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Assessment and Control of Environmental Performance of Bus Transit Operators: Three Cases in a Mid-Sized City

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The purpose of this article is to present and test a model for the assessment of the environmental performance of bus transit operators. The research method was the qualitative modeling. The model was constructed by experts in environmental management and transport management in a focus group session conducted by researchers. Environmental performance is the measurable results of the environmental management system (EMS) of a business activity, constructed according to the environmental policy of the company, its business objectives and environmental targets. Environmental performance was treated as an intangible variate, structured in latent constructs and indicators. From the assessment process results an overall index ranging between 0 and 100 %. Five constructs were used in the model: atmospheric emissions; effluents; solid waste; urban land use; and use of natural resources. The constructs were prioritized with the aid of Analytic Hierarchy Process (AHP). The meanings of the constructs were apprehended by 33 indicators. The model was tested in three bus transit operations in different areas of a Brazilian city of 1,500,000 inhabitants. Indicators were assessed by scales fulfilled by managers of the operations. The overall results were: operator A = 62.39 %; operator B = 68.02 %; and operator C = 65.30 %. For the three operators, the construct that most contributed to the overall performance to stay away from 100 % was atmospheric emissions. In future actions, management of the companies should focus on the indicators that compose the construct, mainly greenhouse gas (GHG) and black smoke emissions, in order to control the variate and eventually improve the environmental performance. The second prioritization for the operators is land use, mainly damage on pavements and traffic congestion.

1. Introduction

Formal concern with environment is recent in the history of mankind. Recently, public and legal pressures have been observed, mainly regarding environmental impact caused by industrial activities. One of the activities that generate more environmental liabilities is road transport (Sellitto et al., 2011). Transport is the economic sector with fastest growing energy consumption and CO_2 emissions. About 75% of its contributions are caused by road transport (Ajanovic et al., 2012), which has significantly increased the carbon footprint (CFP) of industrial activities (Lam et al., 2009). The problem become even worse in peak-time: the effects of emissions increase more than proportionally with low-speed traffic or congestion (Geerlings et al., 2006). Synthesizing, due to its major environmental impact, greening transportation operations can be important when companies want to make their business greener (Björklund, 2011).
Road transportation activities can be of two types: load or passengers transport. Both occur within cities and between cities. This article focuses more at urban transport of passengers. Urban transport happens within a city and can occur in several ways: (i) point-to-point, when passengers enter at one point and come out in another, paying a single fare; (ii) when the passengers pay a fare and must change to a integrator vehicle prior to arrive at the final destination; and (iii) by elapsed time, when the fare is valid for a period of time, for example, one day or one shift, regardless of the number of trips he or she needs to make (Murray et al., 1998).

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In recent years, there is a growing concern about the large contribution made by road transportation sources to pollution in major cities (McNicol et al., 2001). In the future, electric vehicles probably will be a better solution for the problem. By now, hybrid electric vehicles can provide a less problematic alternative, at least while new reliable technologies are not available. A hybrid electric vehicle has an internal usual combustion engine combined with an electric motor as sources of power (Tzeng et al., 2005). Some mitigation can be expected through technological options, but so far, little progress has been confirmed regarding energy use and CO_2 emissions (Girod et al., 2013).

Chester et al. (2010a) used travel surveys and transportation life-cycle inventories to conclude that, in three USA metropolitan regions, automobiles account for 86–96 % of energy consumption and atmospheric emissions. The research also concluded that the region with the larger share of transit ridership also shows the lowest end-use energy and greenhouse gas (GHG) footprint. The research findings confirm the importance of increasing the use of public transportation systems, instead of private transport.

Carrus et al. (2008) investigated why people have difficulties in abandoning private and adopt public transport. Redman et al. (2013) state that technical attributes of public transport, as reliability and frequency are not sufficient to encourage modal shift from private motor vehicles. Instead, most effective attributes in attracting private transport users are largely affective and connected to individual behaviour, perceptions, motivations and contexts. In a wider sense, Van Wee et al. (2005) state that changes in conceptions, such as a shift from car to public transport or from lorry to train, might influence the overall contribution of transportation activities to environmental quality in cities. Cuenot et al. (2012) assessed expected impacts of modal shifting and compared the results to other possible sources of GHG emissions mitigation. The conclusion reinforces the importance of the modal shifting in urban environment.

One way to evaluate the contribution given by bus transit operations to environmental quality is to measure their environmental performance. Environmental performance can be defined as the visible results of an organization's management of the environmental aspects related to its activities, products or services (Mazzi et al., 2012). In the case of public transportation, interest is focused in services, not physical products. Such measurements or assessments usually demand models based on indicators (Chee Tahir and Darton, 2010). Indicators might be grounded on a suitable conceptual framework that explains and prioritizes relationships within and between constructs, in order to assess the systemic performance as a whole, not locally focused (Myhre et al., 2012). Environmental measurements in a system must include the current situation, as well as the life cycle (De Benedetto and Klemeš, 2008). LCA (Life Cycle Assessment) includes the inventory and the assessment of all the impacts that an activity causes on environment throughout the entire life cycle, including manufacturing, distribution, operation, and final disposal or recycling of scraps and wastes (Alarcon et al., 2011). In transportation activities, the environmental impact of production of fuel, manufacture and technical assistance operations, public facilities maintenance, risk of accidents, transport operation and final disposal might be considered (Barany et al., 2010). Parking facilities might also be included (Chester et al., 2010b).

The purpose of this article is to present a model for assessment of environmental performance of bus transit public operators and describe three cases of application of the model. The research method was the qualitative modelling. In evaluating environmental performance of urban transportation activities, Chester et al. (2010a) consider both vehicle operation and non-operation components, such as the supply chain that serves the vehicle manufacture, roadway maintenance, or infrastructure operation. Our model considers direct operation and the operator-owned infrastructure required for the operation, such as vehicle maintenance and administration, as recommended by Shrake et al. (2013) in evaluating environmental performance in the service industry. Public infrastructure, such as pavement maintenance, street illumination, public goods or public consequences of accidents is considered in another part of the same research. Murray et al. (1998) consider that optimal routing and optimized networks can be expected to contribute to enhanced environmental performance. This optimisation depends mainly on public authorities and social necessities of riders, not only on the bus transit operators, and for this reason it wasn`t considered in the research. In the same way, Alberti (1999) states that urban patterns and urban land use can affect environmental performance. As those factors don`t depend on operators, they also weren`t considered.

2. The model

The model was built in two stages. In the first, by literature review, the researchers proposed a structure of five constructs to explain and as fully as possible comprehend the environmental performance of a bus transit operator. The boxes-within-boxes hierarchy concept was used (Simon, 2002). Accordingly, a complex object can be thought of as a sort of boxes-within-boxes hierarchy with an arbitrary number of

levels. Sub-systems behaviour looks like little boxes inside a big box: although their singularity, little boxes interact themselves, mutually affecting each other. The overall system above can be described in terms of the average behaviour of the subsystems. In such systems, called nearly decomposable, interactions within boxes occur more rapidly than between boxes at the same level. The final behaviour can be obtained aggregating sub-systems behaviour, accordingly some integration rule.
In the second part of the modelling process, four experts gathered in a focus group session conducted by the researchers prioritized the constructs by distributing importance among them. Analytic Hierarchy Process (AHP) was used for the prioritization. AHP gives a vector of priorities, which distributes 100 % among the five constructs, the sub-systems, according to their influence in the environmental performance, the overall system. Multicriterial approaches fit well to describe complex systems like transport operations (Čuček et al., 2012). Finally, the experts defined thirty-three indicators that, as much as possible, can capture the entire meaning of the construct in the bus transit operation. The model, composed by the environmental performance of a bus transit operation (EPBTO, the first level), and five constructs (second level), is presented in Table 1. The main references supporting the constructs are also shown.

Table 1: Assessment model: constructs and references

Overall	Construct	Main references
EPBTO	Atmospheric pollution	Fuglestvedt et al. (2008), Uherek et al. (2010)
	Liquid effluents	Chester et al. (2010a), Sellitto et al. (2012)
	Solid wastes	Mejía-Dugand et al. (2012), Steenberghen and López (2008)
	Land use	Eboli and Mazzulla (2007), Stradling et al. (2007)
	Natural resources use	Tzeng et al (2005), Van Wee et al. (2005)

Table 2 shows the preference matrix, as attributed by experts, the prioritization vector calculated by AHP and the CR, the consistency ratio. As CR < 10 %, the prioritization is valid (Saaty, 1980). The matrix was reorganized according the found priorities.

Table 2: Preference matrix, prioritization and CR

	Atmosphere	Natural Resources	Land Use	Solid Waste	Effluents	Prioritization	CR
Atmosphere	1	1 1/2	2	5	6	39 %	0.29 %
Natural Resources	2/3	1	1 1/2	4	5	29 %	
Land Use	1/2	2/3	1	2	3	18 %	
Solid Waste	1/5	1/4	1/2	1	1 1/2	8 %	
Effluents	1/6	1/5	1/3	2/3	1	6 %	

3. Application

Thirty-three scales were fulfilled in consensus by the body of managers of three companies that provide bus transit operation in a Brazilian city with 1,500,000 inhabitants. The scales used the following distribution of weights for the situation of the indicator: [very good = 1; good = 0.75; neutral = 0.5; bad = 0.25; and very bad = 0]. In the city, the service is provided by fifteen companies, organized in three clusters, operating in a cooperative fashion, with proper rules and common strategy. Each cluster operates in a geographical region: north, south, and east. At west, a river boards the city and there is no operation. One company from each cluster was chosen to fulfil the scales. Similar results are not expected inside the cluster, due to the fact that the number, the age, and the technology of the vehicles, and the management style differ among the companies. So, for a complete overview, in the continuity, all the companies should participate of the research.
Table 3 shows the results. The table shows constructs and importance, indicators and importance (calculated by dividing the importance of the construct by the number of indicators within the construct) and the contribution of the indicator to the total environmental performance of the three bus transit operators. Results are aggregated by construct and totally. Table 4 shows the importance, according AHP, and the gaps of the constructs, i.e., the difference between importance and performance. Table 5 shows performance (perf.) and gaps when uniform distribution among constructs is adopted, instead of AHP.

4. Conclusion

The application concludes about the environmental performance of the three bus transit operators. The use of AHP was helpful in finding a trustable prioritization of actions to control environmental performance.

AHP results are more trustable than uniform distribution results, due to the fact that constructs have different potential to cause environmental damage in the case and AHP can capture those differences. Uniform distribution, instead, equals this potential. Operator B has a slightly higher performance, not only by management issues, but also because the part of the city it serves. In the B area, the streets are flatter, there are more open spaces and trees and the average speed is greater, thus reducing the environmental impact caused by the operator.

Table 3: Assessment model

Construct	Indicators	Importance	Operator A	Operator B	Operator C
Atmosphere	CO_2 emission	5.57 %	1.39 %	2.79 %	2.79 %
39 %	Noise in transit	5.57 %	2.79 %	4.18 %	2.79 %
	Noise at bus stop	5.57 %	1.39 %	2.79 %	1.39 %
	Black smoke in transit	5.57 %	2.79 %	2.79 %	4.18 %
	Black smoke in bus stop	5.57 %	1.39 %	2.79 %	2.79 %
	Climate change	5.57 %	4.18 %	4.18 %	1.39 %
	Oil smell	5.57 %	2.79 %	4.18 %	2.79 %
	subtotal		16.71 %	23.68 %	18.11 %
Natural	Energetic efficiency	4.83 %	2.42 %	4.83 %	3.63 %
resources	Use of water	4.83 %	4.83 %	2.42 %	4.83 %
29 %	Use of electricity	4.83 %	3.63 %	3.63 %	4.83 %
	Recycling of parts	4.83 %	2.42 %	3.63 %	2.42 %
	Use of lubricating oil	4.83 %	3.63 %	3.63 %	4.83 %
	Use of greases	4.83 %	4.83 %	4.83 %	3.63 %
	subtotal		21.75 %	22.96 %	24.17 %
Land use	Damage on pavement	2.57 %	1.29 %	1.29 %	1.29 %
18%	Damage on urban elements	2.57 %	1.93 %	1.93 %	1.93 %
	Congestion	2.57 %	1.29 %	1.93 %	1.93 %
	Dust generation	2.57 %	2.57 %	1.29 %	1.93 %
	Vibration	2.57 %	1.93 %	1.93 %	1.93 %
	Bus stops and urban nature	2.57 %	1.93 %	1.29 %	1.93 %
	Bus stops and urban landscape	2.57 %	1.29 %	1.93 %	1.29 %
	subtotal		12.21 %	11.57 %	12.21 %
Solid waste	Scrap tyres	1.33 %	1.33 %	1.33 %	1.33 %
8 %	Scrap batteries	1.33 %	1.33 %	1.33 %	1.33 %
	Office materials recycling	1.33 %	1.33 %	0.33 %	0.67 %
	Maintenance wastes	1.33 %	1.00 %	0.67 %	0.67 %
	Auto-parts wastes	1.33 %	1.00 %	0.67 %	1.00 %
	Passengers wastes	1.33 %	1.00 %	0.33 %	0.67 %
	Subtotal		7.00 %	4.67 %	5.67 %
Effluents	Fuel supply	0.86 %	0.86 %	0.86 %	0.86 %
6 %	Oil waste	0.86 %	0.86 %	0.86 %	0.86 %
	Grease waste	0.86 %	0.86 %	0.86 %	0.86 %
	Battery acid waste	0.86 %	0.86 %	0.86 %	0.86 %
	Sewage liquids	0.86 %	0.43 %	0.43 %	0.43 %
	Washing water effluent	0.86 %	0.43 %	0.64 %	0.64 %
	Buildings water effluent	0.86 %	0.43 %	0.64 %	0.64 %
	Subtotal		4.71 %	5.14 %	5.14 %
Total		100 %	62.39 %	68.02 %	65.30 %

Table 4: Gaps of the constructs according AHP

Construct	Importance	Gaps A	Gaps B	Gaps C
Atmospheric Emissions	39.00 %	22.29 %	15.32 %	20.89 %
Natural Resources	29.00 %	7.25 %	6.04 %	4.83 %
Land Use	18.00 %	5.79 %	6.43 %	5.79 %
Solid Waste	8.00 %	1.00 %	3.33 %	2.33 %
Effluents	6.00 %	1.29 %	0.86 %	0.86 %
Total	100.00 %	37.61 %	31.98 %	34.70 %

Table 5: Results and gaps with uniform distribution of importance instead of AHP

Construct	Perf. A	Perf. B	Perf. C	gaps A	gaps B	gaps C
Atmospheric Emissions	8.57 %	12.14 %	9.29 %	11.43 %	7.86 %	10.71 %
Natural Resources	15.00 %	15.83 %	16.67 %	5.00 %	4.17 %	3.33 %
Land Use	13.57 %	12.86 %	13.57 %	6.43 %	7.14 %	6.43 %
Solid Waste	17.50 %	11.67 %	14.17 %	2.50 %	8.33 %	5.83 %
Effluents	15.71 %	17.14 %	17.14 %	4.29 %	2.86 %	2.86 %
Total	70.36 %	69.64 %	70.83 %	29.64 %	30.36 %	29.17 %

All companies are controlled by the same environmental and transit official agencies and are subjected to the same rules. Moreover, the difficulties of the companies are similar, mainly due to the level of technology that the companies can buy. Due to limited revenues, sometimes, the industry may have some difficulties in making high-technology investments. The social role of the activity is considered by public authorities. Some types of passengers, such as senior citizens above 60 years, people with disabilities, students, people with serious illnesses, have some sort of benefit: exemption or reduction in the fare.

According to the model, the priority for performance control is atmospheric emissions. The result is not surprising, given that the construct was considered as the most important by the proposers of the model. Within the construct, the most problematic indicators are CO_2 emission and Black Smoke emission. The amount of CO_2 is proportional to the amount of fuel consumed in the journey. This amount can be reduced by use of alternative fuels or by reducing the network served by the operator. Both are difficult to achieve. A more viable alternative is to improve efficiency of engines by the use of on-board computers, to track the trip and help driver. Black smoke is composed essentially of soot particles loaded with toxic substances and derives from the persistent use of out-of-date projected or unregulated engines. The alternative is the reduction of the network covered by the operator, which is very difficult to achieve, due to the social role of the service. Another alternative is the gradual upgrade of the engines or at least more rigorous and systematic predictive maintenance practices, including the use of opacimeters.

Further research must consider the totality of actions associated with prioritized indicators and the survey must be extended to the fifteen operators providing bus transit service in the city. Although similarities are expected, similar results are not expected. So, a full survey is necessary to a fully evaluation.

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