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Urban mobility performance indicators: a bibliometric analysis

Indicadores de desempenho em mobilidade urbana: uma análise bibliométrica

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Abstract: This paper aims to identify the most used urban mobility metrics by means of a bibliometric analysis. Therefore, a qualitative and quantitative study was carried out from a selection of 49 articles, between 1989 and 2016. Scopus and Web of Science were used as databases. The performed study verified the predominance of papers focused on environmental and efficiency perspectives in urban transport systems. Furthermore, it was possible to verify the emergence of new approaches such as sustainable mobility, resilient transport and smart mobility. Two hundred and twenty eight categories of metrics and performance indicators were identified and grouped into twelve perspectives. The categorization proposed by this paper can assist researchers on future works on the topic addressed.

Keywords: Urban mobility; Urban transport; Transport systems; Transport networks; Performance indicators; Metrics.

Resumo: *Este trabalho objetiva identificar as métricas de mobilidade urbana mais utilizadas por meio de uma análise bibliométrica. Deste modo, foi realizado um estudo qualitativo e quantitativo a partir de uma seleção de 49 artigos, publicados entre 1989 e 2016. Scopus e Web of Science foram utilizados como bases de dados. Como resultado deste mapeamento, verificou-se a predominância de estudos focados nas perspectivas ambientais e de eficiência nos sistemas de transporte urbano. Além disso, foram identificadas a emergência de novas abordagens, tais como mobilidade sustentável, transporte resiliente e mobilidade inteligente. Um total de 228 categorias de métricas e indicadores de desempenho foram identificados e agrupados em doze perspectivas. A categorização proposta neste artigo pode auxiliar os pesquisadores em trabalhos futuros sobre o tema abordado.*

Palavras-chave: *Mobilidade urbana; Transporte urbano; Sistemas de transporte; Redes de transporte; Indicadores de desempenho; Métricas.*

1 Introduction

The development and growth of urban centers has caused numerous disruptions to society. Congestion, increased pollution from the intense use of private cars and inadequate public transport are some of the problems that contribute to the unsustainability of the current scenario of urban transport and mobility systems.

Studies aimed at minimizing or even extinguishing such disorders have appeared in the literature. It is possible to note the association of several approaches with the purpose of raising awareness among users and encouraging managers to develop solutions taking into account the climatic and environmental factors related to means of transport (Federici et al., 2003).

Metrics and performance indicators stand out as important tools that enable the measurement and evaluation of transport systems and urban mobility and assist managers in the decision-making process,

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as shown by Roth & Kåberger (2002), Zito & Salvo (2011)), Eboli & Mazzulla (2011), Manaugh et al. (2015), among others.

These instruments can be grouped into several strands. Inspired by the works of Jeon & Amekudzi (2005), Miranda & Silva (2012) and Silva et al. (2015), this article aims to build a bibliometric evaluation of the articles that approach this topic and to identify the most used metrics and indicators, pointing out how these performance variables are being addressed in the literature.

The paper is structured as follows: in section 2 a small bibliographical review about the central themes of the research was elaborated; section 3 details the methodological procedure and sequences the stages of study development; section 4 comprises the treatment of secondary data collected; in section 5 the main metrics and performance indicators in the literature were identified. Finally, section 6 points out the final considerations of this research.

2 Theoretical fundamentation

Urban mobility encompasses all modes of the urban transport system. For the management of such a complex system, it is essential to use indicators that indicate which subsystems are adequate and which need greater investments. Costa (2008) argued that sustainable development has directly affected urban planning and decisions. The disorderly growth of cities, environmental degradation, increased pollution, social inequality and, inevitably, economic factors were identified as variables foci in such decisions. Therefore, the importance of using metrics and performance indicators that support the management of resources and the optimization of urban environments is indisputable to ensure the perpetuity of natural resources and the sustained improvement of living conditions on the planet.

Several authors have studied sets of indicators that can be used to measure urban mobility. These indicators can be related to information from regulatory agencies (Jeon & Amekudzi, 2005), from the user perspective (Cheng & Chen, 2015) or from both sources (Eboli & Mazzulla, 2011).

With the spread of sustainable practices, research focused on sustainable mobility in the early 21st century (Black et al., 2002). With the advent of the Internet, the focus is on intelligent mobility (Garau et al., 2016). The occurrence of disasters also gives rise to research focusing on resilient transport systems (Cats, 2016). The study focused on only one modality of transport, such as pedestrian routes (Beiler et al., 2015), is also essential for improving mobility.

The reliability of a transport system is a well-studied aspect (van Lint et al., 2008; Taylor, 2013), as well as the accessibility of the entire population (Helling 1998; Lau & Chiu, 2003; Manaugh et al., 2015), allowing everyone to come and go, including those with reduced mobility or low income. Congestion is another topic that affects mobility (Cao & Menendez, 2015), in this case negatively.

3 Method of research

This study has a descriptive character, classified as quantitative. Already the technical procedure characterizes a systematic bibliographical research, constituted by a survey. The work was systematized in four phases. Initially, Scopus and Web of Science databases were defined as research sources. The following keywords were used: (1) Urban Mobility or Mobility System; (2) Performance Indicator or Metric and (3) Urban Transport/Transportation or Transport/Transportation System or Transport/Transportation Network. The third group of words was inserted in order to broaden the research to encompass terminologies involved by group 1.

By combining the keywords, 571 articles could be obtained, of which 18 (8 from Web of Science plus 10 from Scopus, combining keywords 1 and 2) and 553 (225 from Web of Science plus 328 from Scopus, combining keywords 2 and 3). These results can be visualized in Figure 1; for its part, Figure 2 presents in an orderly way the phases followed in the integral development of the work.

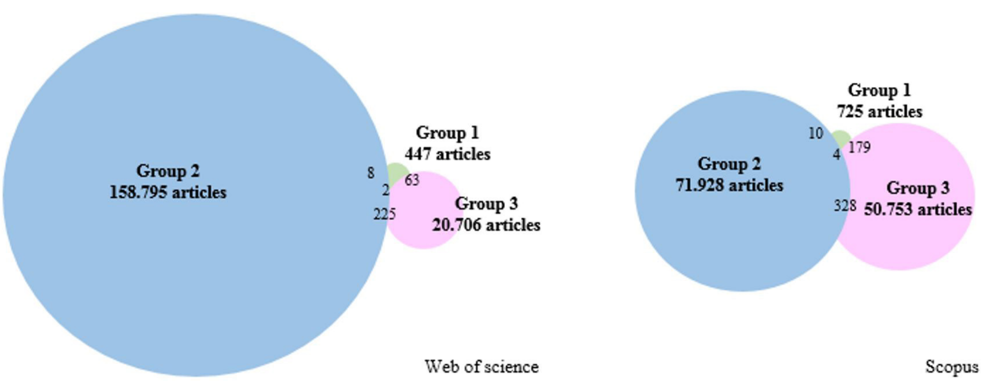

Figure 1. Diagram of interrelation between keywords.

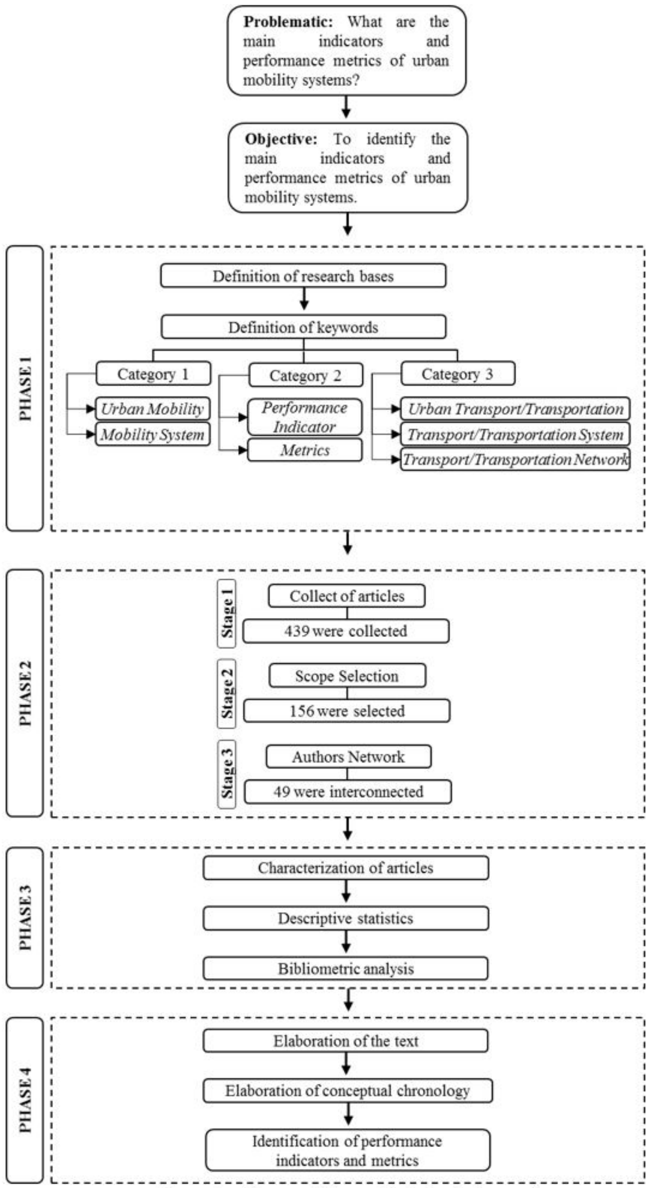

Figure 2. Phases of the methodological procedure.

Then, the article relations from the two databases were unified in a single listing, superimposing the results of the two import searches for a single spreadsheet, which allowed excluding cases of duplicity: 132 articles that appeared in both databases used. After that, the abstracts of the remaining 439 articles were read, with the purpose of selecting only those aligned with the objective of the work, that is, articles with a scope focused on discussing urban mobility indicators, for a city or for only one system/mode of transport. Articles that addressed only theoretical reflections or that indicated a solution, without explicitly a compilation or the use of indicators, were excluded. In this process, the list of articles reduced to 156.

It is understood that the construction of knowledge is done through the contribution of several researchers, which generates a current of thought that is effective in the references of each work. Thus, an analysis of the citations of the selected articles was done with the intention of establishing which are the currents of thought on the theme, which interconnected 49 articles, being this the final selection of articles used.

The third phase included the classification of articles in terms of structure and content. To do so, the spreadsheet with the articles selected was extended to highlight the main points of the publications. The parameters used in this systematization were as follows: author, country of authors, title, year of publication, periodical of publication, classification of the quality of the journal, country of the periodical, quantity of citations, focus (theoretical or practical) objective, sample size, analysis technique, variables used, results obtained and country where the work was developed.

From these data the bibliometric analysis was performed. The Piktochart platform was used to make the maps; for the elaboration of the graphs the Polinode was used. It should be mentioned that these applications are available online.

In the fourth and last phase, the discussion of the articles was structured, aiming to show the evolution of the concepts that surround urban mobility systems, in which they refer mainly to metrics and performance indicators. This discussion provided support for the construction of the conceptual chronology, referring to the proposed theme, and the identification of the main indicators and performance metrics.

4 Publications profile

The study of urban mobility indicators, proposed by the present study, was made through a longitudinal section of the literature that includes the time interval between 1989 and 2016.

As shown in Figure 3, the number of publications illustrating the use of metrics and indicators of urban mobility presented a considerable growth in the period, thus confirming the academic recognition about the validity of the use of these techniques in the evaluation and study of the performance of the systems of transport. It is worth to remember that the reduction in the number of publications in the year 2016 is justified by the fact that not all submissions and acceptance of articles had been fulfilled at the time of the survey.

Table 1 systematizes the use of the keywords in the temporal evolution of the selection of the articles studied. The use of the words "performance indicator" (appears in 88% of articles), "transportation system" (51%) and "urban transport" (39%) stands out. Together, they appear in 16% of articles. In the cut used, urban mobility starts to be measured by metrics and indicators in 2011, with metrics being used in only 22% of articles.

In relation to the countries of the authors that form the bibliographic portfolio, it is possible to observe, through Figure 4, that in the United States are located the largest number of authors who published studies on the subject proposed between 1989 and 2016. Then

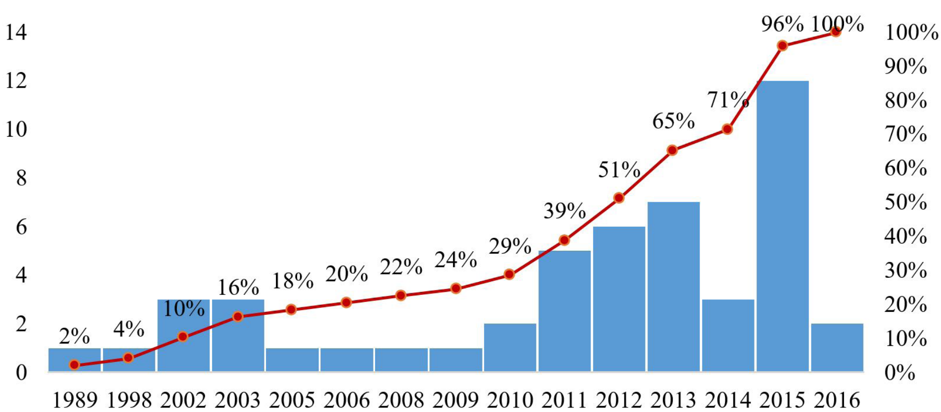

Figure 3. Evolution of the number of publications.

Table 1. Keyword incidence chronology.

KEYWORD/YEAR	1989	1998	2002	2003	2005	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL
Urban mobility	0	0	0	0	0	0	0	0	0	1	2	1	0	2	1	7
Urban transport	1	0	1	1	0	0	0	0	0	3	2	1	2	7	1	19
Urban transportation	1	0	1	0	0	0	1	0	0	0	1	2	1	4	1	12
Transport system	1	1	1	1	0	1	0	1	1	2	2	4	1	3	1	20
Transportation system	1	1	1	1	1	1	0	0	1	4	4	2	0	6	2	25
Transport network	0	0	0	0	0	0	1	0	0	0	2	1	1	3	1	9
Transportation network	0	0	0	0	0	0	1	0	0	0	0	3	0	2	1	7
Performance indicator	1	1	3	3	1	1	1	1	2	4	5	5	2	11	2	43
Metric	0	0	0	0	1	0	0	0	0	1	1	3	1	4	0	11

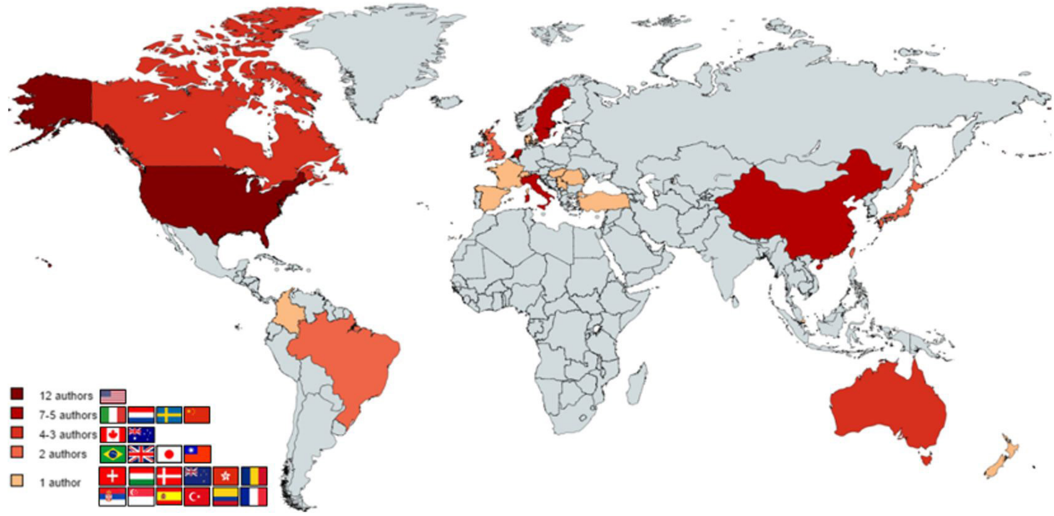

Figure 4. Countries of the authors of the selected articles.

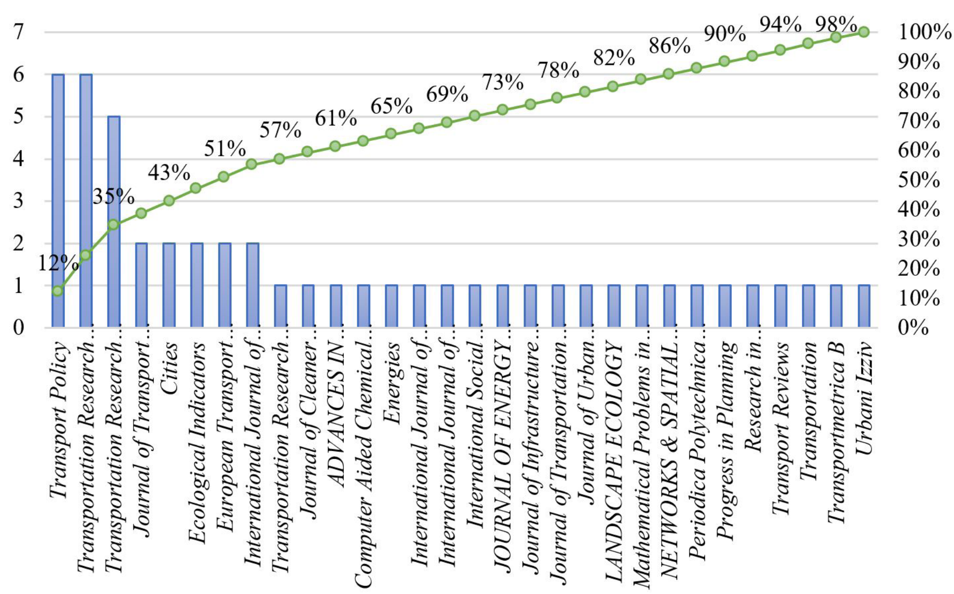

Figure 5. Arrangement of publications by periodical.

appear Italy with seven authors and the Netherlands, Sweden and China with five authors each. The other countries appear with a quantitative between four or less authors who disseminated the knowledge, on the subject in question, during the years previously mentioned.

This research also allowed us to glimpse the degree of relevance of the main journals that compose the bibliographic portfolio. Figure 5 illustrates the layout of journals among journals and highlights "Transport Policy", "Transportation Research Part A: Policy and Practice" and "Transportation Research Record" as the means that most disseminate knowledge regarding performance indicators focusing on transportation efficiency, covering 35% of selected articles.

5 Metrics and urban mobility performance indicators

In order to systematize and interrelate the application areas, Figure 6 outlines an unrelated graph that exposes the links between authors and themes. The size of the marker refers to the number of times the author was quoted within the graph and the color makes explicit the category of the magazine theme. The authors

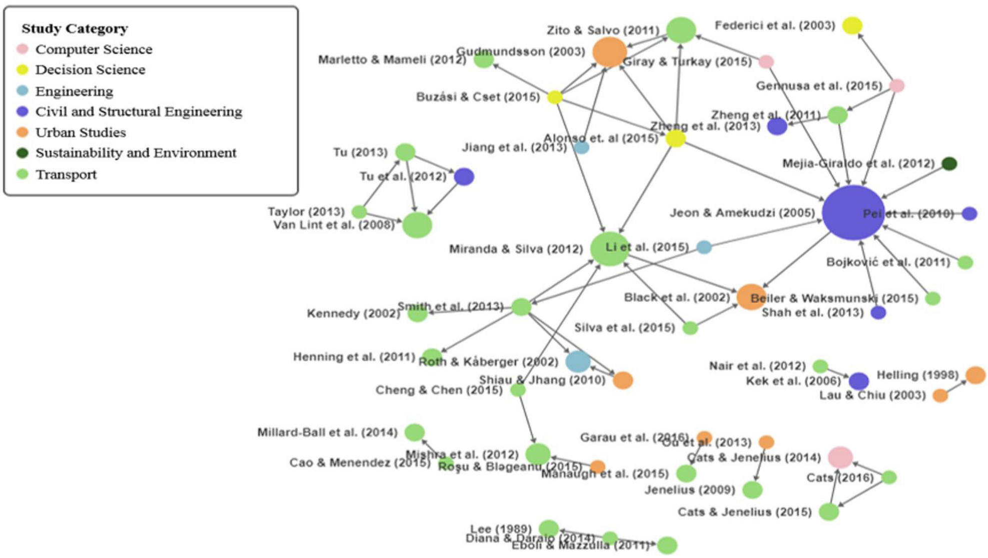

Figure 6. Graph of interrelationship of authors.

with the highest score are the most relevant for the research. The distribution of markers was performed by applying the loupe distribution followed by an enlargement.

It is important to note that the magazines used have themes that are not limited to the category of transportation (cataloged in 51% of articles). The category of urban studies contributes 16%, followed by civil and structural engineering with 12%. Computer science, decision sciences, and other engineering subjects draw 6% of all publications. Finally, the category of sustainability and the environment appears in 2%.

The main highlight in the network of authors is Jeon & Amekudzi (2005), whose article was published in a journal focusing on civil and structural engineering. The relevance of this author is explained by the design of his work that elaborated a framework composed of 137 metrics and indicators to measure the effectiveness and efficiency of transport systems and the potential impacts of these systems on the economy, the environment and the quality of life of the society.

Other authors that stand out are Gudmundsson (2003), who in his work interconnects social science themes with approaches of flexibility, mobility, transport and sustainability, and Miranda & Silva (2012) that published exclusively in the area of transport developing the Index Sustainable Urban Mobility (IMUS).

The use of metrics and performance indicators associated with the transportation system and urban mobility has been observed since the 1980s (Lee, 1989; Helling, 1998). The first approaches observed in these works were carried out according to the perspectives of accessibility and economic aspects, used by Lee (1989). Helling (1998), in turn, made use of the perspective of traffic and urban circulation, as well as of social aspects.

Following the timeline of publications, Black et al. (2002) studied the urban transport system of an Australian city. The authors developed the perspective of non-motorized modes and the environmental perspective because they verified the necessity of the grouping of the idea of sustainability, which is given by the association between social, economic and environmental aspects, to the transport systems.

Roth & Kåberger (2002), Kennedy (2002) and Federici et al. (2003) who included indicators related to safety and urban transport systems also addressed the environmental perspective. The growth of the number of initiatives to conceptualize the term sustainability and apply it to the planning and development of transportation systems is evidenced in the study by Jeon & Amekudzi (2005), who identified emerging ideas and methods of measuring sustainability in the transportation system of North America, Europe and Oceania. In addition to the seven perspectives already described, the authors added three others: political aspects, infrastructure, non-motorized modes and integrated planning.

Finally, the last perspective found in the selection of articles proposed by this study is that of intelligent mobility. Initially discussed by Kek et al. (2006) proposed a simulation modeling to optimize the resources involved in a multiple station of a shared-use vehicle system in Singapore. Figure 7 illustrates the emergence of the perspectives of urban transport and mobility indicators in a timeline.

After using the environmental perspective made by Black et al. (2002) and Kennedy (2002), the approach to sustainability has grown considerably in subsequent works: about 55% of the articles in the selection provide some indication of the environmental/sustainable approach. The increase in the number of studies in this area is justified by the growing concern in the transport systems with the emission of greenhouse gases and the impacts of pollution on the stakeholders' perception (Marletto & Mameli, 2012; Zheng et al., 2013; Beiler et al., 2015).

The environmental approach is not the most discussed in the surveys that use performance metrics in their analysis, although this approach has great representativeness in the literature. The greatest number of metrics and indicators of the paper selection are linked to the urban transport system perspective, treated in 61% of the works, according to Figure 8.

Initially, this study started from the nine perspectives and 87 indicators proposed by the IMUS tool, used by Miranda & Silva (2012) and Silva et al. (2015). Then, the metrics and indicators treated by the other authors were identified, including three more perspectives to the initial role. In Table 2, it is possible to identify the approach of the perspectives by the authors of the selection and the number of indicators used in each study. Metrics and indicators were grouped and rearranged into 228 categories and 12 perspectives, according to Table 3. This regrouping allowed the economic, health and safety, and intelligent mobility perspectives to be elucidated.

In addition to the graph elaborated to illustrate the interrelation between the authors and the subjects of the magazines, subgraphs were constructed in order to elucidate the authors who contributed in the construction of each perspective. In these subgraphs, each node refers to authors who, in turn, are arranged in a timeline. The size of the node is related to the number of metrics and metrics identified in the selection articles. The index H of the journals in

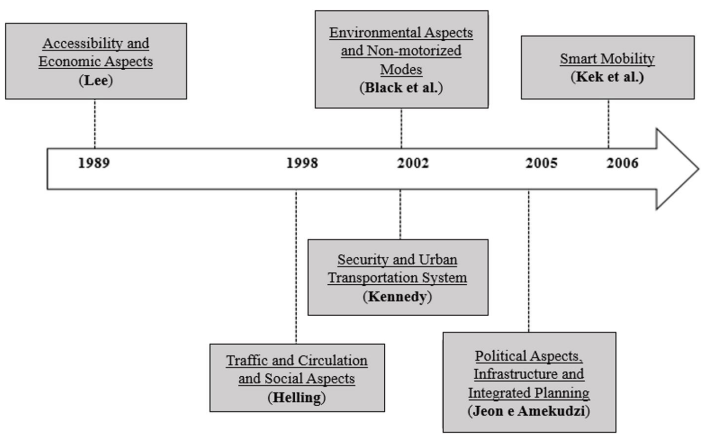

Figure 7. Conceptual chronology of perspectives.

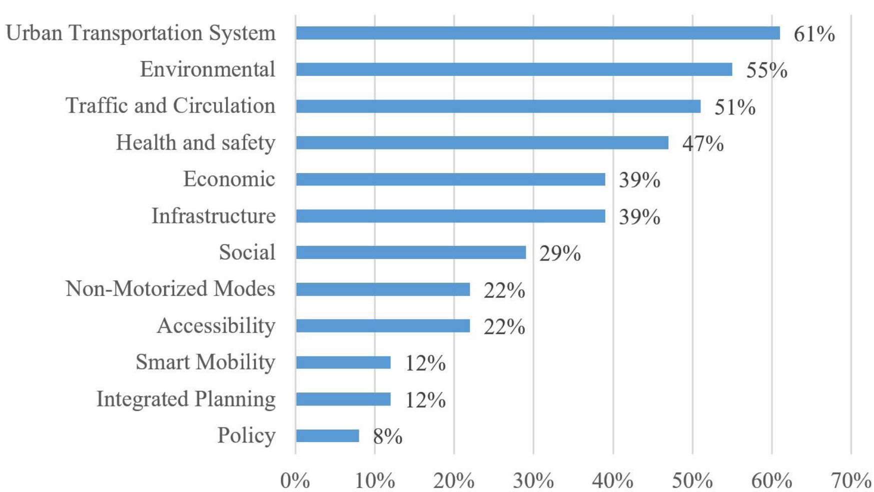

Figure 8. Percentage of authors by perspective.

Table 2. Incidence of the perspectives and quantitative indicators by author.

AUTHOR/YEAR	PERSPECTIVE												
	Accessibility	**Environmental**	**Social**	**Economic**	**Policy**	**Infrastructure**	**Non-Motorized Modes**	**Integrated Planning**	**Health and Safety**	**Traffic and Circulation**	**Urban Transportation System Urbano**	**Smart Mobility**	**TOTAL**
Lee (1989)	0	0	0	2	0	0	0	0	0	0	2	0	4
Helling (1998)	0	0	2	0	0	0	0	0	0	1	0	0	3
Black et al. (2002)	0	4	0	0	0	0	2	0	1	3	2	0	12
Kennedy (2002)	0	2	1	1	0	0	0	0	1	0	2	0	7
Roth & Kåberger (2002)	0	1	0	0	0	0	0	0	0	0	0	0	1
Federici et al. (2003)	0	3	0	0	0	0	0	0	0	0	3	0	6
Gudmundsson (2003)	0	7	0	0	0	0	0	0	1	0	0	0	8
Lau & Chiu (2003)	0	0	1	0	0	0	0	0	0	2	2	0	5
Jeon & Amekudzi (2005)	5	57	4	9	1	14	2	4	5	14	22	0	137
Kek et al. (2006)	0	0	0	0	0	0	0	0	0	0	0	4	4
van Lint et al. (2008)	0	0	0	0	0	0	0	0	0	1	0	0	1
Jenelius (2009)	0	0	0	0	0	2	0	1	0	1	1	0	5
Pei et al. (2010)	0	4	0	1	0	0	0	0	1	0	0	0	6
Shiau & Jhang (2010)	0	4	0	0	0	1	0	0	0	0	1	0	6
Bojković et al. (2011)	0	2	0	0	0	1	0	0	1	1	3	0	8
Eboli & Mazzulla (2011)	0	1	0	1	0	0	0	0	1	1	4	0	8
Henning et al. (2011)	0	1	0	1	1	0	0	0	3	0	3	0	9
Zheng et al. (2011)	2	4	1	0	0	0	0	0	2	0	0	0	9
Zito & Salvo (2011)	0	1	1	1	0	3	2	1	1	2	6	0	18
Marletto & Mameli (2012)	0	5	0	1	0	0	1	0	1	1	1	0	10
Mejia-Giraldo et al. (2012)	0	4	0	0	0	0	0	0	0	0	1	0	5
Miranda & Silva (2012)	9	6	4	3	7	5	8	18	4	5	17	1	87
Mishra et al. (2012)	0	0	0	0	0	3	0	0	0	0	0	0	3
Nair et al. (2013)	0	0	0	1	0	2	2	0	0	0	0	1	6
Tu et al. (2012)	0	0	0	0	0	2	0	0	0	5	0	0	7
Jiang et al. (2013)	1	2	0	2	0	2	2	0	2	3	0	0	14
Ou et al. (2013)	0	1	0	0	0	0	0	0	0	0	0	0	1
Shah et al. (2013)	0	2	0	2	0	1	1	0	1	2	2	0	11
Smith et al. (2013)	0	6	1	4	0	0	0	0	6	0	1	0	18
Taylor (2013)	0	0	0	0	0	0	0	0	0	1	0	0	1
Tu et al. (2013)	0	0	0	0	0	2	0	0	0	3	0	0	5
Zheng et al. (2013)	1	7	3	3	0	0	0	0	1	0	1	0	16
Cats & Jenelius (2014)	0	0	0	0	0	0	0	0	0	3	2	0	5
Diana & Daraio (2014)	1	0	0	2	0	0	0	0	1	0	3	0	7
Millard-Ball et al. (2014)	0	0	0	0	0	0	0	0	0	3	0	0	3
Alonso et al. (2015)	0	2	0	3	0	2	0	0	1	0	2	0	10
Beiler et al. (2015)	5	7	0	0	0	14	0	9	1	0	0	0	36
Buzási & Csete (2015)	0	5	1	3	0	1	0	0	1	2	4	0	17
Cao & Menendez (2015)	0	0	0	0	0	1	0	0	0	5	0	0	6
Cats & Jenelius (2015)	0	0	0	0	0	0	0	0	0	1	10	0	11
Cheng & Chen (2015)	12	0	0	0	0	0	4	0	5	0	41	5	67
Giray Resat & Turkay (2015)	1	5	1	1	0	0	0	0	2	3	2	0	15
Gennusa et al. (2015)	0	1	0	0	0	0	0	0	0	1	0	0	2
Li et al. (2015)	0	0	0	0	0	0	0	0	0	4	1	0	5
Manaugh et al. (2015)	0	0	1	0	0	0	0	0	0	0	0	0	1
Silva et al. (2015)	9	6	4	3	7	5	8	18	4	5	17	1	87
Roșu & Blăgeanu (2015)	1	0	1	0	0	3	0	0	0	0	1	0	6
Cats (2016)	0	0	0	0	0	0	0	0	0	0	4	0	4
Garau et al. (2016)	0	0	0	0	0	2	1	0	0	0	1	4	8
	47	150	26	44	16	66	33	51	47	73	162	16	731

which the articles were published are represented by the pigmentation at the nodes and edges.

According to Figure 9, the most relevant authors were Cheng & Chen (2015), Silva et al. (2015) and Miranda & Silva (2012). The most cited indicators were accessibility to public transportation by low-income people, adapted crossings and parking spaces for people with special needs, accessibility to open spaces and essential services, as well as actions for universal accessibility and user perception of accessibility.

The authors that stood out the most from the environmental perspective were Jeon & Amekudzi (2005), for mentioning 57 indicators within 24 categories. The most cited indicators were air pollution (CO, CO2 and other emissions), fossil fuel consumption, population exposed to traffic noise, energy efficiency, emission of toxic substances, land use and solid waste. Figure 10 explains the relationship between authors in this perspective.

As regards the social perspective, Jeon & Amekudzi (2005), Miranda & Silva (2012) and Silva et al. (2015) cited the highest number of indicators, according to Figure 11. The main indicators identified were social equity (income), number of people employed, and population participation in decision-making.

Figure 12 illustrates the economic perspective subgraph in which the most relevant authors are Jeon

Table 3. Number of categories per perspective.

Perspectives	Number of Categories	%
Urban Transportation System	57	25
Environmental	30	13
Traffic and Urban Circulation	29	13
Integrated Planning	19	8
Infrastructure	16	7
Economic	15	7
Health and Safety	15	7
Accessibility	13	6
Non-Motorized Modes	11	5
Social	8	4
Smart Mobility	8	4
Policy	7	3
TOTAL	228	100

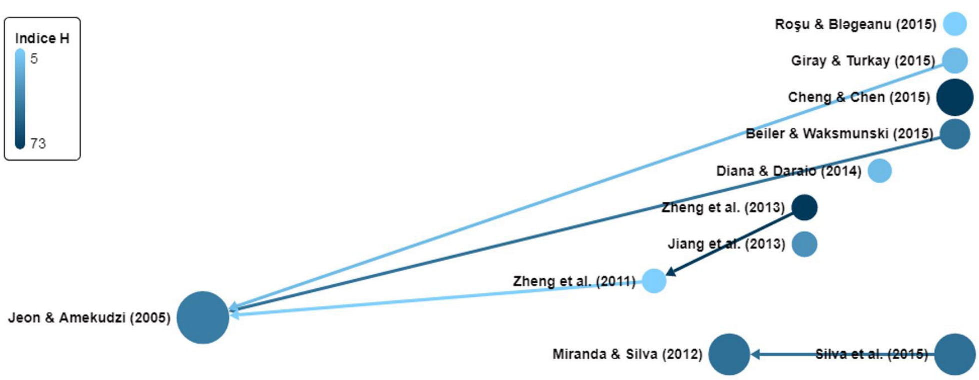

Figure 9. Accessibility perspective graph.

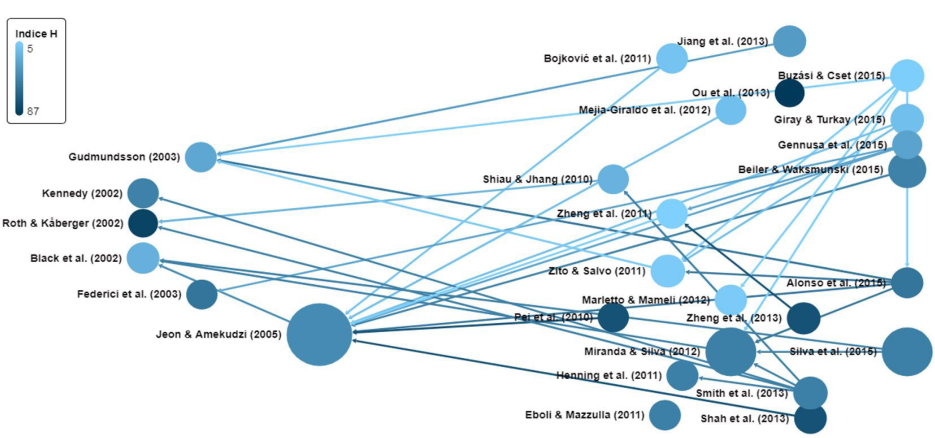

Figure 10. Environmental perspective graph.

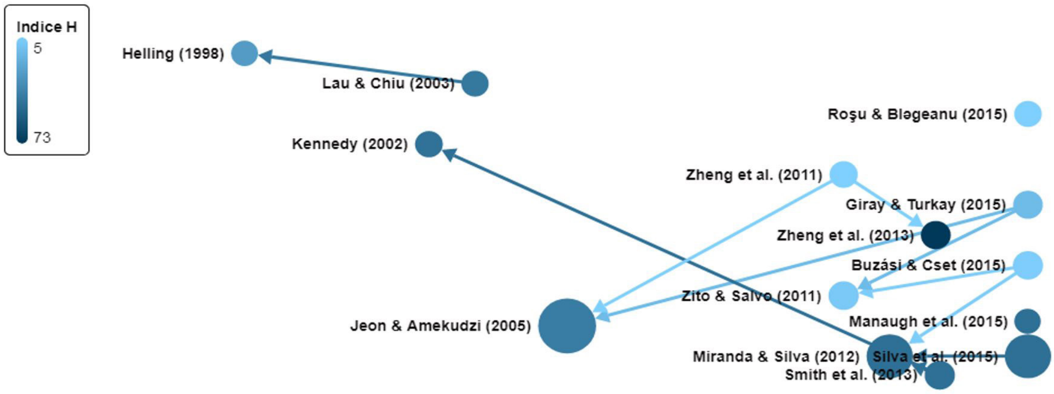

Figure 11. Social perspective graph.

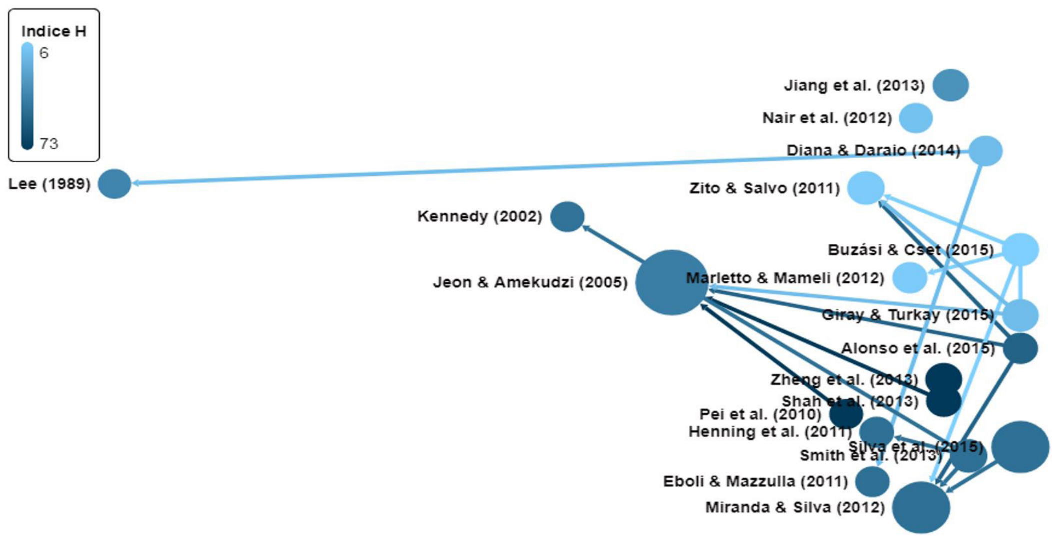

Figure 12. Economic perspective graph.

& Amekudzi (2005) and Miranda & Silva (2012). The most cited indicators were transportation expenses, transportation tariffs per person, transportation costs per household and individual and GDP.

Only four authors contributed with the political perspective, according to Figure 13, with the main indicators identified being fundraising and urban mobility policy. Only the indicators already included in IMUS are included in this perspective. It is worth mentioning that the magazine Transport Policy published three articles of the four that dealt with political aspects.

In terms of infrastructure, the most prominent authors were Jeon & Amekudzi (2005) and Beiler et al. (2015), as shown in Figure 14. The most cited indicators were road length and infrastructure maintenance expenses.

In relation to the perspective of non-motorized modes, Miranda & Silva (2012) and Silva et al. (2015) appear as the main authors. Number of journeys by foot or bicycle, pedestrian routes, extension and connectivity of bicycle lanes, bicycle parking, quality of pedestrian and cycle routes, travel time and actions to reduce motor traffic were the seven most cited indicators in this perspective. It is worth mentioning the contribution of Black et al. (2002) for the dissemination of knowledge regarding this perspective, as shown in Figure 15.

Miranda & Silva (2012) and Silva et al. (2015) also appear in the perspective of integrated planning as main authors, according to Figure 16. The main indicators were: urban population density, mixed use index and urban growth.

From the perspective of health and safety, the greatest number of indicators was identified in the works of Smith et al. (2013), Jeon & Amekudzi (2005) and Cheng & Chen (2015), as shown in Figure 17. The most relevant indicators were accidents with fatality, traffic accidents, safety in the use of public transport service, pollution effect health and medical expenses associated with transportation.

Figure 13. Political perspective graph.

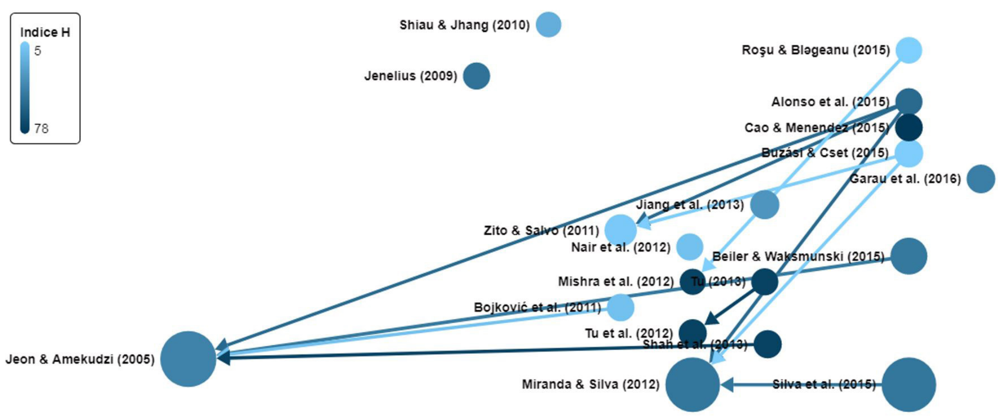

Figure 14. Infrastructure perspective graph.

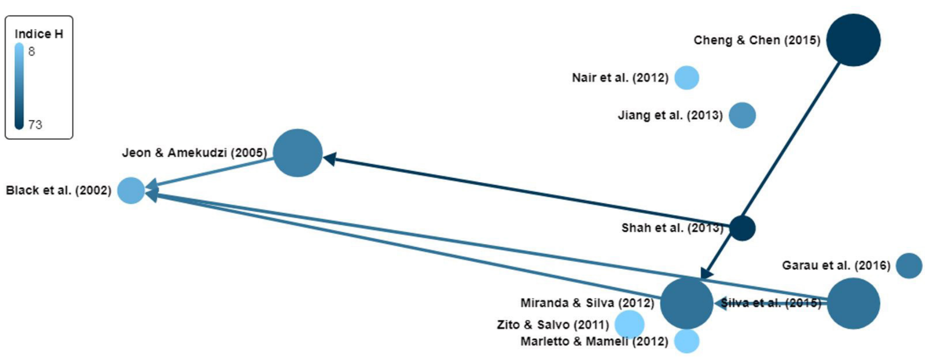

Figure 15. Non-motorized perspective perspective graph.

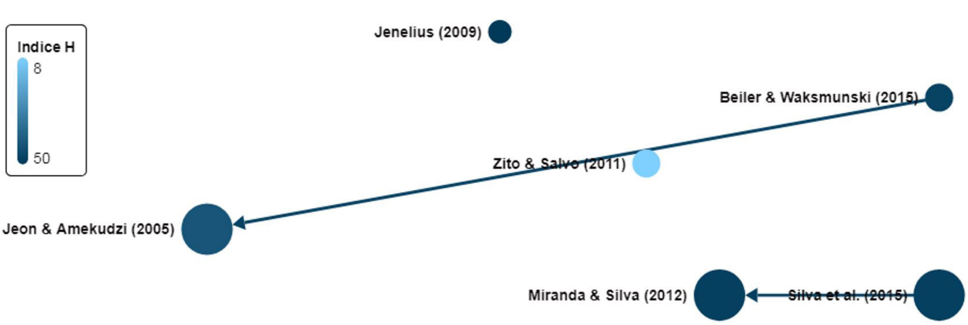

Figure 16. Integrated planning perspective graph.

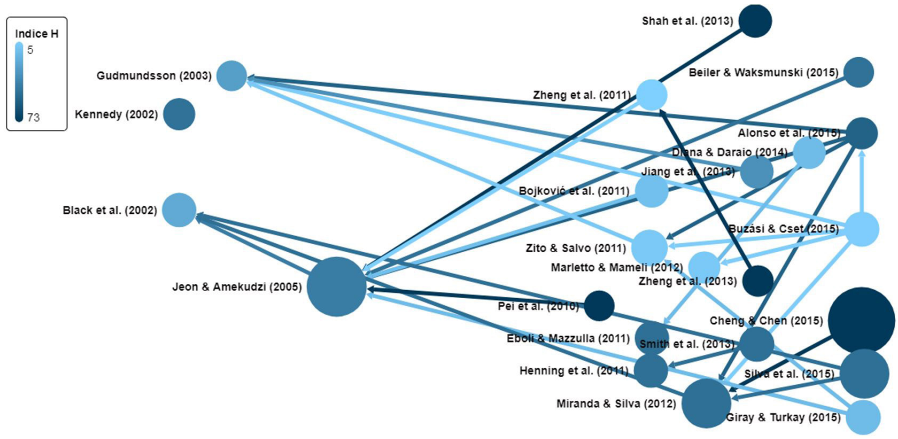

Figure 17. Health and safety perspective graph.

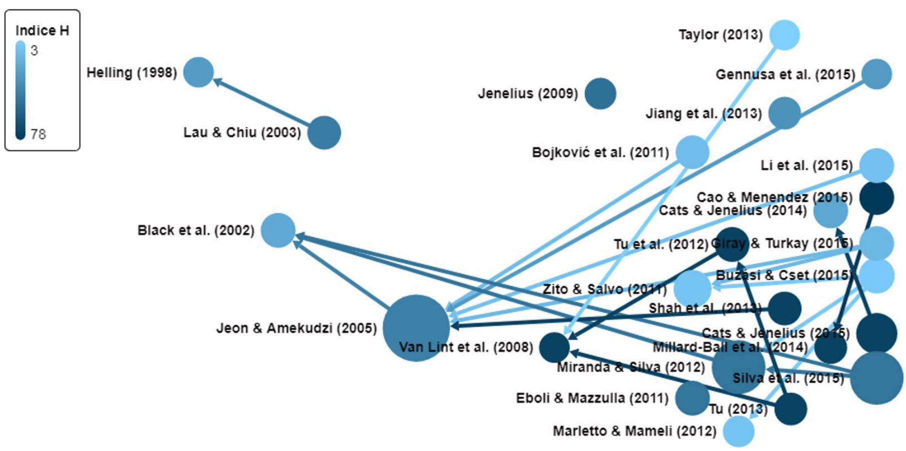

Figure 18. Perspective of traffic and urban circulation graph.

As for the perspective of traffic and urban circulation, once again the prominent authors were Jeon & Amekudzi (2005), as illustrated in Figure 18. Average travel time, congestion, variation in travel time, average traffic speed, personal journeys per day and occupancy rate of vehicles were the main indicators identified.

Figure 19 shows Cheng & Chen (2015) as the most relevant authors in the perspective of urban transport system. These authors addressed indicators based on user perception. User satisfaction with the public transport service, operational costs per vehicle/hour, comfort perceived by the user of the public transport service, user perception of the performance of the transportation system, attendance of public transportation, punctuality, volume of passengers transported per year, perceptions of intermodal transfers, passenger index per km, total travel time of public transport, extension of public transport network, average speed of public transport, use of public transport service, type of transport used and integration of public transport were the main indicators verified.

In the perspective of intelligent mobility, the most relevant authors were Cheng & Chen (2015), Garau et al. (2016) and Kek et al. (2006), according to Figure 20. The main indicators identified were support system for public mobility and bicycle sharing. It is worth mentioning that the sharing of vehicles is a trend made possible by the use of smartphone applications.

Intelligent mobility can be achieved with four factors: local accessibility, national and international accessibility, availability of Information and Communication Technology (ICT) infrastructure and a sustainable, innovative and secure transport system (Batty et al., 2012). Thus, intelligent mobility interconnects other perspectives and its measurement requires involving them.

Finally, Table 4 presents a synthesis of the most used urban mobility metrics, grouped within

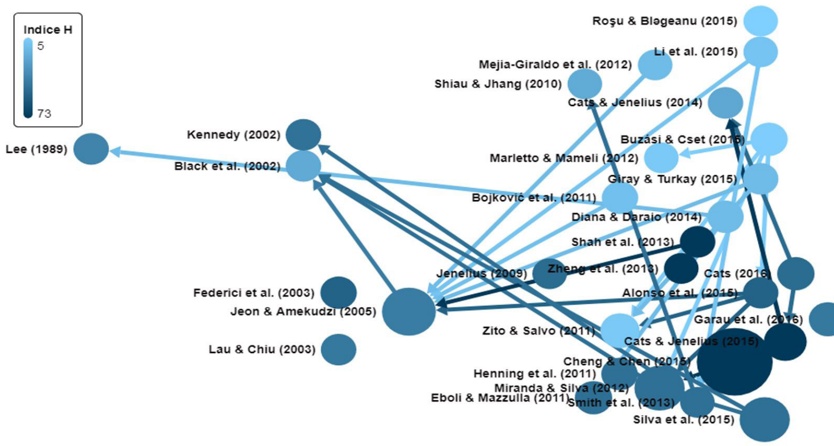

Figure 19. Urban transport system perspective graph.

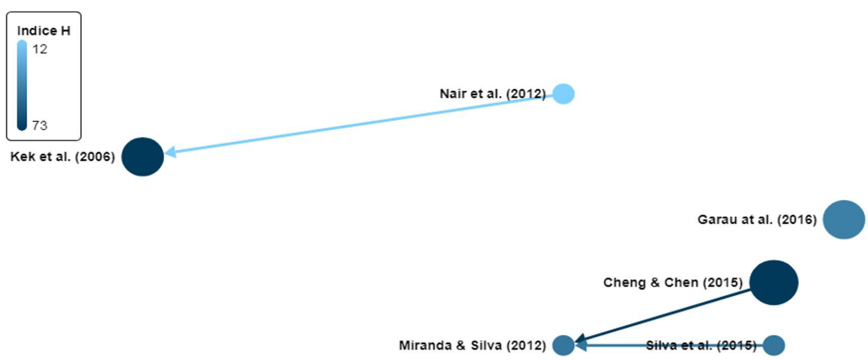

Figure 20. Smart mobility perspective graph.

Table 4. Overview of the most used metrics.

PERSPECTIVE	METRIC
Accessibility	Accessibility to public transport by low-income people
	Crossings adapted for people with special needs
	Parking spaces for people with special needs
	Accessibility to open spaces
	Accessibility to essential services
	Universal Accessibility
	Perception of user about accessibility
Environmental	Air pollution (CO, CO2 and other emissions)
	Fossil Fuel Consumption
	Population exposed to traffic noise
	Energy Efficiency
	Emission of toxic substances
	Land use
	Solid wastes
Social	Social equity (income)
	Number of people employed
	Participation of the population in decision-making
Economic	Transportation expenses
	Transportation rates per person
	Cost with transport by domicile and individual
	GDP

Table 4. Continued...

PERSPECTIVE	METRIC
Policy	Fund-raising
	Urban mobility policy
Infrastructure	Length of tracks
	Expenses with maintenance of infrastructure
Non-motorized modes	Number of trips by foot or bicycle
	Footpaths
	Extension and connectivity of bicycle lanes
	Bicycle rental
	Quality of footpaths and cyclists
	Time of travel
	Actions to reduce motorized traffic
Integrated Planning	Urban population density
	Mixed use index
	Urban growth
Health and safety	Fatalities
	Traffic-accidents
	Safety in the use of the public transport service
	Effect of pollution on health
	Medical expenses associated with transportation
Traffic and Circulation	Average travel time
	Congestion
	Variation in travel time
	Average traffic speed
	Number of personal trips per day
	Occupancy rate of vehicles
Urban Transportation System	User satisfaction with public transport service
	Operating costs per vehicle / hour
	Comfort perceived by the user of the public transport service
	Perception of the user about the performance of the transport system
	Frequency of public transport service
	Punctuality
	Volume of passengers transported in the year
	Perceptions of intermodal transfers
	Passenger index per km
	Total travel time of public transport
	Extension of the public transport network
	Average speed of public transport
	Use of public transport service
	Type of transportation used
	Integration of public transport
Smart Mobility	Public mobility support system
	Bicycle Sharing

the 12 perspectives identified, thus reaching the purpose of the work.

Thus, within the twelve perspectives found, 63 metrics were identified as being the most used in the world to evaluate urban transport and mobility systems.

6 Final considerations

In the scope of its method definitions, this work carried out a detailed review of the metrics and performance indicators of the urban transport and mobility systems, systematizing a corpus of 49 articles linked to the development of academic currents of thought in the area. The articles analyzed emerged from a survey of the Scopus and Web of Science bases focusing the period from 1989 to 2016. This survey was treated according to consistent and filtered procedures of intense production during the period (439 articles were initially recorded based on a research conducted by three groups of keywords). The in-depth analysis included almost half a hundred academic papers whose focuses wewre strictly inserted in the framework of studies oriented to the elaboration and application of indicators of urban mobility.

It was verified the existence of a tendency of growth in the number of publications that involve the subject in question. On the one hand, the results demonstrate unequivocally that there is a technical-academic concern with the construction and application of indicators to guide the evolution of cities and transportation systems in the direction of greater effectiveness. Furthermore, results also point out the case for a wider range of concerns related to the management of mobility, with the positive side effect to facilitate monitoring improvements by social agents interested in the sustainability of urban dynamics. On the other hand, the bibliometric analysis carried out show a clear tendency for the subject to be researched in a structured way, configuring networks of researchers conducing theoretical-conceptual advances of both general (systemic view) and specific orders, in this case with the indisputable merit of realizing deeper contributions in subsystemic perspectives.

A figure of 228 metrics and performance indicators were identified and grouped into twelve perspectives: accessibility, environmental, social, economic, political, infrastructure, non-motorized modes, integrated planning, health and safety, traffic and urban traffic, urban transport system and intelligent mobility. It was verified the predominance of studies directed to the perspectives of efficiency in urban and environmental transport systems.

In addition, this research made it possible to identify the main authors in each research niche in the area of transportation and urban mobility systems. It was also possible to elucidate the most significant metrics and performance indicators in the papers that compose the selection.

When analyzing the chronological aspects regarding perspectives under scrutiny, the analysis concludes that the scope of urban mobility assessment and evaluating is getting more and more complexity. Far from being present in the body of articles studied since the beginning of the period, the new perspectives progressively added to the studied problematic reveal a paradigm construction process.

In this sense, another highlight of this research was the confirmation of the growth of the concept of smarts cities. This term appeared in the selection of articles from the perspective of intelligent mobility and represents a trend of publications in recent years. In addition, the premises necessary for the construction of smart cities have been used to develop improvements not only in transport, but also in the economy, mobility, environment and government.

Thus, the contribution of this work consists of systematizing the possibilities of evolution of a research area, based on the explication of its behavior in almost three decades, and leaving clear indications to the national academic community about which theoretical-conceptual referential is being settled globally, and what expectations can be assumed for future research. Thus, it remains clearly demonstrated that the most recently incorporated perspectives point to gaps in the process of evaluating urban mobility with regard to: political-institutional aspects; integrating urban mobility planning with the other elements and services necessary for the dynamics of cities and surrounding territories; internalization of information and communication technologies in the planning and management of mobility systems. Issues such as public-private alliances, participatory management, social inclusion in planning, nature of institutions and the urban-regional political process, etc. are opportunities to expand the scope of research for the near future.

Finally, it should be emphasized that this work, as proposed and accomplished, is faced with limitations typical of its bibliometric nature. On the one hand, the time cut adopted (1989/2016) dates back to the late 1980s, influenced by the fact that the Brundtland Report was published in 1987. There is no doubt that the Brundtland Repot brought to academic circles linked to urban transport and development the responsibility to advance conceptually respect to links between urban transport and sustainable development. It must be recognized that, although it can be treated as a consistent argument, the initial year of the search in the databases was defined ad hoc. Of course, the definition of 2016 as the final year of the period is simply because it was in the middle of this year that the initial survey was carried out in the databases investigated. Updating the survey, possibly leading to new results, is certainly a permanent requirement. In this sense, this paper intended to leave explicit all its methodological decisions in order to make it easier to reproduce the analysis with the inclusion of more years in the period defined here. That could generate the interest to produce new papers in the same or similar direction.

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