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# EVALUATION OF ROAD TRANSPORT: A LITERATURE REVIEW

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## ABSTRACT

**Goal:** The study aims to consolidate papers published on the evaluation of investments in cargo transportation in Brazil with a focus on the sustainable perspective, taking into account not only economic but also social and environmental concepts.
**Design / Methodology / Approach:** The method used is based on a keyword tree on scientific basis from november 2016 to february 2017 to identify models for evaluating new and existing infrastructure projects, highlighting the main variables adopted and the gaps of these models.
**Results:** The aim of this study is to bring more transparency among different alternatives of road projects.
**Limitations of the investigation:** The keyword tree methodology may not identify important studies in other languages or older.
**Practical implications:** The study is helpful to policy-makers in their decisions to choose a road project for investment.
**Originality / Value:** The originality of this study lies in the sustainable perspective for evaluating road transport.

**Keywords**: Strategic planning; Road transport; Freight transport; Sustainability; Decision making.

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## 1. INTRODUCTION

The transportation infrastructure of a country enables a better flow of goods in terms of volume and time and allows a broad socioeconomic development. Volume, origin and destination, and consumer type of the products are factors that guide the choice of a specific mode of transportation. In Brazil freight transport is based on highways. Its percentage (61%) is very significant, followed by railroad (21%), waterway (14%), pipeline (4%), and air (less than 1%) (CNT, 2016). This imbalance has negative consequences in several aspects, such as the higher cost of freight transport and atmospheric emissions of carbon dioxide (CO2), which are greater in this mode, when compared with others. This topic will be deepened in the present study.

The choice of each mode of freight transport is based on seven main characteristics: possible volume of transport; initial cost of installing or extending a route; cost of operating an existing transport infrastructure; security that the environment provides to the user and worker involved; the possibility of having a door-to-door service; availability of transportation of any type of cargo; and finally, the social impact generated to the population with the use of the chosen mode of transport (Litman, 2015; Wisetjindawat et al., 2015).

The road transport mode is preferable for door-to-door transportation, especially in the case of deliveries of fragmented products, as for example, computers from an online store to the final customer. On the other hand, railways are mainly used for large volumes of low value-added products, as iron ore. For large volumes ships are also used, as they can carry products in container or in bulk between different countries, as for example, the transportation of cars. In this case, the range is a little more limited, since the product has to be near waterways or in some port within the country. In many situations, these modes are combined, resulting in multimodal transportation. The cargo is transported by rail or truck to the port depending on availability, where it will continue by ship to the next destination, whether in the same country or not.

For more specifically commodities there is transportation via pipelines, which allows a continuous flow of gases or fluids that have these characteristics. It is a previously determined door-to-door transportation and allows a large volume shift, as in the example of petroleum or natural gas from the port to the refinery. Finally, air transport has less time of travel and greater security, but at a high cost. It is appropriate for high added value commodities, such as diamond. This also requires a complementary mode for delivery at airports.

In contrast to the explanation above, the circulation of goods in Brazil does not exactly follow the priorities presented. It depends not only on the existing infrastructure in each region but also on political factores. As we have already seen, road transport is predominant in this country.

The impacts of an infrastructure project are analysed from models that consider direct impacts, represented in the majority by three factors: the reduction in total travel time, number of accidents, and transportation costs (McFarland et al., 1993; Kerali, 2000; Sage et al., 2013; Sartori et al., 2014; Barfod et Leleur, 2015; Odoki et al., 2015). More complex models take into account other factors, such as the generation of indirect jobs and the increase of regional GDP. These are few and very specific for each study case.

The environmental impact is still poorly considered in the cargo transport analysis. For Zhou (2012), sustainability in transportation is a recent concept and it is based on several indirect measurements through various transport indicators. The most common suggestion is the change of old habits and the encouragement of people to use more mass transportation, helping in sustainable development.

For the already explained reasons, this paper aims to consolidate other published studies on the evaluation of investments in cargo transportation in Brazil with a focus on the sustainable perspective, taking into account not only economic but also social and environmental concepts.

The article is composed of five sections, including the introduction. They are presented as follows: section 2 brings the methodology used for the review; in section 3 the descriptive analysis; section 4 shows theoretical references for the structuring; and, finally, the fifth section brings the results, conclusions obtained and suggests future studies that can enrich this paper.

## 2. METHODOLOGY

### Scientific research

Scientific research helps in the diffusion of the knowledge generated by other authors and in the investigation of the state of the art for each model to be applied. This study follows classic classification criteria (Gil, 2010) for evaluation of the road infrastructure projects around the world.

Considering the nature of this paper, it is classified as applied since it is oriented for practical application, resulting from several studies published on scientific journals. By this concept there is no intervention in the data surveyed, only the gathering of information for analysis. This assigns an observational caractheristics for the study.

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The approach of the research is qualitative because there are a lot of analisys made from the selection of the variables, such as categorization, classification, interpretation and conclusions. No quantitative study is necessary, similar to Cazeri *et al.* (2017) in a green supply chain management literature review.

The overall objective is considered as exploratory, in order to bring the researcher closer to the theme and justify the problem to become more explicit. Finally, the research is classified as bibliometric because material is published in scientific papers of high impact for the academic society and no laboratorial or documents are consulted.

## Research method

The literature review is the method used in an effort to identify models for evaluating new and existing road infrastructure projects, highlighting the main variables adopted, the gaps of these models and, consequently, opportunities for the development of future studies. From the transport infrastructure model (TIM), the key words used for data collection were “strategic planning”, “road transport”, “freight transport”, “stakeholders”, “sustainability”, “decision making”, and “highway evaluation”. A keyword tree was developed to reach the aim of this paper, Figure 1. It used the boolean logic, which means that a combination with “OR” or “AND” were adopted to make the search.

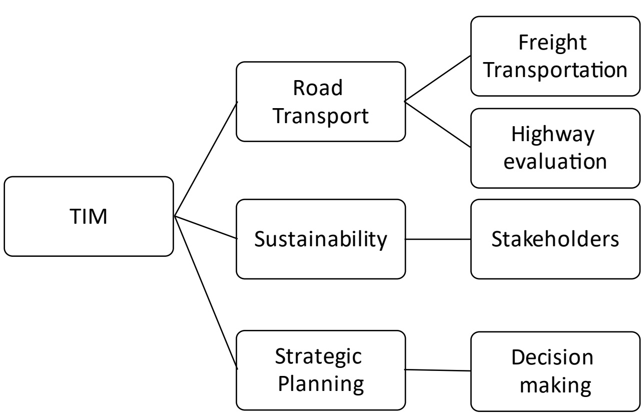


**Figure 1.** Keyword tree
Source: The authors themselves.

The research was made from november 2016 to february 2017, specifically on scientific basis, giving preference to best ranking journals around the world without time specification. In a second round, the investigation was emphasized on material published in the last six (6) years, from 2012. The scientific bases searched were: the journals Capes, Web of Science, Scopus, Wiley, Emerald and SciELO.

As a result of this search, 43 papers matched the field of the present study. The list of the major journals related with these papers are on Figure 2.

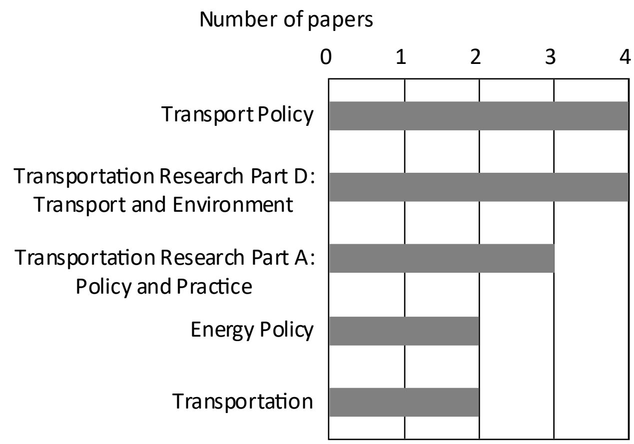


**Figure 2.** Major journals related
Source: The authors themselves.

The major journals are: Transportation Research Part D: Transport and Environment and Transport Policy (4 papers), followed by Transportation Research Part A: Policy and Practice (3 papers), Transportation and Energy Policy (both with 2 papers). Other journals have only one paper associated with each one, so they are not in the figure. Moreover, other sources of search were used here, so it is possible that a document found is not in this database.

Previous analysis occurred to base the indicators that will be found in this study. As previously mentioned, it is expected that these variables are splited in three categories: social, environmental, and economic. Then, a sustainable index could be developed to assess the value of the highway according to the triple bottom line approach, Figure 3.

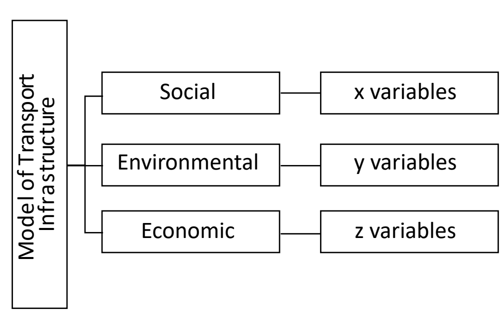


**Figure 3.** Variables categories
Source: The authors themselves.

As a result, the authors’ expectation is to develop a model with the state-of-the art in terms of sustainable indexes.

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Thus, the bibliometric analysis is a crucial step to do it. From there, a robust model will be developed.

## 3. DESCRIPTIVE ANALYSIS

Table 1 shows all the authors and variables considered by each one and their classification as social (S), economic (C) or environmental (E) in order to quantify and understand models.

Table 1 summarizes the 35 variables considered by each author in their twenty three (23) models. Travel time, for example, is the main variable, present in 61% of the models. Environmental impacts is in second place (57%), addressing issues such as emissions, air quality, and climate change. Economic impacts are shown in the fourth position (35%). Three of the favorite variables are responsible for the cost of the highway to users: reduction of travel time, vehicle operating costs, and the number of accidents. If there is no regular maintenance on the roads, the tendency is for this number to increase (Kerali, 2000).

A classification can show a distribuition on social, economic and environmental variables as Cazeri *et al.* (2017) did for the green supply chain management concept. Fifteen variables are considered as social behavior and eighteen as economic, which represent more than the half part. Only two have an environmental profile: atmospheric emissions and European green corridor contibution, which reflects a recent importance to this issue and a difficulty to measure their impacts.

Another important analysis is the number of variables that each model considers, as shown in Figure 4. Most of them have four to seven variables (61%) and only one has more than eight (Litman, 2002).

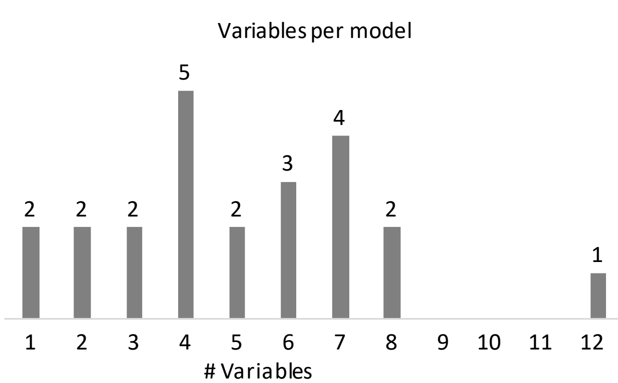


**Figure 4.** Variables per model
Source: The authors themselves.

## 4. LITERATURE REVIEW

Based on Monteiro (2015), the economic development measured by the increase in Gross Domestic Product (GDP) in the long-term can reduce poor rates and improves education, health, transportation and housing conditions. The principal indicator is the Human Development Index (HDI), which calculates the relationship between quality of life and economic development.

For this reason, the tripod of sustainability – social, economic and environmental - has become the subject of great questions in different areas, including the transportation of cargo. The social and environmental criteria are gaining relevance in this scenario over the years. The quantification of economic benefits from transportation are usually observed in long-term periods. It is made from the knowledge of costs to direct users and their externalities (Rabello Quadros et Nassi, 2015).

### Relationship between the influence of infrastructure and regional sustainable development

Many studies indicate the relationship between the regional development and transport infrastructures under economic, social and environmental aspects. The more regions are served and the better the design of a route, the better the consequences for that environment. In Brazil some researchers seek to prove this relationship through significant variables (Sehn, 2009; Silva et Netto, 2010; Lisboa, 2014; Campos, 2015; Monteiro, 2015).

According to Monteiro (2015) the Brazilian railroads continue collaborating for the development of the country. In this study, state GDP and operating income of the company are correlacted during the year. On the other hand, trying to understand the influence that a new railroad can have on municipality, Campos (2015) analyzes the impacts on four variables: income, tax collection in the municipalities involved, employment, and product. The projections are calculated from the variables of municipality GDP per capita, municipality service tax (ISSQN), average income of the worker and formal employment.

Lisboa (2014) identifies some benefits to the region that receives subway stations: the economic development, real estate valuation for the region, the reduction of traffic in the adjacent road system and urban development centered on public transport. A highlight for this study was the identification of stakeholders in an infrastructure project: private and public actors.

For Silva et Netto (2010), a more qualitative multicriteria method is important to relate the increase of infrastructure

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**Table 1.** Overview of the models (variables x authors)

| Variables | Classification | Barfod & Salling 2015 | Bagloee & Asadi 2015 | Odoki et al. 2015 | Rabello Quadros & Nassi 2015 | Barfod & Leleur 2015 | Campos 2015 | Sartori et al. 2014 | Nogués & González-González 2014 | Sage et al. 2013 | Kansas & North Carolina DOT 2013* | Michigan DOT 2013* | Indiana DOT 2013* | Montana DOT 2013* | MPPP tool 2013* | Wang et al. 2013 | Dewan et al. 2013 | Yu & Liu 2012 | Silva & Netto 2010 | Guenther & Farkavcová 2010 | Sehn 2009 | Litman 2002 | Kerali 2000 | Mcfarland et al. 1993 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Travel time | S | x | x | x | | x | | x | x | x | | | | x | x | x | x | | | | | x | x | x | 14 |
| Environmental impact | E | | | x | x | x | | x | x | x | | | | | | x | x | | x | x | | x | x | x | 13 |
| Security | S | | | x | | x | | x | | x | | | | | x | | | x | | | | x | x | x | 9 |
| Operational costs | C | | | x | | x | | x | | x | | | | | x | x | | | | | | | x | x | 8 |
| Economic impacts | C | x | | x | | | | | | x | x | x | | | | x | | | | | x | x | | | 8 |
| Employment | S | | | | | | x | | | | x | x | x | | | | | | x | | | x | | | 6 |
| Transportation cost | C | | | | x | | | | | | | | | x | | | x | | | | | x | x | | 5 |
| Household income | C | | | | | | x | | x | | x | x | | | | | | | | | | x | | | 5 |
| Construction and maintenance cost | C | | | | | x | | x | | | | | | | | | | x | x | | | | | x | 5 |
| Social impacts | S | | | x | | x | | | | | | | | | | | | | | | | x | x | | 4 |
| Traffic volume | C | | x | | | | | x | x | | | | | | | | | x | | | | | | | 4 |
| Quality | S | | | | | | | | | | | | | | | | x | | | | | x | x | | 3 |
| Energy efficiency | C | | | x | | | | | | | | | | | | | | | | x | | | x | | 3 |
| Noise pollution | S | | | | | x | | x | | | | | | | | | | | | | | x | | | 3 |
| Transportation offer | S | | | | x | | | | | x | | | | | | | | | x | | | | | | 3 |
| State GDP | C | | | | | | | | x | | x | x | | | | | | | | | | | | | 3 |
| Flexibility (Logistics) | S | x | | | | | | | | | | | | | | | x | | | | | | | | 2 |
| Reliability | S | | | | | | | | | x | | | | | | | x | | | | | | | | 2 |
| Accessibility | S | | | x | | | | | | | | | | | | | | | | | | x | | | 2 |
| Land occupation rate | C | | | | | | | | x | | | | | | | | | | | | | x | | | 2 |
| Construction time | C | | x | | | | | | | | | | | | | | | | x | | | | | | 2 |
| HDI | S | | | | x | | | | | | | | | | | | | | x | | | | | | 2 |
| Tax collection | C | | | | | | x | | | | | | | | | | | | | | | | | | 1 |
| Demand forecast | C | | x | | | | | | | | | | | | | | | | | | | | | | 1 |
| European green corridor | E | x | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Traffic volume growth rate | C | | | | | | | | | | | | | | | | | x | | | | | | | 1 |
| Visual impact | S | x | | | | | | | | | | | | | | | | | | | | | | | 1 |
| Socioeconomic strength | S | x | | | | | | | | | | | | | | | | | | | | | | | 1 |
| IRR (Internal rate of return) | C | | | | x | | | | | | | | | | | | | | | | | | | | 1 |
| Age group | S | | | | | | | | x | | | | | | | | | | | | | | | | 1 |
| Income (tool plaza) | C | | | | | | | x | | | | | | | | | | | | | | | | | 1 |
| Recovery of liabilities | C | | | | | | | | | | | | | | | | | | x | | | | | | 1 |
| Distance | C | | | | | | | | x | | | | | | | | | | | | | | | | 1 |
| Average speed | C | | | | | | | | x | | | | | | | | | | | | | | | | 1 |
| Inhabitants | S | | | | | | | | x | | | | | | | | | | | | | | | | 1 |

Source: Designed from the source (2018). *Cited by Wang et al. 2013

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efficiency in the country and sustainable development. In this context, thirty stakeholders evaluated different projects under seven criteria: job creation, intermodal connection, environmental impact, social welfare (HDI), costs and benefits, recovery of environmental liabilities, and project execution period. On the other hand, Sehn (2009) adopts a more economic methodology that uses NPV, IRR and B/C (benefits and costs) indicators. The study proposes that only financial success is enough to make a project viable.

According to Monteiro (2015) the Brazilian railroads continue collaborating for the development of the country. In this study, state GDP and operating income of the company are correlacted during the year. On the other hand,  trying to understand the influence that a new railroad can have on municipality, Campos (2015) analyzes the impacts on four variables: income, tax collection in the municipalities involved, employment, and product. The projections are calculated from the variables of municipality GDP per capita, municipality service tax (ISSQN), average income of the worker and formal employment.

Barfod et Leleur (2015) conducted a study that considers cost-benefit analysis (CBA) at the Danish Ministry of Transportation. The VPL is calculated by the difference between the benefits and costs throughout the project. The primary variables are: environmental disturbance in the construction period, construction and maintenance cost, travel time reduction, work completion cost, taxes, and local pollution.

Another study that considered many variables to analyze the potential impact of transport infrastructure is consolidated through sixteen criteria: travel time, distance, traffic, average speed, age group, number of local inhabitants, family income, CO2 emissions, land occupation rate, births and deaths, GDP, distance between accommodation and work, number of vehicles in the region, and number of migrations and marriages (Nogués et González-González, 2014).

However, according to Yu et Liu (2012) the analysis is more focused on highway safety, which is a social, environmental and economic criterion at the same time. For this evaluation are considered: investment, daily average traffic, reduction of fatal accidents, reduction of total accidents, percentage of growth, and project continuity period.

**Models for evaluating transport infrastructure projects**

Infrastructure project evaluation models has the objective to compare two or more alternatives, or even to justify investments from long-term viability. However, a model may also have references in qualitative methods when it is necessary to consider the opinion of the people involved or if it is not possible to give it real values.

Chen *et al.* (2015) analyze the energetic efficiency of 29 regions in China through a quantitative and qualitative model. The variables of the model are: air quality level, energy consumption, employment, capital invested in assets, CO2 emissions, and GDP.

The use of Activity-Based Costing (ABC) is widely used for many applications, including transportation. For transport infrastructure, this analysis is also used, since it considers the trade-off between benefits and costs generated by highways, helping the decision maker in the choice of invest in an alternative.

Eco-Mobility (EM) model considers, besides the ABC, the risk analysis (Monte Carlo simulation) and the multicriteria complementary analysis of decision. Eco-Mobility evaluates alternatives from the sustainability perspective, adopting variables, such as visual impact on cities, economic impact on the region, improved number of users of public transport, and impact on logistics flexibility (Barfod et Salling, 2015).

The MicroBenCost model was developed in the 1990s by the Texas Transportation Institute and is still used nowadays. It helps to evaluate track safety and the increased transport capacity on a highway. The beneficts are the reduction: in the number of accidents, of travel time, and of vehicle operating cost (McFarland *et al.*, 1993).

HDM-4 is a model developed and used by the World Bank. It proposes an evaluation of the performance with regard to four technical criteria: type of pavement, traffic volume, maintenance standards, and regional characteristics. Benefits are identified from three groups. The first one is economic: travel time, reductions in operating costs, and number of accidents. The second one is environmental: environmental impacts (air pollution and energy efficiency). The last one is social: social benefits, and traffic jam (Kerali, 2000).

From the HDM-4 model they also constructed a multicriteria analysis model to optimize necessary investments in highways (Odoki et al., 2015). The criteria present different weights and are classified within the sustainability tripod: traffic jam, energy efficiency, accessibility to schools, hospitals and commerce, number of accidents, atmospheric emissions, and comfort to users. Computational General Equilibrium (CGE) is another model that contributes to estimating only economic impacts: truck operating costs, and travel time (Wang et al., 2013).

The choice of transport projects is also based on the ABC in the European Union. It considers nine factors: operation and maintenance costs, travel time, air pollution, investments in the road, noise, road toll revenue, accidents, climate change, and vehicle operating cost. All data are mon-

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etarized to generate a quantitative and comparative model (Sartori *et al.*, 2014).

Rabello Quadros and Nassi (2015) focus on evaluate Brazilian infrastructure projects based on the opinion of thirty-three professionals. The criteria are intermodality, environmental impacts, financial feasibility of the project (IRR), HDI, atmospheric emissions, transport supply in the region, and transport costs.

## 5. CONCLUSIONS AND DISCUSSION

This paper presents a literature review of quantitative model for evaluating road transport infrastructure projects. The aim of this study is to bring more transparency and to help policy makers when it comes to the choice between investments. The road project under analysis may be new, expanded or improved, depending on the difference between the initial and the final mileage. As already predicted in the study of Bartholomeu et Caixeta Filho (2009)consequently, on carbon dioxide (CO2, a trip on a highway with better conditions of maintenance presents greater environmental benefits than the same trip made in precarious conditions.

Regarding the variables raised in the referential framework, no model adopts all the same variables and the four most relevant ones are considered in this study: travel time, atmospheric emissions, number of accidents, and operating costs. Two variables are present in only one reference model: annual traffic growth rate, and the municipal tax, ISSQN.

For future studies it is recommended to develop a model considering three dimensions of sustainability together to evaluate future road transport projects and assist in decision making by the competent administration: social, economic and environmental. Variables should be quantitative and qualitative, mainly in environmental and social area, ensuring a greater participation of these two dimensions. Air quality, for example, may be an option to measure the environmental impact of a new transport infrastructure. In addition, the perception and feelings of the local residents regarding the enterprise can be captured through the social impact variable.

The final result can help ranking alternatives, whether they are competing or not, justifying the choice by final monetary value per truck projected for the future highway. The greater the value the higher priority the highway has for all *stakeholders*. In order to improve the tool it is suggested to evaluate scenarios for expected demand, considering optimistic and pessimistic projections. In this way, it is possible to re-evaluate whether the project remains advisable throughout the operation period.

## REFERENCES

Bagloee, S. A. and Asadi, M. (2015), 'Prioritizing road extension projects with interdependent benefits under time constraint', Transportation Research Part A: Policy and Practice, Vol. 75, pp. 196–216. doi: http://dx.doi.org/10.1016/j.tra.2015.03.016.

Barfod, M. B. and Leleur, S. (2015), Socio-economic analysis in the transport sector. Available at: http://orbit.dtu.dk/files/104276045/DTU_Transport_Compendium_Part_1_CBA_1.pdf.

Barfod, M. B. and Salling, K. B. (2015), 'A new composite decision support framework for strategic and sustainable transport appraisals', Transportation Research Part A: Policy and Practice, Vol. 72, pp. 1–15. doi: http://dx.doi.org/10.1016/j.tra.2014.12.001.

Bartholomeu, D. B. and Caixeta Filho, J. V. (2009), 'Quantification of the environmental impacts of road conditions in Brazil', Ecological economics, Vol. 68, pp. 1778–1786.

Campos, F. (2015), A influência da Ferrovia Norte-Sul no desenvolvimento regional do território goiano. Universidade Federal de Goiás.

Cazeri, G. T. et al. (2017) 'Performance measurement of green supply chain management: a literature review and gaps for further research', Brazilian journal of operations & production management, Vol. 14, pp. 60–72.

Chen, Y. et al. (2015) 'Bounded and discrete data and Likert scales in data envelopment analysis: application to regional energy efficiency in China', Annals of Operations Research, pp. 1–20. doi: 10.1007/s10479-015-1827-3.

CNT (2016) Boletim Estatístico. Available at: http://www.cnt.org.br/Boletim/boletim-estatistico-cnt.

Dewan et al. (2013) 'Performance evaluation of an online benchmarking tool for European freight transport chains', Benchmarking: An International Journal, Vol. 20, pp. 233–250.

Gil, A. C. (2010) Como Elaborar Projetos de Pesquisa. 5a. São Paulo: Atlas.

Guenther, E.; Farkavcová, V. G. (2010) 'Decision making for transportation systems as a support for sustainable stewardship: Freight transport process evaluation using the ETIENNE-Tool', Management Research Review, Vol. 33, pp. 317–339.

Kerali, H. G. R. (2000) Overview of HDM-4. The Highwa. Washington D.C.

Lisboa, R. (2014) Atores sociais no planejamento de metrôs no Brasil. Universidade Federal do Rio de Janeiro.

Litman, T. (2002) 'Evaluating transportation equity', World Transport Policy & Practice, Vol. 8, No. 2, pp. 50–65.

Litman, T. (2015) Transportation Cost and Benefit Analysis II – Evaluating Transportation Benefits.

Brazilian Journal of Operations & Production Management
Volume 16, Número 1, 2019, pp. 96-103
DOI: 10.14488/BJOPM.2019.v16.n1.a9

McFarland, W. F. et al. (1993) 'MicroBENCOST User's Manual (Draft)', Texas Transportation Institute.

Monteiro, L. C. de S. (2015), Contribuição à análise do desempenho econômico das ferrovias concedidas no Brasil. Universidade Federal do Rio de Janeiro.

Nogués, S. and González-González, E. (2014), 'Multi-criteria impacts assessment for ranking highway projects in Northwest Spain', Transportation Research Part A: Policy and Practice, Vol. 65, pp. 80–91. doi: 10.1016/j.tra.2014.04.008.

Odoki, J. B., Di Graziano, A. and Akena, R. (2015), 'A multi--criteria methodology for optimising road investments', Proceedings of the Institution of Civil Engineers - Transport, Vol. 168, No. 1, pp. 34–47. doi: 10.1680/tran.12.00053.

Rabello Quadros, S. G. and Nassi, C. D. (2015), 'An evaluation on the criteria to prioritize transportation infrastructure investments in Brazil', Transport Policy, Vol. 40, pp. 8–16. doi: http://dx.doi.org/10.1016/j.tranpol.2015.02.002.

Sage, J. et al. (2013), Development of a Freight Benefit/ Cost Methodology for Project Planning.

Sartori, D. et al. (2014), Guide to Cost-Benefit Analysis of Investment Projects. Brussels. Available at: http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf.

Sehn, D. (2009), 'Avaliação econômica de projetos de infraestrutura de transportes: Uma metodologia aplicada à tomada de decisão governamental', Universidade Federal de Santa Catarina UFSC.

Silva, R. B. and Netto, M. A. C. (2010), 'Uma estrutura de apoio à decisão para orientar a escolha de projetos prioritários para a infraestrutura de transporte do Brasil', in XLII SBPO, Sociedade Brasileira de Pesquisa Operacional, Brasil. Bento Gonçalves.

Wang, Z. et al. (2013) 'A Framework for Determining Highway Truck-Freight Benefits and Economic Impacts', Journal of the Transportation Research Forum, Vol. 52, No. 2, pp. 27–43.

Wisetjindawat, W., Oiwa, H. and Fujita, M. (2015) 'Rare mode choice in freight transport: Modal shift from road to rail', Journal of the eastern asia society for transportation studies, Vol. 11, pp. 774–787.

Zhou, J. (2012) 'Sustainable transportation in the US: A review of proposals, policies, and programs since 2000', Frontiers of architectural research, Vol. 1, pp. 150–165.

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