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The use of sustainability indicators in urban passenger transport during the decision-making process: the case of Rio de Janeiro, Brazil

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Transportation is an important sector that has significant economical, social and environmental impacts. In this context, indicators can be used to evaluate sustainable transportation and to guide decision making process. In this paper a set of 20 indicators is selected and used as an example to evaluate their applicability to monitoring the lines of action regarding transportation in the Rio de Janeiro State Climate Plan. The results indicate that certain objectives cannot be monitored from the perspective of the sustainability criteria, and signal the importance of establishing monitoring criteria previously of public policy elaboration process. The use of the proposed indicators could help the public managers to monitor progress toward the goals presented in climate change policy for reducing greenhouse gas emissions and identify whether Rio de Janeiro is progressing toward sustainable development.

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Introduction

The promotion of wellbeing, improved quality of life, equity, economic development and environmental protection for present and future generations are fundamental principles of the current concept of sustainable development [1]. Despite the many recent successes in creating a more integrated and stable world economy, the report of the High-Level Panel on Global Sustainability from the General Secretary of the United Nations [2] concedes that there have also been failures and that the current world order is unable to promote the drastic changes necessary for true 'sustainability'. This report recommends the replacement of existing development indicators (Gross Domestic Product or variants thereof) by more comprehensive and inclusive indicators of wealth.

The 'Inclusive Wealth Report 2012' proposes an approach to sustainability based on social, human, industrial and natural capital with the inclusion of new indicators. Concern exists regarding the degree to which the current indicators of economic systems fail to signal clearly whether the economy is on an unsustainable path. As indicators in this vital context are scarce, potentially misleading signals can be translated into policy mistakes [3]. According to Litman [4••] sustainable development indicators must be carefully selected to accurately reflect various goals and identify problems. Inappropriate or incomplete indicators can misdiagnose problems and misdirect decision-makers.

The development and use of indicators are meaningful for analysing and monitoring sustainable development and in policy making [4••,5–9]. One standard method to reduce complexity of sustainable development and improve communication, while maintaining scientific objectivity, is to use selected indicators [10]. A suitable set of indicators must be an integral part of an assessment methodology to be used for the purposes of measuring sustainability [11]. Indicators should be internally consistent or coherent with respect to measurement assumptions, understandable to the general public, transparent in the sense that they are easily understood and interpreted, useful for decision makers and be available to all interested parties [6,12–15].

Litman [13] concluded that a single indicator is not adequate to encompass sustainability but a set of indicators, which should reflect various goals, objectives and impacts should be used. In general, the more information condensed into a single index the less meaning it has for specific policy targets. Also, indicator data may need to be disaggregated in various ways to support specific types of analysis. Several authors note that the selection of indicators should be driven primarily by the questions to which the indicators are supposed to provide answers [4••,16••,17••,18].

In addition, indicators should be clearly defined, accessible, capable of quantifying, standardised for comparison purposes and reflect various aspects of the study [5,16••,19]. Indicators can also be particularly useful in addressing the growing need for interaction at regional and local scale in sustainability initiatives, and to assist planners and administrators to evaluate policy effectiveness in progressing towards sustainable development [20].

Indicators are increasingly being used to assess the sustainability of transport and facilitate decision making [12]. One of the most common applications of indicators consists in comparing municipalities, notably to support local decision-making processes [6,12,21,22]. The indicators should be based on data that are available [23] or that can be made available at a reasonable cost, and that are of known quality and regularly updated [19]. According to Haghshenas and Varizi [16••], transparency is a criterion for indicator assessment. Indicators should be feasible to understand and possible to reproduce for intended users. Sustainable transport implies finding a proper balance between (current and future) environmental, social and economic qualities [36,37]. Urban passenger transport is essential for sustainable development and urban mobility; this work uses Rio de Janeiro as a case study for the proposal of the applicability of sustainable transportation indicators, based on the selection of indicators from studies, as this city currently has high visibility, having hosted the United Nations Conference on Sustainable Development (Rio +20) in 2012 [1].

Rio de Janeiro is undergoing structural changes in response to the sports agenda; the World Cup will be held in Rio de Janeiro in 2014 and the Olympics in 2016. The state will attract many investments; thus, the use of evaluation criteria regarding the sustainability of these investments can be perceived as an opportunity for sustainable development. This work is motivated by the need of considers indicators as important foundations for defining and monitoring of public policies. In this context,

Table 1

Studies on sustainable urban indicators including transportation

	References	Authors (year)	Country/region	STI Area			
				Total	Env	Soc	Eco
1	Urban sustainable transportation indicators for global comparison	Haghshenas and Vaziri (2012) [16••]	World cities	9	3	3	3
2	Sustainability and livability: summary of definitions, goals, objectives and performance indicators	Litman (2011) [4••]	Worldwide	40	10	11	14
3	Comparative analysis of transportation sustainability in OECD countries	Kim and Han (2011) [31••]	29 OCDE Countries	9	4	2	3
4	Measuring sustainability of transport in the city — development of an indicator-set	Toth-Szabo *et al.* (2011) [33•]	Swedish cities	19	6	8	5
5	Indicators of environmental sustainability in transport	Joumard and Gudmundsson (2010) [17••]	Worldwide	10	10		
6	Measuring the sustainability of cities: an analysis of the use of local indicators	Tanguay *et al.* (2010) [21]	World cities	3			3
7	ELASTIC — a methodological framework for identifying and selecting sustainable transport indicator	Pitfield and Castillo (2010) [32••]	UK	15	3	3	1
8	The role of common local indicators in regional sustainability assessment	Mascarenhas *et al.* (2010) [35]	World cities	1	1		
9	Transport project assessment methodology within the framework of sustainable development	Joumard and Nicolas (2010) [53]	Worldwide	5	2	2	1
10	Sustainable transportation indicator data quality and availability	Litman (2009) [13]	USA and worldwide	35	13	11	11
11	Measurement indicators and an evaluation approach for assessing urban sustainable development: China's Jining City	Li *et al.* (2009) [51]	China's Jining City	3	3		
12	Sustainable transportation indicators, Subcommittee of the Transportation Research Board	Litman (2008) [12]	USA and worldwide	30	9	10	7
13	SMART transportation ranking report	Appleton and Davies (2008) [50]	Canadian cities	5	1		
14	Indicators for the integration of environmental concerns into transport policies	OECD (1999) [26•]	Worldwide	32	8	3	8

Source: Own, based on [16••].
Env, Environmental; Soc, Social and Eco, Economic.

Table 2

Sustainable transportation indicators applicable to urban passenger transport.

Categories	Indicators	Author/year										
		Haghshenas and Vaziri (2012)	Litman (2009)	Litman (2011)	Joumard and Gudmundsson (2010)	OECD (1999)	Kim and Han (2011)	Pitfield and Castillo (2010)	Toth-Szabo *et al.* (2011)	Appleton and Davies (2008)	UNCSD (2012)	Number of times it appears from the studies
Environment	CO_2 emissions, per capita	×	×	×	×	×	×	×	×	×		9
	Land consumption for transport infrastructure (roads, parking, etc.)	×	×	×	×	×			×			6
	Per capita energy consumption, by fuel and mode	×	×	×	×	×		×				6
	Air and noise pollution exposure and health impacts	×	×	×	×	×	×	×	×	×		9
	Vehicle travel by mode (non motorized, automobile and public transport).		×	×		×	×	×				5
	Land use density (people and jobs per unit of land area)		×		×	×						3
	Per capita congestion costs (Total time spent in traffic)	×	×	×			×		×			5
	Total transport expenditures (vehicles, parking, roads and transit services).		×		×							2
Economic	Household expenditure allocated to transport (% budget)	×										1
	Expenditures on transportation for local government (annual, per GDP)	×										1
	Transparency of costs and investments										×	1
	Harmful subsidies and green fiscal policies										×	1
	Transport system diversity/transportation variety	×		×			×	×				4
	Quality of transport for disadvantaged people (disabled, low incomes, children, non-driver, etc.)	×	×	×				×				4
	Access to public transport (population served by public transit near around a train station, subway, bus stop)	×	×		×	×	×	×	×			7
Social	Fatality and injured of traffic accidents per capita or person/km	×	×	×	×	×	×	×	×			8
	Satisfaction of citizens and variety and quality of transport options (walking, cycling, ridesharing and public transport).	×	×	×					×			4
	Safety	×	×	×	×	×		×	×		×	8
	Health			×	×			×			×	4
	Gender equality/equity between societies and groups				×						×	2

Source: own, based on Haghshenas and Vaziri [16••].

Table 3

Applicability of indicators to evaluate the objectives regarding transportation presented in the Rio's climate change plan

Categories	Indicators	Transportation objectives — Rio's climate change plan						
		Expand quality of rail and subway	Expand use of BRT	Promote the use of sustainable biofuels	Programmes compulsory for bus passenger transport	Programme of captive and outsourced fleet vehicles	Inspection and maintenance programme for light vehicles	Biodiesel based on the reutilisation of vegetable oils programme
Environment	CO_2 emissions, per capita	A	A	A	A	A	A	A
	Land consumption for transport infrastructure (roads, parking, etc.)	A	A	A	NA	NA	NA	NA
	Per capita energy consumption, by fuel and mode	A	A	A	A	A	A	A
	Air and noise pollution exposure and health impacts	A	A	A	A	A	A	A
	Vehicle travel by mode (non motorized, automobile and public transport).	A	A	NA	NA	NA	NA	NA
	Land use density (people and jobs per unit of land area)	A	A	NA	NA	NA	NA	NA
Economic	Per capita congestion costs (Total time spent in traffic)	A	A	NA	NA	NA	NA	NA
	Total transport expenditures (vehicles, parking, roads and transit services).	A	A	NA	NA	NA	NA	NA
	Household expenditure allocated to transport (% budget)	A	A	NA	NA	NA	NA	NA
	Expenditures on transportation for local government (annual, per GDP)	A	A	NA	NA	NA	NA	NA
	Transparency of costs and investments	A	A	NA	NA	NA	NA	NA
	Harmful subsidies and green fiscal policies	A	A	NA	NA	NA	NA	NA
Social	Transport system diversity/transportation variety	A	A	NA	NA	NA	NA	NA
	Quality of transport for disadvantaged people (disabled, low incomes, children, non-driver, etc.)	A	A	NA	NA	NA	NA	NA
	Access to public transport (population served by public transit near around a train station, subway, bus stop)	A	A	NA	NA	NA	NA	NA
	Fatality and injured of traffic accidents per capita or person/km	A	A	NA	NA	NA	NA	NA
	Satisfaction of citizens and variety and quality of transport options (walking, cycling, ridesharing and public transport).	A	A	NA	NA	NA	NA	NA
	Safety	A	A	NA	NA	NA	NA	NA
	Health	A	A	A	A	A	A	A
	Gender equality/equity between societies and groups	A	A	NA	NA	NA	NA	NA

Source: Own.
Applicable, A; relate to degree to which data can be acquired; not applicable, NA.

this study presents a set of indicators that could be used to aid the decision-making process in relation to the transportation sector.

The focus of this review is in the selection and use of indicators to assess transport sustainability of the State of Rio de Janeiro Climate Plan. The methodology includes the following steps: firstly, review of the literature that helped in the identification of studies where sustainable transportation indicators in general are discussed, resulting in Table 1; secondly, selection of indicators. First: those commonly used to assess the sustainability of transport, that appeared in the minimum three times from studies, covering the categories environmental, economic and social; and second: selections of others indicators to cover the categories social and economic selected from the outcome document adopted at Rio +20 [1] and other studies, shown in Table 2; and thirdly, evaluation of the way in which each indicator helps measure progress toward the transportation actions as delineated in the climate change plan, resulting in Table 3.

The remainder of this paper is structured as follows. Second section introduces the relationship between transportation and sustainability dimensions; third section addresses the context of passenger transportation in Brazil and in Rio de Janeiro. Fourth section assesses the applicability of sustainable transportation indicators to the Climate Plan objectives for Rio de Janeiro and fifth section presents conclusions and recommendations.

The relationship between transportation and three dimensions of sustainability

Transportation is essential to promoting societal welfare, as it provides accessibility to various human activities. Mobility and transportation play a key role in all three areas of sustainable development; it can not only enhance economic growth and improve accessibility, achieve better economic integration, but also has significant long-term economic, social and environmental impacts. Therefore, the efficient transportation of people and goods must be environmentally sound, safe and accessible to help improve social equity, health and the resilience of cities [1].

Sustainable transportation indicators have been described in numerous studies as statistical measurements that indicate the sustainability of social, environmental and economic development [16••,17••,24,25,26•,27,28]. According to Hens and De Wit [29], long lists of indicators were established to describe the complexity of sustainable development; however recently, these lists have been reduced to sets of core indicators, involving economic, environmental and social aspects of transport — but many of them conclude the need of further research [13,30••].

The function of sustainable transport indicators will be highly dependent on specific context, and can serve different users with different priorities and concerns [18]. Several studies apply Sustainable transportation indicators (STI) to compare and measure progress in transportation toward sustainability in many world cities [34] and regions, and examples are presented in Table 1.

According to Table 1 it is possible to verify that more recent studies present a greater balance between environmental, social and economic indicators. Earlier studies have given less priority to social or economic components of transport sustainability. Also, only few studies directly define sustainable transportation indicators (STI). When the goal is to compare sustainable development indicators (SDI) between cities, the result is the selection of only few indicators for sustainable transport.

The selection of the appropriate indicators to guide sustainable transport assessment presents challenges [32••]. Indicators can also be particularly useful in addressing the growing need for interaction at regional and local scale in sustainability initiatives and to compare the situation with that of other territories [22,35]. Decision-making for sustainability incorporates considerations over long-term economic, social and environmental impacts in their simultaneous evolution [6,12,14,33•,36].

According to Litman [4••] an index that only considers environmental impacts can encourage planning decisions that are economically inefficient, while an index that only considers economic impacts can encourage planning decisions that can be environmentally harmful.

The context of passenger transportation in Brazil and in Rio de Janeiro

Brazil is an emerging country with rapid economic growth [38]. This nation has a population of more than 192 million people [39], with an area of 8 500 000 km^2, and it is the biggest country in Latin America and the fifth largest country in the world in terms of territorial area and population [27]. In Brazil, road passenger transport is mainly characterised by the use of individual transport (cars) followed by urban buses for collective transportation. This means of transport leads to such effects as traffic congestion, increased travel time, and increased pollution and greenhouse gas emissions.

Thus, Brazil faces many challenges in establishing a pattern of sustainable development. In 2012, Brazil launched the Transport and Urban Mobility Sector Plan for the Mitigation of Climate Change (Plano Setorial de Transporte e de Mobilidade Urbana para Mitigação da Mudança do Clima — PSTM [40]). The main objective of the plan is to contribute to the mitigation of greenhouse gas (GHG) emissions in the sector through initiatives that lead to greater use of more energy efficient forms of

transportation and, in the urban mobility sector, the increased use of efficient public passenger transportation systems, thereby contributing to meeting Brazil's voluntary commitments under the UN Framework Convention on Climate Change.

With regard to passenger transport, the PSTM considered current investments in the deployment of collective public transportation infrastructure: urban mobility projects associated with the 2014 FIFA World Cup and based on the Growth Acceleration Programme for mobility in large cities (Programa de Aceleração do Crescimento — PAC Mobilidade Grandes Cidades), and other measures that provide increased urban mobility and accessibility and improvement in urban public transportation, thereby contributing to a reduction of GHG emissions.

A study published by EPE [41] based on a consolidated database by type of transport (freight and passenger) from 1970 to 2010 shows that passenger transport activity (passenger-kilometers) changed considerably during the 1970s. This growing need for mobility increased the activity of 131.9 billion in 1970 to 1584.5 billion passenger-kilometers. The main reason for this change was that railway transport lost ground, especially to road transport, in which participation increased until 2000, with 93.5%, as shown in Figure 1. The figure also indicates, respectively, a significant and a modest recovery in air and rail modes in the first decade of the millennium.

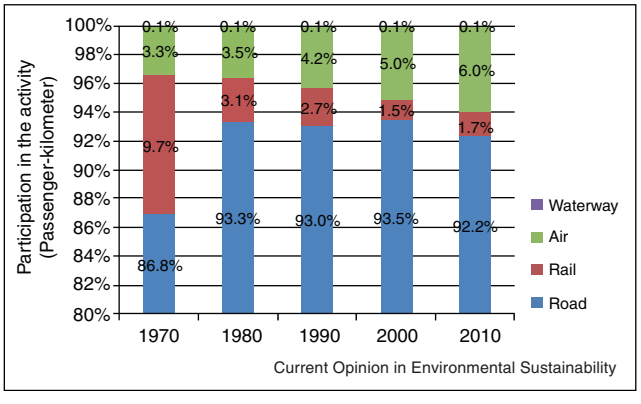
The city of Rio de Janeiro is the second most populous city in Brazil and has 6.4 million inhabitants [39]. Rio de Janeiro is the main point of entry not only for foreign tourists but also for investment, as well as being a destination for great artistic and cultural performances and large-scale international sporting events [42]. This city has the second largest GDP in Brazil and is the headquarters of many of the largest companies in the country. Because of the positive current economic climate, the state received approximately 126.3 billion Reals of public and private investment in a period of only three years (2010/2012) [43].

The state's population is heavily concentrated in the metropolitan area, where the city bus is the main means of collective transportation. It is therefore not surprising to find that this mode of transport is responsible for approximately 75% of trips made using collective modes of transport [39]. Rio de Janeiro aims to reduce transport emissions by 30% by 2030 compared to 2005 by adopting such measures as increasing cycle paths, expanding and improving the subway system and investing in railway and ferry systems [44]. It is desirable that the state maintains its pace of economic growth to meet the demands of the population; however, it must seek up-to-date methods of achieving this change and focus on the green economy and sustainable development. Tools are therefore needed to evaluate transport policies and support the decision-making process. Joumard and Nicolas [53] suggested three economic criteria, four social criteria and eleven environmental criteria to evaluate sustainability of transport projects, enabling the sustainable development concept to be made operational, in addition to an aggregation method for these criteria integrating the social or political preferences of decision-makers or their representatives.

The transportation sector has proven to be particularly difficult territory for the advancement of sustainable development policy [45]. This applies to Rio de Janeiro, in particular to the urban passenger transport that is carbon intensive. Sustainable transport planning recognizes that transport decisions affect people in many ways, so a variety of objectives and impacts should be considered in the planning process [4••,17••,52,54]. According to Zhang *et al.* [46], urban passenger transport structure is a complicated system, and systematic complexity results in the variety of evaluation indicator.

Kennedy *et al.* [47] concluded that it is apparent that few cities worldwide have an adequate governance structure to develop sustainable urban transportation systems with an emphasis on accessibility and mobility. Sustainable transportation indicators can thus serve as a tool for assessing progress toward the transformation of transport in Rio in a sustainable direction. In addition, these indicators may help in monitoring policies, defining and measuring sustainability in transportation planning and responding to unforeseen circumstances.

Figure 1



Evolution of passenger transport activity (1970–2010), Brazil. *Source*: [41].

Proposal for sustainable transportation indicators in Rio de Janeiro

At present in the state of Rio de Janeiro, the use of sustainable transport indicators (STI) for urban passenger transport is proposed to be used by public managers to ensure that growth is achieved in an environmentally

friendly manner. Table 2 summarises a set of 20 sustainable transportation indicators, including the most used (that appeared in the minimum 3 times), identified from 9 of the 14 studies presented in Table 1. We also have considered indicators that were not commonly used, but that could cover the social and economical aspects, including 3 social and economic indicators from UNCSD [1], 2 indicators from Haghshenas and Vaziri [16••], 1 indicator selected from Litman [13] and Joumard and Gudmundsson [17••].

It is important to have a set of simple, effective, feasible and modular indicators to assess the sustainability of urban passenger transport. In evaluating policies to subsidise the decision-making process, the less condensed that the indicators are, the greater the possibility that they can be used effectively [12].

Regarding performance indicators, Henning *et al.* [48] suggest that the number of key performance indicators should be kept to the minimum necessary to enable an understanding of the overall transport performance. In the case of sustainable transport, indicators of performance management could be relevant to assess the efficiency of sustainable transport plans and their effectiveness with regard to fulfilment of sustainable transport objectives [17••]. Georgiadis [49] examined the practice of benchmarking in public transportation and investigates whether it is possible to apply the method in the local public transport system under present circumstances.

For the state of Rio de Janeiro, the lines of action regarding transportation presented in the state's climate change plan will be used as a basis for evaluating the applicability (degree to which data can be acquired) about the use of sustainable transportation indicators [44]. Each indicator must show one aspect of sustainable transportation, as presented in Table 3.

Among the objectives for transportation identified from the state of Rio de Janeiro's Plan for Climate Change, lines 1 and 2 can be evaluated more broadly using sustainable transportation indicators from a social, environmental and economic perspective as follows:

(1) To expand and improve the quality of rail and subway transport services, which are less carbon-intensive than road-based transport and
(2) To expand the use of BRT (Bus Rapid Transit) systems as an economic alternative by making bus systems faster, more comfortable and attractive and by encouraging car users to change to this mode of transport.The evaluation of lines of action 3–8 is restricted to fuel consumption and the monitoring and diagnosis of compliance to emission standards required by environmental laws. Thus, these lines reflect the issue of greenhouse gas and pollutant emissions, specifically:
(3) To promote the use of biofuels, mainly mineral diesel substitutes such as biodiesel and sugarcane-based diesel;
(4) To make the Saving (Economizar) and Green Seal (Selo Verde) programmes compulsory for bus passenger transport, thereby ensuring continuity and promoting the expansion of the entire state's fleet;
(5) To implement a compulsory inspection and maintenance programme for heavy-duty diesel vehicles that is linked to annual licensing;
(6) To implement an acquisition programme of captive and outsourced fleet vehicles;
(7) To strengthen the inspection and maintenance programme for light vehicles that is linked to annual licensing; and
(8) To consolidate the commercialisation of biodiesel based on the Reutilisation of Vegetable Oils Programme (Programa de Reaproveitamento de Óleos Vegetais — PROVE).

As seen in Table 3, a set of 20 indicators may be used to assess the sustainability of each transportation line of action, where applicable, as well as monitoring progress towards the goal of reducing GHG emissions. It is worth noting that the design of the actions presented in the Plan was not based on sustainability criteria, because the focus was on mitigating greenhouse gas emissions and the concept of sustainability is much broader.

It can be observed that certain actions cannot be monitored from the perspective of the sustainability criteria. Of the eight lines of action displayed in the plan, only two could be evaluated according to the proposed set of indicators, as shown in Table 3.

Lines of action 3–8 could be evaluated based on their contribution to the mitigation of greenhouse gas and pollutant emissions and on their ability to monitor progress towards the goal of reducing GHG emissions. It can be seen that issues related to social and economic development were not considered while the plan was developed. Once again, the focus has been on mitigating climate change, rather than sustainability. This focus shows that public policies have not yet incorporated the concept of sustainability and tend to seek specific objectives, thereby disregarding the importance of integrating the various aspects that comprise sustainable development.

Conclusions and recommendations

Indicators are variables that can be used to measure different aspects of the environmental sustainability of transport, and to aid in a variety of decision making situations. More specifically we have selected a set of 20 indicators to evaluate its applicability regarding transportation objectives presented at the Rio's Climate Change Plan.

Brazilian urban passenger transport policies do not incorporate social and environmental sustainability guidelines to a great extent. Indicators can play an important role by identifying what is missing, subsidising database to design public policies and facilitating monitoring of these policies.

A modern management system uses indicators and performance targets, and public policies should operate in the same way. The use of economic instruments, such as tariffs, incentives, subsidies and taxes, should be used to promote the transition towards more sustainable transportation.

Actions are aligned with goals and with sustainability criteria such that public transport policy goals can be monitored and tracked. It is also necessary to establish concomitant forms of measurement to evaluate the performance of the established goals. Using this type of approach, the chances of measure progress are greater, and the process for debate and decision making becomes more transparent, considering that indicators will be available to all stakeholders.

There are some suggestions and limitations in this study. Regarding suggestions, in the specific case of Rio de Janeiro, the set of 20 sustainable transportation indicators presented to measure and assess transportation sustainability may be used by the State Government of Rio de Janeiro that, concerned with the issue, created a committee to monitor specific indicators, considering them as a transversal theme.

The indicators could be applied to other Brazilian states to draw comparisons between regions and monitor progress towards sustainable transport as a tool for countries to measure their progress as well as promote further cooperation between countries. The use of indicators could help to establish and strengthen future transportation sustainability policies and thus contribute to the decision-making process in Brazil. As an area of future research, we suggest to expand the research and inclusion of indicators covering social aspects of sustainability such as well being and quality of life. We find that a great number of studies address the question of sustainable transportation indicators (STI) as part of larger sustainable development indicators (SDI) comparisons between cities, and in these cases, the selected indicators for sustainable transport are only few. Thus, it is possible identify a need for further research focus on STI.

A limitation found in this review is that when plans are too narrowly focused they can miss opportunities to target sustainability. A limitation of our own research is in terms of determining applicability of indicators, since it is not possible to determine whether goals can be assessed with results quantitatively. The article has been limited to make the assessment on a qualitative basis. In general, the limitations of gathering data and the lack of existence of a database can be considered as a limitation for the use of indicators for policy formulation and decision-making and for monitoring policy implementation.

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