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Evaluation of the Digitized Transportation System: An Empirical Case Study in an Uncertain Environment

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Abstract

The transport sector is one of the main sources of greenhouse gas emissions, which puts the environment and climate change at serious risk. Digitalization presents a possible means of reducing these emissions, through promoting sustainable habits and optimizing transportation networks. Hence, this study was keen to clarify the extent of the impact of contemporary technology and its integration into the transportation sector to become eco-friendly by reducing emissions. Accordingly, analyzing and evaluating transportation systems that adopt this technology is vital. Wherein the evaluation is conducted based on a set of criteria related to embraced technologies. In turn, Multi-Criteria Decision Making (MCDM)techniques such as entropy and TOmada de Decisão Iterativa Multicritério (TODIM) have a vital role in obtaining weight for criteria utilized in the ranking process for transportation systems alternatives respectively. As well these techniques are also implemented in the environment of Triangular Neutrosophic sets to bolster the judgments of experts in uncertainty and ambiguity situations.

Keywords: Digitization; Multi-Criteria Decision Making; MCDM; Triangular Neutrosophic Sets; Uncertainty.

1 | Introduction

Globally, the two industries with the highest carbon emissions are energy and transportation. Currently, their frequent use affects the ecosystem due to large carbon emissions [1, 2]. Now people have begun to work on solutions to the problem of carbon emissions, through digital technologies. We have recently witnessed the negative aspects of transportation can include increased carbon emissions, traffic congestion, accidents, and infrastructure strain [3]. For low-carbon transportation systems to emerge, digital technology must be included in the transportation sector. Digital technologies play a pivotal role in enhancing the efficiency, reliability, and security of energy and transportation systems, paving the way for sustainable and low-carbon transportation solutions [4], It is a key enabler necessary to address challenges in transportation systems. One way to reduce these carbon emissions is to convert transport into automated transport.

An important aspect, automatic transport is seen as having a critical role and potential, leading to safer, more efficient, and environmentally friendly transportation systems. The integration of digital technologies into transport has raised many challenges, It is necessary to create regulations that are influenced by technology to guarantee both data rights and data security [3]. Introducing digital technologies into transportation is crucial for shaping low-carbon energy and transportation systems. These technologies offer numerous benefits and possibilities. Digital technologies, such as IoT, cloud computing, and blockchain, enable real-time monitoring of traffic flow, road conditions, and vehicle operations. This leads to optimized traffic flow,

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reduced congestion, and lower fuel consumption, transportation systems require a Concentration on data security and privacy protection. Blockchain technology is mentioned as a promising approach for addressing privacy problems in ITSs [3]. Also, The integration of digital technologies in transportation is crucial for enhancing logistics and freight management [5]. The impact of digital technologies on transportation is not limited to reducing carbon, but also enhances economic growth and increases the ease of transportation.

Digital technologies use digital systems, tools, and processes to create, store, and manage information including a wide range of digital technologies [6]. The Internet of Things (IoT) plays a crucial role in automatic transportation by enabling the connectivity of vehicles, infrastructure, and traffic management systems. Can help provide a strong foundation for ITSs to perceive and identify traffic aspects traffic flow management,Also tracking, and tracing of goods. Furthermore, Blockchain technology enhances the efficiency and security of automated transportation systems also proposed to enhance security and privacy in intelligent transportation systems (ITSs) [3]. Artificial intelligence has been employed to make optimized decisions in vehicle routing, charging, and parking, contributing to the efficient management of logistics-relevant metrics such as cost and emissions, Also Big Data Analytics is used for analyzing large volumes of data to derive insights for improving transportation and logistics operations. Cloud computing is automatic transportation facilitates data management, computational resource allocation, and the provision of services for intelligent vehicles, contributing to the development of efficient and intelligent transportation systems [7].

To this day, we are witnessing a great interest in automatic transport for its benefits in improving the ecosystem and therefore this improvement is due to humans for a better life. As we see the interest in digital technologies in all journals. These developments underscore the significant impact of digital technologies and their integration into the transportation sector, particularly in the context of automatic transport. These technologies contribute to expanding the boundaries of possibilities and enhancing efficiency and innovation.

Given the importance of volunteering digital technologies in transportation systems and reducing emissions, scholars have appraised the role of these technologies For instance, [8] exploited the ability of MCDM to treat such problems in the same vein [9]. Although MCDM tech has a wide range of uses. However experts or decision makers suffer from uncertainty [10], so we will work in neutrosophic with multi-criteria decision-making (MCDM) type triangular neutrosophic set.

- Through examining research, we were able to pinpoint the issues that transportation causes carbon emissions, and by applying digital technologies, we can reduce emissions by converting transportation to digitization.
- Must first determine how much digital technologies have affected or applied to transportation, To convert transportation into digital transportation.
- Evaluating the transportation systems that digitize its operations using multi-criteria decision-making (MCDM) collaborated with Neutrosophic theory.
- Validate the framework and how it is applied through a case study.

2 | Related Work

Here, we show some previous studies that rely on the introduction of digital technologies in transportation towards low-carbon transport and apply multi-criteria decision-making (MCDM) in transportation systems for evaluation.

2.1 | Digital Technologies in Transportation

From perspective of [3] The Concentrate was on an approach Concentrated on a sustainable environment using digital technologies in transport for a better future. All sources to convert transport to low carbon transport automatic transport. Another point of view [5] To promote logistics transport, digital technologies must be enabled in transport. From vision of [11] in the context of low-carbon transportation, security is a significant concern, and various defense technologies have been developed to address potential threats. From the standpoint of [12] the application of digital technologies, such as RFID, in railway transport has the potential to revolutionize the industry by improving efficiency, safety, and competitiveness.

Hence, According to previous studies, it Concentrates on digital technologies in transport, etc., which has the potential to efficient transport and reduce emissions. Subsequently, we concentrate on studying digital technologies in moving to the security and efficiency of the system, to promote a better ecosystem.

2.2 | Evaluationing Role of Digital Technologies in Transportation

In this section, we review the earlier research that employed MCDM in the transportation sector. [8] The integration of MCDM with CI and SFS in transportation has provided a robust and stable decision-making framework for evaluating logistics AVs, considering the relationships between criteria, and controlling ambiguity and uncertainty in the data. Offered [9] Multiple Criteria Decision Making (MCDM) techniques such as ELECTRE and Analytic Hierarchy Process (AHP) have been applied to address critical decision-making scenarios, particularly in the digitalization and electrification of public transportation systems. The integration of Spherical Fuzzy Sets (SFSs) with these methods has been proposed to handle imprecise information.

Overall, the integration of MCDM with uncertainty theory as neutrosophic in transportation has provided a robust and stable decision-making framework for evaluating transportation, considering the relationships between criteria, and controlling ambiguity and uncertainty in the data.

3 | Methodology

Here we present the methodology for evaluating digital technologies in transportation. The evaluation process for conducted for companies based on a set of criteria. The evaluation of digital technologies is affected by many aspects, just as with a typical decision-making problem. Hence, MCDM techniques are adopted and enhanced with uncertainty theory referred to as neutrosophic theory to enhance the ability of MCDM techniques in dealing with ambiguous situations and in processing complete data. Hence, this study combines the triangular as a branch of neutrosophic theory with entropy and TODIM as the technique of MCDM.

Accordingly, the evaluation process in this study is divided into a group of stages:

Stage 1: Insightful survey.

This phase comprises the essential information that is gathered using a variety of techniques, including field trips and company surveys.

First, we use previous research to determine which criteria are most influential.

Secondly, We also created surveys so that managers and other professionals who played a role in our search could evaluate the criteria that we had specified.

Stage 2: Calculation identified criteria's weights.

One crucial step that is accomplished by determining the weights of the criteria is the valuation of the identified criteria. Herein, we are employing entropy technique to work under triangular as branch of neutrosophic theory for generating criteria's weights through following set of steps:

Based on the preferences of each panel member according to scale, various neutrosophic decision matrices have been created and are listed in [13].

Utilize to transform the neutrosophic scales into precise values through employing Eq. (1).

$$s(r_{ij}) = \left| l_{ij} \times m_j \times u_{ij}) \frac{T_{ij}+I_{ij}+F_{ij}}{9} \right| \tag{1}$$

Where l, m, u denote lower, medium, upper of the scale neutrosophic numbers, T, I, F are the truth-membership

These matrices are volunteering Eq. (2) to aggregate it into a single decision matrix.

$$Y_{ij} = \frac{(\sum_{i=1}^{N} Q_{ij})}{N} \tag{2}$$

Where Qij refers to the value of the criterion in the matrix, N refers to the number of decision-makers.

Eq. (3) is utilized to normalize the aggregated decision matrix.

$$Norm_{ij}=\frac{y_{ij}}{\sum_{j=1}^{m} y_{ij}} \tag{3}$$

Where $\sum_{j=1}^{m} y_{ij}$ represents the sum of each criterion in an aggregated matrix per column.

We are computing entropy based on Eq. (4).

$$e_j = -h \sum_{i=1}^{m} Norm_{ij}\, In\, Norm_{ij} \tag{4}$$

Where $h = \frac{1}{In(m)}$ (5)

M refers to several alternatives.

Compute weight vectors through employing Eq. (6).

$$W_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} \tag{6}$$

Stage 3: Ranking the alternatives

Normalized decision matrix Eq (7). For beneficial attributes.

$$P_{ij} = \frac{X_{ic}}{\sum_{i=1}^{n} X_{ic}} \tag{7}$$

Relative weight criteria, Eq (8).

$$W_{cr} = \frac{W_c}{W_r} \tag{8}$$

W_r is the maximum of the weights.

Dominance degree of the alternative, Eq. (9).

$$\delta(A_i, A_j) = \sum_{c=1}^{m} \emptyset_c(A_i, A_j) \qquad \forall(i,j)$$

$$(A_i, A_j) = \begin{cases} \sqrt{\frac{W_{cr}(P_{ic}-P_{jc})}{\sum_{c=1}^{m} w_{rc}}} & \text{if } (P_{ic} - P_{jc}) > 0 \\ 0 & \text{if } (P_{ic} - P_{jc}) = 0 \\ \frac{-1}{\theta}\sqrt{\frac{(\sum_{c=1}^{m} W_{cr})(P_{ic}-P_{jc})}{w_{cr}}} & \text{f } (P_{ic} - P_{jc}) < 0 \end{cases} \tag{9}$$

- Overall dominance degree of alternative.
- Ranking of the alternatives based on dominance degree (scores).

4 | Descriptive Analysis

This section describes the standards required to improve transportation using digital technologies. We identified the most influential criteria that relate to digital technologies for improving transportation. These criteria are summarized in the following Table 1 based on the study [3, 11].

Table 1. Utilized criteria in evaluation process.

Criteria	Description
intrusion detection system. 'C1'	The capacity of the IDS to rapidly identify assaults is what draws a lot of attention to it. Generally speaking, the host or network intrusion detection system will identify any anomaly in the system and sound an alarm. As per the technical foundation of intrusion detection.
secure smart grid. 'C2'	In recent years, the concept of the smart grid has emerged through which information is exchanged and monitored to stimulate decision-making regarding control of the energy system
Infrastructure. 'C3'	Infrastructure provides the basis for implementing digital technologies
embracing digital edges as defense technologies. 'C4'	Digitalization as a result has led to effective and efficient advancements in the energy and transportation sectors.
Authentication. 'C5'	One way to defend against attacks is authentication
confidentiality. 'C6'	The first line of defense to ensure confidentiality is data security.
Sustainability 'C7'	the potential of technologies to mitigate emissions or energy usage and thereby promote environmental sustainability
Customer satisfaction 'C8'	the system's capacity to enhance client satisfaction overall by cutting waiting times or offering more convenient offerings
Regulatory compliance 'C9'	The system's capacity to adhere to all pertinent regulations and standards
Accessibility 'C10'	People can access the transportation system more easily.

Following that, decision-makers are helping to rank the four options according to the specified standards on scale in ref [13].

5 | Case Study

We are applied methodology as triangular as a branch of neutrosophic theory with entropy and TODIM as techniques of MCDM.

Applying several of equations are listed in following steps.

Step 1: Three neutrosophic decision matrices are created based on the preferences of three decision-makers.

Step 2: The constructed neutrosophic decision matrices transformed into de-neutrosophic decision matrices based on Eq. (1).

Step 3: We aggregated these matrices into tringular deneutrosopic decision matrix through Eq. (2), as listed in Table 2.

Step 4 We calculate entropy ($e\ j$) by utilizing Eq. (4), to generate weights as in Table 3.

Step 5: We are employing Eq. (7), to normalize the aggregated decision matrix to generate Table 4.

Step 6: we calculate the Overall dominance degree of the alternative. Eq. (10). Based on first calculate Relative weight criteria. Eq (8). Also Dominance degree of the alternative.Eq. (9). Ranking of the alternatives based on dominance degree (scores), Eq. (11), In Table 5.

Table 2. Aggregated decision matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Tran-Sys 1	2.961	2.961	1.85	0.705	4.894	6.74	4.66	5.01	3.883	3.07
Tran-Sys 2	6.461	4.894	3.91	1.138	6.74	6.461	1.855	5.35	1.05	1.02
Tran-Sys 3	3.91	6.672	5.84	1.85	6.53	3.05	2.288	1.883	2.127	2.2
Tran-Sys 4	1.85	3.91	5.772	2.2	2.961	1.694	2.983	4	3.32	6.53

Table 3. Calculation of weights based on entropy and neutrosphic

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Tran-Sys 1	-0.318	-0.293	-0.238	-0.253	-0.338	-0.367	-0.366	-0.362	-0.36	-0.342
Tran-Sys 2	-0.363	-0.352	-0.335	-0.317	-0.364	-0.367	-0.290	-0.365	-0.23	-0.201
Tran-Sys 3	-0.349	-0.367	-0.366	-0.363	-0.362	-0.301	-0.318	-0.249	-0.32	-0.302
Tran-Sys 4	-0.256	-0.328	-0.366	-0.367	-0.275	-0.22	-0.347	-0.345	-0.36	-0.343
$= \sum_{i=1}^{m} Normij$	-1.28	-1.34	-1.30	-1.30	-1.34	1.25	-1.32	1	-1.28	-1.18
$E_j = -K \sum_{i=1}^{m} p_{ij} \ln p_{ij}$	0.929	0.968	0.942	0.940	0.967	0.908	0.954	-0.72	0.929	0.858
$W_j = \frac{1 - E_J}{\sum_{j=1}^{n}(1 - E_j}$	0.030	0.013	0.246	0.025	0.013	0.039	0.019	0.741	0.030	0.06

Table 4. Normalize decision matrix based on TODIM and neutrosophic.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Tran-Sys 1	0.1949	0.1605	0.1067	0.1195	0.2315	0.375	0.395	0.308	0.373	0.2398
Tran-Sys 2	0.4253	0.2654	0.2249	0.193	0.319	0.359	0.157	0.329	0.101	0.079
Tran-Sys 3	0.2574	0.3618	0.3362	03145	0.309	0.169	0.194	0.115	0.2049	0.1714
Tran-Sys 4	0.1221	0.2121	0.3320	0.3728	0.14	0.094	0.2529	0.246	0.319	0.509

Table 5. Overall dominance degree of alternative and rank.

			Rank
Tran-Sys 1	-44.03	0	4
Tran-Sys 2	-30.97	0.60	2
Tran-Sys 3	-22.53	1	1
Tran-Sys 4	-32.19	0.55	3

6 | Conclusions

In this study, we attempted to apply digital technologies to transportation for low-carbon transportation. Based on specific criteria, previous studies have applied several techniques that help provide a sustainable environment.

Transportation systems (Tran-Sys) are under pressure to implement digital technologies due to the continuous development of these technologies and constant competition. Here we build TODIM to evaluate manufacturing companies. Criteria in this process constitute a general role in evaluation. Therefore, we have identified the most influential criteria associated with transportation as digital technologies. TODIM technique is supported by neutrosophic theory where each method serves a crucial purpose

For instance, Entropy is used to generate a vector of criteria's weights. The results from these techniques indicated that C8 has the highest weight value while C2 and C5 have the lowest values. Wherein these weights are utilized in TODIM to recommend optimal Tran-Sys. The results from these techniques indicated that Tran-Sys 3 is optimal and other manufacturers are ranking as Tran-Sys3>Tran-Sys2>Tran-Sys4>Tran-Sys1.

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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.

Conflicts of Interest

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

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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