Indicators for Sustainability Assessment in City Logistics: Perspectives of Society and Logistic Service Providers

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ABSTRACT

The urban logistics system greatly affects the liveability of the urban environment and the health of citizens through transport-related externalities. Urban logistics practices are being implemented to contribute to the sustainability of the urban environment. To make informed decisions, actors and stakeholders require knowledge about these practices and their impacts. This paper proposes a set of measurable indicators for sustainability assessment. For assessing sustainability, it is key to comprehensively consider sustainability dimensions. Therefore, the starting point of this paper is the Sustainable Development Goals (SDGs), to have a holistic view of sustainability, combined with existing indicators in the city logistics literature, to ensure relevance to the context. Moreover, it is important to consider the perspective of different actors and stakeholders. The novelty of this work is the definition of indicators from the perspectives of both the citizens as stakeholders and the logistics service providers as actors. The set of indicators is tested in two previous studies, showing that it is possible to evaluate the sustainability performance of urban logistics practices. Future work includes using the set of indicators in a real case study, to test the attainability and relevance of the indicators. This set of indicators should be used to evaluate urban logistics practices, with the aim of increasing the knowledge that actors in the urban freight transport system have regarding these practices. This knowledge can help decision-makers in the private and public sectors to make decisions that facilitate a more sustainable urban freight transport system.

Keywords: Urban freight transport systems, Sustainability assessment, Urban logistics practices.

INTRODUCTION

Transport-related externalities (such as greenhouse gas emissions, congestion, air pollution and noise) affect the urban environment as well as the health of citizens (*1*), bringing several sustainability challenges in the urban freight transport system. Freight flows are growing (*2*), causing an increase in transport-related externalities, exacerbating the problem. Different sustainable urban logistics practices (e.g., electric vehicles, consolidation strategies, cargo bikes) are being developed and implemented in an attempt to reduce the externalities. Decision-makers in both the private and public sectors require access to knowledge about the sustainability of these practices, for example how these practices impact the working conditions in the city. This knowledge is needed to understand and compare different solutions in terms of sustainability impacts (*3, 4*).

Sustainability assessments enable the understanding of whether a practice leads towards sustainable development (*5*). An option for carrying out a sustainability assessment is to define a set of indicators that characterize sustainable development and to use this set to quantify the impacts of a practice (*5*). In the literature, various sets of indicators for sustainability assessment in the urban freight transport system are proposed (see the Background section for an overview of existing sets of indicators). However, these sets of indicators either do not contain measurable indicators, include only some dimensions of sustainability, or consider the perspectives of only one stakeholder in the urban logistics system. Thus, there is a lack of a set of measurable indicators that considers different sustainability dimensions and stakeholders' perspectives.

In this paper, the aim is to define a set of measurable indicators that comprehensively considers sustainability dimensions, that is relevant to the context of city logistics, and that includes different actors' and stakeholders' perspectives. We achieve this by combining the Sustainable Development Goals (SDGs) developed by the United Nations (UN) (*6*) with the existing indicators in the city logistics literature. To the best of our knowledge, no other paper in the literature starts from the SDGs to define a set of indicators. Moreover, the perspective of the Logistics Service Providers (LSPs) is considered: the other novelty of this work is to have different indicators at the societal level and at the LSP level. This is done to enable the understanding of how the LSPs can affect the societal level indicators and how these in turn impact LSPs and their economy. Many indicators can be used to assess the sustainability of urban logistics practices. The aim of this paper is to form a set of indicators with a balance between specificity and aggregation since a large number of indicators would be overly complex to handle, while the contrary would not allow for a holistic view.

The paper is structured as follows: in the Background section, an overview of the city logistics field with its stakeholders and challenges is provided; in the Methodology section, the methodology is described; in the Results section, the set of indicators is presented; in the Discussion section, the research contributions are discussed, together with future work and limitations; and finally, in the Conclusion section, the conclusions and the key takeaways of the work are provided.

BACKGROUND

Sustainability has become a concern for transport policy and planning in the past years and many efforts have been made to promote sustainable development to transportation. The transportation of goods within the city boundaries, i.e., the urban freight transport system, is the focus of this paper. The urban freight transport system is responsible for a variety of externalities (for example, air pollution, noise, accidents, vibration, land use and visual intrusion) (*7*). The growth of the freight flows expected in the future (*2*) will further increase the impacts of these externalities. To reduce these impacts, new solutions for city logistics have been designed and several projects have been undertaken in the past years (*8*).

There are many stakeholders in the urban freight transport system. In this paper, we differentiate between stakeholders and actors in a system, as defined in (*9*):

"Stakeholders are all that have an interest in the system of urban freight transport (individuals, groups of people, organisations, companies, etc.); whereas actors are those that have a direct influence on the system. Therefore, all actors are stakeholders, but not all stakeholders are actors."

According to this definition (*9*), shippers, LSPs, authorities and customers are the actors. The main stakeholders are citizens, vehicle manufacturers, landowners, public transport operators, and trade and commercial organisations (*9*). This holds in general for urban logistics practices. When considering specific technologies such as electrification, digitalization or automation, it might be relevant to consider additional stakeholders. Both actors and stakeholders take decisions that directly or indirectly affect the urban freight transport system. The complexity of the urban freight transport system is illustrated in part by the diversity of the stakeholders involved and by their varying scopes and purposes. It is therefore important to consider this diversity when selecting and defining the indicators.

In the literature, there is a strong focus on green logistics, defined as the study of the environmental effects (mainly greenhouse gas emissions) of the activities involved in transporting, storing, and handling physical products as they move through the supply chain (*7*). A review of indicators for sustainability in city logistics (*10*) finds that most of the studies on sustainable transportation include environmental aspects such as greenhouse gas emissions, noise and fossil energy consumption, but not all consider other dimensions of sustainability. According to another review (*11*), earlier studies give priority to the environmental dimension, and only more recent studies present more balance between sustainability dimensions. In the context of green logistics, environmental logistics practices include all environmental activities relating to logistics and supply chain management that minimise negative environmental impacts (*12*). According to a literature review on sustainable city logistics (*13*), the social issues are not analyzed extensively, despite being essential to sustainable development.

In this paper, the focus is on sustainability with a more holistic perspective than just the environment. According to the International Institute for Sustainable Development, sustainable development is that which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (*14*). Sustainability is also at the basis of the Agenda 2030 and the SDGs developed by the UN (*14*). To study sustainable development, the environmental dimension is not enough, and a holistic perspective and an integrative approach are needed (*5*). In this paper, we start from the SDGs to study the dimensions of sustainability as holistically as possible, and we define sustainable urban logistics practices as all activities that aim to increase the sustainability of the urban freight transport system.

Using indicators has several advantages: indicators can be used to make the notion of sustainability measurable, and they can be useful tools for communicating with stakeholders (*10*). However, it is difficult to find a general set of indicators for sustainable transportation due to the diversity of values, scientific disciplines, and planning tasks (*5*). Various attempts of sets of indicators for sustainability assessment in city logistics can be found in the literature. In Table 1 eighteen papers containing sets of indicators are listed, together with their characteristics. The table shows that 12 papers consider at least three sustainability dimensions (i.e., economic, social, and environmental). Only four papers consider multiple actors and stakeholders, while other papers either do not mention specific actors or consider only one actor's perspective. None of the papers provides different definitions of indicators for different actors or stakeholders. Most of the papers include a definition of the indicators, while only four include a metric, and therefore provide measurable indicators.

The literature confirms that there is a need of viewing sustainability from a holistic perspective, comprehensively considering its dimensions (*5*). In this paper, we aim to satisfy this need by starting from the SDGs developed by the UN. Moreover, it is also important to consider different actors' and stakeholders' perspectives (*9*). The set of indicators proposed in this paper provides indicators both at a societal and an LSP level, enabling citizens as stakeholders to be represented and LSPs as actors to better understand the sustainability impacts of urban logistics practices.

METHODOLOGY

The process represented in Figure 1 is followed to select the indicators. From an analysis of the literature, the papers in Table 1 are collected, as they contain indicators for sustainability assessment or they present a review of indicators for urban logistics practices. From these papers, 71 different indicators are collected. At the same time, from the SDG indicators list (*6*) the indicators that are relevant for the urban freight transport system are selected (11 SDG indicators). These 11 SDG indicators are the basis for the indicators at the societal level, which are defined using the city logistics literature. In this way, the indicators at the societal level are holistic in terms of sustainability dimensions, but they are also relevant to the context of city logistics. These indicators represent the citizens as stakeholders and can be used by decision-makers both in the private and public sectors to understand the impacts of urban logistics practices on society. In this paper, the perspective of LSPs is also considered, since they are often considered responsible for decreasing the negative impacts of logistics operations (*29*). Moreover, different groups or stakeholders often prefer different indicators (*5*). Therefore, 18 indicators at the LSP level are defined to represent the LSPs' perspective. These indicators are derived both from the indicators at the societal level and the indicators collected from the city logistics literature.

TABLE 1 Papers from the literature that propose sets of indicators or review the literature on indicators for urban logistics practices. For each paper, the table includes information about the included sustainability dimensions, included actors and stakeholders, definitions of indicators and measurability of indicators (i.e., if a metric is included for each indicator).

Authors	Year	Ref	Sustainability	Actors and Stakeholders	Def	Measurability
Rześny-Cieplińska and Szmelter-Jarosz	2020	(*15*)	Environmental	N/A	Yes	No
Russo and Comi	2020	(*16*)	Economic, Social, Environmental	N/A	No	No
Aljohani and Thompson	2019	(*17*)	N/A	Authorities, LSPs, customers, shippers, citizens	Yes	No
De Mello Bandeira et al.	2019	(*18*)	Economic, Social, Environmental	N/A	Yes	Yes
Jamshidi et al.	2019	(*8*)	Economic, Technical and logistics, Environmental, Social	Authorities	No	No
Kiba-Janiak	2019	(*19*)	N/A	Authorities	Yes	No
Bandeira et al.	2018	(*11*)	Economic, Social, Environmental	LSPs	Yes	Yes
Buldeo Rai et al.	2018	(*10*)	Profit, Planet, People, Policy	Authorities, LSPs, customers, shippers, citizens	Yes	No
Nathanail et al.	2017	(*20*)	N/A	Authorities, LSPs	No	No
Behrends	2016	(*21*)	Economic and environmental	N/A	No	No
Cheba and Saniuk	2016	(*22*)	Economic, Social, Environmental	N/A	Yes	Yes
Rao et al.	2015	(*23*)	Economic, Social, Environmental	N/A	Yes	No
Morana and Gonzalez-Feliu	2015	(*24*)	Economic, Social, Environmental	Operational logistics managers	No	No
Awad-Núñez et al.	2015	(*25*)	Economic, Social, Environmental, Accessibility, Location	N/A	Yes	No
Gonzalez-Feliu and Morana	2014	(*26*)	Economic, Service quality, Environmental, Social	Authorities	Yes	Yes
Lindholm and Behrends	2012	(*3*)	Economic, Social, Environmental	N/A	No	No
Behrends et al.	2008	(*27*)	Economic, Social, Environmental	Authorities, LSPs, customers, shippers, citizens	No	No
Anderson et al.	2005	(*28*)	Environmental	N/A	No	No

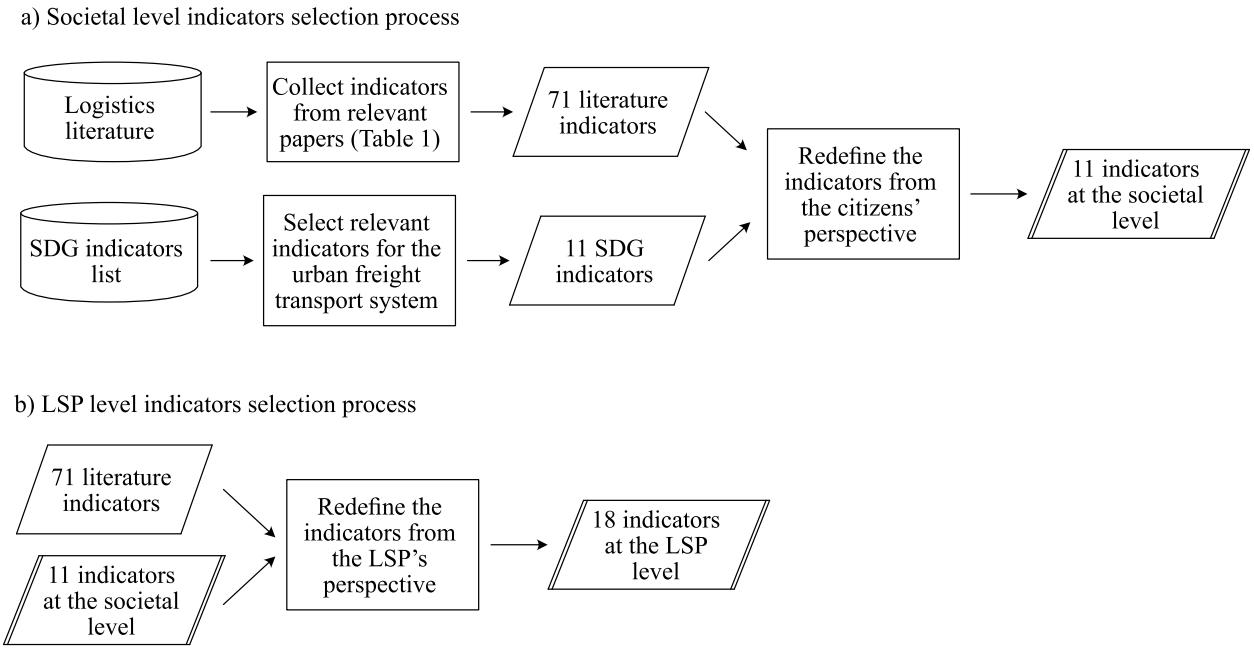

FIGURE 1 Graphical visualization of the methodological process to select the indicators

When selecting indicators, the SMART criteria (an acronym for specific, measurable, attainable, relevant and timely) should be applied (*5*). In this paper, the first two criteria of SMART are applied. First, the indicator is defined clearly; second, a unit of measurement is assigned. The other three criteria should be tested when applying the indicators to a case study and can be used to further define the definitions and unit of measurement of the selected indicators. More discussion regarding these types of testing is present in the Discussion section.

RESULTS

The indicators selected using the process described in the Methodology section are shown in Figures 2 and 3. In the following subsections, the indicators are motivated: from the SDGs to the societal level indicators (Figure 2) and from the societal level indicators to the LSP level indicators (Figure 3). All the indicators are defined within the boundaries of the urban freight transport system. The order of presentation of the indicators is not representative of their importance; all of them are crucial for sustainability assessment.

Indicators at the societal level

As described in the methodology, in this work the SDGs are taken as a starting point. From the SDGs indicators list (*6*), the authors selected the sub-goals and relative indicators that relate to the urban logistics environment. The goals that are found to contain indicators relevant to the urban logistics context are Goal 3, Goal 8, Goal 9, Goal 11 and Goal 13 (*6*). In this subsection, the connection between the SDG indicators and the indicators found in the literature is presented, resulting in 11 indicators at the societal level (Figure 2).

Goal 3 (*Ensure healthy lives and promote well-being for all at all ages*) contains sub-goals on deaths and injuries from road traffic accidents and therefore is connected to **road safety** (*8, 10, 11, 30*), defined as the number of injuries due to road traffic accidents per year. **Air pollution** is relevant as it affects the mortality rate attributed to ambient air pollution (*8, 10, 11, 18, 19, 21, 24, 26, 30*). It is defined as the emission levels of air pollutants, measured as the pollutant's concentration (annual mean levels of fine particulate matter in µg/m3). Air pollution is also relevant in Goal 11 (*Make cities and human settlements inclusive, safe, resilient and sustainable*), as it connects to the reduction of the environmental impact of cities.

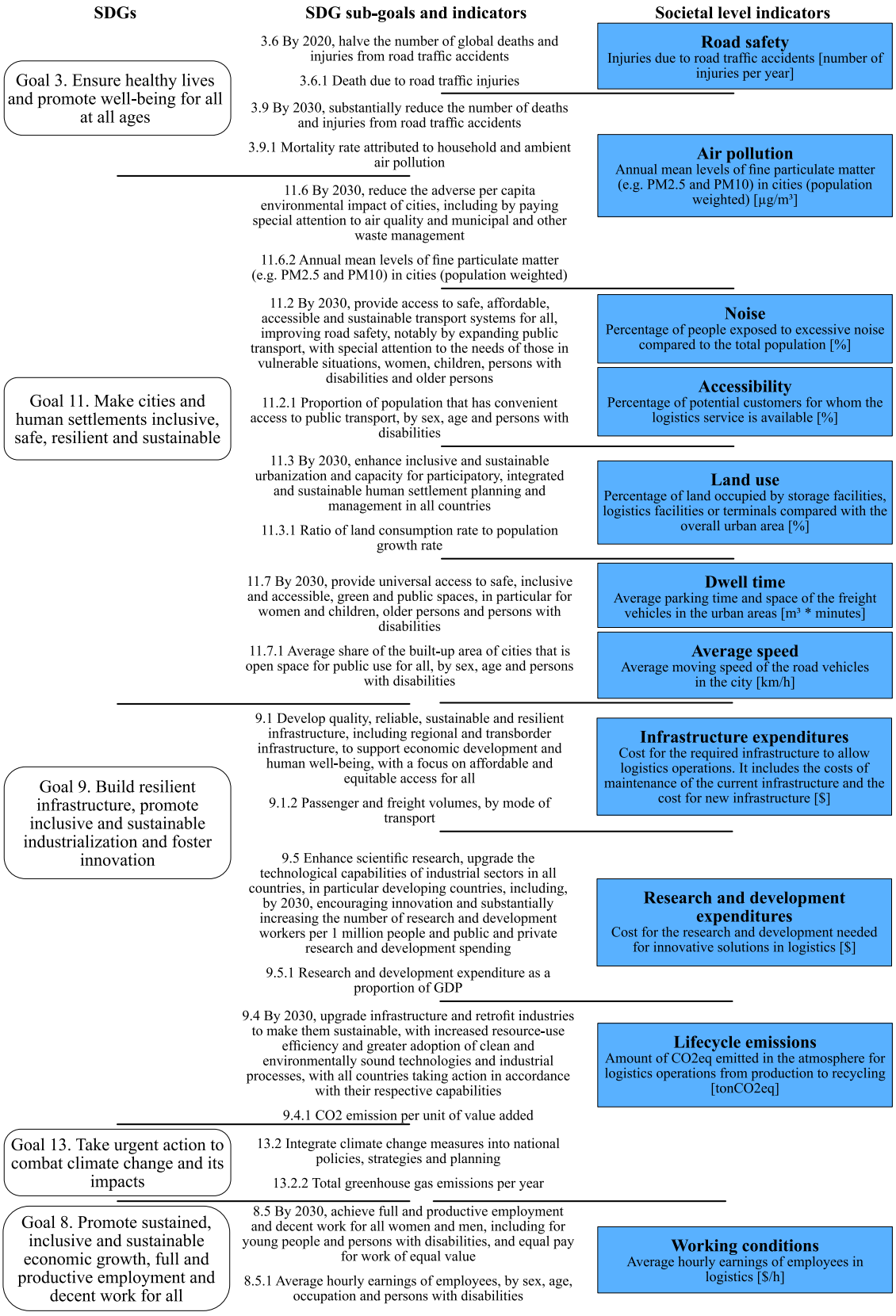

FIGURE 2 Visual representation of the connection between the SDGs and the societal level indicators

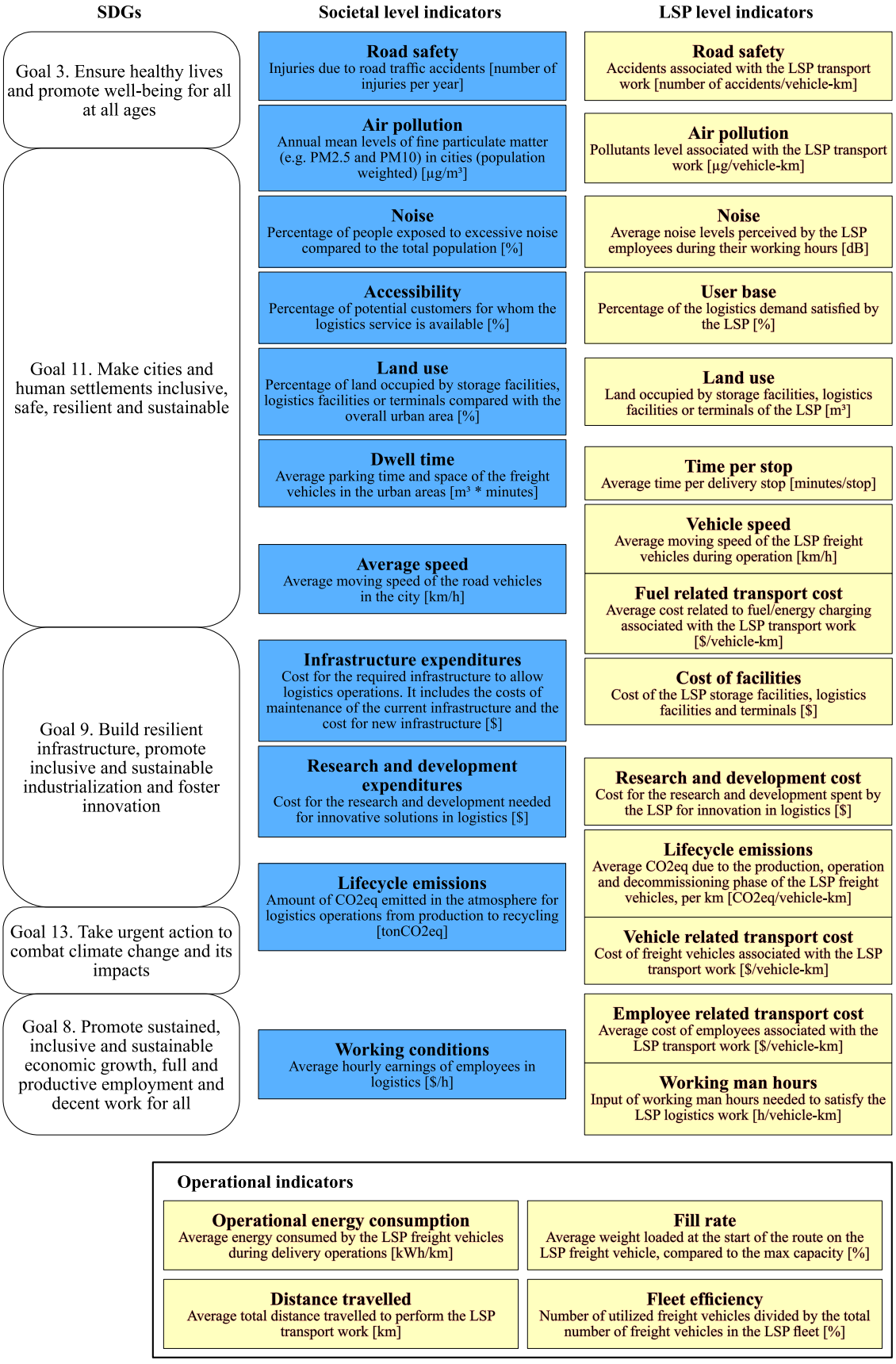

FIGURE 3 Visual representation of the complete set of indicators. The SDGs are listed on the left, the societal level indicators are listed in the center in blue and the LSP level indicators are listed on the right in yellow.

As Goal 11 relates to cities and urban environments, it is the goal with the strongest connection to the urban logistics context. **Dwell time** (*21*) is chosen as a measure of the conflict level that there is between the society and transportation in terms of the use of shared space, and it is defined as the average time for which the freight vehicles are parked in the urban areas, multiplied by the space that the freight vehicles occupy. **Accessibility** (*8, 19, 20*) is connected with the proportion of the population that has convenient access to transport services, and it is here defined as the percentage of potential customers for whom the logistics services are available. **Land use** (*8, 10, 30*) is connected with sub-goals related to sustainable urbanisation, and it is defined as the percentage of land occupied by storage facilities, logistics facilities or terminals compared with the overall urban area. **Average speed** (*8, 11, 21, 24, 31*) is selected as a measure of road congestion in urban areas, and it is defined as the average moving speed of the road vehicles (km/h). This indicator does not have a straight forward connection with any of the SDG sub-goals and indicators. However, we believe it can be connected with Goal 11. Even though it is not mentioned specifically in the SDG sub-goals and indicators, **noise** (*10, 11, 21, 30*) is also added as it is frequently mentioned in the literature on sustainable city logistics. It is defined as the percentage of citizens exposed to excessive noise in the urban areas, and therefore connected to Goal 11.

Goal 9 (*Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation*) targets the development of sustainable and resilient infrastructure and therefore is connected with **infrastructure expenditures** (*8, 10, 19, 30*), defined as the expenditures for the required infrastructure (including freight infrastructure, road infrastructure, charging infrastructure, and fuelling infrastructure) to allow logistics operation and includes the cost of maintenance (e.g., due to wear and tear) and of building new infrastructure. As one of the sub-goals is connected with scientific research and innovation, **research and development expenditures** (*8*) is selected and defined as the expenditures for research and development needed for innovative solutions in logistics.

Goal 13 (*Take urgent action to combat climate change and its impacts*) is related to **lifecycle emissions**. Emissions are also connected with Goal 9, as one of the sub-goals relates to increased resource efficiency and greater adoption of clean and environmentally friendly technologies. Taking a life cycle perspective is crucial when analysing a problem from a holistic perspective. Therefore, a life cycle approach (*18, 31*) is employed: lifecycle emissions are defined as the amount of CO_{2eq} emitted in the atmosphere for logistics services from production to recycling, measured in tonCO_{2eq}.

Goal 8 (*Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*) is connected with working conditions. Employment is frequently mentioned in the literature as an indicator of social sustainability (*8, 10, 18, 24, 26, 30*), in terms of working conditions, salary and number of job opportunities. The latter varies depending on the concept, but also on many other factors (e.g., company market share, business models, legislative context). **Working conditions** is defined as the average hourly earnings of employees, according to the SDG indicator expressed by the UN **(UN, 2021a)**.

Indicators at the LSP level

To enable the understanding of how the LSPs can affect these societal indicators and how these in turn impact the LSPs and their economy, corresponding indicators at the LSP level are chosen and connected to the ones at the societal level, as it can be seen in Figure 3. For some of the societal level indicators, it is straightforward to find related indicators at the LSP level. For some other indicators, costs should be taken into account, as these costs might be affected at the LSP level: in these cases, two LSP level indicators correspond to one societal indicator.

Road safety can be translated as accidents associated with the LSP transport work (measured in the number of accidents per vehicle-km). Similarly, the contribution of logistics activities on **air pollution** can be quantified at the LSP level with the pollutants emissions associated with the LSP transport work (in µg per vehicle-km) (*8, 10, 11, 18, 19, 21, 24, 26, 30*). In these two cases, the indicators are different at the LSP level because they consider only logistics operations rather than the urban environment as a whole. By affecting the values of these indicators, LSPs involved in the transport of goods can improve their sustainability performance and help achieve Goal 3.

When it comes to average speed, the LSP level indicator is twofold. On one hand, **vehicle speed** (defined as the average moving speed of the LSP freight vehicles in km/h) affects directly the operational speed in the overall city environment. On the other hand, **fuel-related transport cost** (measured in \$/vehicle−km) (*21*) is also connected to and affected by operational speed. Another conflict that has been described relates to dwell time, which is directly affected by the **time per stop**. Accessibility goals can be measured by understanding the **user base** (percentage of logistics demand satisfied by the LSP) (*8, 20*). However, it is important to also consider that accessibility goals can be challenging, as they can increase the cost associated with the logistics operations. **Land use** can be easily translated to a LSP level indicator by considering the square meters occupied by storage facilities, logistics facilities and terminals

of the LSP. **Noise** is defined as the average noise levels perceived by the LSP employees during their working hours. These indicators are all connected to Goal 11.

Connected to both land use and infrastructure cost, the **cost of facilities** needs to be considered, defined as the cost of the LSP storage facilities, logistics facilities or terminals, both in terms of construction but also in terms of maintenance and operations (*8, 10, 30*). **Research and development cost** is a cost that is present also at the LSP level, measured inside the LSP. With these costs, organisations can influence Goal 9.

When looking into lifecycle emissions, the corresponding LSP level indicator includes two components. On one hand, the **emissions per km** occur during the operational phase (*11, 31*). On the other hand, the **emissions per vehicle** consider both the average production and decommissioning emissions associated with the LSP freight vehicles (*18, 31*). These two combined give the overall lifecycle emissions of freight transportation, measured in CO_{2eq} per vehicle-km. **Vehicle-related transport cost** (\$/vehicle – km) is also considered here. This cost accounts for the cost of the freight vehicles in the fleet associated with the LSP transport work, and it includes both the initial purchasing cost of vehicles and the needed maintenance (*24, 31*). The emissions are strictly related to both Goal 9 and Goal 13, and the vehicle-related transport cost is indirectly related to the emission per vehicle, as the price for different vehicle technologies can vary significantly.

As previously mentioned, employment is considered in the literature and accounted for by many authors (*8, 10, 18, 24, 26, 30*). Therefore, when it comes to working conditions, two indicators are chosen: the **employee-related transport cost** (\$/vehicle – km), as the average cost of employees associated with the LSP transport work, and **working man-hours**, defined as the input of working man-hours needed to satisfy the transport demand (measured in hours per vehicle-km). These indicators are added at the LSP level as organizations can influence Goal 8 by varying salaries and work opportunities.

All indicators listed above are more or less directly connected with the sustainable development goals and the societal indicators defined in the previous section. However, a few more indicators are often used in the literature to measure the efficiency of the operations of the transportation itself. Therefore, the following four indicators are included. **Operational energy consumption** is an indicator of the average energy consumed by the LSP freight vehicles during delivery operations (in kWh/km) (*10, 11, 21, 30, 31*). **Fill rate** is measured as the average weight loaded at the beginning of the route on the LSP freight vehicle, compared to the maximum capacity (*8, 10, 11, 30, 32, 33*). **Distance travelled** is an indicator for the average total distance travelled to perform the LSP transport work (*31*). **Fleet efficiency** is defined as the number of utilized vehicles divided by the total number of vehicles in the LSP fleet (*26*). These four operational indicators can affect some of the indicators mentioned above. For example, operational energy consumption affects the emissions per km, but also the fuel-related transport cost and air pollution. For this reason, it is important to include them, as they can be leverage points for LSPs to improve their sustainability performance and help achieve the SDGs.

DISCUSSION

The set of indicators developed in this paper contains indicators selected following the process described in the Methodology section. To ensure a holistic perspective of sustainability, the SDG indicators are taken as a starting point. The SDGs are used as a starting point in a case study carried out to evaluate possible transport policies in the city of Curitiba (*34*). The SDGs are also used in a review to understand the interactions between the goals and the policies in the passenger transportation sector (*35*). The focus of both the case study and the review is passenger transport, and they provide a good example of using the SDGs to assess policies. In this paper, we focus on the urban freight transport system and on creating a set of indicators starting from the SDGs. However, the SDGs do not mention two aspects that are connected to city logistics: these are noise and average speed, as presented in the Results section. In this work, these two indicators are added both to the societal and the LSP level, since they are considered important in the city logistics literature.

The indicators are divided into the societal and the LSP level. In the literature, three perspectives for evaluating mobility services are considered in (*36*) and (*37*): these are the user, the organisational, and the societal perspective. In this work, the user perspective is not considered explicitly but integrated with the societal perspective, but the other two perspectives are included (the LSP level is considered as the organisational level). The societal level indicators represent the overall society with its needs. These indicators can be utilized by the public sector (i.e. policy-makers) to identify actions needed to move towards a more sustainable urban freight transport system. The indicators at the LSP level guarantee the representation of the LSPs that are part of the urban freight transport system: these indicators enable the LSP to understand how their actions affect the societal indicators, and how a change in the societal goals affects their costs (and potentially foresee business risks).

A difficulty associated with working with a holistic perspective, and at the same time aiming to select measurable indicators, is that the former implies a high level of aggregation, while the latter involves a level of detail that allows for obtaining numerical values. In this paper, a specific definition and metric are added to each indicator. These are needed to clarify what is meant by the single indicators, and allow their evaluation, but alternative definitions or metrics could instead be used. Only one of the possible definitions is chosen to limit the complexity of the set of indicators. Below are examples of how some indicators could be defined differently.

- **Noise** is here defined as the percentage of people exposed to excessive noise (at the societal level) and as average noise levels perceived by the employees (at the LSP level). Noise could be instead measured, for example, as the distance travelled through sensitive areas, or the vehicle's noise intensity, or by calculating the number of vehicles registered within the EU noise standards (*10, 21, 30*).
- The problem of **road safety** is complex and multi-dimensional (*38*), and considering only the number of injuries could be a limiting factor. The set of indicators does not include perceived safety, which can influence the decision-making process of modal choice (*39*). Perceived safety can be defined as the users' perception of the level of danger and comfort (*40*). However, it is hard to measure and quantify, and it is found mainly in the context of people mobility, therefore it has been discarded in this work.
- There are important factors other than **working conditions** that affect the working environment and employment, such as the benefits of employees or the rate at which employees leave or are hired by a LSP. However, working conditions, defined as average earnings in this paper, are considered to be particularly relevant in the context of the sharing economy and the gig economy, where differences in working contracts (e.g., for bike riders that perform deliveries) have various social implications (*41, 42*).

Similar considerations can be done for other indicators as well. As the set of indicators is expected to be used as a whole (i.e., considering all the indicators), a holistic view of the impacts on the system can be obtained.

Another challenge with using a set of indicators to assess urban logistics practices is finding relevant data. In the literature, many studies use different indicators and present the results in various ways. Moreover, assumptions are often made in specific case studies, together with explanations and conditions only valid for that study, making the data non-relevant. These differences could hinder the use of the indicators. However, indicators can be also used qualitatively or semi-quantitatively. A combination of qualitative insights and quantitative data can be used to indicate the impacts of a sustainable urban logistic practice. This type of analysis can be found in a report by the authors (*43*), where the impacts of electrification, consolidation, cargo bikes and automation are analysed and assessed using the set of indicators presented in this paper. In the report, findings from the literature and case studies serve as input to the set of indicators. The result of the work is a sustainability assessment of the four practices, visualized graphically. This type of analysis also allows for a comparison between the four practices and enables an understanding of how the concepts can be combined (*44*).

Two previous studies by the authors (*43, 44*) show that it is possible to use the set of indicators to evaluate the sustainability performance of urban logistics practices. However, there is a need to further evaluate the attainability and relevance of the indicators chosen. This should be done, for example, by testing the set of indicators on a real case study. This type of work is planned as future work. It is also suggested that a revision of the indicators should be carried out if applying the set of indicators to a specific case study, in case more specificity is needed. The set of indicators is meant to give an idea of what indicators should be used and to make sure that the sustainability dimensions defined in the SDGs are comprehensively included.

Two more considerations regarding the set of indicators are discussed here. First, the urban freight transport system should be considered as a whole: it is important to consider that urban logistics practices have dynamic effects (such as rebound effects) on the whole system. The proposed set of indicators is a tool for understanding the impacts of an urban logistics practice at a specific moment in time, rather than how the system develops over time. Moreover, an increase in transportation costs might affect a single LSP, but could have a different effect on the global economy. Therefore, it is often not straightforward to understand whether an increase or decrease in an indicator has a positive impact. Second, it is key to consider the urban context in which the concept is applied. It is always important to consider the goals of the urban environment under assessment in the sustainability assessment. Applying the proposed set of indicators methodology to an urban logistics practice and considering the impacts on the overall system (i.e., which indicators increase and which decrease) is a first step towards understanding the dynamics of the system. To assess sustainability, all the indicators should be evaluated, as they ensure that the sustainability dimensions defined in the SDGs are comprehensively considered. Depending on the context, a change in some indicators might be preferred compared to others, but the advantage of using such a set of indicators is the holistic view that it provides, potentially allowing unintended side effects to be detected.

CONCLUSION

This paper presents a set of measurable indicators derived from the SDGs and the city logistics literature, to ensure the inclusion of sustainability dimensions and the relevance to the context of city logistics. Moreover, the indicators are defined both at the societal level (i.e., how the urban freight transport system affects the citizens as stakeholders in the system) and at the LSP level (i.e., how the LSPs' actions affect the societal indicators and how the LSPs' costs are affected). Starting from the SDGs and dividing the indicators between societal and LSP levels are the novelties of this work. The set of indicators can be used to analyse urban logistics practices based on their sustainability impacts. The takeaways of the paper are the following.

- In the indicator selection process, a balance is needed between aggregation and specificity. A large number of indicators would make the assessment overly complex; the contrary would not allow for a holistic view of sustainability.
- It is possible to use the SDGs to understand what needs to be considered when discussing sustainability. However, the SDGs do not include all impacts on society of the transport system, as there is no mention of noise and congestion in their SDG sub-goals and indicators. In this work, we include noise and average speed as indicators.
- It is difficult to evaluate quantitatively the impact of urban logistics practices. A semi-quantitative approach is suggested and evaluated in previous studies (*43, 44*), which show that it is possible to use the proposed set of indicators to evaluate the sustainability performance of urban logistics practices.

The continuation of this work includes using the set of indicators in a real case study, to test the attainability and relevance of the indicators in a more specific setting. The contribution of this paper is the creation of a set of measurable indicators that include sustainability dimensions, consider indicators at the societal and LSP levels, and it is relevant to the urban freight transport system. This set of indicators is meant to be used to evaluate urban logistics practices, with the aim of increasing the knowledge that actors and stakeholders in the urban freight transport system have regarding these practices. This knowledge can help decision-makers from both the public and private sectors to make decisions that facilitate a more sustainable urban freight transport system.

DECLARATIONS

The authors declare that they have no competing interests.

AUTHORS CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: CA, AP, SW, JM; data collection: CA; analysis and interpretation of results: CA; draft manuscript preparation: CA. All authors reviewed the results and approved the final version of the manuscript.

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