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Perception of Users on the Environmental Impact Caused by Public Transport Operation

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The objective of this article is to present a model for the assessment of the perception of users on the environmental impact of public transport operation. Public transport operations can contribute to urban pollution control. The research method was the survey with 300 users of public transport in a Brazilian city with 1,500,000 inhabitants. Previous research was used to calculate the sample. Environmental impact of public transportation is an observable set of consequences on the environment, due to the operation. It is treated as a systemic multivariate structure of latent constructs, obtained by literature review, and indicators. Experts in environmental and transport management deployed the constructs in twenty-nine formative and suggested ten reflective indicators that generated scales fulfilled by respondents. Final constructs were reorganized by exploratory factor analysis (EFA): atmospheric emissions; noise pollution; urban space; safety; and waste. Results were analyzed by structural equation modeling (SEM) with SmartPLS2.0 software. The reliability of constructs, the composite reliability, average variance extracted, and *t*- score were calculated. The main conclusion was: safety and atmospheric emissions of vehicles are the factors that most influence the perception of users about environmental impacts. Environmental image influences positively on the overall image of the service and on the satisfaction of the user, but satisfaction doesn´t increase proneness of users to increase ridership.

1. Introduction

Formal concerns with environmental issues are recent in the history of mankind. In recent years, public and legal pressures have been increased regarding environmental impact caused by anthropic activity, particularly industrial activities. Such pressures encourage the debate and stimulate more research on how to make industrial activity more sustainable (Sellitto et al., 2011). Among many others, transport activities have the potential to damage the environment, either in terms of emission of pollutants as well as in risk of environmental accidents (Uherek et al., 2010). Increased road transportation observed in recent years has increased the carbon footprint (CFP) of industrial urban activities (Lam et al., 2009).

Quoting US EPA reports, Barany et al. (2010) report some liabilities imposed by transportation systems to the environment in the USA: transportation accounts for almost 30% of the greenhouse gas (GHG) emissions; transportation is the fastest-growing source of GHG; and transportation is the largest individual source of GHG. Similar liabilities in Europe were quoted by Steenberghen and López (2008).

Road activities include load and passengers transportation. Passengers` transportation systems provide various types of urban mobility and other benefits to users: access to professional, social, entertainment and cultural life, as well as healthcare or education services. On the other hand, transportation systems put pressures on the human and natural environment, contributing for the urban degradation (Gudmundsson, 2001). Barany et al. (2010) argue that some means for reducing the pollution caused by transportation are changing the habits of users, reducing private transport, and improving the technology of vehicles and sub-systems. Stile et al. (2011) argue that optimizing performance of transport networks can also contribute to reduce environmental impact.

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The effects of environmental degradation due to traffic, such as particulates or nitrous dioxide emissions, in certain circumstances, can have more health impacts than emissions from industrial activities or power generation plants. So, knowledge on transportation systems environmental performance can be of interest in improving life quality, mainly in urban environment (Van Wee et al., 2005).

Turn public transportation systems more sustainable and in the same time use the urban mobility to promote economic prosperity are some of the objectives shared by cities administrations (Gudmundsson, 2001). Measurement of eco-efficiency or environmental performance can help achieve one of these objectives: turn the system more sustainable (Gudmundsson, 2001). Such kind of measurement usually demands measurement models based on indicators (Chee Tahir and Darton, 2010). The use of indicators is dependent on a suitable conceptual framework to explain relationships between construct, and to comprehend and assess the environmental performance as a whole (Myhre et al., 2012)

Measurements in a system must include not only the current environmental situation, but all the phases of the life cycle of the system (De Benedetto and Klemeš, 2008). LCA (Life Cycle Assessment) is defined as the inventory and assessment of the impacts that a system or activity can cause on environment throughout the entire life cycle, from the raw material extraction to the final disposal (Alarcon-Garcia et al., 2011). In transportation, the environmental impact of extraction and refining of fuel, manufacture, technical assistance, operation and disposal of vehicles should be considered (Barany et al., 2010). Chester et al. (2010a) argue that also parking facilities should be considered in environmental impact calculations.

Flaws may be found in methodologies used in determining environmental impacts in public transportation. Among others, two fragilities in environmental impact assessments (EIAs) that interest to the current research were pointed out: the lack of a more consistent and complete set of indicators, apprehending multiple characteristics of the impact; and the omission of energy aspects in the evaluation (Van Wee et al., 2005). About energy, Pistikopoulos et al. (2010) state that energy supply networks are becoming unsustainable, requiring greater efficiency in the use. It requires, among many other factors, the optimization of public transportation systems. Another characteristic of interest is the use of multicriterial approaches, due to the inherent complexity observed in transport systems (Čuček et al., 2012).

Transportation activities and environmental impacts have a mutual relationship with complex characteristics. The greater the public transport activity, the less the private transport need; the less the private transport, the less the environmental impact in cities caused by cars. But the greater the public transport activity, the greater the environmental impact caused by public transport. So, finding the optimal point can hide some difficulties that not always appear at first sight.

Another kind of measurement that can help cities administration in making public transportation systems more sustainable is the perception of users on environmental impact of the service. Previous research demonstrated that new or infrequent passengers of public transportation are more prone to become permanent if they have information and are satisfied on key factors concerning the service (Watkins et al, 2011). Environmental impact can be a key factor in passenger`s satisfaction (Eboli and Mazzulla, 2007) and can be used to attract and maintain users in the public transportation system (Anable, 2005).

The purpose of this article is to introduce and test a model for evaluation of perception of public transport users on the environmental impacts caused by the operation. The model was tested in a Brazilian city, with about 1,500,000 inhabitants. The research method was a survey with users of the system. As a secondary objective, the research seeks to verify if the improvement of the environmental image of the service can help bring new users or at least to make permanent the sporadic or infrequent ones. The reduction in the number of passengers in the main Brazilian cities became an important problem. Data from the Brazilian Agency (NTU, 2012) pointed out that in the last fifteen years the monthly number of passengers carried in the nine major cities fell from about 450 million in 1994 to about 330 million in 2010. At the same time, the distances travelled have increased from about 180 million to 200 million kilometres. This means that even if the routes followed the growth and diversification of the cities, the attractiveness of the service declined. Previous research (Stradling et al., 2007) pointed out that extending the network coverage may be the most attractive factor for users. The conclusion is that the low attractiveness caused by other factors is more important than the increase in coverage occurred in recent years. New factors of attraction should be tested so that the system can recover its attractiveness.

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2. The model

The model was built in two stages. In the first, by literature review, the researchers proposed a structure of eight constructs that may explain the perception of users on the environmental impacts of the operation. In the second, experts gathered in a focus group session conducted by the researchers attributed indicators to the constructs. The indicators were transformed into scales applied to three hundred frequent users of

the service. Many times, two or more scales were necessary to fully apprehend the meaning of the indicator, as pointed out by the experts. An important remark done by experts was: every environmental impact has to be considered in two manners, one during travel, usually in high-speed, another in congestions or in bus stops, when the speed is zero and the concentration rises significantly. This remark is consistent with Eboli and Mazzulla (2007) that advised for the importance of bus stops in managing customer satisfaction in public transportation. Chester et al (2010b) differentiate off-peak and peak travel times. It is also consistent with Chester and Horvath (2009) that included infrastructure in environmental studies on public transportation. Satisfaction with service and proneness to abandon private transport were tested as possible effects of good images of the service.
The model is presented in Table 1. The main references supporting the constructs are also shown. Figure 1 synthesises hypotheses and assumptions tested in the survey.

Table 1: Assessment model

Overall	Construct	Indicators	Main references
Environmental perception	Atmospheric pollution	Influence on temperature GHG in travel and at bus stops Smells in travel and at bus stops Influence on dust generation	Fuglestvedt et al. (2008), Uherek et al. (2010) Chester et al. (2010b)
	Noise pollution	Noise in travel and at bus stops	Uherek et al. (2010)
	Land use	Pavement damage Urban equipment damage Building damages	Hwe et al. (2006), Ismail and Hafezi (2011)
	Visual pollution	Influence of vehicles on landscape Influence of bus stops on landscape	Mejía-Dugand et al. (2012)
	Local habits and communities	Influence on cultural habits Influence on jobs Influence on neighbourhood	Stradling et al. (2007); Watkins et al. (2011)
	Wastes	Wastes produced by passengers Wastes produced by vehicles Fuel and greases leakages Traffic congestion	Steenberghen and López (2008)
	Safety	Risk of accidents with vehicles Risk of accidents at bus stops	Eboli and Mazzulla (2007), Stradling et al. (2007)

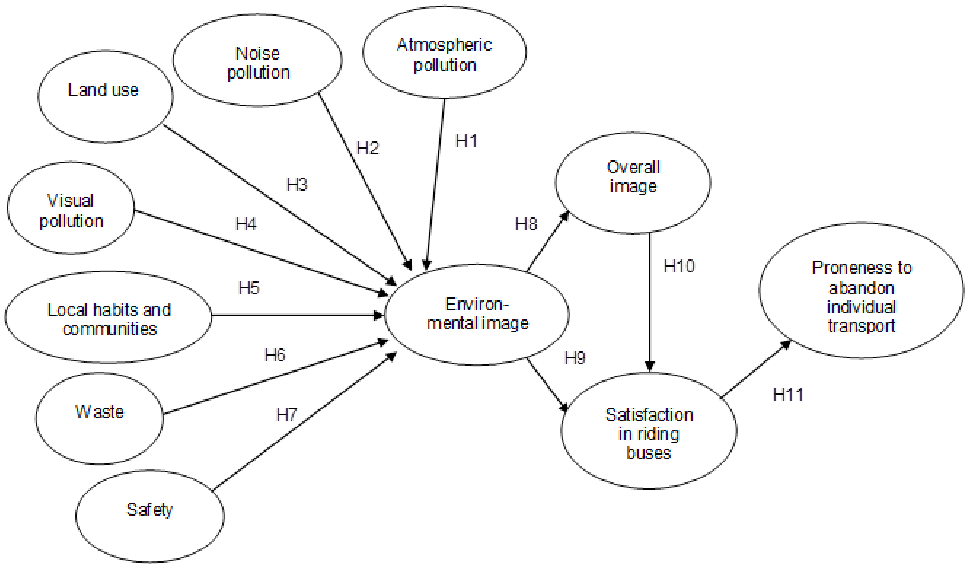

Figure 1: Assessment model and hypotheses

Hypotheses H1 to H7 are of the type: if [construct] is well evaluated by the rider, then his or her environmental image about the operation improves. Hypotheses H8 to H11 investigate on the relationships between environmental image, overall image, satisfaction in riding a bus, and proneness to ride a bus instead of the car, increasing the ridership of public transportation.

3. Application

Thirty-nine scales were fulfilled by three hundred frequent passengers of a medium-sized Brazilian city. Twenty-nine scales investigate indicators that form the environmental image (the construct appears as a manifestation of the items) and ten investigate indicators that reflect its manifestations, respectively, formative and reflective indicators. As reflective manifestations, an overall image of the operation, the satisfaction of the user, and a proneness to increase ridership of public transportation are expected. Scales and demographic considerations of the sample are omitted for avoid turning the text too much long. The sample size was calculated based on a similar previous survey in the region. In a scale ranging from 0 to 1, the mean was 0.68 and the standard deviation was 0.21. Considering the same scale and admitting probability of 95 % (z = 1.92) for an error no larger than 0.025 (± 2.5 %), the application of Eq.(1) pointed out n = 272. Rounding up, n = 300 was adopted.

$$n = \frac{\sigma^2 . z_\gamma{}^2}{\varepsilon^2} \tag{1}$$

Scales must have high degrees of unidimensionality; reliability; and content, convergent and discriminant validity (O'Leary-Kelly and Vokurka, 1998). Unidimensionality can be verified by EFA (exploratory factor analysis). Loading factors must be > 0.30 (Hair et al., 2009). Reliability can be tested by Cronbach's alpha (> 0.6) (Hair et al. (2009) and a more robust parameter, the composite reliability (Raykov and Shrout, 2002). Content validity was grounded on previous research and theory. Convergent validity can be verified by t- values of the factors` loadings (> 2.0) (Fornell and Larcker, 1981). Discriminant validity can be verified by the average variance extracted (AVE) of constructs (> 0.5) (Fornell and Larcker, 1981).
EFA was made with the aid of SPSS for Windows by principal component method. KMO measure of sampling adequacy was 0,765 (OK if > 0.5). Bartlett`s sphericity test accepted the sample at a significance level of 0.000. Approximated chi-square is 3737 with a degree of freedom of 406.
Due to unidimensionality, constructs and indicators were rearranged. Due to low load factor, one indicator was removed from the model. Figure 2 shows the screen of the application. Table 2 and 3 show quality criteria and results, respectively. The application ran under Smart-PLS 2.0 (Ringle et al., 2005).

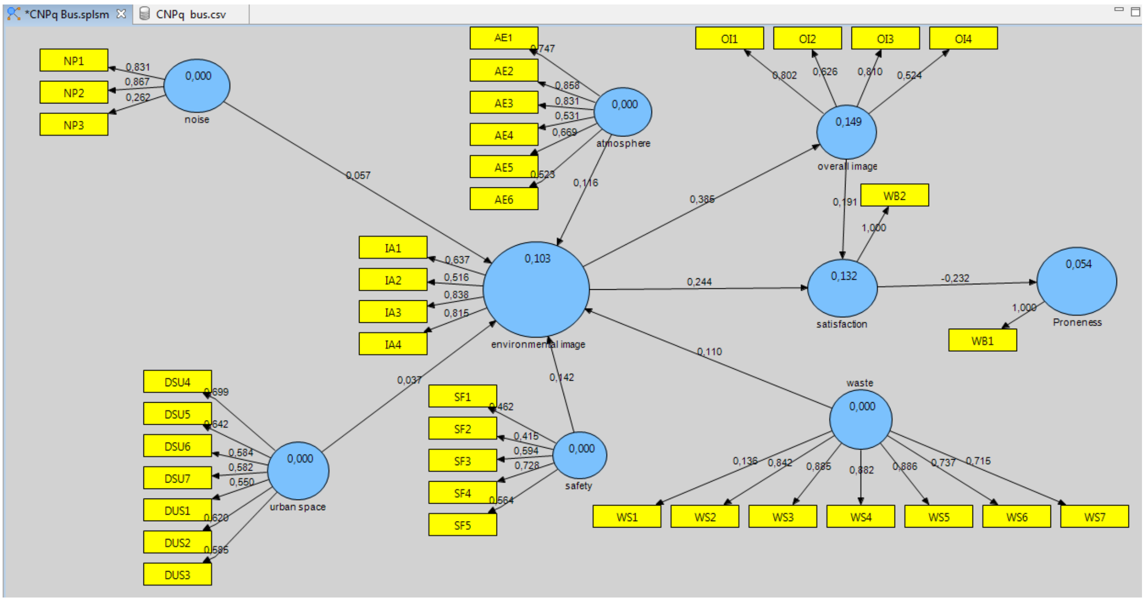

Figure 2: Application according to PLS method

Table 2: Quality criteria of the application according PLS method

construct	AVE	Composite Reliability	R Square	Cronbach´s Alpha
proneness	1.00	1.00	0.053	1.00
atmosphere	0.50	0.85		0.81
environmental image	0.51	0.80	0.103	0.66
noise	0.50	0.72		0.63
overall image	0.49	0.79	0.149	0.67
safety	0.32	0.69		0.45
urban space	0.37	0.81		0.75
waste	0.59	0.90		0.87
satisfaction	1.00	1.00	0.132	1.00

Table 3: Path coefficients according PLS method

	proneness	environmental image	overall image	satisfaction
proneness				
atmosphere		0.115		
environmental image			0.385	0.244
noise		0.057		
overall image				0.191
safety		0.142		
urban space		0.037		
waste		0.110		
satisfaction	-0.232			

4. Conclusion

The study concluded that all constructs rearranged by EFA positively influence in the environmental image of public transportation. The construct with larger influence is safety, followed by atmospheric emissions. Environmental image affects both the overall image of the service and user satisfaction in riding public transportation. A positive environmental image affects user satisfaction more than the overall image of the service. A numerical reasoning can be made based on path coefficients of Table 3.

However, the path coefficient between satisfaction and proneness to abandon the private transport is negative. This path coefficient indicates that, despite the actions of companies and public authorities that contribute to positive environmental and overall image, which turns into user satisfaction, this satisfaction does not turns into willingness to take public transport instead of private. Other factors related to user`s behaviour must be investigated in order to understand why ridership does not grow in the same proportion as the population, although all the efforts made by stakeholders.

The model has some flaws. In some constructs, AVE and Alpha were low. Two indicators had the *t*-scores well below 2. One indicator was removed. As this is a first application of the model, some scales must be reformed or even substituted for future applications, so also a higher R^2 can be reached.

Further research must focus at the improvement of the model.

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