

# Use of multi-criteria decision analysis to classify and regulate interstate bus services in Brazil

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**ABSTRACT**

Interstate bus services in Brazil can occur between nearby or distant municipalities. In the former situation the bus service should be classified as 'semi-urban'; it is delegated by Federal concession that requires a bidding process and must be provided by urban buses. In the latter situation the bus service should be classified as 'road'; it is directly authorized by the public authority and must be provided by coaches. Brazilian law distinguishes between 'nearby' and 'distant' cities when the service occurs with 'urban' or 'regional' characteristics, but does not specify parameters for that distinction. This paper presents a multi-criteria method used to better classify and regulate those bus transport services. The method was applied to categorize 11 interstate markets of which 4 were considered to be 'semi-urban'. In conclusion, the study served as a basis to support a government decision.

**RESUMO**

Os serviços de ônibus interestaduais no Brasil podem ocorrer entre municípios próximos ou distantes. Na primeira situação, o serviço deve ser classificado como 'semiurbano', delegado por permissão pelo Poder Público Federal, exigindo processo licitatório e operado com ônibus urbanos. Na outra situação, o serviço deve ser classificado como 'rodoviário', o qual é diretamente autorizado pela autoridade pública e deve ser operado por ônibus rodoviários. A lei brasileira diferencia cidades 'próximas' ou 'distantes' quando o serviço ocorre com características 'urbanas' ou 'regionais', mas não especifica parâmetros para essa distinção. Este artigo apresenta um método multicritério utilizado para melhor classificar e regular os serviços de transporte interestadual de passageiros. Como resultado, a técnica foi aplicada em 11 mercados interestaduais, dos quais 4 foram considerados 'semiurbanos'. Em conclusão, o estudo foi utilizado para apoiar a decisão do governo.

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## 1. INTRODUCTION

In Brazil, road passenger transport services can occur within the same Brazilian state or between different states. In the first case, the services are under state/Federal District responsibility and, in the second, they are under Federal responsibility (Nunes, 2010). There are two types of interstate passenger transport services: 'semi-urban' and 'road'. Although both of them are interregional transport services under Federal responsibility, they have several operational and regulatory differences.

The interstate 'semi-urban' bus service is the one which, while maintaining urban characteristics, traverses the limits of Brazilian states (in Brazil, the Federal District is treated as a state). For that, according to national regulations, it is necessary to use city buses with

controlled bus fares. The ‘semi-urban’ regulatory model is based on exclusive concessions and requires a bidding process to select a company to perform the operation (Nunes, 2010; Schiller, 2018). In such cases, the fares are usually cheaper and the frequency of buses is usually higher, both in comparison to a ‘road’ service (Brandão Filho *et al.*, 2016).

On the other hand, any company that meets certain prerequisites can operate the ‘road’ interstate bus service (Schiller, 2018). This service should be offered on interstate routes with regional transport characteristics, using coaches and charging non-regulated fares (Brazil, 2001; Schiller, 2018). The fares are usually more expensive and the frequency of buses is usually lower than ‘semi-urban’ services (Nunes, 2010). Also known as ‘long distance coach services’, the ‘road’ bus service has been delegated by a nonexclusive authorization model (free competition environment) since 2015, due to the deregulation process (Brazil, 2001; Schiller, 2018). Table 1 displays the differences between ‘road’ and ‘semi-urban’ interstate bus service.

**Table 1** – Differences between ‘road’ and ‘semi-urban’ interstate bus services

	<b>Road</b>	<b>Semi-urban</b>
Definition:	Transport passenger services with origin and destination in different States, with regional transport characteristics.	Transport passenger services between cities of different States, with urban transport characteristics.
Bus Feature:	Coach Bus: more comfortable, and people should travel seated	City Bus: less comfortable, and people can travel standing
Fare Control:	Freedom of bus fare, and usually more expensive fare tickets.	Controlled bus fare, and usually cheaper fare tickets.
Type of Concession:	Directly authorized by the public authority (non-exclusive authorization)	Requires bidding process (exclusive concession)
Concession period:	Indefinite period of service provision	Limited period of service provision (max. 15 years)
Competitive environment:	Free competition environment	Limitation of competitors
Feasibility guarantee:	Investor risk	Need to ensure economic viability for the investor

Source: Brazil (2001)



**Figure 1.** Interstate bus service between Poços de Caldas and Divinolândia (40 km apart) with coaches and between Brasília and Luziânia (60 km apart) with city buses

Before 2013, the bus services were classified as ‘road’ whenever the extension of the line exceeded 75 km (Brandão Filho *et al.*, 2016). However, that distance should not be the unique criterion to determine whether the service is ‘semi-urban’ and it is also not a good parameter

for measuring the ‘urban characteristics’ (Ojima, 2007). For instance, between Poços de Caldas city (in Minas Gerais State) and Divinolândia city (in São Paulo State) there are 40 km without urban transport characteristics. Consequently the operation is currently conducted using coaches. On the other hand there is the example of the bus services between Brasília (in the Federal District) and Luziânia (in Goiás State), cities 60 km apart, that are served by urban buses (Figure 1).

Because of inadequate use of distance as the unique criteria, many transport services have been wrongly classified. As a result, some markets operated by road services have been requesting to switch to semi-urban services, and vice versa. That required studies to develop a new classification method that could support the decisions of the public authority. According to Brazilian Law 010.233/2001 (Brazil, 2001), the National Land Transport Agency (ANTT) is responsible for determining whether a bus service should be classified as ‘semi-urban’ or ‘road’.

To try to solve the problem, a preliminary method was proposed by Brandão Filho *et al.* (2016), which considers territorial continuity and the integration of municipalities (Figure ). However, this method requires a ‘technical analysis’ that has not yet been presented. A methodological complement is needed to guide any such technical analysis.

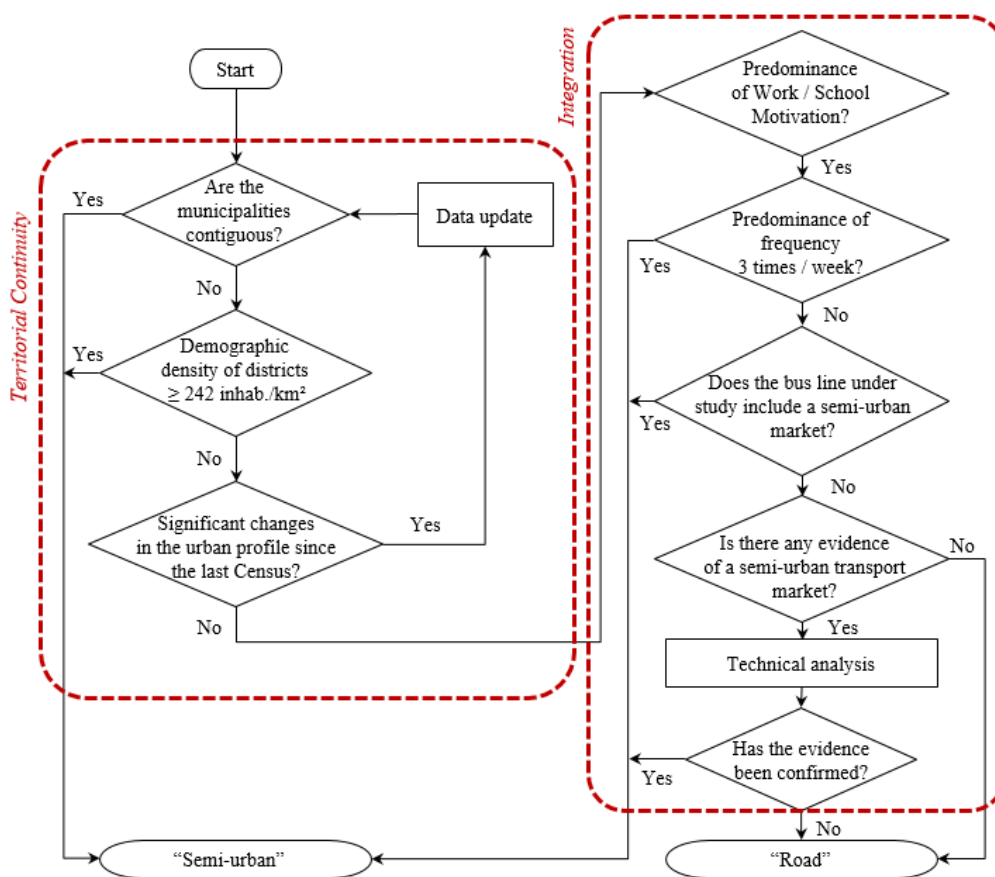


Figure 2. Preliminary flowchart for classifying interstate passenger transportation services. Source: Brandão Filho *et al.* (2016)

To complement the paper presented by Brandão Filho *et al.* (2016), the main objective of this study is to develop a method to measure the degree of ‘urban characteristics’ in order to classify the interstate bus transport services and assist the sector regulation (Brazil, 2001). In the case of a bad classification, there could be serious operational and regulatory problems, such as expensive bus fares or insufficient bus frequencies (Nunes, 2010).

## 2. LITERATURE REVIEW

### 2.1. Multi-Criteria Decision Analysis

Classic Operational Research (OR) has developed some positive paradigms in the search for good solutions to certain problems (Bortoluzzi *et al.*, 2017). With one such paradigm, depending on the complexity of the decision to be made, decision-makers can propose different values and preferences in an attempt to solve those problems (Marttunen *et al.*, 2017). For that reason, the Multi-Criteria Decision Analysis (MCDA) approach appears as the methodological alternative to be used (Marttunen *et al.*, 2017).

In essence, the MCDA consists of a systematic evaluation of alternatives in terms of multiple and often conflicting objectives (Marttunen *et al.*, 2017). In some cases, it is necessary for decision-makers to increase their degree of understanding of the decision to be made, especially when presenting their different points of view (PV), in order to find the best solution in a 'constructivist' way. When that occurs, the technique is known as Multi-Criteria Decision Analysis – Constructivist (MCDA-C) (Costa *et al.*, 2017).

The MCDA-C is originally constructed in four stages: (i) Decisional Context Identification; (ii) Problem Structuring; (iii) Multicriteria Model Structuring; and, (iv) Evaluation of Potential Actions (Costa *et al.*, 2017; Ensslin *et al.*, 2001).

The first stage begins the identification of aspects of the object to be studied. The problem structuring (second stage) seeks to define the title of the problem and to determine the family of Fundamental Points of View (FPV). In this paper, in order to define the FPV criteria it is necessary to search for specific literature on urban mobility, land-use, and spatial configuration (Adelt *et al.*, 2018; Banister, 2008; Da Silva *et al.*, 2008; Davidson *et al.*, 2007; Gouvêa, 2010; Waddell, 2011).

At the stage of Multi-criteria Model Structuring (third stage), initially, decision makers define the focus on which they intend to act and what aspects they consider to be essential for their analysis. Subsequently, that materializes in the form of 'evaluation axes', which enable the transition from a cognitive map to a multicriteria model (Costa *et al.*, 2017; Ensslin *et al.*, 2001). In the last stage (Evaluation of Potential Actions), the performance of the actions is evaluated. For that, an additive aggregation formula is used, which makes it possible to aggregate the local performances of the actions in a global evaluation (Costa *et al.*, 2017; Ensslin *et al.*, 2001).

### 2.2. Transport with urban characteristics

Regarding the Problem Structuring stage (second stage) and Multicriteria Model Structuring stage (third stage), in the context of transport with urban characteristics, the structure to be developed must consider social and technological interactions, taking into account the interplay of agents' choices and situational constraints (Adelt *et al.*, 2018). That is because urban mobility involves relatively complex aspects, such as land-use and spatial configuration (Da Silva *et al.*, 2008; Davidson *et al.*, 2007; Gouvêa, 2009; Ojima, 2007).

According to Banister (2008), considering a sustainable mobility, a multicriteria analysis must involve a demand of people, according to their interests, associated with a minimization of their travel time (such as increasing bus frequency). Moreover, supposing that demand could be based on activities, travel is generated according to the daily actions performed by families and people (Davidson *et al.*, 2007; Ojima, 2007).

As Davidson *et al.* (2007) clarify, an activity-based platform implies that modeled travel is derived within a general framework of the daily activities undertaken by households and persons, such as work or school and personal maintenance (e.g., health services, food shopping). Finally, transport systems are sensitive to policy changes over time (Nunes, 2010; Waddell, 2011), so that any changes affect travel demands (Davidson *et al.*, 2007). This means that the FPVs to be considered must deal with: (i) social aspects; (ii) political-institutional aspects, and; (iii) technical and operational aspects.

### 3. MATERIAL AND METHODS

To achieve the proposed objectives, researchers developed a set of measures to be applied to public management groups. The selected group was composed of specialists in transport regulation from the National Land Transport Agency (ANTT) of Brazil, including its managers and superintendent. In an attempt to avoid only portraying the Agency's positions, one of the concerns in the choice of these participants was the need for the specialist to have experience external to ANTT and, preferably, contact with the regulated market.

In general, this research found that the difference between 'semi-urban' and 'road' bus services depends on social, political, institutional, technical and operational aspects (Adelt *et al.*, 2018; Banister, 2008; Davidson *et al.*, 2007; Ojima, 2007). In that kind of complex situation, MCDA makes it feasible to evaluate several alternative models or variants based on many quantitative/qualitative criteria (Quadros e Nassi, 2015). According to Macharis and Bernardini (2015), there are numerous Multi-Criteria Decision techniques in use in transport activities and that includes passenger and freight transportation. Other papers that have used the multi-criteria techniques have cited their use in transportation planning (De Luca, 2014) and mobility/logistics (Macharis *et al.*, 2010, Ferretti e Degioanni, 2017) or for ranking railway projects (Mandic *et al.*, 2014), or to evaluate preferential options among modes of transport (Sayers *et al.*, 2003), or to guide a furniture industry production manager (Bortoluzzi *et al.*, 2017).

This study used a constructivist analysis (MCDA-C), grounded in a learning pattern, such as that used by Ensslin *et al.* (2000) or Bortoluzzi *et al.* (2017). The structure proposed is multidimensional and integrates mental maps with the Measuring of Attractiveness by means of a Categorical-Based Evaluation Technique (MACBETH) (Bana e Costa and Vansnick, 1994, 1999; Bana e Costa *et al.*, 2012; Bortoluzzi *et al.*, 2017). In the field of transport, Da Silva *et al.* (2008) used this same method to establish the key elements of a sustainable urban mobility approach in Brazil, and Costa and Granemann (2017) developed a technique, using MCDA-C, to evaluate the quality of semi-urban interstate bus services.

Following the guidelines of Ensslin *et al.* (2000), the MCDA-C technique used in this paper is detailed in two main stages:

- Stage 1: Structuring

Preparation stage that develops a better communication environment among the many actors involved (Ensslin *et al.*, 2000).

(i) structuring of the Mental Map (MM) and the value tree (diagram with the hierarchical objectives);

(ii) structuring of all Fundamental Points of View (FPV) and, if necessary, decomposing it into Elemental (or Elementary) Points of View (EPV);

(iii) structuring of the descriptors.

- Stage 2: Evaluation

Step to elaborate a multidimensional and quantitative model, establishing values for each FPV depending on their contribution to the study (Ensslin *et al.*, 2000).

(i) develop the value functions for each FPV;

(ii) establish weights (compensation rates);

(iii) evaluate the system impact profile and verify the behavior of the model;

(iv) interpret the results.

## 4. MULTICRITERIA CHARACTERIZATION OF INTERSTATE BUS PASSENGER TRANSPORT SERVICES

### 4.1. Structuring phase

To construct the mental map and the value tree, during the structuring phase six decision makers were identified: four ANTT regulatory specialists with professional experience external to the Agency, one manager and one superintendent (both from ANTT but with market network experience). Although the number of decision makers may have been a limiting factor, together and based on a literature review (Adelt *et al.*, 2018; Banister, 2008; Davidson *et al.*, 2007; Nunes, 2010; Ojima, 2007; Waddell, 2011), they identified three FPV capable of influencing interstate bus service regulation: (i) social aspects; (ii) political-institutional aspects; (iii) technical and operational aspects. Those FPV were decomposed into 14 EPV, divided into 8 Sub-Elemental Points of View (Sub-EPV), as displayed in Figure 3. Table 2 presents the full set of FPV, EPV and Sub-EPV. It is important to note that the decision makers made these subdivisions also considering the views of agents external to ANTT (such as users and entrepreneurs) obtained in work meetings and public consultations.

Table 2 – List of EPV

Fundamental Points of View (FPV)	Elemental Points of View (EPV)	Sub-Elemental Points of View (Sub-EPV)
1. Social Aspects	1.1. Interdependence of Health Services	1.1.1. Number of hospital beds per inhabitant 1.1.2. Existence of basic health care services 1.1.3. Existence of emergency services
	1.2. School Interdependence	-
	1.3. Work Interdependence	-
2. Political-Institutional Aspects	2.1. Availability of Public Policies for Urban Mobility in the City	-
	2.2. Request from External Entity to Operate the Transport Service	2.2.1. Performed by public authority 2.2.2. Performed by private entity
3. Technical and Operational Aspects	3.1. Urban infrastructure	3.1.1. Existence of bus stop infrastructure 3.1.2. Line extension percentage on roadways 3.1.3. Line extension percentage on unpaved road.
	3.2. Bus Occupancy Rate <sup>1</sup>	-
	3.3. Existence of Clandestine Transportation	-
	3.4. Bus Line Extension	-
	3.5. Fare Amount	-
	3.6. Frequency <sup>1</sup>	-
	3.7. Additional Services <sup>1</sup>	-
3.8. Vehicle Features <sup>1</sup>	-	
3.9. Internal Urban Transport in the City <sup>2</sup>	-	

Notes: <sup>1</sup> EPV considered only when a regular offer of interstate bus passenger service exists. <sup>2</sup> EPV considered only when there is no regular offer of interstate bus passenger service.

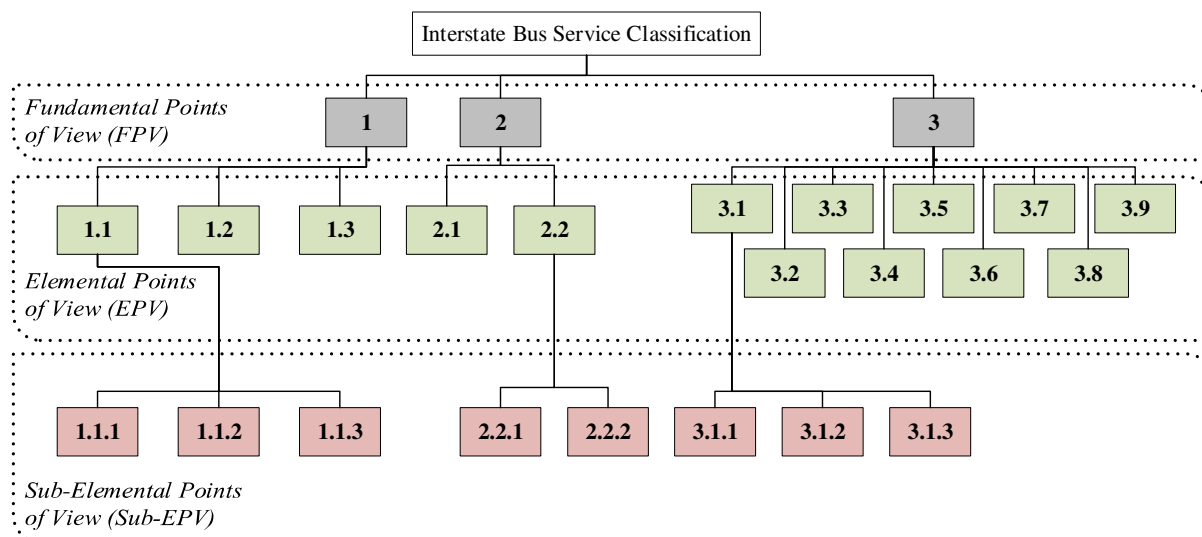


Figure 3. General view of the FPV tree

#### 4.1.1. Social aspects

As displayed in Table 2, to specify the social aspects of each city involved in the study, 3 Elemental Points of View (EPV) were considered. For this analysis, the specific values of each indicator were compared among the cities evaluated. This comparison aims to analyze the types of interdependence of one city with another, which are: health service interdependence, school interdependence, and work interdependence. If there is a great interdependence of these indicators between two cities, there is a tendency to have urban transport characteristics between them (Adelt *et al.*, 2018; Davidson *et al.*, 2007; Ojima, 2007).

#### 4.1.2. Political-institutional aspects

For the political-institutional aspects, the study analyzed the availability (or existence) of public policies for urban mobility in the city. Whenever there are policies like these, the urban organization is better structured (Waddell, 2011).

Another way to consider the existence of 'political-institutional aspects' is when an external entity (such as a bus company or a municipal government) requests ANTT for a public transport operation between those cities. In this respect, there is probably an urban cluster, indicating urban characteristics in the region.

#### 4.1.3. Technical and operational aspects

The definition of 'technical and operational aspects' is not a simple task. This analysis involves factors, such as: urban infrastructure; existence of clandestine transportation (without authorization of the public authority); bus line extension; or fare prices. There are situations that indicate a trend towards 'urban transport characteristics', such as: the existence of clandestine urban transportation; good availability of urban infrastructure; shorter extension of the bus line or relatively low fare prices, considering inter-municipal transport characteristics.

If there is a regular offer of interstate bus passenger service in the city, it is feasible to describe the degree of urbanity using the bus occupancy rate and frequency (Banister, 2008; De Luca, 2014). In the same way, if there are additional services (i.e., package service/ transport of luggage under orders) or bigger vehicles in use (i.e., coaches with toilets) it means that the

transport should be classified as 'not urban'. Supposing that there is no interstate transport service in the region, then it is relevant to observe whether urban transport (public municipal transport) is available inside the analyzed city or not.

## 4.2. Evaluation Stage

The study used the Unique Synthesis Criterion Approach to construct the descriptor. This approach creates functions that combine and then maximize preferences of alternatives over attributes, constructed according to the collaborator performances (Guitouni e Martel, 1998; Ensslin *et al.*, 2000; Ishizaka and Siraj, 2017). In this study, each transport market was represented by a function composed of all attributes that influence 'semi-urban' or 'road' classification, accompanied by their respective weights. This function is analogous to that presented in Ensslin *et al.* (2000) and in Bortoluzzi *et al.* (2017), as displayed in the following equation:

$$P(m) = \sum_{c=1}^{19} w_c (P_{FPV_c}(m))$$

where  $M$  is the group of markets that will be analyzed;  
 $P(m)$  is the overall score of  $m \in M$ ;  
 $m$  is the market composed of two cities;  
 $FPV_c$  is the Fundamental Points of View linked to criteria  $c$ ;  
 $w_c$  is the weight (or 'compensation rate') for the criterion  $c$  which impact on each  $FPV_c$ ;  
 $(P_{FPV_c}(m))$  is the local score.

In this paper,  $w_c$  ( $c = 1, \dots, 19$ ), which indicates each EPV or Sub-EPV analyzed. Although this study performed the complete analysis, just the FPV 1 (social aspects) are presented in detail for better representation. The FPV 2 and 3 are treated analogously.

### 4.2.1. Construction of value functions

To construct the value functions MACBETH was used, as developed by Bana e Costa and Vansnick (1994). According to Ensslin *et al.* (2000), to use the MACBETH it is necessary to question the decision maker about the attraction difference between two elements of analysis. Usually, the answer is one of the following:

- Null;
- Very weak attraction difference;
- Weak attraction difference;
- Moderate attraction difference;
- Strong attraction difference;
- Very Strong attraction difference;
- Extreme attraction difference.

If necessary, two ordinal scales can be combined (i.e.: 'weak-moderate' or 'moderate-strong'). When this happens, the MACBETH software uses diffused linear programming, according to the model requirements.

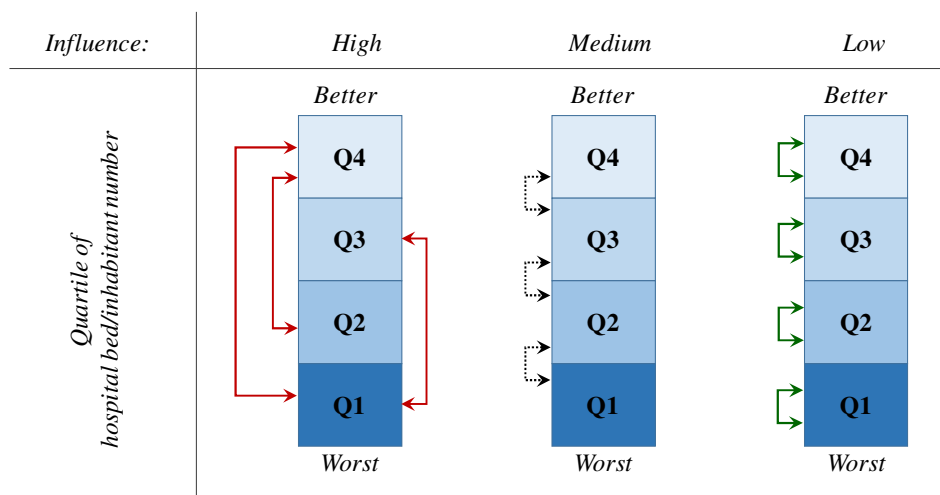
The impact level of the criterion ('Level 1' – high influence – or 'Level 3' – low influence) and the scales types were developed according to the decision maker's preference. The scale values



were set to make higher values represent ‘semi-urban’ transport characteristics, while lower values represented ‘road’ bus service transport.

Regarding the EPV 1.1 (‘interdependence of health service’), when there are two relatively close cities with severe distinction between the availability of their health services, a flow of people is created between those cities (Ojima, 2007; Pires *et al.*, 2010), indicating a ‘semi-urban’ or ‘metropolitan’ transport characteristic (Gouvêa, 2009). This occurs for several reasons, such as trips for health treatment or doctor’s appointments. In the context of rural residential areas, this approach is known as ‘public service facilities integrity’ and is part of ‘social equilibrium’ (Ma *et al.*, 2019). To calculate the interdependence of health service, the numbers of hospital beds per inhabitant in each city were used as reference, compared with quartile position in the national ranking. The Brazilian Institute of Geography and Statistics (IBGE) gives the national ranking.

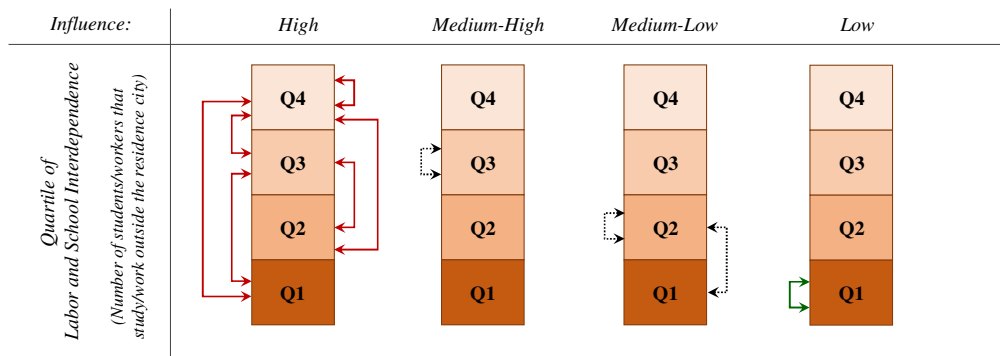
The criterion used to define the function values was the interquartile gap. The greater the interquartile gap positioning for each city, the greater the influence of hospital services is between them. For instance, if the city ‘X’ is positioned in the first quartile (worst health structure) and the city ‘Y’ is positioned in the fourth quartile (better health structure), there is considered to be ‘high’ influence between both cities, because there will be a flow of people from ‘Y’ to ‘X’. However, if both cities are in the fourth quartile, the influence will be low. The value functions used for this criterion were ‘high’, ‘medium’ or ‘low’ influence between cities, according to the Figure (the arrows indicate the positioning/gap between cities).



**Figure 4.** Value functions for ‘hospital bed/inhabitant number’. Note: the arrows indicate the positioning/gap between cities

To measure the ‘existence of basic health care services’ and the ‘existence of emergency services’: ‘yes’, was used if one city has the service and the other does not; or ‘No’, if both cities have or do not have those services.

In regard to ‘school interdependence’ and ‘work interdependence’, they were structured using quartiles in a similar way to the ‘interdependence of health service’. However, in this respect, the number of students (or workers) that study (or work) outside their city of residence was used, according to IBGE classification (Figure). All the other value functions for the model (FPV, EPV and Sub-EPV) were determined in similar ways.



**Figure 5.** Value functions for ‘school interdependence’ and ‘work interdependence’ Note: the arrows indicate the positioning/gap between cities

A matrix was developed for semantic judgments using the MACBETH software and considering the value functions as reference. After the judgments, the scale value is given by the software (Bana e Costa and Vansnick, 1999). The EPV 1.1 (Sub-EPV 1.1.1, 1.1.2 and 1.1.3) are displayed in Table 3, and the EPV 1.2/EPV 1.3 are displayed in Table 4. All the other matrixes (FPV 2 and 3) were determined analogously.

**Table 3 – Matrix of semantic judgment for EPV 1.1**

1.1.1. Number of hospital beds per inhabitant					
Basis of Comparison		Judgments			Value Functions
Level 1 Level 2 Analogously Level 3	High influence	Level 1	Level 2	Level 3	Current scale
	Medium influence	Level 1	null	strong	100.00
	Low influence	Level 2		null	55.56
		Level 3		null	0.00
1.1.2. Existence of basic health care services					
Basis of Comparison		Judgments			Value Functions
Level 1 Level 2	There is influence	Level 1	Level 2		Current scale
	There is no influence	Level 1	null	extreme	100.00
		Level 2		null	0
1.1.3. Existence of emergency services					
Basis of Comparison		Judgments			Value Functions
Level 1 Level 2	There is influence	Level 1	Level 2		Current scale
	There is no influence	Level 1	null	moderate	100.00
		Level 2		null	0

**Table 4** – Matrix of semantic judgment for EPV 1.2 and 1.3

Basis of Comparison		1.2. School Interdependence / 1.3 Work Interdependence				Value Functions	
		Judgments					
		Level 1	Level 2	Level 3	Level 4	Current scale	
Level 1	High influence	Level 1	null	moderate	v. strong	extreme	100.00
Level 2	Med-High influence	Level 2		null	wk-moderate	mod-strong	40.00
Level 3	Med-Low influence	Level 3			null	wk-moderate	0.00
Level 4	Low influence	Level 4				null	(-)40.00

**4.2.2. Establishment of weights**

The weights (‘compensation rates’) were determined according to the decision makers’ choices, especially considering the relevance of each criterion according to the experts’ experience. In this case, for example, the experts considered that the political-institutional aspects have less relevance than the social or technical-operational aspects for the following reasons:

- Some existing public policies are not well defined (Da Silva *et al.*, 2008), while others may have been induced by specific interests – according to Nunes (2010), some politicians are supporters or owners of bus companies;
- Some regional public policies may not correspond to the reality of the municipality (Gouvêa, 2009).
- The mere existence of a public policy does not guarantee its effectiveness (Pires *et al.*, 2010).
- The social aspects are treated as equally relevant to those technical-operational aspects, since they are complementary in terms of transport demand/offer (Davidson *et al.*, 2007).

The weights of each EPV and Sub-EPV were also assigned in an analogous way. Each criterion was ranked by level, assuming the given weight. Those weights were normalized to a percentage value obtained from the semantic judgment matrix. This technique followed the procedure proposed by Bana e Costa e Vansnick (1994), based on MACBETH methodology.

**Table 5** – Final weight of the variables, when there is a regular offer of interstate bus passenger services

FPV		EPV		Sub-EPV	
1	40%	1.1	20%	1.1.1	20%
				1.1.2	30%
				1.1.3	50%
		1.2	40%		
		1.3	40%		
2	20%	2.1	55%		
		2.2	45%	2.2.1	35%
				2.2.2	65%

**Table 5** – Final weight of the variables, when there is a regular offer of interstate bus passenger services (continue)

FPV		EPV		Sub-EPV	
3	40%	3.1	11%	3.1.1	39%
				3.1.2	51%
				3.1.3	10%
		3.2	13%		
		3.3	16%		
		3.4	12%		
		3.5	12%		
		3.6	16%		
		3.7	9%		
3.8	11%				

Tables 5 and 6 displays the normalized compensation rates in cases where there is, and there is no, a regular offer of interstate bus passenger services. In both cases, the FPV 1 (Social Aspects) and FPV 3 (Technical and Operational Aspects) each represent 40% of all the final weight of the model. The remaining 20% were attributed to FPV2.

**Table 6** – Final weight of the variables, when there is no regular offer of interstate bus passenger services

FPV		EPV		Sub-EPV	
1	40%	1.1	20%	1.1.1	20%
				1.1.2	30%
				1.1.3	50%
		1.2	40%		
		1.3	40%		
2	20%	2.1	55%		
		2.2	45%	2.2.1	35%
				2.2.2	65%
3	40%	3.1	19%	3.1.1	39%
				3.1.2	51%
				3.1.3	10%
		3.3	28%		
		3.4	22%		
3.5	22%				
3.9	9%				

#### 4.2.3. Threshold calibration: 'semi-urban' or 'road'?

Having identified the weights and value functions of each variable, it was necessary to define a threshold value to classify the market as 'semi-urban' or 'road'. The threshold value delimits the border between 'semi-urban' and 'road' transport services, according to the overall score of each market –  $P(m)$ . The higher the overall score of the market, the more 'semi-urban' it will tend to be. So, if this overall score value is above the threshold, the market will be considered as 'semi-urban'. There is an indeterminate zone around the threshold. If the overall score is in this zone it means that the market is not precisely classified and requires further study. Figure 6 illustrates that situation.

To calculate the threshold value, 10 known markets were selected, five already operated as 'semi-urban' and five already operated as 'road' services between cities short distances apart (less than 100 km). Those markets were chosen because there the public authority has no doubts about their classification in view of their social and technical-operational characteristics. Just to test the model's behavior, the study included the market between Rio de

Janeiro city and São Paulo city which is unquestionably a ‘long distance’ market and a ‘road’ service. In other words, it is inconceivable to transport passengers between Rio de Janeiro and São Paulo (440 km apart) in urban buses. Table displays the selected markets.

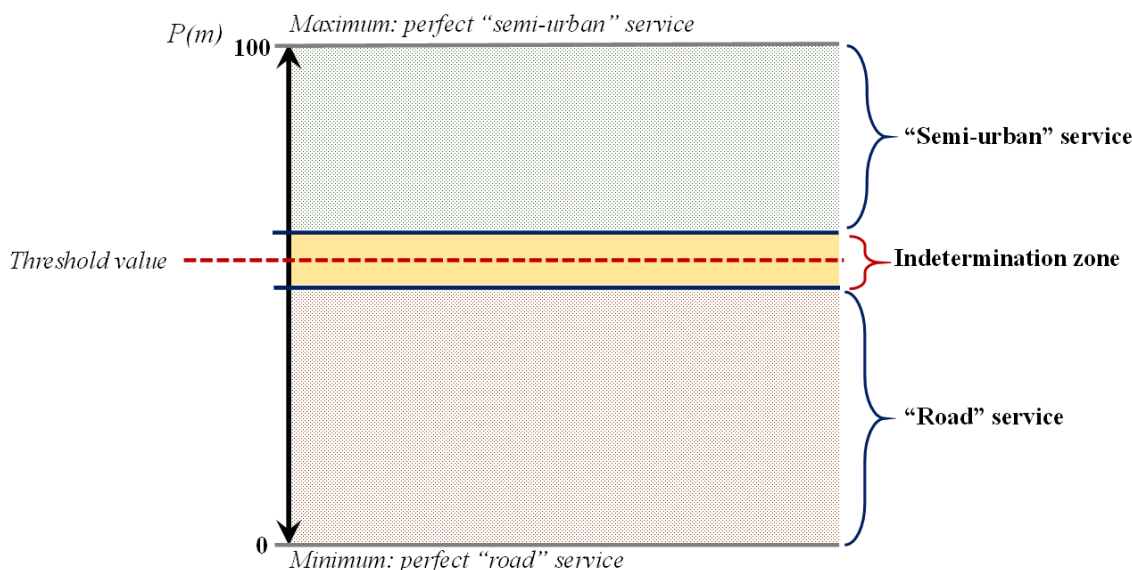


Figure 6. Representation of the MCDA-C model developed to classify the market as ‘semi-urban’ or ‘road’

Table 7 – Markets used for calibrating the threshold

‘Road’ service (Long Distance)	‘Road’ service (Short Distance)	‘Semi-urban’ service
Rio de Janeiro/RJ - São Paulo/SP (440 km)	Venceslau Braz/PR - Itararé/SP (75 km)	Florianópolis/PI – Barão de Grajaú/MA (6 km)
	Espinosa/MG – Jacaraci /BA (85 km)	Luziânia/GO - Brasília/DF (60 km)
	Lagarto/SE - Paripiranga/BA (40 km)	Três Rios/RJ - Chiador/MG (30 km)
	Nanuque/MG - Ibirapuã/BA (60 km)	Ourinhos/SP - Marques dos Reis/PR (9 km)
	Espírito Santo do Pinhal/SP - Jacutinga/MG (28 km)	Taguatinga/DF - Valparaiso/GO (45 km)

Legend: PR = State of Paraná; SP = State of São Paulo; PI = State of Piauí; MA = State of Maranhão; MG = State of Minas Gerais; BA = State of Bahia; GO = State of Goiás; DF = Federal District; SE = State of Sergipe; RJ = State of Rio de Janeiro;.

Table 2 – Final value function for each market

	Market (cities)	Overall Score
‘Road’ service (Short Distance)	Venceslau Braz/PR - Itararé/SP	40.24
	Espinosa/MG - Jacaraci/BA	43.06
	Lagarto/SE - Paripiranga/BA	47.41
	Nanuque/MG - Ibirapuã/BA	51.65
	Espírito Santo do Pinhal/SP - Jacutinga/MG	59.52
‘Semi-urban’ service	Florianópolis/PI - Barão de Grajaú/MA	66.37
	Luziânia/GO - Brasília/DF	72.57
	Três Rios/RJ - Chiador/MG	73.09
	Ourinhos/SP - Marques dos Reis/PR	73.98
	Taguatinga/DF - Valparaiso/GO	84.54
<b>Threshold</b> (average between 59.52 and 66.37 – indeterminate zone)		<b>63</b>
‘Road’ service (Long Distance)	Rio de Janeiro/RJ - São Paulo/SP	7.33

The overall score for each market was calculated using the proposed method and the data collected. The threshold value was considered as the average value obtained between the maximum overall score for 'road' market and the minimum overall score for 'semi-urban' market. The indeterminate zone was the difference between those maximum and minimum values. Table 8 sets out the overall score for each market and the threshold values.

#### 4.2.4. Market analysis

The public authority listed 11 interstate bus services markets that were uncertain about their current categorizations (markets operated by road services that have been requesting to switch to semi-urban services, and vice versa). Those uncertainties were generated by several causes, such as user, company or municipal requesting.

Considering the need to technically categorize these 11 unknown interstate bus services markets (which have regular offer of interstate bus passenger service), each of them was inserted in the developed model for analysis. The overall score of each of them was obtained using the proposed method (Table 3).

**Table 3** – Unknown interstate bus service markets to be categorized

Market (cities)	Overall Score	Distance (km)
Guaçuí/ES - Natividade/RJ	39.95	58
S. J. da Boa Vista/SP - Poços de Caldas/MG	45.94	48
Poços de Caldas/MG - Divinolândia/SP	48.36	40
Brasília/DF - Formosa/GO	52.52	80
Espírito Santo do Pinhal/SP - Andradas/MG	53.52	25
Socorro/SP - Bueno Brandão/MG SC	60.11	38
Agudos do Sul/PR - São Bento do Sul/	62.49	40
Andradas/MG - São João da Boa Vista/SP	67.65	38
Jacutinga/MG - Itapira/SP	70.80	34
Extrema/MG - Bragança Paulista/SP	71.38	35
Selviria/MS - Ilha Solteira/SP	78.23	18

## 5. RESULTS

To represent the result, all the 'road service', 'unknown', and 'semi-urban service' overall scores were ranked in the same table (Table 4). For better comprehension, each analyzed market was referenced by a letter (from letter 'A' to letter 'V'), and displayed graphically in Figure.

According to these results, the markets 'G' (Guaçuí/Natividade), 'H' (S. J. da Boa Vista/ Poços de Caldas), 'I' (Poços de Caldas/Divinolândia), 'J' (Brasília/Formosa) and 'K' (Espírito Santo do Pinhal/Andradas) could be classified as 'road' according to the proposed method. In this respect, the public authority will directly authorize them for an indefinite period with freedom to determine the bus fare. In the other situation, the markets 'N' (Andradas/São João da Boa Vista), 'O' (Jacutinga/Itapira), 'P' (Extrema/Bragança Paulista) and 'Q' (Selviria/Ilha Solteira) could be classified as 'semi-urban'.

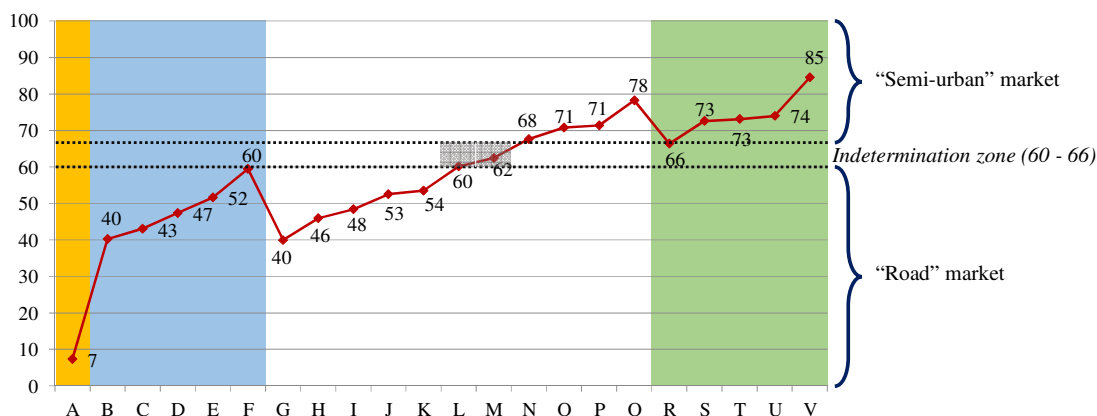
Using this methodology, the public authority has grounds on which to initiate a bidding process, aiming at a future delegation of interstate bus transport service with urban characteristics. The bidding notice must ensure the economic viability of the market, considering 15 years operation with controlled bus fare.

The markets 'L' and 'M' could be classified as road if the absolute threshold value is considered as a reference (63 points). However, these markets have overall score values closer to the threshold value and should not be definitively classified (they are displaced in the

indeterminate zone). The markets ‘L’ and ‘M’ require further studies to improve the accuracy of the model, taking into account some specificities of each city.

**Table 4 – Ranking of overall score for each bus service classification**

Service classification	Ref.	Market (cities)	Overall Score	Distance (km)
‘Road’ service (Long Distance)	A	Rio de Janeiro/RJ - São Paulo/SP	7.33	440
	B	Venceslau Braz/PR - Itararé/SP	40.24	75
	C	Espinosa/MG - Jacaraci/BA	43.06	85
‘Road’ service (Short Distance)	D	Lagarto/SE - Paripiranga/BA	47.41	40
	E	Nanuque/MG - Ibirapuã/BA	51.65	60
	F	Espírito Santo do Pinhal/SP - Jacutinga/MG	59.52	28
	G	Guaçuí/ES - Natividade/RJ	39.95	58
	H	S. J. da Boa Vista/SP - Poços de Caldas/MG	45.94	48
	I	Poços de Caldas/MG - Divinolândia/SP	48.36	40
	J	Brasília/DF - Formosa/GO	52.52	80
Unknown	K	Espírito Santo do Pinhal/SP - Andradas/MG	53.52	25
	L	Socorro/SP - Bueno Brandão/MG	60.11	38
	M	Agudos do Sul/PR - São Bento do Sul/SC	62.49	40
	N	Andradas/MG - São João da Boa Vista/SP	67.65	38
	O	Jacutinga/MG - Itapira/SP	70.80	34
	P	Extrema/MG - Bragança Paulista/SP	71.38	35
	Q	Selviria/MS - Ilha Solteira/SP	78.23	18
	R	Floriano/PI - Barão de Grajaú/MA	66.37	6
	S	Luziânia/GO - Brasília/DF	72.57	60
	T	Três Rios/RJ - Chiador/MG	73.09	30
‘Semi-urban’ service	U	Ourinhos/SP - Marques dos Reis/PR	73.98	9
	V	Taguatinga/DF - Valparaíso/GO	84.54	45



**Figure 7.** Graphic arrangement of the results obtained.

In the end, this result makes it possible to affirm that the developed method was able to rank the markets. Through this technique, the classification of the markets occurred more objectively, according to the pre-established criteria of FPV, EPV and Sub-EPV.

**6. DISCUSSION**

The MCDA-C proved to be appropriate for the proposed goal. However, this technique requires careful definition of criteria and choice of specialists. Even in situations where there is a restriction on the number of specialists, it is possible to take advantage of the existing literature to define the FPV, EPV and Sub-EPV.

In the case of this paper, defining urban characteristics as being an agglomeration of information on social, political-institutional and technical-operational aspects proved effective. Subsequently, the weighting of the criteria and their respective allocation in the Macbeth software are also sensitive activities and must be preceded by justifications. Once all the steps have been completed, the method becomes robust and able to substantiate the decision of the public authority.

## 7. CONCLUSION

This paper shows how scientific theory, based on a Multi-Criteria Decision Analysis-Aid – Constructivist (MCDA-C) technique, can be useful when handling policy decision-making. As a constructivist approach, the method opens space for discussion and brainstorming, enabling the creation of duly substantiated regulations.

The study presented a method to classify the interstate bus transport services in Brazil as ‘semi-urban’ or ‘road’. This method complements the one presented by Brandão Filho *et al.* (2016) and becomes useful for public authority decision-making. The ‘semi-urban’, delegated by Union concession, requires bidding process and must be provided by urban buses. The ‘road’, authorized by the public authority, needs to be provided by coaches. The model developed measures the degree of ‘urban characteristics’ using the MCDA-C technique, supported by the MACBETH software.

The study was important as a subsidy for the decision-making of National Land Transport Agency (ANTT) managers. As a result, at least four markets should be indicated to conduct bidding processes.

The proposed technique can help solve local problems in other countries in the same way that it has been successful in Brazil. In order to adapt the method, some points of view can be inserted or excluded. In addition, where appropriate, the indicator weights can be changed as desired.

As a suggestion for new research, it would be possible to test new criteria to define urban characteristics and compare them to this study, in ways such as: using Big Data through smartphones to characterize demand and flow of people between municipalities; using the Social Vulnerability Index (IPEA, 2015) as an element of social and urban profile integration; and hierarchizing and weighting the municipalities according to their size.

As a lesson learned, it has been proven that transport policies should not be implemented with incomplete regulation; correcting their failures may require much more effort in the future.

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