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Indicators for assessment progress towards urban freight transport sustainability

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Abstract

Today, assessing the sustainability of urban freight transport is crucial to deal with its negative impact. In this context, many indicators were developed to track the progress of sustainable transport system. These indicators guarantee communication and facilitate the interaction between private and public actors. However, selecting the appropriate indicator presents a particular challenge because of the large number of the available indicators. This study provides a literature review to discuss the selection of sustainability indicators in the field of transport and focus on the main methodological choices. Its aims to identify and to compare the advantages and limitations of selecting approaches. A total 14 studies conducted in the period 2002-2022 are examined. Important methods to select indicators are summarized. The obtained results show that most researchers focused on public transport; as well as a lack of consideration of others sustainability dimensions was highlighted. Then, the most frequently-used methods to select indicators are based on previous literature and properties. A set of recommendations is presented in order to develop future research.

Keywords: Sustainability indicators, Urban freight transport, Sustainability, Sustainability dimensions, Assessment methods

1. Introduction

The urban freight transport is an important component of the economic development. However, this system is characterized, in practice, by a significant gap between the behaviors and needs of the urban economic agents, on the one hand, and the capacities of the transport and logistics companies, on the other hand (Dablanc, 2007). For years, it has faced numerous problems, which prevented its sustainable development, and multiple difficulties resulting from the lack of assessment tools (Ayadi et al., 2021). Thus, the use of sustainability indicators allows for the assessment and monitoring of freight activities. The problems related to the assessment of transport sustainability are studied by several previous works. In this paper, we present a state of the art dealing with the assessment of freight transport and

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public transport. From these research works, we identify the research gaps and the limits in this field to position oneself in the literature.

The main objective of this paper is to identify the trends and gaps of existing approaches fused to select sustainability indicators in transport field. The following research questions are answered in this paper:

- How important is the use of indicators in evaluating the sustainability of the transport system?
- What are the existing approaches applied to select transport indicators?
- What are the existing research gaps?

2. Relevance of sustainability indicators

In general, indicators are the basis of information systems or decision support tools (Bouni, 1998). They are widely used to measure the system performance (Gudmundsson et al., 2016; Shiao and Liu, 2013). As stated by (Ducq, 2007), “a performance indicator is a quantitative or qualitative measure that can define the effectiveness of the decision variables in relation to the achievement of the objective defined at the level of decision considered.”

Indicators are viewed as powerful tools for several reasons. In fact, they allow making a good diagnosis system, monitoring the effects of different interventions and measuring the importance of different sectors in achieving sustainability. Currently, there is broad consensus on the role of indicators in monitoring the improvements of the decision-making process and assessing the progress in achieving some goals and government policies (Munier, 2011). Many indicators were introduced in the literature (Crainic, 2008; Fontaine et al., 2017; Gudmundsson et al., 2016; Joumard & Gudmundsson, 2010; Russo & Comi, 2012). They have different forms and produce various types of information. In this section, we discuss two types of indicators: elementary indicators and composite indicators.

- Elementary indicators do not depend on other indicators to evaluate a particular situation. As they are generally operational, these indicators are local in nature and are generally used to analyze the physical system.
- A composite indicator, also known as an index, is a combination of several elementary indicators via mathematical aggregation. It is usually employed to describe a specific context. The process of constructing a composite indicator consists in weighting the elementary indicators and aggregating them into a composite indicator (Munda, 2005; Nardo et al., 2005; Saisana and Tarantola, 2002).

3. Existing approaches to selecting sustainability indicators

The aim of this section is to evaluate the most used methods for selecting indicators. In this context, we present in Table 1 approaches for selecting sustainability indicators in the field of transport. The approaches presented in Table 1 are organized into five parts. The first part contains sustainability dimensions and the second part specifies properties. The third part presents the methods used in the literature for selecting indicators. The fourth part specifies the number of indicators selected. Finally, each approach is presented according to their field of application. In addition, Table 1 is listed in chronological order of approaches.

Several studies introduced (Castiglione et al., 2022; Filippi et al., 2010; Marcucci et al., 2015; Mazzarino and Rubini, 2019; Melo and Baptista, 2017; Palacios-Argüello et al., 2018; Patier and Browne, 2010; Russo and Comi, 2011; van Duin et al., 2012) indicators to assess the sustainability of transport fields. In the literature, there is not a lack of assessment tools but a lack of unification in those approaches (Gonzalez-Feliu, 2018a; Russo and Comi, 2010). There is neither a standardized selection approach nor a set of standardized indicators to assess transport sustainability. One of the first works proposing a set of indicators to assess the sustainability of urban transport is that of (Melo and Costa, 2011). The literature shows that the number of transport sustainability assessment indicators was gradually increasing. The use of indicators is critically important to help transport actors develop good practices and planning procedures. However, a lack of uniformity in sustainability information has led researchers to organize sustainability indicators by proposing selecting approaches. Each indicator selected must clearly refer to each sustainability dimension to describe a typical scenario of transport. The choice of appropriate indicators can be established by both private and public actors to define their potentially interests. We present below a not systematic review of the existing work dated from 2005 to 2022 proposing sustainability indicators for transport. In this literature we only present the

approaches for selecting elementary sustainability indicators and not the approaches for constructing composite indicators. Only 14 works elaborate on the selection method.

(Mihyeon Jeon and Amekudzi, 2005) presented a review of the main approaches proposed in North America, Europe and Oceania. Then, they defined a set of transport sustainability indicators based on cause-effect relationships. The aim of the study was to help companies monitor the sustainability of transport. This study indicated that there was no standard framework for assessing progress towards transport sustainability. In the same context, (Litman, 2007) presented a set of transport sustainability indicators, drawn from the literature, to assist in planning processes. Researcher recommended the following properties to select indicators: completeness, data quality, net effects, comparability, comprehensibility, accessibility, transparency, profitability and performance targets. (Dobranskyte-Niskota et al., 2007) establish city logistics indicators, drawing from a document by the EC JRC that features a validated methodology and a set of standard indicators designed for sustainable urban transport.

(Yigitcanlar and Dur, 2010) defined indicators based on Delphi method. Although (Melo and Costa, 2011) have focused on assessing the sustainability of urban freight transport. This study was considered as one of the first study proposing a set of urban freight transport indicators.

The dashboard was a decision support tool widely used in urban logistics. In this context, (Gonzalez-Feliu and Morana, 2014) employed an expert-based procedure to streamline the indicators and utilized a consensus search method for validation. In contrast, in another study (Morana and Gonzalez-Feliu, 2015), operational managers, lacking expertise in city logistics, were consulted. In this paper, the authors integrate a statistical method with a consensus search procedure. They built a dashboard to assess the sustainability of urban logistics projects resulting from the socio-constructive learning approach. Researchers defined indicators according to traditional dimensions (economic, environmental and social/societal) to support decision-making in the management of tactical and operational urban logistics. These indicators generally concern the direct impacts of urban logistics activities, i.e. the impacts linked to the phase of use of the vehicles, road infrastructures and logistics buildings necessary to carry out these activities. (Andriankaja et al., 2015; Cheba and Saniuk, 2016) employed an expert-based approach to select a set of indicators.

(Jain and Tiwari, 2017) suggested an indicator selection approach applying properties, causal chains and causal networks. In the first step, a list was identified from the literature. On the one hand, these indicators were grouped by factors and classified according to four sustainability dimensions. On the other hand, the relationships between the identified factors were determined in several causal chains. In the second step, the causal chains defined in the previous step were linked in a causal network. Then, the factors were classified according to their position in the causal network as sender, ordinary and receiver. Finally, the indicators were evaluated by the properties.

(Ibadi, 2017) proposed a set of transport sustainability indicators that will help in the development of policy strategies to mitigate the negative impacts of transport activities. The set of indicators was identified from the literature, and then it was selected utilizing properties.

(Nadi and Murad, 2017) presented a review of the literature aimed to studying existing work dated from 2000 to 2016 on sustainability indicators for public transport. Five key performance indicators were defined (congestion, accidents, air pollution, noise pollution and land use) to determine the level of sustainability of a city.

In the review of (Gonzalez-Feliu, 2018a), a set of indicators for evaluating the sustainability of urban logistics was defined. The indicators were classified according to the three traditional dimensions of sustainability. Researcher mentioned that the consideration of sustainability as well as the choice of indicators depends on the type of actors.

Rai et al. (Rai et al., 2018) introduced a set of urban freight transport indicators with an operational objective of sustainability. Five experts from their academic research unit participated in the internal selection process for indicators. Then, an external validation exercise was carried out by other experts from the University of Hasselt. In this study, six selection properties were guided indicators selection process. Finally, these indicators were hierarchically structured according to four sustainability dimensions, namely profit, planet, people and politics.

The studies presented in this literature were explicitly focusing non-spatial indicators. With this in mind (Gonzalez-Feliu, 2018b) presented an overview based on accessibility and attractiveness indicators of freight transport and urban logistics, from the point of view of intelligence territorial. From this study, five categories of indicators were defined: infrastructure, determinants of the generation of goods, severity and compatibility of accessibility measures and the category of distance, time and cost.

Furthermore, (Sdoukopoulos et al., 2019) measured progress towards transport sustainability. In this context, a detailed review identifying the most commonly used indicators according to the three traditional dimensions was

presented. Researchers noticed an increase at an almost linear rate of indicator-based approaches. (Yang et al., 2020) proposed indicators to help transport actors evaluate urban plans and alternative infrastructure designs. After a review of the literature since 2009, the authors extracted 64 indicators of transport and spaces. Then, a multi-criteria analysis was used based on 3 properties and consulting experts to define the final set of selected indicators.

(Kraus and Proff, 2021) conducted a literature review on sustainable transport to select a set of transport sustainability indicators according to the three sustainability dimensions. Researchers selected indicators from 21 articles, focusing on those properties: irrelevant, measurable, unacceptable and redundant. After verifying the requirements, 33 indicators were identified.

The following section presents a synthesis of the selection approaches presented in Table 1.

Table 1. Approaches to selecting sustainability indicators in the field of transport

Dimensions		Properties	Methods			
Traditional	Others			Number of indicators	Application	Reference
*		--	Literature, Causal relationships	60	PT, FT	(Mihyeon Jeon and Amekudzi, 2005)
*		Comprehensive, Data quality, Net effects, Comparable, Easy to understand, Accessible and transparent, Cost-effective, Performance targets	MCA	35	PT, FT	(Litman, 2007)
*	*	--	Literature	55	PT, FT	(Dobranskyte-Niskota et al., 2007)
*		--	Delphi	30	PT, FT	(Yigitcanlar and Dur, 2010)
*	*	Scientific validity, Relevant, Net effects, Evidence of links of cause and effect Cost effectiveness, Responsiveness to change, data availability, Representativeness, Comparability to target, Transferability,	MCA, Questionnaire, Expert consultation,	44	FT	(Melo and Costa, 2011)
*		--	Co-constructive method	34	FT	(Gonzalez-Feliu and Morana, 2014)
*		--	Co-constructive method Statistical method	28	FT	(Morana and Gonzalez-Feliu, 2015)
*		--	Expert consultation	9	FT	(Andriankaja et al., 2015)
*		--	Expert consultation	11	PT, FT	(Cheba and Saniuk, 2016)
*		--	Literature	5	PT	(Nadi and Murad, 2017)
*	*	Specific, Measurable, Achievable, Relevance, Data availability	Literature, MCA, Causal relationship	32	PT	(Jain and Tiwari, 2017)
*		Comprehensiveness, Data quality, Comparability, Easiness to understand, Accessibility and Transparency	Literature, MCA	8	PT	(Ibadi, 2017)
*	*	--	Literature	13	FT	(Gonzalez-Feliu, 2018b)

*	--		Literature	25	FT	(Gonzalez-Feliu, 2018a)
*	*	Dynamic, communicative, comprehensive, feasible, interpretable and relevant.	Literature, MCA, Expert consultation,	45	FT	(Rai et al., 2018)
*		Vague nature, High interest, Increased complexity, Specific, Availability of data	Literature, MCA	47	PT, FT	(Sdoukopoulos et al., 2019)
*		Relevance, independence, Necessary evaluation items inclusion	Literature, MCA, expert consultation	64	PT	(Yang et al., 2020)
*		Relevance, measurability, the avoidance of redundancy, and validity	Literature, MCA	33	PT, FT	(Kraus and Proff, 2021)

FT: Freight Transport; PT: Public Transport; MCA: Multi-Criteria Analysis

4. Research trends and gaps

In the remainder of this section, we will discuss the application filed of the selecting approach presented in Table 1. Secondly, we will discuss the sustainability dimensions related to the selected indicators. Then, the used properties will be presented and their importance will be discussed. Finally, the methods used to select transport sustainability indicators will be outlined.

- Table 1 presents studies dealing with the selection of indicators applied to assess the sustainability of freight transport, that of the public transport or both of them. We note that few studies defined a set of specific indicators related to freight transport.
- According to Table 1, the number of indicators included in each selecting indicators approach remains undefined (Asmelash and Kumar, 2019), it ranges from 5 to 64. In fact, the most important thing is to use a manageable set of indicators and to avoid the employment of a small number of indicators that is unrealistic and does not necessarily present all the sustainability dimensions (Illahi and Mir, 2020; Reisi et al., 2014). Our analysis demonstrates that the majority of the existing approaches considered the traditional dimensions. However, some approaches added other dimensions, especially mobility dimension and the activity dimension (Jain and Tiwari, 2017; Melo and Costa, 2011) as well as the political dimension (Rai et al., 2018). Subsequently, (Gonzalez-Feliu, 2018b) considered a new category of spatial indicators. In this context, we notice that, in the literature, no standardized sustainability dimension has been generalized other than the traditional ones. Nowadays, the urban freight transport has generated problems that affected significantly the sustainability of this field. The different dimensions should be selected and defined to guide the actors in evaluating the sustainability of the urban freight transport. For this reason, we propose to integrate other sustainability dimensions, such as political and spatial, into economic, environmental and social/societal.
- The analysis of the literature shows that the most important studies (Jain and Tiwari, 2017; Kraus and Proff, 2021; Litman, 2007; Melo and Costa, 2011; Rai et al., 2018; Sdoukopoulos et al., 2019; Yang et al., 2020) adopted properties to select indicators. These properties were used to examine the indicators applicability in different domains to attain specific purposes and to facilitate indicators selection. The number of the considered properties is very large and varies from one approach to another. In this particular context, we selected the most frequently utilized properties in literature. The chosen properties are detailed below:

Firstly, the **predictability** of an indicator makes it possible to predict future situation and to identify the appropriate interventions in the transportation domain. In this context, to apply quickly preventive actions, the predictability of an indicator is very important for both private and public actors.

Secondly, the **relevance** of an indicator provides correct interpretations and, subsequently, leads the actors to make good decisions.

Thirdly, the **understanding** of an indicator allows the easy implementation by the transport stakeholders. In fact, this property ensures that the considered indicator provides clear information about the transport sustainability.

Fourthly, the **data availability** is very important in order to ensure the efficiency and the high speed of the performed evaluation. Indicators should be provided by reliable sources. Thus, sometimes certain surveys and data collection are necessary.

Fifthly, the **achievability** of an indicator can provide the necessary information about transport at an acceptable cost and time.

- Table 1 presents the different methods used to select a set of transport sustainability indicators. Then, the fundamental methods used to select a set of transport sustainability indicators are determined. Various approaches referred to the literature to select indicators. It's the most used method. Other approaches were applied to select indicators based on the Delphi method (Pathak et al., 2019; Yigitcanlar and Dur, 2010) designed to obtain consensus from a group of experts. The majority of the existing approaches applied Multi-Criteria Analysis (MCA) by considering multiple properties to select indicators. Other researchers consulted experts to refine their analysis in terms of selecting indicators. These studies (Jain and Tiwari, 2017; Mihyeon Jeon and Amekudzi, 2005) combined several methods by identifying indicators derived from causal relationships and properties. After analyzing the used methods, we notice that the multi-criteria analysis is more objective, systematic and efficient in terms of time and human resources, compared to Delphi. The causal chain framework was designed to structure the problem into causal relationships. However, it is not flexible in representing the links between problems. We recommend employing MCA methods like AHP, TOPSIS, etc., as they can be automated and don't require real-time feedback from field stakeholders for computation, ensuring a reliable means of obtaining results. However, it is acknowledged that alternative methods may be applicable in various contexts.

5. Future research orientations

After analyzing the results, we can suggest some opportunities for future research to fill the gaps in the literature in assessing urban freight transport.

- In the first line research, we intend, in future work, to examine urban freight transport. We notice that the most of research studied public transport. For this reason, more attention should be paid to urban freight transport.
- In the second research opportunity, we proposed a conceptual framework which takes into consideration not only traditional dimensions, but also other critical and important dimensions.
- A third research perspective concerns selecting methods. we recommended to select indicators based on literature and the following properties: predictability, relevance, understanding, data availability and achievability.
- A fourth research direction is related to proposing standard set of urban freight transport indicators to assess the sustainability. Then, aggregating this set of indicators into a composite indicator to facilitate the assessment.

6. Conclusion

Despite the remarkable progress of urban freight transport, this sector generates problems that prevent sustainability. Additionally, in a competitive environment, sustainability assessment is increasingly difficult. Therefore, sustainability indicators were considered as one of the tools that help decision-makers assess sustainability status of urban freight transport. In this paper, we presented a definition of sustainability indicators and their importance. Second, the existing approaches applied to select indicators in transport field were examined. Furthermore, a short discussion and critical analysis of the different approaches illustrated in the literature were presented. Finally, we identified four research direction that merit investigation in future work.

Based on the obtained findings, we showed that it is necessary to consider not only the traditional dimensions, but also other important dimensions to assess the transport system. Third, we proved that the use of properties facilitates the selection of sustainability indicators and guides actors to choose the most appropriate indicators in a short time. Fourth, as neither a standard selection approach nor a set of standardized indicators was introduced to assess the urban freight transport sustainability. In addition, it is important to note that the individual assessment of the indicators is complex, given the multidimensionality of the set of indicators. In this context, an aggregation of these indicators into a composite indicator is therefore a solution to assess the urban freight transport sustainability.

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