Neutrosophic Systems with Applications, Vol. 16, 2024
https://doi.org/10.61356/j.nswa.2024.16204

Modeling Metaverse Perceptions for Bolstering Traffic Safety using Novel TrSS-Based OWCM-RAM MCDM Techniques: Purposes and Strategies

Mona Mohamed [1,*], Asmaa Elsayed [2], and Marwa Sharawi [3]

[1] Higher Technological Institute, 10th of Ramadan City 44629, Egypt; mona.fouad@hti.edu.eg.
[2] Faculty of computers and informatics, Zagazig University, Egypt; aa.ahmed023@eng.zu.edu.eg.
[3] College of Engineering and Applied Sciences, American University of Kuwait, Safat, Kuwait; mamostafa@auk.edu.kw.

* Correspondence: mona.fouad@hti.edu.eg

Abstract: The Metaverse has the potential to revolutionize various aspects of human life, including transportation systems. The integration of the Metaverse into intelligent transportation systems has the potential to significantly improve traffic safety in smart cities. By creating a virtual replica of the physical world, the Metaverse can provide a platform for testing new traffic management systems, road designs, and vehicle technologies in a controlled and safe environment before implementing them in the real world. One way to integrate the Metaverse into intelligent transportation systems (ITS) is by enhancing traffic safety. This can be achieved by developing an evaluation model that considers both safety and traffic efficiency. The proposed evaluation methodology encompasses three phases. Firstly, the obligations/criteria, and subsidiary obligations are modeled into nodes within levels based on Tree Soft Sets (TrSSs). Secondly, the Opinion Weight Criteria Method (OWCM) is utilized for generating the weights for obligations and subsidiary obligations. Finally, the Root Assessment Method (RAM) harnesses the generated weights for assessing and ranking alternative approaches to improving traffic safety in smart cities. The utilized techniques are working under the authority of neutrosophic theory to support these techniques in uncertain and ambiguous circumstances. Subsequently, the proposed methodology is tested in a case study that considers three alternative approaches to improving traffic safety in a smart city. The criteria for evaluation include safety and traffic aspects. The results of the case study indicate that the proposed evaluation model effectively ranks the alternative approaches based on their safety and traffic efficiency. This suggests that the Metaverse can be effectively integrated to enhance traffic safety and improve overall transportation efficiency. Overall, the results of the case study suggest that the proposed evaluation model effectively ranks the alternative approaches based on their safety and traffic efficiency. This indicates that the integration of the Metaverse can indeed enhance traffic safety and improve overall transportation efficiency in smart cities.

Keywords: Intelligent Transportation Systems; Opinion Weight Criteria Method; Tree Soft Sets; Root Assessment Method; Metaverse; Neutrosophic Theory.

1. Introduction

Among the most horrifying and deadly incidents in the world are traffic accidents. For instance, statistics according to [1] on fatal collisions in the US demonstrate the sharp rise in single-vehicle, run-off-road incidents. Evidence of this [2] indicated that around 1.3 million individuals worldwide lose their lives in road accidents each year, while 20 to 50 million more have non-fatal injuries and impairments. There are several explanations for this high frequency of accidents, which are covered in [3], which are situated in blunders made by humans such as overindulgent speed during driving, driving when intoxicated and therefore losing focus, and disregard for safety gear such as seat belts and helmets when operating a scooter.

That is why [4] demonstrated that innovative technologies of information and communications technology (ICT) have a crucial role in the operational planning of transportation systems by boosting the flow of observed data, enhancing the speed and caliber of information, and enabling real-time monitoring and coordination of operations. While emerging technologies like 5G, blockchain (BC), AI, and IoT [5] promise to revolutionize urban administration. These technologies have the power to change everything from energy grids and traffic systems to waste management, public safety, and citizen services. Even in 2021, according to [6], the Metaverse (Met) has grown in popularity. Additionally, it is the merging of the digital and real worlds into one virtual one. Hence, the technology behind it is augmented reality (AR) and virtual reality (VR), which allow for multimodal interactions with digital objects, virtual surroundings, and humans.

Eventually, [7] reported that uniform data standards for smart communities, smart buildings, and smart transportation may be adopted, combining to create a Metaverse of smart cities. Furthermore, Pradhan et al. [8] depicted that the concept of the Metaverse has been popularized in science fiction literature and media, and is now being actively developed and invested in by major tech companies. It has the potential to impact various sectors, such as e-commerce, gaming, entertainment, education, and marketing, and could reach a value of $5 trillion by 2030.Through [9], individuals can create and experience their own digital identities and environments through Met technology. It is a dynamic and evolving space that has the potential to revolutionize the way we interact with each other and with digital information. With the ability to provide real-time communication and experiences, Met has been compared to a next-level version of the internet. For instance, Seoul, South Korea, according to [10], has committed around $180 million to build a Metaverse ecosystem and has already launched the world's first urban Metaverse app. In the same vein [11], WayRay fosters an augmented reality (AR) navigation system that gives drivers real-time access to extremely accurate route and environmental data, enhancing road safety.

In confirmation of [7], scholars of [12] thought that the intervention of Met in transportation resulting in traffic issues would be fixed, that safety would improve, and that accidents would be prevented. Overall, Met leveraged in traffic into different perceptions where it can be used as a precautionary measure for implementing shared economies in traffic [13], as a driving instructor for novices [3], and additionally [14] employed Met as controlling drivers and public transportation vehicle training.

Herein, we are harnessing these perceptions of Met in traffic as alternatives to analyze and evaluate the role of Met. This evaluation is being conducted based on a set of obligations and subsidiary obligations. The relation between obligations and subsidiary obligations is elaborated and modeled into nodes of levels through leveraging tree soft sets (TrSSs), which were proposed by Smarandache [15], who is the founder of uncertainty theory "neutrosophic theory". Obligations and their subsidiaries, which are modeled into TrSSs, are analyzed and weighted by applying the Opinion Weight Criteria Method (OWCM), which was introduced by Ahmed [16] and utilized for the first time in evaluating blockchain Cybersecurity in [17]. The generated weights from OWCM are harnessed into the Root Assessment Method (RAM) that is suggested by Anvari in [18] to rank the determined alternatives of Met and recommend the optimal. Eventually, these techniques are included in Multi-Criteria Decision Making (MCDM) and work under the authority of neutrosophic theory to support MCDM techniques when there is incomplete data. Also, to support experts when there is ambiguity.

2. Around Related Literature

The objective of this section is to showcase general scholars' perspectives on Met technology and its role in traffic. For instance, [19] defined Met as a vast network of interconnected virtual worlds that augment and partially overlay the real world. In an immersive, scalable, synchronous, and permanent environment, users may engage and communicate with one another through avatar-based virtual worlds, as well as experience and consume user-generated content. There are incentives in an economic system for participating in the Met. While Todorovic et al. [20] revealed that autonomous vehicles are one alternate mode of transportation that might be included in the Metaverse. These vehicles are highly advanced and constantly advancing technologically. That is due to the large volumes of driver data that might be generated by the deployment of the vehicles in the virtual environment. This data could then be utilized to train autonomous vehicles for use in real-world situations. Because all avatars, vehicles, and services are linked to BC, [21] indicated that it is much simpler to keep an eye on how clients behave in the Metaverse. As a result, it is simpler for the sharing economy authority to provide the following clients with a better experience. Further details about AR or other technology integration in vehicles may be found in recent research on traffic safety [22]. Hence, [23] demonstrated that deploying these technologies is crucial in forecasting the driving conditions of vehicles, which enhances the precision of traffic safety detection.

Following that, [3] examined the possibilities of the Met and its alternatives to traffic safety. Logarithmic methodology of additive weights (LMAW) utilized under fuzzy for calculating criteria's weights, which are used in TOPSIS to rank candidates of alternatives. Three possibilities for evaluating freight fluidity are put forth in [24, 25]: using existing data to quantify fluidity through global control of freight operations, integrating freight activities into the Metaverse, and doing nothing. While thirteen criteria are used in the multi-criteria decision-making process. These criteria are grouped under four main aspects: technology, governance, efficiency, and environmental sustainability. These criteria are harnessed by LMAW, which is based on Dombi norms for obtaining the criteria's weights. Also, an extended evaluation based on the Distance from Average Solution (EDAS) approach is adopted for ranking alternatives. The findings indicated that the best course of action is to integrate freight activities into the Metaverse to measure fluidity; the least beneficial course of action is to take no action at all.

3. Problem Description and Wording

This study investigates how Met technology could enhance traffic safety and transit convenience. Whilst Met in traffic may play role as virtual driver training, keep an eye on and control traffic flow, and self-driving vehicle. These perceptions were treated in the study as alternatives. Moreover, these alternatives are evaluated based on set of obligations and subsidiary obligations. Herein, we are wording the problem which study discusses and try to solve. Firstly, alternatives of Met in traffic define as:

3.1 Interpretation of alternatives [3]

- $\mathcal{A}_1$: Simulation-Based Training for Drivers: Simulation-Based Training for Drivers: The Metaverse can provide immersive virtual reality simulations for driver training programs. This allows new drivers to practice various scenarios, including adverse weather conditions, heavy traffic, and emergency situations, in a safe environment before they hit the road.
- $\mathcal{A}_2$: Predictive Analytics for Accident Prevention: By analyzing traffic data and historical accident records within the metaverse, city authorities can identify high-risk areas and predict potential accident hotspots. This allows for targeted interventions, such as traffic calming measures, improved signage, and enhanced enforcement, to prevent accidents before they occur.
- $\mathcal{A}_3$: Virtual Traffic Calming Measures: City planners can use the Metaverse to test and simulate various traffic calming interventions, such as redesigned intersections, roundabouts, or traffic circles, before implementing them in the physical environment. This ensures that proposed changes are effective in improving safety without causing unintended consequences.

These alternatives will be ranked based on based on set of obligations and subsidiary obligations. Hence it is necessary to define these obligations and its subsidiary as:

3.2 Interpretation of Obligations and its Subsidiary [3, 14-25]

3.2.1 Safety feature C_1(beneficial):

- C_{12}: The necessity of a stable internet connection(non-beneficial):
  The 5G technology connection speed needs to be quick and reliable since system issues might arise from latency, loss of connection, or internet connection failure.
- C_{12}: Ensure data security (beneficial): Ensuring data security in the metaverse is a critical concern, especially since it operates directly through the internet and involves people's sensitive information. The cost of ensuring data security in the Metaverse for transportation in smart cities can vary depending on various factors such as the size of the Metaverse, the amount of data being processed, and the level of security measures required.
- C_{13}: Accuracy needs in data collection (non-beneficial): To avoid manipulation and inaccurate results, a survey or study's data gathering process plays a significant role. It also implies exactitude in application.
- C_{14}: Communication and payments (beneficial): are crucial for the success of the Metaverse in the context of transportation in a smart city. Communication is key to ensuring a smooth and efficient transportation experience for users, and any disruption in communication can lead to significant inconvenience and potential safety issues. Therefore, a high-capacity communication system is necessary to provide uninterrupted communication between vehicles, infrastructure, and users.

3.2.2 Traffic feature C_1(non-beneficial):

- C_{21}: Optimize traffic flow (beneficial): the Metaverse can significantly optimize traffic flow in smart city transportation beyond what has been achieved with Intelligent Transport Systems (ITS). By creating a virtual replica of the physical world, the Metaverse can provide a platform for testing and simulating traffic management strategies and systems in a controlled and safe environment. This can lead to the development of more effective traffic management plans, resulting in reduced congestion, improved traffic flow, and shorter travel times.
- C_{22}: Road accidents (non-beneficial): The Metaverse can significantly contribute to reducing road accidents in traffic safety by providing a virtual environment for training drivers and testing new transportation technologies. By creating a 3D environment, drivers can be trained to handle various traffic scenarios and improve their driving behavior, which can help achieve a zero road accident society. The Metaverse can also be used for testing and evaluating new traffic management technologies, such as autonomous vehicles and smart traffic signals, leading to improved traffic flow and reduced accidents. Additionally, the Metaverse can provide real-time monitoring and communication between transportation providers, enabling them to quickly respond to changing traffic conditions and optimize traffic flow, further reducing the risk of accidents.
- C_{23}: Improve road safety (beneficial): the integration of the Metaverse in transportation planning can significantly improve road safety. The Metaverse can provide a platform for real-time communication and coordination between transportation providers, enabling them to quickly respond to changing traffic conditions and optimize traffic flow. This can lead to improved traffic flow, reduced congestion, and improved road safety.

4. Methodology

Herein, we introduce a hybrid method, the OWCM-RAM method, using the structure of TrSSs to make it easier to divide criteria into levels and sublevels, get weights using the OWCM method, and then rank alternatives based on hierarchy using the RAM method. As shown in Figure 1.

Subsequently, this section divides into sub-sections. Each one has a responsibility for providing certain information.

4.1 Preliminaries

4.1.1 Tree Soft Set (TrSSs) [15]

The concept of TrSoT introduced by Smarandache [16] also, he is founder for Neutrosophic theory. Whilst Smarandache described and defined this concept as:

Let $\mathfrak{H}$ be a universe of discourse, and $\mathcal{H}$ a non-empty and subset of $\mathfrak{H}$, whilst the powerset of $\mathcal{H}$ denoted as P($\mathcal{H}$).

- Main nodes encompass main attributes/criteria/factors and symbolled as $\mathfrak{R}$. Accordingly, $\mathfrak{R}$ has set of $\mathfrak{R}_s$ with (one-digit indexes) = {$\mathfrak{R}_1$, $\mathfrak{R}_2$,… $\mathfrak{R}_n$}.
- Sub-nodes which have two-digit indexes and symbolled as:
  {$\mathfrak{R}_{11}$,.. $\mathfrak{R}_{1n}$} are sub-nodes of $\mathfrak{R}_1$, {$\mathfrak{R}_{21}$,.. $\mathfrak{R}_{2n}$} are sub-nodes of $\mathfrak{R}_2$, and {$\mathfrak{R}_{31}$,.. $\mathfrak{R}_{3n}$} are sub-nodes of $\mathfrak{R}_3$.
- Generally, a graph-tree is formed, that we denote as Tree(ℵ), whose root is considered of level zero,
- Then nodes of level 1, level 2, up to level n.
- We call leaves of the graph-tree, all terminal nodes (nodes that have no descendants).
  Then TrSS is: F: P(Tree(ℵ)) → P($\mathcal{H}$).
- All node of TrSSs of level m are: Tree(ℵ) = {ℵi1 | i1= 1, 2, ... }.

4.2 Modelling Main Obligations/Criteria and its Subsidiary into TrSSs

- **A**ssign main obligations/ criteria into nodes which resident into level 1. Moreover, subsidiaries of obligations/ criteria are forming into sub-nodes of nodes of level 1. Thus, these sub-nodes are resident into level 2.
- Communicate with panel of experts who related to our field to rate obligations and its subsidiaries modelled into TrSSs

4.3 Weighting Obligations and Subsidiaries based on OWCM Method [16]

Opinion Weight Criteria Method, it's a type of combinative approach which combines subjective and objective methods. So, to extract weight for each obligation /criterion the following steps must be applied:

- Decision matrices are constructed based on number of DMs for evaluating alternatives based on main criteria through utilizing single value Neutrosophic scale (SVNS) as in [17].
- The constructed Neutrosophic matrices are convert to deneutrosophic matrices through Eq. (1).
  $$\mathrm{De_{ij}} = \frac{2+\mathrm{T}-\mathrm{I}-\mathrm{F}}{3} \quad (1)$$
  Where:
  T, $\mathcal{F}$, I refer to truth, false, and indeterminacy respectively.
- Deneutrosophic matrices are aggregated into single matrix called aggregated matrix by Eq. (2).
  $$\wp_{\mathrm{ij}} = \frac{\sum_{\mathrm{ij}}^{\mathrm{n}} \mathrm{De_{ij}}}{\mathbb{N}} \quad (2)$$
  Where:
  $\mathrm{De_{ij}}$ refers to value of criterion in deneutrosophic matrices, $\mathbb{N}$ refers to number of experts.
- Normalizing the decision matrix using Eq. (3).
  $$\boldsymbol{\mathcal{R}_{ij}} = \frac{\wp_{ij}}{\wp_j^{max}} \quad (3)$$
  Where $\boldsymbol{\mathcal{X}_j^{max}}$ is the max value for each obligation.
- Calculating the average score using Eq. (4).
  $$\boldsymbol{\mathcal{K}} = \frac{\mathbf{1}}{\mathbf{N}} \sum_{\mathbf{i=1}}^{\mathbf{m}} \boldsymbol{\mathcal{R}_{ij}} \quad (4)$$

Where N numbers of alternatives.

- Calculating the degree of preference variation using Eq. (5).

$$\mathcal{Q}_j = \sum_{i=1}^{m} [\mathcal{R}_{ij} - \mathcal{K}]^2 \quad (5)$$

Determine the difference in preference level using Eq. (6).

$$\varphi_j = 1 - \mathcal{Q}_j \quad (6)$$

Final step to get weight for each criteria use Eq. (7).

$$\mathcal{W}_j = \frac{\varphi_j}{\sum_{j=1}^{n} \varphi_j} \quad (7)$$

4.4 *Ranking the Alternatives based on RAM Method [19]*

RAM method is used to rank the alternatives based on a radical expression which its radicand and index are the sums of benefit and cost criteria of each alternative.

The criteria must be divided into beneficial and non-beneficial

- Normalize the aggregated matrix in previous step using

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (8)$$

- Compute the weighted normalized matrix

$$\mathcal{Y}_{ij} = r_{ij} \cdot \mathcal{W}_j \quad (9)$$

Where $\mathcal{W}_j$ the weighted values for each criteria calculated by OWCM method

- Calculate the summation for beneficial criteria and non-beneficial criteria using

$$\mathcal{S}_{+i} = \sum_{j=1}^{n} \mathcal{Y}_{+ij} \quad \text{for beneficial} \quad (10)$$

$$\mathcal{S}_{-i} = \sum_{j=1}^{n} \mathcal{Y}_{-ij} \quad \text{for non-beneficial} \quad (11)$$

- Calculate the overall score for each alternative by Eq. (12)

$$\mathcal{RI}_i = \sqrt[2+\mathcal{S}_{-i}]{2 + \mathcal{S}_{+i}} \quad (12)$$

Finally, ranking alternatives based on the value of $\mathcal{RI}_i$ as the bigst value of $\mathcal{RI}_i$ the higher priority of its alternatives. It usually that small gab between the overall score of $\mathcal{RI}_i$ value as results are very close to each other so they cannot be ranked. To Solve this problem we must equalize the $\mathcal{RI}_i$ value to be in the range of [0, 1] and normalized it using min-max normalization method.

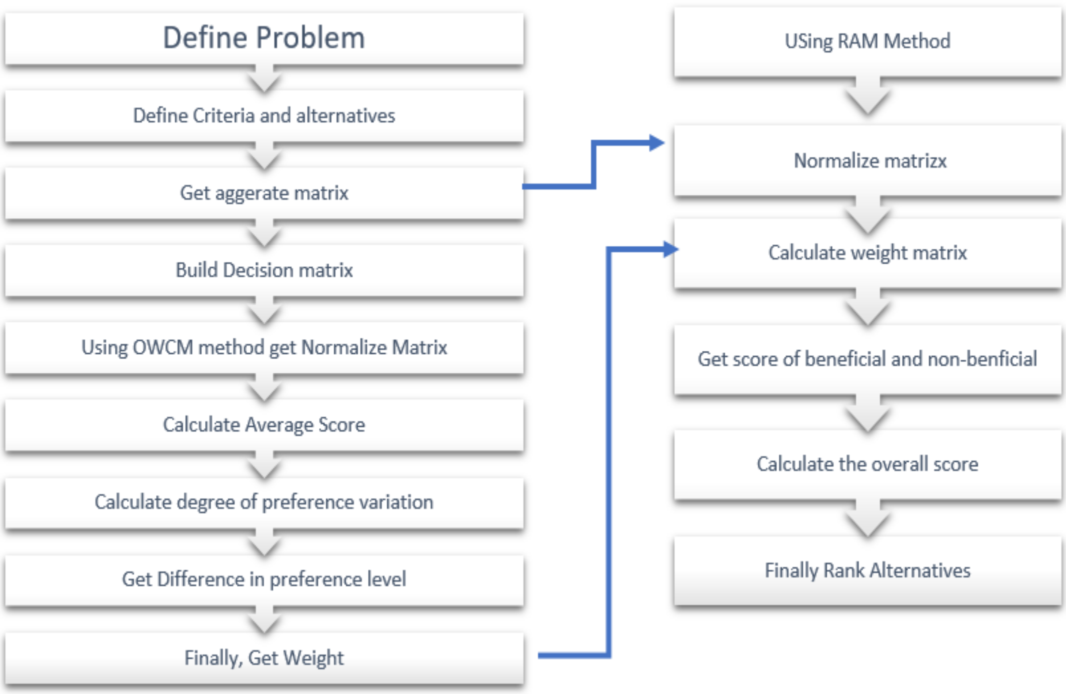

Figure 1. Evaluation methodology based on OWCM-RAM schema.

5. Case Study

The potential for the Metaverse to enhance traffic safety in smart cities is indeed significant. The ability to create a virtual replica of the physical world allows for extensive testing of traffic management systems, road designs, and vehicle technologies in a safe and controlled environment. This minimizes the risks associated with implementing new solutions directly in the real world and allows for thorough experimentation and optimization. Traffic simulations within the Metaverse can simulate various scenarios, including different weather conditions, road layouts, and traffic volumes. By running simulations, potential safety issues can be identified, and solutions can be developed and refined before implementation. This proactive approach can lead to the implementation of more effective traffic management systems and ultimately reduce accidents and congestion. The Metaverse provides an immersive platform for training drivers and traffic management personnel. Through realistic simulations and scenarios, individuals can develop their skills and understanding of traffic safety challenges, leading to improved decision-making and responses in real-world situations. Utilizing the Metaverse for real-time monitoring of traffic enables rapid responses to accidents, road closures, and other incidents. By analyzing traffic data and trends in real-time, traffic management personnel can make informed decisions to mitigate risks and improve safety on the roads. The Metaverse's data analysis capabilities allow for the identification of trends and patterns in traffic data. This information can inform the development of more effective traffic management strategies, leading to improved safety outcomes and enhanced efficiency in the transportation system. Integrating the Metaverse with traffic safety initiatives in smart cities has the potential to significantly improve road safety, reduce traffic congestion, and enhance the efficiency of the transportation system. By providing a platform for testing, training, monitoring, and analysis, the Metaverse can help create a safer and more sustainable transportation system for all users. Leveraging the Metaverse's capabilities for traffic safety in smart cities offers numerous benefits and opportunities for innovation. By harnessing its potential for simulation, training, real-time monitoring, and data analysis, cities can make significant strides towards achieving safer and more efficient transportation networks.

Hence, we are implementing the previous steps in the methodology section in real case study to verify the accuracy of this methodology toward ranking the alternative and selecting the optimal alternative.

5.1 Experimental of Proposed Methodology

First of all, Using OWCM method to get weights for each level of TrSSs as following:

1. Decision makers express their opinions and then transformed into crisp numbers then get the aggregate matrix as Table 1.
2. Using Eq. (3) for normalizing the decision matrix in Table 2.
3. Then, use Eq. (4) to get average score as Table 3.
4. Use Eq. (5) to calculate the degree of preference variation represented in Table 3.
5. After that determine the difference preference level using Eq. (6) in Table 3.
6. Finally, calculate weight using Eq. (7) as in Table 3.
7. Repeat the previous steps on sub criteria of level $1\mathcal{C}_{11}, \mathcal{C}_{12}, \mathcal{C}_{13}, \mathcal{C}_{14}$ as shown in Table 4 and Table 5.
8. The last level, repeat the previous steps on sub criteria of level $1\mathcal{C}_{21}, \mathcal{C}_{22}, \mathcal{C}_{23}$ as shown in Table 6 and Table 7.
9. Final weights for all levels of TrSSs are illustration in Figure 2.

Table 1. Decision matrix for level 1.

	$\mathcal{C}_1$	$\mathcal{C}_1$
$\mathcal{A}_1$	0.594444444	0.433333
$\mathcal{A}_2$	0.422222222	0.838889
$\mathcal{A}_3$	0.444444443	0.56

Table 2. Normalized decision matrix for level 1.

	$\mathcal{C}_1$	$\mathcal{C}_1$
$\mathcal{A}_1$	1	0.516556289
$\mathcal{A}_2$	0.710280374	1
$\mathcal{A}_3$	0.74766355	0.66754967

Table 3. Final weight for level 1.

	$\mathcal{C}_1$	$\mathcal{C}_1$
$\mathcal{K}$	0.819314641	0.72803532
$\mathcal{Q}_i$	0.049669549	0.122346682
φ_i	0.950330451	0.877653318
$\mathcal{W}_i$	0.519879042	0.480120958

Table 4. Decision matrix for sub-criteria of level 1 C1.

	$\mathcal{C}_{11}$	$\mathcal{C}_{12}$	$\mathcal{C}_{13}$	$\mathcal{C}_{14}$
$\mathcal{A}_1$	0.473333333	0.55	0.3777778	0.6233333
$\mathcal{A}_2$	0.391111113	0.4855556	0.6411111	0.6466666
$\mathcal{A}_3$	0.64333333	0.6488889	0.3855555	0.6388889

Table 5. Final weight for sub criteria of $\mathcal{C}_1$.

	$\mathcal{C}_{11}$	$\mathcal{C}_{12}$	$\mathcal{C}_{13}$	$\mathcal{C}_{14}$
$\mathcal{K}$	0.781232012	0.865296803	0.73021371	0.983963367
$\mathcal{Q}_j$	0.079956407	0.032149168	0.10925055	0.000675083
φ_j	0.920043593	0.967850832	0.89074945	0.999324917
$\mathcal{W}_j$	0.230786663	0.2074245	0.2646358	0.2971531

Table 6. Decision matrix for sub-criteria of level 1 C2.

	$\mathcal{C}_{31}$	$\mathcal{C}_{32}$	$\mathcal{C}_{33}$
$\mathcal{A}_1$	0.52999999	0.418889	0.445556
$\mathcal{A}_2$	0.58222221	0.501111	0.45
$\mathcal{A}_3$	0.732222233	0.487778	0.467778

Table 7. Final weight for sub-criteria of $\mathcal{C}_2$.

	$\mathcal{C}_{31}$	$\mathcal{C}_{32}$	$\mathcal{C}_{33}$
$\mathcal{K}$	0.839656027	0.936438	0.971496
$\mathcal{Q}_i$	0.041108568	0.01551	0.001264
φ_i	0.958891432	0.98449	0.998736
$\mathcal{W}_i$	0.325918751	0.33462	0.339462

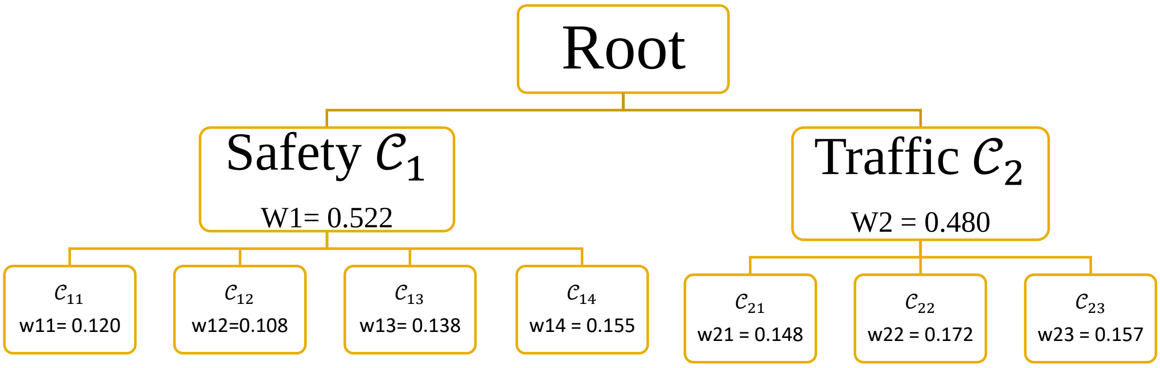

Figure 2. Final weights.

Second step, using RAM method to rank alternative for each level of tree as following:

1. Get normalized decision matrix for $\mathcal{C}_1$ *and* $\mathcal{C}_2$ and weights as Table 8 using Eq. (8).
2. Determine the weight normalized obtained from OWCM method using Eq. (9) as Table 9.
3. Then, calculate the sum of scores of beneficial and non-beneficial criteria (10, 11).
4. Calculate overall score of each alternative using Eq. (12).
5. Finally, rank alternatives based on value of dominance degree. As Table 10.
6. Repeat these steps for level 1 $\boldsymbol{\mathcal{C}_1}$ to get result in Table 11 and Table 12.
7. Repeat these steps for level 1 $\boldsymbol{\mathcal{C}_2}$ to get result in table 13 and Table 14.

Table 8. Normalized decision matrix of level 1.

$\boldsymbol{r_{ij}}$	$\boldsymbol{\mathcal{C}_1}+$	$\boldsymbol{\mathcal{C}_2}-$
$\boldsymbol{Alt_1}$	0.288924559	0.327774583
$\boldsymbol{Alt_2}$	0.302300696	0.453709028
$\boldsymbol{Alt_3}$	0.408774746	0.218516389

Table 9. weight matrix.

$\boldsymbol{y_{ij}}$	$\boldsymbol{\mathcal{C}_1}+$	$\boldsymbol{\mathcal{C}_2}+$
$\boldsymbol{Alt_1}$	0.151069497	0.156391639
$\boldsymbol{Alt_2}$	0.158063456	0.216478953
$\boldsymbol{Alt_3}$	0.213735363	0.104261093

Table 10. Final rank for level1.

	$\boldsymbol{S_+}$	$\boldsymbol{S_-}$	$\boldsymbol{\mathcal{RI}_i}$	Normalized $\boldsymbol{\mathcal{RI}_i}$	Rank
$\boldsymbol{Alt_1}$	0.151069497	0.156391639	1.425	0.14634146	2
$\boldsymbol{Alt_2}$	0.158063456	0.216478953	1.419	0	3
$\boldsymbol{Alt_3}$	0.213735363	0.104261093	1.46	1	1

Table 11. Decision matrix of sub criteria $\boldsymbol{\mathcal{C}_1}$.

	C11 -	**C12 +**	**C13 -**	**C14 +**
$\boldsymbol{\mathcal{A}_1}$	0.370478413	0.4251701	0.252459	0.3091881
$\boldsymbol{\mathcal{A}_2}$	0.151691949	0.127551	0.2754098	0.3091881
$\boldsymbol{\mathcal{A}_3}$	0.477829638	0.4472789	0.4721311	0.3816237

Table 12. Decision matrix of sub criteria $\mathcal{C}_1$.

	$\mathcal{S}_+$	$\mathcal{S}_-$	$\mathcal{RI}_i$	Normalized $\mathcal{RI}_i$	Rank
Alt_1	0.0941513	0.0796387	1.425	0.6	2
Alt_2	0.0618728	0.0564132	1.422	0	3
Alt_3	0.1078035	0.1229888	1.427	1	1

Table 13. Decision matrix of sub criteria $\mathcal{C}_2$.

	C11 +	C12 -	C13 +
$\mathcal{A}_1$	0.423529	0.356997	0.305325
$\mathcal{A}_2$	0.174118	0.240041	0.210059
$\mathcal{A}_3$	0.402353	0.402962	0.484615

Table 14. Decision matrix of sub criteria $\mathcal{C}_2$.

	$\mathcal{S}_+$	$\mathcal{S}_-$	$\mathcal{RI}_i$	Normalized $\mathcal{RI}_i$	Rank
Alt_1	0.110702	0.061369	1.437	0.545455	2
Alt_2	0.058792	0.041264	1.425	0	3
Alt_3	0.135734	0.069271	1.447	1	1

6. Conclusions

This study has presented a MCDM framework to evaluate three alternative approaches to traffic safety in the Metaverse, considering criteria across two key aspects. For this purpose, a hybrid OWCM-RAM model has been presented based on the TreeSoft set. The findings show that the Metaverse A3 is the best choice for traffic safety alternatives in the Metaverse. To conclude, traffic safety systems in the Metaverse has strong potentials. In the Metaverse, traffic simulations can be run with different scenarios, including different weather conditions, road layouts, and traffic volumes, to identify potential safety issues and develop solutions. This can lead to the implementation of more effective traffic management systems, resulting in fewer accidents, reduced traffic congestion, and shorter travel times. The Metaverse can also be used to train drivers and traffic management personnel, providing them with realistic and immersive experiences that can help them better understand and respond to traffic safety challenges. This can lead to improved driving skills, better traffic management decisions, and a safer transportation system overall. In addition, the Metaverse can be used to monitor traffic in real-time, enabling traffic management personnel to quickly respond to accidents, road closures, and other incidents. By analyzing traffic data in the Metaverse, traffic management personnel can identify trends and patterns, enabling them to develop more effective traffic management strategies and improve traffic safety.

Acknowledgments
The author is grateful to the editorial and reviewers, as well as the correspondent author, who offered assistance in the form of advice, assessment, and checking during the study period.

Author Contributions
All authors contributed equally to this research.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Funding

This research was not supported by any funding agency or institute.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

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Received: 29 Nov 2023, **Revised:** 04 Mar 2024,
Accepted: 30 Mar 2024, **Available online:** 02 Apr 2024.