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PROPOSAL OF CONCEPTUAL MODEL OF ENVIRONMENTAL IMPACTS IN THE TRANSPORT AND URBAN MOBILITY SYSTEM

PROPOSTA DE MODELO CONCEITUAL DOS IMPACTOS AMBIENTAIS NO SISTEMA DE TRANSPORTES E MOBILIDADE URBANA

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Abstract

Negative impacts from the urban mobility system are one of the main challenges for urban planning today. The understanding of the cause and effect process and the relations between them is fundamental for environmental management aiming at reducing the manifestation of negative externalities of those impacts. The purpose of this work is to develop a proposal for a conceptual model of the environmental impacts resulting from the transportation and urban mobility. The research was done on bibliographic databases used to establish the relationship between environmental aspects and impacts in an integrated way through a Related Flow of Environmental Events, an instrument for integrating the events responsible for the transforming activity and its potential effects on the environment. The research made it possible to identify a range of impacts related to the transportation and urban mobility system, as well as to identify the hypothetical relationships between the causative factors and the environmental impacts.

Keywords: Environmental impacts. Urban mobility. Transportation. Urban environmental quality. Assessment of environmental impacts.

Resumo

Impactos negativos oriundos do sistema de mobilidade urbana são um dos principais desafios para o planejamento urbano na atualidade. A compreensão do processo de causa e efeitos e relações entre si é fundamental para a gestão ambiental visando a redução da manifestação de externalidades negativas dos impactos. O objetivo do trabalho é desenvolver uma proposta de modelo conceitual dos impactos ambientais decorrentes do sistema de transportes e mobilidade urbana. Foi feita pesquisa em bases de dados bibliográficos utilizados para estabelecer a relação entre de aspectos e impactos ambientais de forma integrada por meio de Fluxograma Relacionado de Eventos Ambientais, instrumento de integração dos eventos responsáveis pela atividade transformadora e os seus efeitos potenciais ao ambiente. A pesquisa permitiu identificar a gama dos impactos relacionados ao sistema

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de transporte e mobilidade urbana, assim como identificar as relações hipotéticas entre os fatores causadores e os impactos ambientais.

Palavras chave: Impactos ambientais. Mobilidade urbana. Transportes. Qualidade ambiental urbana. Avaliação de impactos ambientais.

Introduction

Transport and urban mobility have been a central concern in the debates on urban planning and sustainability due mainly to negative impacts on the environmental and to quality of life of the population. MARTINE (2007) highlights the importance of equating population and territory in a way that causes the least environmental damage and better promotes sustainability, economic growth and social development.

According to the Brazilian Urban Mobility Policy (BRASIL, 2012), urban transport refers to the set of modes and services of public and private transport used for the transport of people and cargo; and urban mobility refers to the condition in which the displacement of people and goods are performed in urban space. The concepts are complementary, in which the first refers to the infrastructure itself, while the mobility expresses the ease of people to travel in the urban context (BRASIL, 2012, BRASIL, 2005).

The problem is highlighted as motor vehicles become the main mode of transport, causing an imbalance in the demand and supply opportunities over other modes in the urban system, such as public transit and active transportation (cycling and pedestrian). This imbalance ultimately results in burdens to society.

For the United Nations the emerging challenge in the transport sector is to improve the quality of travel by minimizing socioeconomic and environmental externalities, based on more sustainable and increasingly non-motorized modes (UN-HABITAT, 2015).

Every day, it is estimated that millions of dollars of burden are generated due to problems related to the inefficiencies of the urban mobility system, leading to congestion, environmental pollution, increased fuel consumption, delay-time, etc. (ANTP, 1999, Scaringella, 2001, IPEA, 2013, Cintra, 2013 e Firjam, 2013).

Especially in developing countries, there is an accelerated increase in motorization rates, being more frequent, longer, and with fewer occupants in vehicles, triggering several environmental, social and economic problems (Seabra et al., 2013).

Overall, Brazil has a recent history with urban planning, and even more with sustainable urban mobility, given, for example, the enactment of the Brazilian Urban Mobility Policy in 2012 (Law 12587/2012). This brings important advances in the environmental and urban policies, highlighting the following principles: mitigation of environmental, social and economic costs of the displacement of people and goods; encouraging technological development and the use of renewable and clean energy sources; prioritization of collective transport projects structuring the territory.

At the technical and academic level there is a growing concern with the identification, characterization and measurement of environmental impacts, both positive and negative. Even so, national scientific research addresses a limited number of potential effects of the transport system and predominates qualitative approaches without establishing a quantitative environmental impact investigation process. At the same time, a considerable range of impacts are still neglected, limiting an integrated understanding of the cause and effect factors.

Thus, in-depth knowledge of this process becomes a fundamental tool to support strategies for mitigating negative impacts and enhancing positive ones. The organization of concepts of analysis methods that serve as reference for scientists and technicians is fundamental to elucidate the processes that generate these impacts, allowing a properly identification of the relationships of the transport and urban mobility system.

Tahzib; Zvijáková (2012) point out that transport impacts can be classified into three basic categories: direct (immediate and well understood environmental consequences), indirect (secondary consequences) and cumulative (additive, multiplicative or synergistic consequences, which consider varied effects of direct and indirect impacts, which are often unpredictable). To Sharma; Kumar (2012) indirect effects may have greater consequences than direct effects, but are generally not well known, with relationships involved, often misunderstood and difficult to establish.

The relationship between transport and the environment is interdisciplinary, and thus impact assessment requires a deep understanding of the reciprocal influence between the physical environment and transport infrastructure (TAHZIB; ZVIJÁKOVÁ, 2012). Soria-Lara et al. (2014) states that environmental impact assessment is a comprehensive analysis of the likely effects of projects that significantly change the environment, providing decision makers with an indication of the possible environmental consequences of their selected policies.

However, the results of this assessment may yield unreliable results where many relevant impacts are not evaluated. As a result, impact assessments are often very focused on negative impacts, neglecting smaller and positive impacts, reducing the identification of opportunities and positive issues of the projects under evaluation (SORIA-LARA et al., 2014).

Thus, it appears that there is a need to develop a conceptual model for the assessment of impacts arising from the transport system in the country. For Rodrigue (2017) the total costs incurred by transport activities, especially environmental damage, are generally not fully considered, underestimating the magnitude of impacts.

In this sense, the work aims to contribute to the need to unify the main relationships between interventions and environmental changes, and the manifestation of potential environmental impacts, in a way that allows a systemic and integrated view. Thus, the purpose of this paper is to propose a conceptual model of the synergistic relationships of environmental impacts, resulting from the transport and urban mobility system.

This research can contribute to the unification of concepts, resulting from an existing bibliographic basis so that impact assessments can be optimized, allowing to relate the impacts from the transport and urban mobility. At the same time, this conceptual model can trigger more specific investigations of this process, as well as subsidizing environmental licensing process (demanded by Environmental Authorities), and Neighbourhood Impact Studies (demanded by local Municipality Authorities), in which there is a knowledge gap towards integrated investigation of the impacts generated by the transport system, affecting the quality and effectiveness of these studies.

The formulation of this conceptual model is necessary since public decisions related to alternatives to improve urban mobility generally take into consideration economic aspects, neglecting other impacts, including positive ones of alternative approaches, compromising the quality of the decisions taken and, consequently, fundamental data that could better development the quality of life of the population and environmental quality.

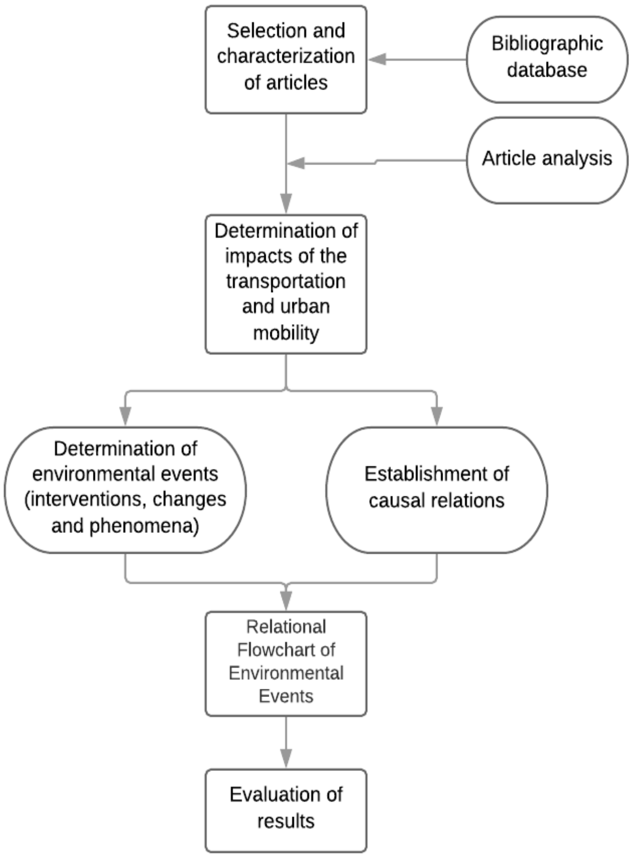
In addition, this research will support the process of assessing the environmental impacts of the transportation system in Brazilian municipalities, given the similar problems throughout the country regarding the identification and qualification of environmental impacts and their hierarchical relationship with other impacts and interventions that originated these. In this sense, the knowledge of the causal relations system between the impact and impact elements enables more efficient mitigation actions to be established, since the treatment of primary impacts may prevent secondary consequences from being manifested.

This work is characterized by a bibliographic research that seeks to understand and delineate an integrated conceptual model of the originating processes and their potential environmental effects that result from the current transport and urban mobility system.

Methodology

The proposed method is delimited by three steps: selection and characterization of articles, compilation of the environmental impacts presented in these articles and the development of related flowchart of environmental events. Figure 1 presents the logical sequence of the methodological steps of the research performed.

Figure 1. Flowchart of the steps of the research



Selection and characterization of articles

The first stage of the research was the selection of scientific articles that addressed research related to transport and urban mobility, covering discussion about impacts on society and used methodologies.

To this end, it was conducted researches in different scientific databases, selected for their broad scope and commonly used for academic consultations, being selected the following databases: Google Academic, Scielo and DOAJ (Directory of Open Access Journals).

To search the articles, it was used index in Portuguese and English: *Transport and Urban Mobility*, sorted by relevance. In the Google base, due to the high number of results, articles related to the theme were selected until the moment when, with the advancement in the search pages they started to deviate from the theme not being of interest to the search.

In the Scielo database 233 article results were observed, and in the DOAJ database 140 results. Some articles were common among the bases, and repeated articles were excluded and were evaluated in order to identify discussions addressing the manifesting environmental effects on the transport and urban mobility system. by affinity of themes, based on the stratification of the concept of environment.

From the selection of articles, they were registered and referenced in a spreadsheet allowing the analysis and extraction of data of interest necessary to determine the environmental impacts of the transport and urban mobility system to construct a conceptual model of causes and effects.

The selected articles include periods from the 1980s onwards, but predominantly from 2000. The impacts were classified by their nature (positive or negative) and were divided into themes within the environmental aspect of influence of each impact (physical, chemical, biological, social, cultural and urbanistic).

Sánchez (2006) defines the environmental aspect as the mechanism through which a human action causes an environmental impact. Thus, environmental impact is the result of human action or activity, which is its cause. This differentiation is fundamental and is a common problem observed in impact assessment studies and, may compromise the judgment of the object of analysis and, therefore, the quality of the study or research. According to ISO: 14001 (ABNT, 1997) environmental impact is a consequence of productive activities or services, industrial process or transportation, are causes of environmental modifications or impacts.

Compilation of environmental impacts listed in articles

To compile the environmental impacts, it was registered the negative and positive impacts attributed to the transport and urban mobility system contained in the articles.

According to CONAMA Resolution 306/2002, environmental impact refers to any change in the physical, chemical and biological properties of the environment, caused by any form of matter or energy resulting from human activities that directly or indirectly affect health, safety and well-being of the population, social and economic activities, biota, the aesthetic and sanitary conditions of the environment and the quality of environmental resources. Also, according to the above-mentioned Resolution, environment refers to the set of conditions, laws, influence and physical, chemical, biological, social, cultural and urbanistic interactions, which allows, shelters and governs life in all its forms. These concepts were the basis for understanding environmental events, allowing them to be classified into themes that may facilitate the understanding of each of the aspects and impacts listed.

It is noteworthy that the scope includes urban displacements, not being evaluated non-urban displacements or derived from commercial logistics (port, air, interurban road), not excluding, however, the existence of cargo vehicles near the normal flow of cities.

In evaluating the articles, they were mainly observed the introductory and methodological parts aiming to identify discussions and contextualization of the research on the theme of urban mobility. Being recorded changes and potential environmental effects, which are manifested from the transport system and urban mobility.

Related Flowchart of Environmental Events of the Transport and Urban Mobility System

From this knowledge compilation, it was evaluated the need to understand the theme as an integrated system, aiming at understanding the causal relations between the impacts and their original processes. For this, we used the instrument Related Flowchart of Environmental Events (FREA), developed by Macedo (1994), widely used in environmental licensing processes of activities or productive organizations, such as environmental impact studies and related reports.

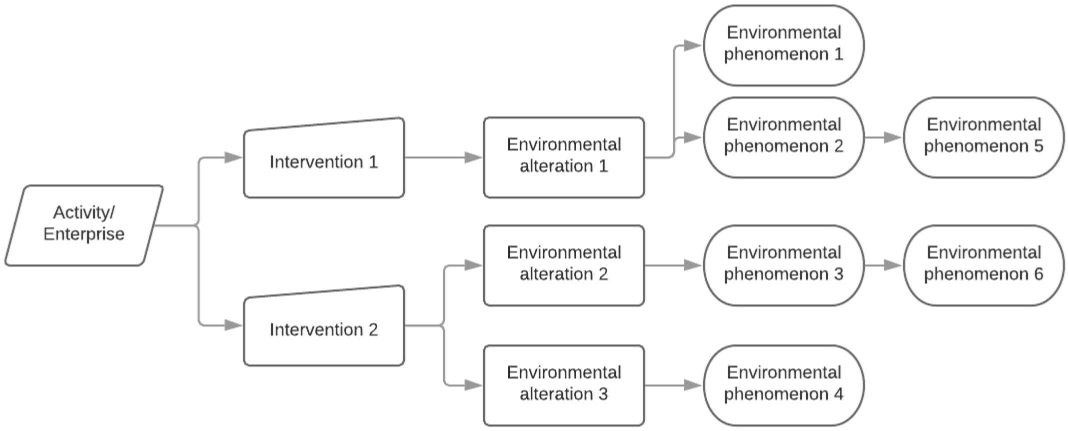
This flowchart integrates the events responsible for the transformative activity (or enterprise) and their potential effects on the environment, through interventions, changes and environmental phenomena, allowing to identify the chain of relationships between them. This integrates a broader methodology for impact assessment through the Environmental Impact Assessment and Management Model (MAGIA) which consists of the conception of the environmental situation of the relationships arising from the enterprise; definition of environmental events and cause and effect relationships (FREA); and the composition of an impact hypothesis.

Thus, considering the concepts of environmental aspects and impacts of the transportation system, cited by the articles, they were outlined in a FREA. The initial stage is the understanding of the problem, activity or enterprise to be evaluated according to the socioeconomic and environmental interrelationships, called environmental events, which, according to Spilliere & Beaumord (2006) are the events responsible for the transformative activity. environment, a process capable of altering the ecosystem.

The transformative activity entails three main environmental events: the Environmental Interventions (IN), which are the operational actions or tasks verified in the activity; environmental changes (AA), which are the environmental aspects involved or modifications generated in the environment as a result of the activity; and environmental phenomena (FA), which are the expected effects arising from, or potential environmental impacts.

These are characterized by the performance of environmental factors impacted by them, constituting the key set of environmental management and impact assessment processes (MACEDO, 1994). Figure 1 presents a generic FREA model, systematizing from a study activity. This will have interventions which will generate environmental changes, which in turn will manifest environmental impacts or phenomena, which may be isolated impacts or other sub-level impacts.

Figure 2. Generic model of the Related Flowchart of Environmental Events – FREA. Source: The author.



The flowchart allows to identify the degree of sensitivity of environmental factors, measured according to the proximity of the environmental impact to the change. An environmental impact derived from another will have a lower sensitivity, whereas the impact closer to the generating source (change or intervention) will have a higher sensitivity. This is because if the closest environmental impact is eliminated, the rest of the impact chain will be too. This will make the environmental impacts closer to the aspect more sensitive.

From this, it was possible to identify the AA resulting from the described interventions, responsible for the changes in the environment, allowing a more accurate identification of the potential impacts generated by the system under study. The organization of this set of relationships results in a flowchart (FREA), presented graphically, simplifying the understanding of the processes. According to Macedo (1994) this flowchart allows a specific delimitation of the points considered of most importance for the study activity. As the hypothesis works with an activity in operation and not a with a project to be build, the understanding of the processes is important for the optimization of its environmental performance.

For the present study, the environmental event of interest is the displacement of people and goods. In this proposal, the analysis of impacts, their causes and effects could be elaborated according to several analysis tables, considering here the current conditions of the transportation system usually adopted in Brazilian municipalities, taking into consideration the position evidenced in the bibliographies consulted. Thus, the general context to which the analysis is based is the current conditions of the transport system typically observed in Brazilian cities, and four different IN were identified: public transport, private motor vehicle transport, pedestrian transport and bicycle transport.

Results and discussion

The negative impacts derived from the transport and urban mobility system have profound effects on society, as their social, economic and environmental costs undermine full human development, directly influencing the population's quality of life. The United Nations has specific programs to address this issue, pointing to the urgent need to mitigate these impacts (UN, 2016). One of the goals of the SDG (Sustainable Development Goals) program, for example, is to provide access to safe, sustainable and affordable transport systems for all by improving road safety, with a focus on expanding public transport (UN, 2017).

In Brazil, the main Governmental Authority operating in this area is the Ministry of Environment. By overemphasizing road transport, traditional transport planning has contributed to the isolation and disintegration of communities, generating many negative impacts of the urban mobility system (BRASIL, 2015). The Ministry of the Environment (MMA, 2011) adds that the transport sector is the one that most impacts on air quality, accounting for 90% of polluting gas emissions.

The Ministry emphasizes that the adoption of efficient measures in the management of urban mobility requires the need for specific studies of the externalities of this system such as the emission of pollutants, noise generation, congestion, accidents, demand for infrastructure area, a barrier effect that makes it difficult. pedestrian and cyclist movement etc. (MMA, 2011 and MCIDADES, 2015).

Thus, the results obtained through the bibliographic analysis, allow to identify and contextualize the environmental impacts resulting from the transport and urban mobility system, allowing to delimit causal factors for the composition of a conceptual model about the environmental impacts of this model.

The proposed conceptual model was obtained from the development of the Related Environmental Events Flowchart (FREA) that allows the clear identification of the environmental event generating flows and their effects that will lead to the generation of potential positive or negative impacts of the urban mobility and transport system.

Selection of scientific articles, characterization and environmental impacts of the transport and urban mobility system

The research resulted in the analysis of 172 articles of interest (national and international) (see Appendex), among the three identified bases, consisting of national and international journals (Table 1). Most of these were obtained through Google's academic base with the selection of 101 articles (59%), followed by Scielo with 52 articles (30%) and DOAJ with 19 articles (11%).

Table 1. General characterization of the evaluated articles. Source: The author.

Database	Number of articles	Number of articles (%)
Google scholar	101	59%
Scielo	52	30%
DOAJ	19	11%
Total	172	100%

At this stage it was possible to identify different approaches of the theme and impact factors related to the transport and urban mobility system, both from methodological research and from theoretical discussions contained in these studies.

The environmental impacts identified from the evaluation of the articles totalled 30 (Table 2). It is noted that the construction of this occurred according to the approach of the articles, and from the impact number 17 there is a change in the approach of the nature of impacts, considering the positive impacts.

This was due to the fact that part of the articles studied the benefits resulting from active transport (bicycles and pedestrians), and thus the discussions and conclusions pointed by the related research unequivocally suggest for the manifestation of positive impacts, except for conflict-related impacts due to the implementation of bicycle lanes instead of parking lanes or parking spaces.

The results will be presented initially with their quantitative approach, evaluating the number of articles by cited impacts and topics of interest, and then, the theoretical discussion was held about the impacts of the transport and mobility system according to the authors of the analysed articles.

Quantitative description of results

Considering the impacts evaluated, the most cited by the authors was congestion or increase in peak-time duration, cited by 88 articles (51.2% of the total), followed by air pollution, cited in 79 articles (45.9%), and increased travel times due to congestion cited by 43 articles (25%). Another relevant impact was related to noise level, mentioned in 33 articles (19.2%) (Table 2).

It was clear from the approaches that the negative relationship arising from the intensive use of cars, and most of the impacts are due to the increase in motorization rates, which make the flow inefficient (congestion) and increase fuel consumption (cited in 24 articles, 14 % of the total), and generate public health issues (cited in 21 articles, 12.2% of the total) in addition to causing economic losses (cited in 20 articles, 11.6% of the total). It is worth mentioning citations of the reduction of public/natural areas due to the increase of road infrastructure and the spread of cities (cited in 21 articles, 12.2% of the total).

Less cited negative impacts were: reduced tourism activities, reduced worker productivity, reduced quality of life, urban environmental quality, increased psychological/stress problems, reduced pedestrian and cyclist areas, and reduced social interactions. These receive 10 or mentions each.

It is noteworthy that the number of citations is a qualitative measure aiming to construct a conceptual model, not assigning value about each of these impacts in terms of their relevance or importance, and some impacts may exert effects of greater magnitude, persistence or environmental severity, but less studied.

Active modes of transport (mainly bicycles and pedestrians) are generally associated with positive impacts, the most cited being the beneficial effects on users' health (15 citations, 8.7% of the total), as well as the reduction of air pollution (12 citations, 7% of articles), reduction of economic expenses with travel or costs resulting from road infrastructure (11 citations, 6.4% of the total), and reduction of travel times for short sections (11 citations, 6.4% of the total).

The least cited positive impacts refer to the reduction of transport accidents, congestion, the use of natural resources and fuel, the improvement of environmental quality, attracting investments, fostering the local economy and sustainable tourism, improving safety, as well as improving the quality of life. The latter are cited in less than 10 selected articles. However, the positive correlation between the increase in accidents and the increase in the number of cyclist users is highlighted in some studies, but generally non-fatal accidents.

According to the classification by theme, most of these impacts can be classified as impacts related to the social environment (which include economic implications, population comfort and public health) comprising 27 raised impacts (93.1%).

Regarding the theme, the impacts that can integrate the chemical and physical type, characteristics expressed in 9 (31%) and 8 impacts (27.6%), respectively. Chemical type impacts refer to changes in quality or chemical composition such as fuel consumption, environmental quality, air pollution. Impacts to the physical type can interfere with the obstruction of spaces, time, sound pressure, urban infrastructure, etc.

In the urban type, 7 impacts were identified (24% of the total). These refer to interference in the infrastructure and use of urban space. Impacts of the cultural type, related to influences on tourism and understanding about environmental quality, are present in 3 impacts (10.3%).

Table 2. Impacts cited by related articles and impact code on the relational flowchart of environmental events. The themes are defined according to the typology of impacts according to Conama Resolution 306/2002: physical (F), chemical (Q), biological (B), social (S), cultural (C) and urbanistic (U). Source: The author.

ID	Impact	Theme of the impact	Related articles	Number of citations	Number of citations (%)
1	Reduction of tourism activities	S, C	35, 87, 89, 136, 154	5	2,9%
2	Increased peak congestion	F, Q, U	1, 3, 7, 8, 9, 11, 13, 15, 17, 18, 19, 20, 21, 22, 23, 27, 28, 29, 30, 32, 33, 34, 41, 44, 47, 48, 53, 54,55, 58, 59, 60, 62, 63, 66, 67, 68, 69, 70, 73, 75, 76, 79, 80, 81, 82, 83, 84, 85, 87, 88, 89, 90, 91, 103, 104, 105, 106, 108, 110, 112, 114, 117, 119, 120, 121, 122, 123, 125, 127, 128, 130, 140,141, 144, 147, 148, 150, 152, 162, 163, 164, 166, 168, 169, 170, 171, 172	88	51,2%
3	Increased commute time	S, F	1, 3, 5, 8, 9, 10, 11, 14, 19, 22, 23, 27, 32,33, 34, 43, 45, 48, 49, 50, 53, 54, 64, 72, 73, 75, 76, 84, 95, 108, 110, 112, 114, 121, 122, 123, 125, 149, 159, 162, 169, 171, 172	43	25,0%
4	Reduction of workers productivity	S	6, 40, 85, 149, 150, 171	6	3,5%
5	Increase in fuel consumption	Q, S	2, 3, 21, 44, 48, 50, 58, 66, 69, 74, 75, 79, 84, 90, 92, 110, 115, 121, 122, 125, 154, 163, 166, 170	24	14,0%
6	Economic losses	S	6, 10, 27, 44, 47, 47, 54, 64, 69, 70, 73, 74, 75, 110, 121, 122, 149, 151, 169, 172	20	11,6%
7	Reduction of air quality	Q, B, S	2, 9, 10, 11, 12, 18, 20, 21, 22, 23, 24, 25, 27, 28, 29, 32, 33, 34, 35, 39, 44, 47, 49, 50, 51, 54, 55, 57, 58, 59, 61, 62, 64, 65, 66, 67, 68, 69, 73, 74, 75, 79, 80, 82, 83, 84, 85, 86, 87, 89, 90, 91, 92, 95, 98, 99, 104, 110, 114, 115, 120, 121, 123, 125, 130, 141, 144, 147, 148, 151, 154, 155, 156, 159, 162, 163, 164, 168, 170	79	45,9%
8	Public health problems	S	3, 10, 11, 24, 38, 51, 61, 65, 66, 67, 74, 83, 84, 100, 101, 144, 150, 156, 158, 167, 168	21	12,2%
9	Reduction of quality of life	S	4, 5, 15, 27, 28, 35, 84,150, 159, 164	10	5,8%
10	Noise level increase	F, S, B	18, 21, 23, 29, 35, 37, 44, 47, 49, 54, 57, 69, 80, 82, 87, 89, 98, 100, 101, 110, 114, 121, 124, 126, 130, 131, 144, 150, 152, 154, 159, 164, 170	33	19,2%
11	Reduction of environmental quality	F, Q, B, C, S, U	6, 7, 12, 21, 22, 28, 29, 63	8	4,7%
12	Increased psychological problems / stress	S	31, 130, 150, 164	4	2,3%
13	Reduction of pedestrian and cyclist area	U, S	9, 21, 32	3	1,7%
14	Reduction of public and green areas.	U, B, S	2, 9, 11, 15, 21, 28, 35, 40, 63, 66, 69, 79, 81, 110, 111, 131, 138, 139, 145, 151, 162	21	12,2%
15	Reduction of social interactions	S	7, 9, 146	3	1,7%
16	Increasing in accidents	S	2, 3, 9, 10, 11, 16, 20, 23, 27, 28, 30, 47, 48, 49, 51, 54, 57, 69, 72, 73, 75, 83, 87, 95, 98, 105, 116, 121, 122, 128, 141, 143, 144, 149, 152, 159, 163, 166, 167, 170, 172	41	23,8%
17	Reduction in the number of accidents	S	6, 21, 52, 93, 161	5	2,9%
18	Congestion peak reduction	F, Q, U	71, 91, 103, 133, 161	5	2,9%
19	Reduced travel time	S, F	1, 5, 6, 26, 36, 77, 93, 109, 138, 157, 165	11	6,4%
20	Reduction in natural resource use	F, Q, S, B	2, 7, 21, 36, 78, 104	6	3,5%
21	Redução no consumo de combustíveis	F, Q, S	2, 6, 26, 52, 78, 157	6	3,5%
22	Reduction of atmospheric emissions and noise	Q, B, S	2, 7, 48,52, 71, 78, 93, 131, 138, 157, 161, 165	12	7,0%
23	Improvement in environmental quality	F, Q, B, C, S, U	6, 7, 15, 26, 77, 87, 104, 105	8	4,7%

24	Improvement in public health	S	5, 31, 36, 38, 52, 56, 78, 91, 93, 98, 109, 138, 146, 160, 161	15	8,7%
25	Investment attraction and sustainable tourism	S, B, U	6, 26, 87, 89, 136	5	2,9%
26	Improved security	S	6, 26, 36, 71, 82, 158	6	3,5%
27	Improved quality of life	S	4, 5, 24, 26, 104, 105, 109, 139, 160	9	5,2%
28	Reduction of economic expenses.	S	6, 15, 26, 36, 42, 56, 78, 138, 160, 165, 172	11	6,4%
29	Promotion of local commerce	S	6, 26, 104	3	1,7%
30	Increase in social conflicts	S	103, 105, 133	3	1,7%

Table 3 summarizes the analysis of impact themes cited in the articles by nature of impact (positive or negative). The themes are intrinsic to the practical quality of impacts, with the social dimension being the most present in these, in 14 negative (50%) and 13 positive (43%) impacts, reflecting direct manifestation in social, socioeconomic, and public health. Characteristics related to the chemical type were observed in 04 negative (13%) and 05 positive (17%) impacts, mainly related to the change of nature's chemical characteristics with the emission of atmospheric pollutants, influenced by the increase in fuel consumption or by the characteristics of traffic flow efficiency.

The physical and chemical type received four citations each, characteristics that contribute to the alteration of this kind, such as changes in vehicle volume, noise, travel time and use of natural resources. The biological type can be specifically associated with impacts of impacts on the natural environment and human welfare, being mentioned in 04 negative and 04 positive impacts (13% for each). Impacts associated with the urban type were mentioned in 04 negative (13%) and 03 positive (10%) impacts, which influence the urban environment, infrastructure and land use. The cultural type was verified in two negative and positive impacts (7% in each), being related to tourism activities and environmental quality, which encompasses all the listed topics.

Table 3. Classification of impacts listed by theme and nature (positive or negative). Source: The Author.

Theme of the impact	Nature of the impact		Number of impacts per theme			
			Negative		Positive	
	Negative	Positive	Total	%	Total	%
Social	Reduction of tourism activities Increase in travel time Reduction of worker productivity Increase in fuel consumption Economic losses Public health problems Reduction of quality of life Reduced air quality Increase in noise level Reduction of environmental quality Increase in psychological problems / stress Reduction of pedestrian and cyclist area Reduction of public and green areas Reduction of social interactions Increase in social conflicts	Decrease in the number of accidents. Reduction in the number of accidents. Reduction in travel time. Reduction in the use of natural resources. Reduction in fuel consumption. Reduction of atmospheric emissions and noise. Improve in environmental quality. Improve in public health. Attraction of investment and sustainable tourism. Improve in safety. Improving in quality of life. Reduction of economic expenses. Promotion of local commerce.	15	50 %	13	43%
Chemistry	Increase in peak congestion, Increase in fuel consumption, Reduction of air quality, Reduction of environmental quality	Reduction of peak congestion, Reduction in the use of natural resources, Reduction in fuel consumption, Reduction of atmospheric emissions and noise, Improve in environmental quality	4	13 %	5	17%
Physical	Increase in peak congestion, Increase in travel time, Increase in noise leve Reduction of environmental quality	Reduction of peak congestion, Reduction in travel time, Reduction in the use of natural resources, Reduction in fuel consumption, Improve in environmental quality	4	13 %	5	17%
Biological	Reduction in air quality, Increase in noise level, Reduction of environmental quality, Reduction of public and green areas	Reduction in the use of natural resources, Reduction of atmospheric emissions and noise, Improve in environmental quality, Investment attraction and sustainable tourism	4	13 %	4	13%
Urbanistic	Increase in peak congestion, Reduction of environmental quality,	Reduction of peak congestion, Improve in environmental quality,	4	13 %	3	10%

	Reduction of pedestrian and cyclist area, Reduction of public and green areas	Investment attraction and sustainable tourism				
Cultural	Reduction of tourism activities, Reduction of environmental quality	Attraction of investment and sustainable tourism; Improve in environmental quality,	2	7 %	2	7%

Most of the studies assessed deal with the most obvious impacts of the transport system, such as congestion and air pollution. However, several impacts, which, although recognized by the scientific community, do not present validated case studies or quantitative measurement methodologies that allow a satisfactory inference as to their importance, magnitude, and the need to justify stronger measures for their mitigation.

This has also been noted about positive impacts as one of the main arguments for convincing decision makers and the population about the benefits of incorporating accessibility and sustainable urban mobility measures. These are based on the emphasis on non-motorized modes and efficient public transport.

This situation is aggravated when observed that even with the existence and recognition, by the scientific community, of the externalities of the transport system, these pass by political and institutional debates. Sometimes proposed solutions are inefficient in the long run and do not consider beyond economic aspects, given the technical challenges and discussing how to manage the growing scarcity of space.

Related Flowchart of Environmental Events - FREA

The consultation of the bibliographic works made it possible to compose the FREA applied to the evaluation of the transport and urban mobility system, based on interrelated events, which are triggered in a logical order of events that start from macro activities, for specific purposes, which may be deepened. according to the specific needs of method users.

In this proposed model, the transformative activity (urban displacement) manifests itself through environmental interventions (defined as: public transport, transport by private motor vehicles, bicycle and pedestrian transport). From these environmental events were identified the environmental changes (developments of interest of each environmental intervention in order to establish relationship between the interventions and the environmental impacts generated), which in turn gave rise to environmental phenomena (impacts) (see Figure 3).

The application of FREA to the urban mobility system showed a positive adherence, allowing a clear understanding of the analysed system, differentiating aspects of impacts, that is, the causal relationships of the object of study.

Nevertheless, due to the approach using a complex system for analysis (transport system and urban mobility) there are limitations inherent to the instrument, which is generally applied to simple systems (activities with better defined delimitation). For the construction of the flowchart it is necessary to assume that it originates from potential impacting activity.

Thus, the composition of the FREA followed the approach of the studies consulted, structured on the assumption of the current condition of the transport infrastructure of most Brazilian cities, with the predominance of individual displacements (automobiles), public transport with efficiency problems (predominantly generators of negative impacts) and displacement of pedestrians and cyclists (predominantly positive impact generators).

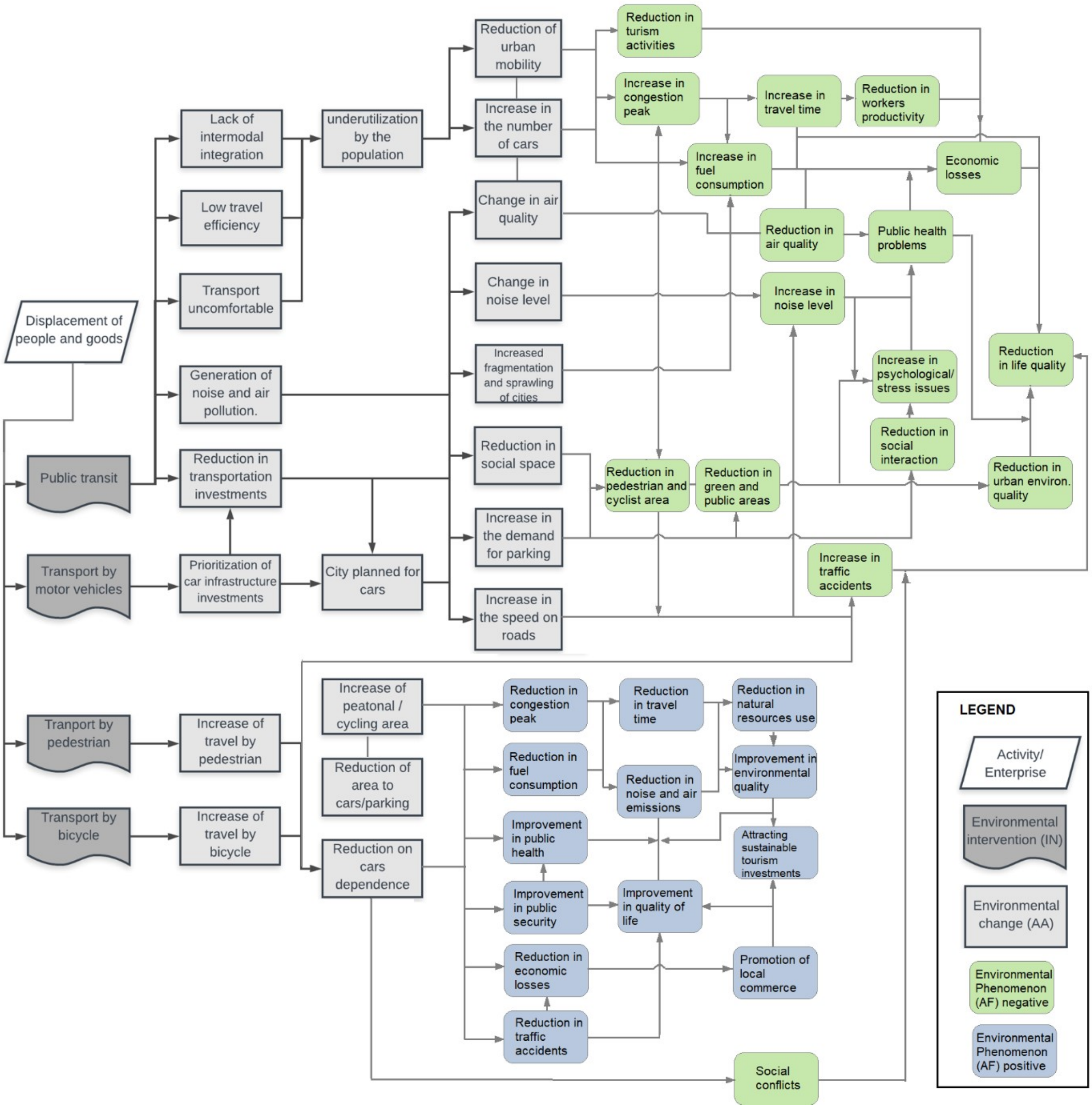
It is crucial to note that as conditions can be improved (e.g. increased displacement by active transport, reduced dependence on cars and improvements in public transport efficiency) the incidence and magnitude of negative impacts will be reduced. Thus, it is observed that the proposed model reflects a condition of fragility in public transport services and mode division with predominance of cars.

Thus, although these impacts are all previously identified by the scientific research consulted, it is essential for the reader to critically evaluate the set of identified impacts, adjusting them to specific case studies. Considering therefore the inherent limitations of the methodology employed.

The assembled impact system (Figure 3) made it possible to verify problems arising from the excessive use of private cars that, associated with operational problems do not fully meet the needs of the population, causing underutilization of public transport and, consequently, constitute a factor for the reduction of urban environmental quality.

It does not necessarily mean that these impacts are only negative, however, as cited by the articles, this is due to the current mobility model in place in Brazilian cities. Although public transport is one of the main modes of operationalization of the concept of sustainable urban mobility, with the potential to reduce negative externalities (congestion, pollution, etc.), its inefficient conditions in the country (low efficiency, productivity, uncomfortable, emission pollution and noise, lack of integration, etc.) positions it, together with the car, as sources of negative impacts. As a result, it is expected that, as the population improves its economic condition, one of its priorities is the acquisition of a private vehicle as a substitute for the bus (see Mobility of Urban Population Survey: NTU, 2017).

Figure 3. Related Flowchart of Environmental Events (FREA) applied to the analysis of the transportation and urban mobility



This results in a reduction in overall urban mobility from increased car traffic, environmental and public health problems due to noise and air pollution, spatial inequalities issues such as urban fragmentation and sprawl, reduction of public areas (mainly due to road and parking system extensions).

From these changes can be characterized the environmental and socioeconomic impacts, such as increased congestion peaks, which will increase commuting time and fuel consumption, decreasing worker productivity. This intense use of vehicles reduces the living areas, green areas and pedestrian and cyclist areas, which influence people's preferences for cars given all the inconveniences and inconveniences of public transport.

The current condition of the transport system favours high rates of transport accidents that end up victimizing vulnerable users (pedestrians and cyclists), as well as affecting tourism activities, which will ultimately impact the population's quality of life. It is important to highlight the correlation between the increase of public transport trips and the lower incidence of serious traffic accidents.

In contrast to the negative impacts, there is currently a process of progressive increase in the inclusion of cyclists and pedestrians in urban displacements. The increased participation of these modes in commuting decreases dependence on motor vehicles, increasing physical activity levels, reducing congestion peaks) and commuting time (in the case of short commutes). They are also associated with reduced fuel consumption, noise emission and air pollutants, as well as economic support for local businesses.

A city designed for pedestrians and cyclists increases safety in the mobility of the people, reducing accident rates, improving economic dynamism, attracting investment and contributing to the qualification of more sustainable tourism. A high volume of tourist traffic can contribute to the degradation of tourist values, thus reducing the tourist attractiveness of the place.

Conclusion

The improvement of urban mobility conditions and quality of life of the population necessarily involves the development of an urban planning that considers impacts in an integrated and synergistic way. Thus, the understanding of negative and positive impacts is indispensable for a qualified management of urban centres, being an urgent demand of society for more productive, competitive, more dynamic, inclusive and healthy cities.

The knowledge gathered could suit as a basis for the improvement of technical studies such as environmental impact assessment, neighbourhood impact and viability studies, which are generally insufficient in their integrated analyses, as well as the incorporation of synergistic effects into the environment field of transport and urban mobility.

The work contributes to unify different researches related to urban mobility in favour of the improvement of the understanding and the planning and action strategies, alerting to the set of implications that deserve attention, from decision makers, as well as in the technical-scientific environment, orienting the searches and consultation of specialized bibliographies.

The bibliographic base researched provided a starting point for the understanding of the environmental impacts from the transport and urban mobility system, especially applied to the Brazilian reality. Negative impacts related to the motorized collective and individual transport system were verified, while positive impacts related to the insertion of active transport in the participation of displacements in Brazilian cities.

While on the one hand there is considerable research addressing certain impacts and areas of knowledge, especially internationally, on the other hand, there are areas that need further study. Thus, it generates research opportunities and technical demands in order to explore the theme further, with important reflexes of the sustainable development of the country and the quality of life of the population.

It is noteworthy that the inherent complexity of transport systems, where inseparable activity of urban dynamics imputes a limitation on the work by not inserting in the model the transport interaction with land use, accessibility etc. Thus, as a recommendation it would be appropriate to analyse changes in these processes, such as regulatory aspects, private public transport, implementation of improvements in active transport, etc.

Nevertheless, the research achieved its purpose of proposing a conceptual model that encompasses the main environmental impacts from the transport and urban mobility system in an integrated and synergistic manner, which may guide future studies to minimize negative impacts and enhance the positive ones. .

The developed FREA has transformed a complex conceptual model into ordered fractions that allow a global understanding of the environmental manifestations of the transport and urban mobility system. At the same time, it allows to know the specific developments within this chain. It also allows inferring about the primary and secondary impacts, providing important information for the management and control of impacts. Thus, eliminating (or mitigating) predecessor impacts would eliminate secondary ones, improving efficiency in impact management.

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