Assessing sustainability of transport system through index: A state-of-the-art review

**Hana Ayadi** (hana.ayadi@u-picardie.fr)
Paris 8 University

**Mounir Benaissa**
University of Sfax

**Nadia Hamani**
University of Picardie Jules Verne

**Lyes Kermad**
Paris 8 University

**Keywords:** Composite indicator, Sustainability, Assessment, Freight transport, Public transport, Sustainability dimensions, Literature review, Index

**Posted Date:** November 1st, 2022

**DOI:** https://doi.org/10.21203/rs.3.rs-2194307/v1

**License:** This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

The transport is one of the most important sectors that affect the economic development. However, its sustainability may be disturbed due to the remarkable increase in the number of vehicles in city centers and its bad consequences, hence the importance of assessing the transport system and the performance of its different components. Therefore, several evaluation methods were introduced to help decision-makers assess sustainability and many indicators were developed to track the progress of sustainable transport system. This work provides a literature review about the existing approaches used to assess transport sustainability through composite indicators. It aims at analyzing the trends in the existing literature, identifying gaps in evaluating sustainability and suggesting future research perspectives. A total of 47 studies conducted in the period 2002–2022 are examined. The obtained results show that few researchers focused on freight transport and most researchers considered only traditional sustainability dimensions. In addition, the performed analysis demonstrates that the use of different methods of normalization, weighting and aggregation influences the result given by composite indicator. Finally, a set of recommendations for precise and correct sustainability assessment is presented in order to develop future research.

1 Introduction

Theoretically speaking, a well-managed transport system ensures the good functioning of the different sectors and, consequently, plays an important role in the economic development of the country. However, with the remarkable increase in the number of trips and heavy goods vehicles, the current transport system generates problems of congestion, insecurity, pollution, etc. Indeed, it causes more greenhouse gas emissions and consumes great amount of energy. In the last decade, local authorities and transport stakeholders have become aware of the importance of solving these issues. Therefore, special attention has been paid to sustainable transport. However, to attain this objective the current transport system should be reconstructed by evaluating its present status using adequate tools to assess transport sustainability. In general, evaluating sustainability in different areas is always difficult and requires the development of specific indicators. For this reason, the use of methods relying on composite indicators allows assessing and monitoring the transport system as well as developing good practices. The objectives of this paper are: i) to identify the trends and gaps of the existing approaches used to assess sustainability in the transport field, and ii) to propose future research directions. The following questions are answered in the present manuscript.

- What are the current research trends in assessing transport sustainability through composite indicators?
- What are the existing research gaps and what are the possible research works in this domain?

This review paper is organized as followed. Section 2 defines composite indicators. Section 3 provides an overview about the existing approaches employed the composite indicators to evaluate the transport sustainability. Section 4 analyzes the obtained results. Section 5 discusses research trends and gaps in
the research on the sustainability of the transport system and identifies some directions for future research. Finally, Section 6 provides a brief conclusion.

2 Definition Of Composite Indicators

Obviously, it is quite difficult to assess sustainability based on a set of elementary indicators. Therefore, the best alternative is to aggregate them into a composite indicator. As defined by [1], the latter “is the mathematical combination of single indicators that represent different dimensions of a concept whose description is the objective of the analysis”. It has some benefits and suffers from some limitations. On the one hand, a composite indicator provides a simplified, coherent and multidimensional view of a system. It also allows the prioritization and analysis of the current situation and facilitates communication between stakeholders. On the other hand, its main disadvantage is that it can send misleading messages, which leads to wrong decisions. For this reason, the steps of its construction, presented in Fig. 1, must be clearly and adequately defined.

- Normalization is required only if the indicators are incomparable, i.e. if they have different measurement units. In the case where all elementary indicators are expressed in the same units (or dimensionless), normalization is not required. In the application of Multiple-Criteria Decision-Making (MCDM) methods, "benefit" type elementary indicators and "cost" type elementary indicators are normalized differently.
- The weighting step affects significantly the composite indicator and the obtained results. It is the process of attributing different levels of importance to each indicator. The most intensely used weighting methods are classified into three categories;
  - The Equal Weighting method is an objective technique that gives all variables the same weight.
  - Objective data-based methods in which weights are determined using statistical-based techniques.
  - Subjective participation methods that take into account the subjective opinions of experts and/or stakeholders.
- Aggregation is a mathematical combination of elementary indicators. In this step, the aggregation technique should be adequately chosen to construct a composite indicator. Aggregation can be classified into three classes whose characteristics are presented in Table 1 [2–4].
  - The compensatory technique operationalizes weak sustainability by including additive aggregation methods (e.g. arithmetic mean). In other words, full compensation between elementary indicators is applied, showing that an unfavorable result of one indicator can be compensated by an unfavorable result of another elementary indicator.
  - The partially compensatory technique operationalizes the limited sustainability by using techniques based on the geometric mean. In this case, elementary indicators are mutually and preferentially independent, but they have certain limitations related to the compensations of indicators.
  - The non-compensatory technique operationalizes strong sustainability. This aggregation method is used when full compensation between elementary indicators is deemed unacceptable. Thus, an
unfavorable result of one indicator cannot be compensated by a favorable result provided by another indicator

<table>
<thead>
<tr>
<th>Aggregation technique</th>
<th>Compensatory</th>
<th>Partially compensatory</th>
<th>Non-compensatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability perspective</td>
<td>Weak sustainability</td>
<td>Limited sustainability</td>
<td>Strong sustainability</td>
</tr>
<tr>
<td>Priority</td>
<td>Economic</td>
<td>Balance between dimensions</td>
<td>Environmental</td>
</tr>
<tr>
<td>Target</td>
<td>Short term</td>
<td>Medium term</td>
<td>Long term</td>
</tr>
<tr>
<td>Principle</td>
<td>No environmental protection without a strong economic base</td>
<td>Reconcile environmental protection, social equity and economic growth</td>
<td>Sustainability of the human capital cannot be ensured without taking into account the capacities of the ecological support</td>
</tr>
</tbody>
</table>

### 3 Literature Review

Due to the interdependency of freight transport and public transport, both systems are presented in this section. From these research works, we extract the existing approaches to assess transport sustainability using indicators and composite indicators and we identify the research gaps in this fields.

Black [5] used an index to measure the public transport sustainability by taking into account the potential mobility in a country. In his study, the sustainability of nine indicators was measured by the Principal Component Analysis (PCA) method. Besides, Rassaaf and Vaziri [6] introduced a composite indicator to rank countries according to the transport sustainability achieved in these regions. This indicator was developed by aggregating 33 elementary indicators using the concordance analysis technique. Dobranskyte-Niskota et al. [7] proposed a composite indicator to assess the sustainability of the transport activities. Another composite indicator was presented by Campos et al. [8] to evaluate sustainable mobility. The introduced elementary indicators were weighted by the Analytic Hierarchy Process (AHP) method.

Researchers, in [9–11], applied cartographic composite indicators relying on a spatial analysis of a geographic information system. More precisely, Yigitcanlar and Dur suggested, in [11], a composite indicator to compare and assess urban sustainability and, then, to aid decision makers in forming sustainable transport development policies. Dizdaroglu and Yigitcanlar [9] developed a composite indicator to spatially analyze the local development plan and the existing planning policies. The obtained results show an increase in pollution caused by transport and the poor accessibility of the public
transport. Nadi and Murad [10] assessed the urban transport sustainability employing composite indicator. They modeled five sustainability indicators using a geographic information system. The proposed composite indicator provided a spatial measure of sustainability and defined the current situation in the Jakarta city.

A. N. R. da Silva et al. [12] introduced an index of sustainable urban mobility by aggregating 87 elementary indicators of public transport sustainability. Authors, in [13], proposed a composite indicator to extract indicators widely employed in the literature. Zito and Salvo [14] selected a set of elementary indicators of transport sustainability to assess the effects of policy measures on the urban level in Europe. These indicators were aggregated utilizing Euclidean distance to construct a composite indicator.

Kolak et al. [15] suggested a composite indicator applying the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. Their main objective was to assess the sustainability of the transport networks in 15 European countries and to identify the elementary indicators that should be taken to enhance sustainability. Ramani et al. [16] proposed an index to evaluate the sustainability of the transport corridors. In this study, the Multi-Attribute Utility Theory (MAUT) method was applied to determine the current status of the corridor. In the same context, Awasthi and Chauhan [17] presented a composite indicator of transport sustainability using the AHP method and Dempster-Shafer theory. The main objective of the research work was to assess the impact of sustainable transport solutions, such as multimodal transport, mode sharing, intelligent transport, etc., on city sustainability. In another study, the AHP method was used by Shiau [18] to weight 10 indicators and assess sustainable transportation strategies. A literature review [19] conducted between 1999 and 2010 showed that no study has developed a composite indicator to address freight transport issues. Haghshenas and Vaziri [19] proposed a composite indicator to compare the transport sustainability of 100 cities around the world. The authors weighted nine transport indicators applying the equal weighting method. Researchers, in [20], suggested an index based on four sustainability dimensions to integrate sustainability into transport planning. In this study, equal weighting was also applied to each indicator and sustainability dimension. Researchers assessed the sustainability of three transportation plan alternatives in the Atlanta metropolitan area. Zheng et al. [21] aggregated a set of elementary indicators into a composite indicator. The study aimed, essentially, at evaluating the transport sustainability in the United States.

Reisi et al. [22] aggregated nine elementary indicators into an urban transport index to assess the current transport policies under different sustainability dimensions. The study was conducted in Melbourne, Australia. Shiau et al. [23] developed a list of elementary indicators selected by the rough set theory to measure the transport sustainability. Two of these indicators were related to the freight transport. Then, the PCA method was applied to aggregate these indicators and determine sustainability in the city of Taiwan from 1993 to 2010. The authors, in [24], formalized a composite indicator to assess the urban transport sustainability and identify sustainable policies. Alonso et al. [25] evaluated the sustainability of transport in 23 European cities employing a CI index to measure the sustainability of urban passenger transport systems. Nine elementary indicators were weighted using the equal weighting method and
aggregated into three indexes representing the traditional sustainability dimensions. Verma et al. [26] suggested a composite indicator to measure the sustainability impacts of the transport practices on the variation in three traditional sustainability dimensions. In their work, the authors utilized AHP method to weight sustainability indicators. Their main objective was to study the effects of implementing congestion pricing in Bangalore, India on environmental, economic and social dimensions.

Ahangari et al. [27] developed a national composite indicator to compare the United States transport sustainability with that in 28 European countries from 2005 to 2011 by aggregating 10 indicators. Miller et al. [28] defined an index to analyze the public transport by applying different normalization techniques. Rajak et al. [29] proposed a fuzzy model to evaluate the performance of the transport system and identify gaps between four sustainability dimensions (economic, environmental and social dimensions as well as the transportation system efficiency). First, a fuzzy transport sustainability index was calculated to measure transport sustainability. Then, the main barriers preventing sustainable transport were identified to determine the areas with the lowest sustainability. Finally, appropriate actions were derived to improve the sustainability of the urban transport companies.

A multi-criteria approach was applied, in [30], to assess the transport sustainability and address the problem of developing the best practices under uncertainty. The defined economic, environmental and social indicators were prioritized to select the most appropriate alternative. Other researchers [31] compared the sustainability of the public transport. Then, using 15 indicators weighted by the equal weighting method, a composite indicator was calculated to identify transport gaps between different cities. Gudmundsson and Regmi [32] analyzed the transport sustainability in four Asia-Pacific cities using the urban transport index. The latter was developed from 10 elementary indicators applying the equal weighting method. Costa et al. [33] introduced an urban mobility index to evaluate transport sustainability utilizing equal weighting. This index was applied in Greater Vitoria, Brazil.

Mahdinia et al. [34] weighted and aggregated the economic, environmental and social/societal indicators into an index using PCA/Factor Analysis (FA) statistical methods. Danielis et al. [35] developed a composite indicator by employing different normalization, weighting and aggregation methods to assess the sustainability of urban mobility. The authors proved that the use of different methods significantly affects the values obtained by composite indicator. Lopez-Carreiro and Monzon [36] presented an approach to evaluate sustainability and smart mobility in some Spanish cities. Some elementary indicators were selected and aggregated into an index to determine the intelligence of the urban mobility. Similarly, Bandeira et al. [37] used a multi-criteria fuzzy approach to assess the sustainability of the distribution chain and select sustainable configurations for freight transport operations. Researchers aggregated a set of freight transport indicators into a composite indicator. Subsequently, a sensitivity analysis was performed to assess the influence of the weights assigned to the input parameters on the final priority ranking and, thus, on the final decision. The introduced composite indicator was utilized to evaluate alternative courier operations in Rio de Janeiro, Brazil, by comparing the traditional distribution with the e-tricycle one. This study allowed companies and transport operators to compare quickly and
easily the alternative configurations of their distribution chains and, then, to rank them according to sustainability.

Pathak et al. [38] suggested a composite indicator to assess the sustainability of freight transport. Their objective was to identify undervalued areas and plan appropriate corrective actions to improve them. This study added three emerging dimensions (efficiency, advanced technology and safety) to the traditional sustainability dimensions. Firstly, a list of key success factors affecting freight transport sustainability was presented after reviewing the existing literature and applying a Delphi method. Secondly, the Total Interpretive Structural Modelling (TISM) method was used to identify the structural relationships between the key success factors and to determine their influence on each other. Subsequently, the Fuzzy Analytical Hierarchy Process (F-AHP) was applied to prioritize these factors. The obtained results prove that the advanced technology dimension is the most important followed by the social dimension and the safety dimension. Another study [39] used equal weighting to weight the elementary indicators. In order to improve the potential of the public transport, the authors calculated four composite indicators (economic transport, environmental transport, social transport and sustainable transport) to compare the sustainability of the public transport in seven cities namely Pune, Surat, Ahmedabad, Chennai, Kolkata, Bangalore and Mumbai.

Kumar and Anbanandam [40] proposed an assessment approach to improve social sustainability in freight transport industry. In a first step, enablers, dimensions and attributes used to measure the social sustainability of freight transport were selected from a literature review and were validated by industry experts. The proposed approach took into account 74 attributes divided into 16 dimensions and 4 enablers of social sustainability (internal human resources, external population, stakeholder participation and macro-social performance). Afterwards, the fuzzy logic method was utilized to calculate the social sustainability index. In a third step, the approach was validated by experts and freight transport industry in a region of northern India. Hendiani and Bagherpour [41] introduced a sustainability composite indicator applying Z-number to assess the freight transport sustainability under traditional dimensions (economic, environmental and social). The Z-number was adopted to propose a possibilistic approach that eliminates the mathematical sophistication. In other words, the suggested model includes linguistic possibilistic variables based on the verbal certainty of experts. This model was validated by comparing its results by those provided by both conventional fuzzy sets and crisp approach whose superiority was demonstrated by its better results.

Kumar and Anbanandam [42] developed an index to assess the environmental and social sustainability of the freight transport industry. After identifying sustainability attributes from experts, the importance weight of the sustainability dimensions and indicators was computed with the Fuzzy Best Worst Method (F-BWM). Then, the low sustainability attributes were quantified. The application of the developed index in an Indian freight industry allowed identifying the unsustainable attributes and defining adequate policies to improve the environmental and social sustainability of the freight transport industry. Yazdani, Pamucar, et al. [43] presented a decision-making approach by combining the multi-criteria methods with Rough Set Theory (RST). The proposed approach was particularly applied to assess the sustainability of
the transport companies. The Rough DEcision-MAking Trial and Evaluation Laboratory (R-DEMATEL) and the Rough Multi-Attributive Border Approximation Area Comparison (R-MABAC) methods were applied to appraise sustainability. Finally, this approach was used to evaluate the sustainability of seven Spanish freight transport companies. In fact, the latter use different modes of transportation (e.g. truck and train) and different vehicle fleets.

Illahi and Mir [44] suggested a fuzzy composite indicator of urban mobility. In this study, sustainability indicators were normalized, weighted and aggregated by employing FA method. This composite indicator was used to compare the sustainability of 16 cities in India. The same researchers [45] defined an index to evaluate the sustainability of the transport industries from a holistic perspective. In this study, different methods, such as equal weighting, fuzzy logic and PCA method, were combined to construct the proposed index. The PCA method was utilized to transform a larger number of indicators into a smaller set of 10 indicators. Then, these statistically weighted indicators were combined using fuzzy logic to create three fuzzy weighted indicators; each of which corresponds to three traditional sustainability dimensions (economic, environmental and social/societal). Authors, in [46], proposed a composite indicator to assess the sustainability of the public transport based on PCA/FA methods.

Fulzele and Shankar [47] developed a composite indicator to assess the sustainability of freight transport operators. The degrees of importance of the indicators of the three sustainability dimensions were determined by the consensus model. The developed composite indicator handled the imprecision in decision making by using Fuzzy Evidential Reasoning Algorithm (FERA) combined with Dempster-Shafer theory. The FERA technique was also adopted to aggregate belief degrees by managing uncertainties associated with subjective judgments and incomplete information. A sensitivity analysis was performed in order to examine the robustness of the model output. Pathak et al. [48] used FERA technique to assess freight transportation sustainability based on competitive priorities. They identified key sustainability success factors that influence the following four main competitive priorities: cost, delivery, quality, innovation and flexibility. The authors highlighted the lack of the operators’ sustainability assessment capacity and that of monitoring tools to evaluate their sustainability practices. On the other hand, researchers, in [49], examined the transport sector based on the Grey-Decision Making Trial and Evaluation Laboratory (G-DEMATEL) method. They identified the barriers to the implementation of sustainable transport. The objective of the study was to identify the interrelationships between the barriers and to prioritize them according to their causal relationship.

In our previous work, we introduced a Facility Location index according to Sustainability perspectives (FLS) [50]. A Fuzzy Full Consistency Method (F-FUCOM) was applied to estimate the importance weight of the proposed indicators. Then, the fuzzy Multi-Attribute Ideal Real Comparative Analysis (F-MAIRCA) was conducted and the Fuzzy Preference ranking Organization Method for Enrichment Evaluation (F-PROMETHEE) was applied to rank the location of logistics platform under weak sustainability and limited sustainability, respectively. Sustainable Freight Transport index was also developed according to Sustainability perspective (SFTS) to assess urban freight sustainability [51].
4 Results And Analysis

In the following sub-sections, we will discuss the relevant aspects of sustainability studied in the current research work. Sub-sections 4.1 and 4.2 describe the application field of composite indicators and their sustainability dimensions related to these indicators. The following sub-sections present methods employed to construct composite indicators.

4.1 Application field of composite indicators

It is important to emphasize that few studies proposed composite indicators to assess the sustainability of freight transport. Almost half of the studies proposed composite indicators to evaluate sustainability in public transport. However, the other research works dealt with freight transport and public transport (cf. Figure 2).

4.2 Sustainability dimensions

At each sustainability dimension, a set of elementary indicators were defined. In the previous studies, the number of indicators employed in each approach varies from 5 to 233.

Regarding the sustainability dimensions of these indicators, more than half of the existing approaches considered only the traditional dimensions of sustainability (economic, environmental and social/societal). Over a quarter of these approaches added other sustainability dimensions (political, spatial, activity, mobility, etc.) to the three mentioned ones. Figure 3 shows the dimensions retained to the construction of the composite indicators, while Fig. 4 presents the others dimensions.

4.3 Normalization methods

Regarding normalization, the majority of composite indicators adopted Min-Max normalization (Rescaling). According to Nardo et al. [52], this method is the most useful to normalize data. On the other hand, the Z-score method was used to a lesser extent. It was efficiently applied in cases where extreme values could be unreliable outliers. However, the third normalization method is based on categorical scaling and Distance from a Reference (DR). Despite the ease implementation of the categorical normalization methods (i.e. Likert scale and lookup table), they were not intensively utilized due to their dependence on the stakeholders' opinions. Similarly, the normalization methods relying on distance from a reference (e.g. average, leader) have other limitations. In fact, they are not very reliable because they depend on extreme values. Figure 5 defines the existing normalization methods.

4.4 Weighting methods
The weighting approaches are classified into three categories: equal weighting, weighting based on expert opinion and weighting relying on statistics. At least two fifths of the existing approaches were given equal weighting. The application of this weighting was fairly simple. Indeed, this approach was of little use in the case where the data points were correlated and the time scale for the transport assessment was long. As it has some limitations, AHP, BWM [42], FUCOM [50] and Delphi comprise the most often implemented participatory methods. The application of the latter is important because it involves the opinions of many experts with different backgrounds. Nevertheless, managing a larger dataset using these participation methods is difficult. On the contrary, statistical methods, such as DEA and PCA/FA, applied to determine weights from the collected data were not intensively employed in previous studies. Despite their efficiency, these techniques require feasibility checks. The different used weighting methods are presented in Fig. 6.

4.5 Aggregation methods

Aggregation methods can be classified into three categories: compensatory approaches, partially compensatory approaches and non-compensatory approaches. It is obvious that the linear aggregation method and simple additive rules are the most adopted techniques. In fact, the aggregation methods reward the indicators proportionally to the assigned weights and the compensation remains, in this case, constant. In other words, the majority of the existing approaches use compensatory methods and favor weak sustainability. Few studies [30, 32, 43] opted for partially compensatory aggregation with limited sustainability. In [6], the authors proposed a non-compensatory composite indicator by favoring strong sustainability. Other works [35, 50, 51] introduced composite indicators by applying different compensation techniques. The aggregation methods are presented in Fig. 7.

4.6 Consideration of uncertainty

One third of proposed composite indicators approaches took uncertainty into account to construct the composite indicator and most of them used fuzzy logic since it integrates expert’s opinions in the decision making process. The fuzzy decision rules were applied in [37, 44, 45], while linguistic variables were employed in [29, 40, 41, 51]. Different MCDM methods coupled with fuzzy set theory were utilized to build composite indicators [30, 38, 42, 43, 50]. In fact, the application of MCDM methods helps actors evaluate the transport sustainability by weighting the used indicators and identifying the best solution.

5 Discussion

In this article, we conduct a review of 47 articles published between 2002 and 2022. The literature analysis, highlights major limitations. We present the existing approaches to construct composite indicators. The purpose of this section is to (i) analyze research trends and gaps and (ii) identify future research orientations.

- We notice that few researches studied freight transport. First, we intend, in future work, to examine urban freight transport.
As shown in the literature review, the traditional dimensions, the main focus of previous studies, do not consider sustainability aspects in an exhaustive way and are, therefore, insufficient to reflect the real status of transport system. For these two reasons, we proposed a conceptual framework that considers not only the traditional dimensions, but also other essential and important ones, such as political and spatial dimensions, to assess freight transport at large scale.

It is also clear that the number of elementary indicators was not specified in previous studies. According to Sdoukopoulos et al. [53], the average number of indicators used to construct composite indicators should be equal to 23 to facilitate the application of the employed of assessing methods. Then, we recommended to use a manageable set of indicators and avoid the employment of a small number of unrealistic indicators that do not necessarily present all the dimensions of sustainability.

Fourthly, we note that the utilization of different methods of normalization, weighting and aggregation influences the result given by a composite indicator. In fact, most studies that proposed composite indicators applied equal weighting or AHP method. However, the FUCOM method is more efficient than the AHP method as it is more stable, more reliable and more robust. In fact, it is widely used in the literature in different fields thanks to its easy implementation. It is also obvious that elementary indicators can be aggregated into a composite indicator either by mathematical formulations or by MCDM methods. It is worth to note that the majority of the used methods applied the compensatory aggregation technique in short-term decision making. Thus, it is important to employ different aggregation techniques to illustrate the nuances in the stakeholder's views.

6 Conclusions

Transport system plays a decisive role in the economic progress and the development of other sectors. However, the assessment of its current sustainability situation is widely recommended as this sector faces, nowadays, many problems that should be solved. In this context, sustainability indicators were considered as one of the tools that help decision-makers evaluate sustainability by providing relevant information about the current status of transport system. In this paper, we presented a review of sustainability assessment approaches in the transport field published over the two last decades. First, the concept of composite indicators and its different construction steps were presented. Second, the existing approaches applied to select indicators and propose indexes were examined. Third, the obtained results were analyzed. Furthermore, some research trends, a short discussion and a critical analysis of the different approaches illustrated in the literature were provided. Finally, we identified the gaps in evaluating sustainability and future research orientations that should be further focused on future work.

The results obtained by the performed analysis showed that most of the existing studies dealt with public transport. Furthermore, the majority of the existing approaches are based exclusively on sustainability considering the traditional dimensions by including undefined number of elementary indicators. Moreover, the use of different normalization, weighting and aggregation methods provide different result of composite indicators.
Based on the obtained findings, we proposed the following research perspectives. First, we suggested extending research in the field of freight transport. Second, we showed that it is necessary to consider not only the traditional dimensions, but also other important dimensions to assess the transport system. It was also noted that the definition of sustainability dimensions is very crucial in the process of evaluating the sustainability of freight transport from a global perspective. Then, we suggest using a manageable number of elementary indicators to facilitate the application of composite indicators. Finally, we proposed to choose the most appropriate method of normalization, weighting and aggregation to construct composite indicators.

Declarations

Ethical Approval

Not applicable.

Competing interests

The authors declare no conflict of interest.

Authors’ contributions

Conceptualization, H.A. and N.H.; methodology, H.A., N.H., M.B. and L.K.; validation, H.A., N.H., M.B. and L.K.; formal analysis, H.A.; writing—original draft preparation, H.A.; writing—review and editing, H.A., N.H., M.B. and L.K. All authors have read and agreed to the published version of the manuscript.

Funding

This study received no funding from any organizations.

Availability of data and materials

Not applicable.

References


32. Gudmundsson H, Regmi M (2017) Developing the sustainable urban transport index


46. Illahi U, Mir MS (2021) Sustainable Transportation Attainment Index: multivariate analysis of indicators with an application to selected states and National Capital Territory (NCT) of India.
Table 2
Table 2 is available in Supplementary Files section.

**Figures**

**Figure 1**

The successive steps of the construction of an index
Figure 2

Application fields of composite indicators
Figure 3

The sustainability dimensions retained to the construction of the composite indicators
Figure 4

Others sustainability dimensions

Figure 5

- Min-Max
- Z-score
- Categorical scaling
- Distance from a reference
The normalization methods

- Equal weighting: 41%
- Weighting based on expert opinion: 17%
- Weighting based on statistics: 42%

Figure 6

The weighting methods

- Compensatory: 82%
- Partially compensatory: 7%
- Non-compensatory: 4%
- Different compensation: 7%
Figure 7

The aggregation methods

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table2.doc