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OPERATIONAL SUSTAINABLE URBAN MOBILITY INDEX

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ABSTRACT
Elements are presented for the definition of an index capable of quantifying the sustainability of urban mobility system operations, considering environmental, economic, and social aspects. By weighing operational indicators, the index is expressed on a scale from zero to ten, allowing the evaluation of the evolution of operational sustainability over different time scales (according to the data collection periodicity) and spatial scales (according to the scope of the collected data). Uses of the index include social awareness of the effects of modal choices and guiding public policies aimed at the sustainability of urban mobility systems.

Keywords: Performance evaluation; Transportation systems; Sustainability; Indicators.

1. PROPOSAL

1.1. Overview

The Operational Sustainable Urban Mobility Index (OSUMI) is characterized by the use of operational indicators only, without regard to infrastructure aspects, effectively combining diverse data in a sustainability measure of the operation of urban mobility. It encompasses environmental, social, and economic dimensions. OSUMI provides information about a city's mobility operations, enabling the setting of quantitative goals for sustainability improvement.

1.2. Design conceptions

The evaluation of the transportation system is based on the Brazilian federal classification, which distinguishes between motorized and non-motorized modes of transportation (Brasil, 2012). This classification includes both public and private modes of transport and applies to terrestrial transportation in urban contexts; its analysis includes only people transportation.

1.3. Analysis criteria

Selection of OSUMI operational indicators is based on the systematic review by Kraus e Proff (2021). The environmental dimension includes air pollution, energy consumption, noise emissions, greenhouse gas emissions, and renewable energy use. The social dimension covers safety, health, travel time, accessibility, and congestion. The economic dimension considers operational costs, utilization rates, investment costs, demand levels, and reliability. Each indicator is scored on a scale of zero to ten using reference values. These ideas can be translated into:

$$\text{OSUMI} = \alpha\left(\frac{\sum_{i=1}^{n} x_i r_i}{\sum_{i=1}^{n} x_i}\right) + \beta\left(\frac{\sum_{i=1}^{n} y_i r_i}{\sum_{i=1}^{n} y_i}\right) + \gamma\left(\frac{\sum_{i=1}^{n} z_i r_i}{\sum_{i=1}^{n} z_i}\right) \tag{1}$$

in which

α, β, γ OSUMI environmental, social, and economic factor;

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x_i, y_i, z_i environmental, social, and economic proportion of the indicators;
r_i indicator value.

2. LITERATURE REVIEW

2.1. Indexes

Some sustainability indexes studied are IMUS (Costa, 2008) which focuses mainly on infrastructure aspects; the Sustainable City Index Report Corporate Knights Inc. (2023), which ranks cities based on sustainable measures across 12 indicators; and the Green City Index Siemens AG (2012), which provides an environmental evaluation across different continents. These indexes help identify relevant indicators for quantifying urban mobility operational performance.

2.2. Data Acquisition

Regarding the collection and analysis of transportation data, the study by Prabha e Kabadi (2016) discusses methods of obtaining data for intelligent transportation systems. On the other hand, Baroni e Souza (2015) provides a systematic overview of data acquisition regulations in Brazil. Additionally, Ryus *et al.* (2003) provides a general contextualization of data collection and analysis methods.

2.3. Sustainability

In assessing the sustainability of the indicators used in the study, various aspects evaluated in the Rietveld (2001) study are taken into account. This study aims to shed light on the distinctions between non-motorized, private, and individual transportation concerning social, environmental, and economic considerations. Additionally, priority is given to non-motorized transport over motorized collective transport, as determined by law. (Brasil, 2012)

3. MATERIALS AND METHODS

3.1. Case Study: OSUMI LEVEL 0

The presentation is limited to OSUMI Level 0, a version of the index considering only travel mode (motorized—public or private— and non-motorized). The case study focuses on seven Brazilian cities for which OD survey data with quantified trips by travel mode are available.

- **Step 1: Data acquisition**. In Table 1 the travel data from OD reports are utilized, for a single day's timeframe within the specified metropolitan region (Coordenação da Região Metropolitana de Curitiba - COMEC (2014); Companhia do Metropolitano do Distrito Federal (2018); Observatório da Mobilidade Urbana - UFSC (2019); Secretaria de Estado de Transportes do Rio de Janeiro (2017); Prefeitura Municipal de Salvador (2012), Companhia do Metropolitano de São Paulo - Metrô (2019); Secretaria dos Transportes Metropolitanos - STM (2011)).

- **Step 2: Indicator Selection**. For simplified analysis, two indicators are selected: "non-motorized x motorized"(I1) and "private x public"(I2). I1 measures the proportion of non-motorized travels relative to the total number of travels, I2 represents the ratio of public travel to motorized travel. The highest value references of both indicators correspond to all travels made by non-motorized mode or by public transportation, respectively. To assess each dimension's contribution, each indicator's integral value needs to be appropriately weighted.

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Table 1: Overview of Origin-Destination Data

City	Year	Raw Data (Travels x1000)			
		Public	Private	Motorized	Non-motorized
Rio de Janeiro	2003	9.237	3.291	12.529	7.386
Campinas	2003	1.027	1.135	2.162	1.414
Campinas	2011	1.372	2.072	3.444	1.294
Salvador	2012	2.455	1.330	3.785	2.151
Florianópolis	2015	453	854	1.301	436
Curitiba	2017	1.595	2.740	4.384	1.810
Brasília	2018	1.346	2.409	3.792	1.445
São Paulo	1977	9.580	5.683	15.263	6.041
São Paulo	1987	10.455	8.187	18.642	10.758
São Paulo	1997	10.473	9.985	20.458	10.974
São Paulo	2007	13.913	11.254	25.167	12.927
São Paulo	2017	15.295	12.985	28.280	13.727

- **Step 3: Set up sustainability factor for analysis**. The user assigns a factor to each sustainability perspective, with the total sum equal to one. In this case study, only the environmental factor is considered, while the other factors are given a factor of zero. Then, from Eq. (1), $\alpha = 1$, and $\beta = \gamma = 0$.

- **Step 4: OSUMI$_0$ Score**. Using the reference values, the indicator results are normalized. The final score is calculated as a weighted mean with the normalized results from each indicator:

$$\mathrm{OSUMI}_0 = \frac{2rI_1 + rI_2}{3}. \tag{2}$$

4. PRELIMINARY RESULTS

As an application example of OSUMI, Figure 1 shows the case of São Paulo using OD survey data. It can be seen that after the year of 1987 non-motorized travel decreased, and public transportation travel also decreased from 1987 to 1997 and from 2007 and 2017, meaning that the user didn't migrate to public motorized transportation.

Additionally is possible to verify in Figure 2, that even though Campinas has a better result in public transportation (I2), indicator 1 has more impact in environmental analysis, which gives Curitiba a better score.

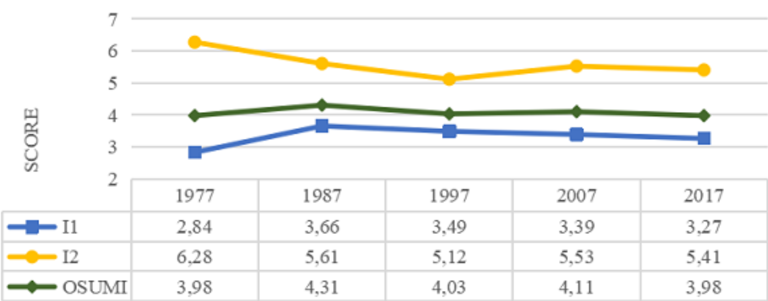

Figure 1: São Paulo City OSUMI$_0$ over the years

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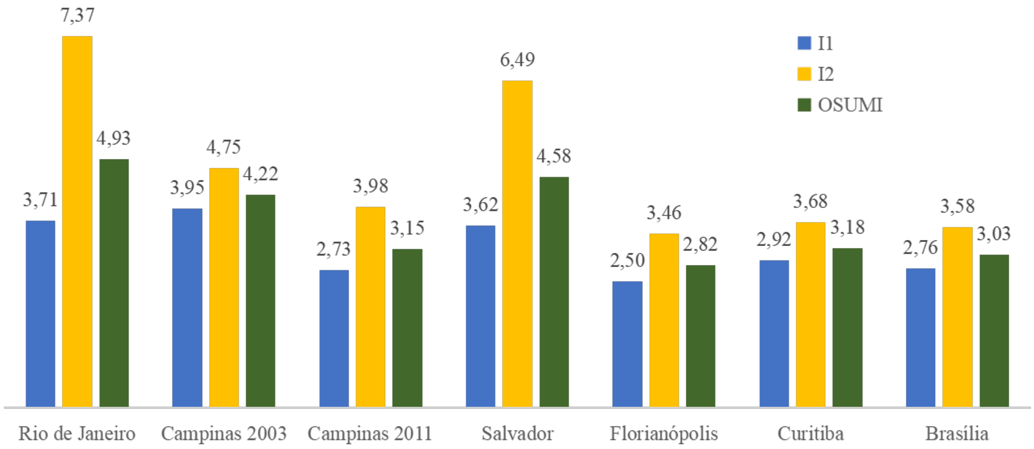

Figure 2: Indicators and OSUMI$_0$ scores for each city

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