Evaluating the Transport Sustainability of the OECD Countries with MCDM Approach

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Abstract

Transportation is one of the most energy-consuming sectors all over the world. Delivering goods and services to clients requires the use of transportation, which has also a variety of menaces, including climate change, environmental harm, health hazards, deteriorating air quality, and rising greenhouse gas emissions. One of the greatest and most serious environmental issues is climate change, which is exacerbated by greenhouse gas emissions and air pollution. The transportation industry, which generates greenhouse gases, is one of the primary causes of these issues. Implementing sustainable transportation is a practical solution to these issues since it lowers air pollution. Due to the availability of several aspects, the sustainability of the transportation system may be evaluated using Multi-Criteria Decision-Making (MCDM) process, which can deal with benefit and cost criteria simultaneously. The main goal of this study is to evaluate and examine the transport sustainability of selected OECD countries, in which the average annual growth in transportation energy use is predicted to be 1.4% until 2040, by an integrated MCDM framework, which consists of entropy integrated Proximity Indexed Value (PIV) method. Our analysis results indicate that Germany and the United Kingdom are found to be the best-performing countries in terms of transport sustainability among the OECD countries. As a result, this analysis may be useful for stakeholders in the transportation sector.

Keywords: Multi-Criteria Decision Making, Proximity Indexed Value, OECD, Transport, Sustainability

1. Introduction

Economic growth has had a significant impact on world civilization. One of the most damaging consequences of global economic expansion is environmental degradation. Global warming is one of humanity's most difficult challenges since it needs long-term, broad, and sophisticated solutions. Many nations strive to increase industrial output while reducing their energy usage and emissions (Chang et al. 2013). Transport is essential to human well-being because it allows people, products, and services to move. It is also an essential infrastructure for contemporary living (Mo and Wang, 2019). Transportation that is sustainable means moving people and goods while minimizing harm to the environment and society and preserving economic growth (Djordjević et al. 2021). The bulk of the world's population lives in cities, which serve as economic development and production hubs but, if developed incorrectly, can result in social inequities and lasting environmental harm. The negative consequences of urban transportation may compromise sustainability aims (Alonso et al. 2015). Rapid economic growth is facilitated by the expansion of the transportation sector, but there are negative social and environmental effects as well, such as pollution and energy waste (Tian et al. 2020). Due to the usage of fossil fuels, 27% of all greenhouse gas (GHG) emissions are caused by the transportation sector, and vehicle travel greatly increases air pollution. In the absence of serious government action to lower GHG emissions and energy consumption, this trend is anticipated to continue (Wang et al. 2022). Sustainability in transportation has been a contentious issue over the past years because of the need to lower GHG emissions and combat climate change. Performance evaluation is necessary to solve transportation-related environmental and energy challenges, which is an important step since it provides policymakers a framework (Wang, 2019). Therefore, it is crucial to assess the OECD members' transportation sustainability using the Multi-Criteria Decision-Making (MCDM) technique, which can tackle solving problems with many conflicting criteria. In this research, we evaluate the performance of selected OECD countries' transport sustainability throughout the 2018–2019 period using a newly developed MCDM approach named proximity indexed value. The remainder of our paper is structured as follows. The second section provides a literature overview of papers on transportation sustainability. The technique is covered in the third section, and the conclusions are covered in the last section.

2. Literature Review

Recently, transport sustainability has drawn the interest of researchers. When evaluating a country's performance, the MCDM and Data Envelopment Analysis (DEA) frameworks are frequently used. Some of these studies are given below.

Mo and Wang (2019) investigated whether vehicle travel was environmentally sustainable in selected OECD countries from 2000 to 2014. They use two data envelopment analysis (DEA) methods to measure how sustainable road transportation is. The models provide two unified criteria for sustainability performance that account for both transportation operations and environmental consequences. They conclude that from 2000 to 2014, the analyzed nations' general managerial disposability performance increased due to technological progress and stricter limitations on fuel efficiency and automotive emissions.

Wang et al. (2022) evaluate the development of road transportation networks in order to determine which of them may be developed successfully in OECD countries. The framework procedure is proposed, as well as the integrated MCDM technique to assess transportation sustainability. Based on actual facts, the entropy technique determines the weight of the choice criterion. The CoCoSo technique is used to rank OECD nations' road transportation sustainability performance. Their research indicated that Japan, Germany, and France had the best sustainability performance.

Tian et al. (2020) measure regional transportation sustainability that takes systemic, economic, social, and environmental elements. They then provide a super-efficiency slacks-based DEA to gauge the sustainability efficiency of the transport sector. An empirical investigation to assessing transportation sustainability in a Chinese province, from 2000 to 2015 is given to illustrate the value of the suggested technique. The empirical findings show that the investigated region’s transportation sustainability is inefficient, and the primary cause of this is a lack of effectiveness in social and environmental elements.

Wei et al. (2021) evaluate the efficacy of the Chinese transportation industry using decision techniques. The improved approach successfully manages the uncertainty and takes into account all feasible weights, producing better output to direct the creation of efficient efficiency-improving policies. The empirical findings of this study show that China's growth has been uneven and that the transportation efficiency of the Chinese areas is insufficient. They also show that efficiency levels between regions vary substantially.

3. Methodology

3.1 MCDM Framework

Because of the concept's multidimensionality, MCDM methodologies have drawn the attention of different fields. MCDM methodologies are applicable for the assessment outlined in this study since cost and sustainability concerns are multifaceted and comprise numerous conflicting factors. MCDM techniques may analyze criteria of incommensurable units of measurement (e.g., ratios, percentages) as well as those of both benefit (positive) and cost (negative) influence (Mulliner et al. 2016).

3.1.1 Shannon Entropy Method

Shannon (1948) initially proposed the idea of the entropy approach to characterize the uncertainty of an information theory. After that, it was applied to other study areas. One of the sectors where the Shannon entropy approach may be used based on initial data objectively is the weight attribution in MCDM issues (Yang et al. 2018; Yazdani et al. 2020). The following lists the steps in the Shannon entropy method.

We take into account that m alternatives are available to assess "n" criteria. "$(x_{ij})_{m*n}$" is the decision matrix. The normalization phase is completed as indicated below (Poongavanam et al. 2021).

$$p_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij}$$

(1)

where " p_{ij}" denotes the normalized decision values.

The information entropy value is calculated as follows.

$$E_j = - (\ln m)^{-1} \sum_{i=1}^{m} p_{ij} \ln p_{ij}$$

(2)

where "E_j" signifies the information entropy values.

The criteria weight is presented as follows.

$$w_j = (1 - E_j)/(n - \sum_{j=1}^{n} E_j)$$

(3)

3.1.2 Proximity Indexed Value (PIV) Technique

Mufazzal and Muzakkir (2018) introduced the (PIV) technique. The advantage of this method over the TOPSIS approach is that it lessens the rank reversal phenomenon. Furthermore, the PIV method's computing operations are shorter and simpler than the other MCDM methods. The PIV methodology, which is a relatively new technique, is used in this study due to its advantages (Wakeel et al. 2021).

Step 1. Identify alternatives and criteria

Step 2. Identify the decision matrix

$$Y = \begin{bmatrix} Y_{11} & \cdots & Y_{12} & \cdots & Y_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ Y_{21} & \cdots & Y_{22} & \cdots & Y_{2n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ Y_{m1} & \cdots & Y_{m2} & \cdots & Y_{mn} \end{bmatrix} \quad (4)$$

where Y denotes the decision matrix, m signifies the number of alternatives, and n is the number of criteria.

Step 3. Normalization of Decision Matrix

The following formula is used to determine the normalized performance values.

$$y_{ij}{}^{*} = \frac{y_{ij}}{\sqrt{\sum_{k=1}^{m} y_{kj}^{2}}} \tag{5}$$

$where\ y_{ij}{}^{*}$ denotes the normalized decision matrix values.

Step 4. Weighted Normalized Values

The normalized performance values are calculated as follows.

$$V_{ij} = w_j . y_{ij}{}^{*} \tag{6}$$

where V_{ij} denotes the weighted normalized values.

Step 5. Determine the Weighted Proximity Index

It is calculated by subtracting the weighted normalized value from either the greatest or minimum value.

$$u_{ij} = \begin{pmatrix} v_{jmax} - v_{ij}, \ for\ benefit\ criteria \\ v_{ij} - v_{jmin}\ for\ cost\ criteria \end{pmatrix} \tag{7}$$

Step 6. Determine the Overall Proximity Indexed Value

It is determined by summing the weighted performance index values collectively.

$$d_i = \sum_{j=1}^{n} u_{ij} \tag{8}$$

Step 7. Rank the alternatives

The option with the lowest d_i value reflects the least deviation from the best and is thus chosen first.

4. Empirical Results

In this paper, we use a novel MCDM technique, the PIV technique, to evaluate the transport sustainability of selected OECD countries, which are determined based on available data. Our dataset is retrieved from the OECD Statistics database. In this framework, we determine total employees in the transportation sector, total investment in the transportation sector, Gross Domestic Product (GDP) contribution from the transport sector, and GHG emissions from the transport sector as evaluation variables. Initially, we present the criteria weights obtained by the entropy method.

Table 1. Objective Weights Obtained by the Entropy Method

Variables	Objective Weights
Total Investment	0,165
Total Employee	0,168
GDP Contribution	0,161
GHG Emissions	0,170
Renewable Energy Supply	0,167
Freight Volume	0,166

Source: Authors' Calculations.

After determining the criteria weights, we evaluate the transport sustainability of selected OECD countries by the PIV technique. The analysis results are reported in Table 2.

Table 2. The PIV Results of the Transport Sustainability for the Selected OECD Countries

OECD Countries (2018)	PIV Values (2018)	OECD Countries (2019)	PIV Values (2019)
Germany	0,161	Germany	0,167
France	0,275	United Kingdom	0,271
Poland	0,277	France	0,278
United Kingdom	0,285	Poland	0,285
Norway	0,301	Norway	0,299
Sweden	0,305	Italy	0,305
Italy	0,317	Sweden	0,306
Spain	0,318	Spain	0,324
Latvia	0,323	Latvia	0,328
Finland	0,335	Finland	0,341
Lithuania	0,339	Lithuania	0,342
Switzerland	0,342	Switzerland	0,344
Austria	0,348	Austria	0,352
Hungary	0,358	Estonia	0,360
Estonia	0,362	Hungary	0,360
Czech Republic	0,365	Czech Republic	0,368
Slovak Republic	0,371	Slovak Republic	0,378
Slovenia	0,376	Slovenia	0,379
Belgium	0,376	Luxembourg	0,392
Luxembourg	0,390	Belgium	0,394

Source: Authors' Calculations.

As per analysis results, the best-performing OECD members in terms of sustainable transportation are determined to be Germany, the United Kingdom, and France mostly due to intense technological innovations. Most OECD countries under investigation have displayed similar performance results over the 2018-2019 period.

5. Conclusions

The development of transportation is essential to a developing economy. Since sustainable development has been regarded as a worldwide priority, interest in applying it to the transportation industry has increased recently. Transportation is one of the prominent sectors that interact with the environment in a complex way. However, transportation significantly undermines efforts to improve the environment and the climate (Bojković et al. 2010). The transportation sector fosters social welfare, economic growth, and the development of jobs. Global economic growth is fueled by the need for transportation. It facilitates better living and strengthens the economy. However, advancements are made at the environment's price. Because of their heavy reliance on fossil fuels, the industrial and transportation sectors are often regarded as significant greenhouse gas emitters notwithstanding their economic advantages. Thus, this might have an adverse effect on the environment and human health (Khurshid et al. 2023). Therefore, it is essential to evaluate transport sustainability by the MCDM framework, which can deal with conflicting criteria simultaneously. By utilizing an integrated MCDM technique, this study seeks to assess the transportation sustainability in OECD nations. We focus on selected OECD countries due to the lack of data in the database of OECD. Using the entropy approach, the weights of the sustainability evaluation criteria are established. To this end, we employ the PIV technique, which is one of the novel MCDM techniques, to assess the transport sustainability in the OECD countries. As per the analysis results, Germany, the United Kingdom, and France are the OECD countries with the highest performance values over the 2018-2019 period. Although there have been significant variations in a few of these nations in certain years, overall, the performance of these countries has been rather constant over time. These countries display better performance as they provide better economic growth and investment in comparison to other OECD countries. These are nations with advanced and intense transportation and infrastructure systems that help them stand out. It is interesting to note that all of these countries either are members of the EU or are subject to its environmental laws. The 2009 Fuel Quality Directive of the EU mandates a decrease in the greenhouse gas intensity of transportation fuels and air pollutant emissions (Mo and Wang, 2019). On the other hand, the performance of OECD countries such as Luxembourg, Austria, Belgium, and Greece remained lower in comparison to other countries. These countries should focus on increasing investments and the share of GDP in the transportation sector while lowering the negative effect of the transportation sector namely GHG emissions simultaneously. An extensive evaluation of transportation sustainability during the study period may be firmly founded on the previously mentioned examination of the environmental, social, and economic aspects of transportation sustainability. The following tendencies of the research nations may be observed by investigating the performance of high-performing

countries' transport sustainability described above. When all dimensions are taken into account, the study results demonstrated that the OECD states under examination demonstrate substantial performance changes mostly due to technological and economic advancement differences. It is important to acknowledge that there are certain differences in the geographical growth and trends of sustainable transportation in OECD countries. The study's conclusions might be interpreted as reflecting each country's level of development in different ways.
Our empirical results may serve as a base for stakeholders in the transportation sector. Besides, novel and different MCDM techniques can be used to evaluate transportation sector performance.

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