are more rational and believable.

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