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Ecosocioeconomics and logistics of urban delivery: Sustainability indicators

Ecosocioeconomics e logística de entrega urbana: indicadores de sustentabilidade

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ABSTRACT:

The aim of this work is to investigate the logistics of urban light weight delivery by assessing sustainability indicators. To this purpose, a case study in the city of Curitiba, Brazil, was chosen. City planning demands alternative solutions to everyday problems, among which use of urban space and mobility are relevant due to fast and rather chaotic growing. Urban mobility −a complex network comprising

RESUMO:

O objetivo deste trabalho foi investigar a logística urbana de entrega por meio da avaliação de indicadores de sustentabilidade. Foi realizado, um estudo de caso na cidade de Curitiba, no Brasil. O planejamento urbano exige soluções alternativas para os problemas diários, entre os quais o uso do espaço urbano e mobilidade são relevantes devido ao crescimento rápido e bastante caótico. A

a variety of actors and areas; has social, economic and environmental impacts that might be underestimated in planning and implementation of actions. In the present research, two light weight deliveries actually used in Curitiba were compared: motorbikes and bicycles. The analysis is based on the methodology using the principles of the eco-socio-economy of organizations. This approach considers the complexity of subsystems linked, and the effectiveness beyond the organization but on the social demands in the urban territory. The use of bicycles was studied using data from EcoBike, an experience from the eco-socio-economy (ecosocioeconomics, ie, experiences that have effective learning for sustainable development) Ecobike was analyzed here and compared to the generic case of deliveries by motorbikes. Indicators for accidents (with and without death), fossil energy used, CO2 emissions, and operative costs were considered. Results: All sustainability indicators assessed favor the use of bicycles (as the case study of Ecobike) over motorbikes.
Keywords: bicycles, motorbikes, social sustainability.

mobilidade urbana compreende uma variedade de atores e áreas; tem impactos sociais, econômicos e ambientais que podem ser subestimados no planejamento e implementação de ações. A análise baseia-se na metodologia utilizando os princípios do eco-sócio-economico das organizações. Esta abordagem considera a complexidade dos subsistemas associados, bem como a eficácia além da organização, mas sobre as demandas sociais no território urbano. O uso de bicicletas foi estudado usando dados de Ecobike, uma experiência do eco-economia-sócio (ecosocioeconomics, ou seja, as experiências que têm uma aprendizagem eficaz para o desenvolvimento sustentável) Ecobike foi analisado aqui e em comparação com o caso genérico de partos por motos. Indicadores de acidentes (com e sem morte), energia fóssil utilizada, de emissões de CO2, e os custos operacionais foram considerados. Todos os indicadores de sustentabilidade avaliados favoreceu o uso de bicicletas (como o estudo de caso da Ecobike) sobre motos.
Palavras-Chave: Bicicletas, Motos, Sustentabilidade Social.

1. Introduction

Modern cities are the origin and end-point of most goods' deliveries. Thus, urban planning and mobility should find solutions for this problem.

In order to achieve sustainability of delivery systems, urban planning deals with regional problems with particular characteristics, according to socioeconomics and political realities. Therefore, based on current knowledge, alternative solutions covering simultaneously an array of ecological, social and economical issues are desirable. This approach considers the complexity of subsystems linked, and the effectiveness beyond the organization but on the social demands in the urban territory (Sampaio et al,2009; Sampaio, 2009).

2. Urban logistics

The last 50 years have seen significant changes in populations in Brazil, which has been mainly transformed from rural to urban with estimated 82% of settlements in urban areas. The development of transport and the infrastructure associated with are drivers of change of urban patterns and lifestyles (Dutra, 2004).

Ogden (1994) defines urban delivery of goods as "movement of goods, not people, towards, from, through and into urban areas". Urban logistics is then a set of coordinated actions between private and public stakeholders focusing on improving the delivery of goods and services in urban areas (Franca, Rubin, 2005).

The parcel service is growing following the globalization of the economy and the commercialization via internet (Dutra, 2004; Silva et al 2012; Silva et al 2013a; Silva et al 2013b). Thus, there is a need to permanently develop new strategies to satisfy customers localized in urban areas. The last portion of the delivery logistic, known as "the last mile", is considered the most expensive, inefficient, and contaminating relative to longer distance transport. Since the parcels are low weight and volume but occur in large quantities, it is complex portion of logistics with difficulties to adapt new techniques and modes of operation to satisfy urban clients (Gevaers et al, 2011).

The increasing number of deliveries with smaller sizes suggests the promotion in the use of lighter vehicles as motorcycles and bicycles. This last option even has advantages for traffic and urban pollution. At present, an increasing number of the so called "bike messengers" is seen in cities worldwide, even in those which traditionally did not have preferences for the use of bicycles. These deliveries transport small volumes and correspondence within city limits. The Netherlands, Denmark, and Germany are examples of countries where bicycles are common in urban transport. For instance, in The Netherlands, 30% of all urban small parcels are delivered by bicycles, in contrast to only 1% in US cities (Brown, 2003).

In addition, the increasing use of the motorcycle as a light delivery vehicle responds to the need of fast and reduced price service, due to lower costs compared to vans or cars.

However, motorcycle accidents have been increasing dramatically, with significant mortality in Brazil. In developed countries, for example Norway, Sweden, Denmark, Finland, The Netherlands, UK, Australia and the USA, mortality by motorcycle accidents has been decreasing. On the contrary, in developing countries the rate of accidents and mortality has been either increasing or staying constant (Elvik , 2010).

In spite of having advantages for health and the environment, bicycles as a means of transport also carries risks and rates of traffic accidents and mortality are significant, especially in children and younger adults (Bacchieri et al, 2005).

In Brazil, studies on traffic accidents pointed out to underestimation rates of accidents by motorcycles and bicycles when used for delivery transportation. Data should be then carefully analyzed not to underestimate number of victims.

Due to the aforementioned, a trade-off between sustainability and economical development should be considered for the complex issue of light delivery transport in cities.

3. Research

We focus on the city of Curitiba (Capital of Paraná's State), which, starting in the 1970s, has become an example of a modern city including urban solutions with creativity and

innovation. The media has portrayed Curitiba as an ecological, model capital city, with high quality of life as a consequence of proper urban planning.

In this context, urban planning is challenged to be an instrument for promoting at development as well as the protection of the environment at the same time. For instance, in this century mitigation and adaptation to climate change is one of the major challenges.

The aim of the present work is to investigate urban logistics by analysing sustainability indicators through an experience of ecosocioeconomics in an urban environment, located in the city of Curitiba.

Thus, the present study is based on the principles of ecosocioeconomics for organizations (SAMPAIO, 2009). This is a framework for subsystems management including indicators that are beyond immediate results but intend to reach effectiveness outside the organization and in the social dimension of the urban territory.

3.1 Methodology

Data on motorcycling and bicycling delivery transport for the city of Curitiba, State of Paraná, Brazil, was obtained in order to investigate and compare both means of transportation. Data related to criteria to assess transport sustainability were chosen to be: traffic accidents and mortality; atmospheric pollution; investment; operational cost, and vehicle cost.

Data from public and private sources were complemented by interviews with delivery enterprises during 2013/2014, to assess the sustainability of urban logistics based on motorcycles or bicycles.

3.2 Data sources

The National Traffic Authority of Brazil (Denatram, 2013), reported that in 2013 Curitiba had 128,882 motorcycles registered, being 13.4% of the total vehicle fleet. So far, data on number of bicycles in the city is not known.

The number of motorcycles registered for delivery is not accurate due to the informal portion of the activities. According to the union of drivers workers of motorcycles, SINTRAMOTOS (2013), a significant number of vehicles are owned by drivers/workers and do not have registration. The union informed that, in 2013, they estimated between 12,000 to 14,000 motorcycles daily working on delivery, though only 4,000 were registered. The same union, SINTRAMOTOS (2013), also registered bicycles dedicated to city delivery; however they had no statistics yet and the informality might be even larger than for motorcycles.

It would be useful to have the number of deliveries to compare to the number of motorcycles and bicycles driven. SINTRAMOTOS (2013) reported that it is impossible to assess this parameter, as the informality is much larger than formality and most deliveries are not registered. Besides, a trip may involve several deliveries and that is not recorded. Software technology would facilitate gathering information if all companies would register their activities, but this is not the case at the moment in

Curitiba. On the other hand, companies that register the activity were not willing to bring that detailed information. In an interview with the bikers association Ciclo Iguaçu (2013), they empirically estimated that 3% of all light deliveries in Curitiba are done by bicycles. However, the estimate may not be accurate.

On the other hand, an interview with the enterprise Ecobike (2013) gave details on city roads and traffic issues related to bicycle use. Ecobike informed that they do not generally use bike lanes for deliveries, but prefer to go on normal streets shared with automobiles. This choice was justified by the following: (I) there are no bike lanes all over the city; (II) bike lanes are not interconnected; (III) existing bike lanes are mostly not located in central areas or in areas of major demands; (IV) the road conditions of bike lanes is not always good and compares badly to automobile streets.

Curitiba has a temperate subtropical climate with generally mild winters, though some periods may include significant rain and temperatures as low as 2ºC. Questioned on limitations by weather conditions, delivery bikers reported that when well equipped winter weather is not a limitation.

Both type of enterprises, motorcycle- and bicycle-based, informed quite precisely the average distance driven by an individual vehicle, and the number of workers in activity. Therefore, we will use below the ratio of driven km per worker as a quantitative indicator of the activity.

Data on the incidence of traffic accidents in the city were obtained from the Fire Department of the State of Paraná, who has a record of street assistance to all kind of accidents, and are in charge of vehicle-involved accidents. The headquarters in Curitiba has registered all events with date, place, vehicles and persons involved, and it is accessible online (Fireman, 2014).

4. Results

4.1 Motorcycle and bicycle accidents

Table 1 depicts the number of accidents involving motorcycles and/or bicycles, as reported for 2013 by the Fire Department (Fireman, 2014) for the city of Curitiba and the State of Paraná, respectively. It can be observed that the number of accidents with motorcycles is much larger than with bicycles, and the Fire Department also reported that the former are more violent. The causes for the difference were explained as: (I) larger number of motorcycles; (II) the higher the speed the more serious the consequences; (III) motorcycle drivers are generally less careful than bikers.

Table 1 have all data to assess the portion of accidents whether in the city of Curitiba or in the State of Paraná, and for bicycles or motorcycles, respectively. It is striking that the majority of accidents involve either one of the light vehicles which are studies here for deliveries. For instance, (I) 57.2% of total accidents in the city include a motorcycle or a bicycle, while this proportion is 63% for the whole State of Paraná; (II) in the city, bicycles are involved in 9% of the total accidents reported, while motorcycles in 48.8%; (III) bicycles in the city involved 7.2% of the bicycle accidents in the whole state, while motorcycles in the city accounted for 8.7% of all motorcycle accidents in the state; and

(IV) in the city there were 5.4 times more accidents with motorcycles than with bicycles, which in the whole state there were 4.5 times more.

Table 1: Number of accidents involving motorcycles and bicycles during 2013.

Type of accident	City of Curitiba	State of Paraná
Car-bicycle accident	169	2,065
Car-motorcycle accident	1,573	16,791
Bicycle-bicycle accident	4	72
Truck-bicycle accident	9	156
Truck-motorcycle accident	88	933
Motorcycle-bicycle accident	30	705
Motorcycle-motorcycle accident	85	1,517
Bus-bicycle accident	9	91
Bus-motorcycle accident	34	318
Bicycle alone accident	218	3.006
Motorcycle alone accident	578	7.157
Total accidents in motorcycle and bicycle	2,797	32,811
Total accidents in all vehicles	4,892	52,119

In Brazil, the motorcycle fleet is steadily increasing. According to the Observatório das Metrópoles from the Universidade Federal do Rio de Janeiro (IPPUR, 2014), the number of motorcycles in Brazil rose 349% between 2001 and 2012, and in the same period in Curitiba the increase was 291%. In the State of Paraná there are currently 1,264,000 motorcycles, of which 128,882 were registered in Curitiba. In the larger State of São Paulo 4,700,000 motorcycles were registered. It is interesting to know an indicator from insurance companies. For the whole State of Paraná, insurance companies reported that 29% of compensations given to families due to vehicles' accidents in 2013 were for motorcycles. In the State of São Paulo, as much as 31% of compensations for traffic accidents were given to motorcycles. These striking figures are in agreement with data from Table 1.

4.2 Surveyed delivery companies

In Tables 2 the interviews of two companies dedicated to city delivery are depicted; one exclusively using motorcycles and the other using only bicycles. Both enterprises are based in the city of Curitiba.

The company using motorcycles has been in business longer than the bicycle one, and it has a significant larger size with 150 employees. Connecting to the previous section

note the number of 12 accidents per year reported in the interview. There is a difference in load capacity between both delivery means; however the distance travel per day is not as significantly different. This may be due to deliveries in central locations that do not involve large distance each. Both companies reported small number of employees assisting special training courses (10% for motorcycles and 16% for bicycles). It is relevant to note the difference in maintenance requirement between both means of delivering.

Table 2: Questionnaire delivery companies

	Curitiba, Paraná, Brazil	
Name of company	EcoBike Bicycle delivery	Company Motoboy Motorcycle delivery
City and State	Curitiba, Paraná	Curitiba, Paraná
Contact person	CEO	CEO
In business since	2.5 years	12 years
# Registered employees	18	150
# Employees attending special skills course	3	Around 15
Maximum load delivered	8 - 15 kg	20 kg
Maximum distance delivered	15 km	Within city and suburbs
Delivery time	Up to 1 hour	Around 40 min
Accidents	Only 1 in 2.5 years in business	Around 12 accidents per year
Major and minor maintenance	Minor weekly	Bimonthly large repair, weekly oil change
Cost of maintenance	R$ 75 per month	R$ 100 per mnth
Average daily distance traveled	km per day	120 km per day

4.3 Combustion emissions to air

In Brazil, legislation directed to limit emissions in motorcycles was first passed in 2002. The program was named "Programa de Controle da Poluição do Ar por Motociclos e Veículos Similares – PROMOT" (Program to control air pollution in motorcycles and similar vehicles), and was set by Resolution #297/2002 do CONAMA (IBAMA 17/2002; and later CONAMA 342/2003). This established limits similar to Euro I and was based on early directives of the European Union (97/24/EC). Afterwards, the legislation was updated and the latest from 2009 reached level Euro III. At present, maximum emissions of carbon monoxide (CO) cannot exceed 2.0 g/km, free hydrocarbons were limited to 0.8 g/km, and nitrogen oxides (NOx) limited to less than 0.15 g/km.

Table 3 depicts parameters for the use of a 125c.c. motorcycle model Fan, compared to a bicycle Caloi intended for delivery, both manufactured in Brazil. Emission data for carbon monoxide (CO), Hydrocarbons, and NOx were taken from the manufacturers manual, and they should be therefore considered valid for a new motorcycle. As shown, all emissions are well below the stated by the Brazilian regulation. CO2 emissions are based on fuel consumption of 1 litre gasoline per 35 km distance, and the emission factors were obtained from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Direct CO2 emissions assumed 10% addition to account for gasoline refinery and delivery to local gas stations, resulting in 76 gCO2 /km. This result was obtained from Table 3.2.1 of IPCC (2006) and from Table A3.8 of IEA (2005). Emissions of nitrous oxide (N2O) and methane (CH4) were obtained from Table 3.2.3 from IPCC (2006), which add

Table 3: Characteristics, cost, and emissions for light delivery vehicles. The motorcycle corresponds to a 125c.c. Fan model, and the bicycle brand Caloi

	Motorcycle	Bicycle
Delivery load capacity	20 kg	8 kg
Distance driven with 1 litre gasoline	35 km	Does not use fuel
Cost to drive 1 km, in Brazilian currency Real$ (R$ 3,00/litre)	R$ 0.085	
Fuel cost to drive 100 km	R$ 8.75	
CO emissions	0.648 g/km	
CO emissions during 1 day activity, estimated 100 km	64.80 g/km	
Hydrocarbon emissions	0.189g/km	
Hydrocarbon	18.90 g/km	

emissions during 1 day activity, estimated 100 km		
NOx emissions	0.074 g/km	
NOx emissions during 1 day activity, estimated 100 km	7.40 g/km	
CO2 emissions	78.5 gCO2eq./km	
CO2 emissions during 1 day activity, estimated 100 km	7.85 kgCO2eq.	
Cost to buy vehicle	R$ 5,600	R$ 800
Cost of security equipment	R$ 150	R$ 320
Cost for maintenance, monthly	R$ 150	R$ 38

1.2 gCO_2 eq./km for N_2O, and 1.3 gCO_2 eq./km for CH_4. The CO_2 equivalent was calculated using 300 gCO_2eq./g N_2O emitted and 25 gCO_2eq./g CH4 emitted. These global warming potentials are the standard considered for a 100-year period (IPCC, 2006). Thus, total GHG emissions per km are estimated to 78.5 gCO_2eq. In an average working day driving 100 km, a motorcycle produces GHG emissions of nearly 8 $kgCO_2$eq., which are saved if a bicycle were otherwise used.

5. Discussion and conclusions

The results are clearly depicted in the tables above, and the reader can extend further the discussion that for space reasons will be short here.

A note on the limitations to assess accidents data to the delivery activity is in order. As mentioned above, the informality of the delivery business in the city of Curitiba and the State of Paraná has not allowed identifying the number of motorcycles and/or bicycles actually used in delivery. Thus, data in Table 1 are important and give a general idea but do not discriminate the diversity of activities to which light vehicles were used at the moment of the accidents.

Regarding the externalities related to social issues, we may assume that the traffic accidents occurred are indicators of life quality, and, as seen, accidents involving motorcycle are more numerous than for bicycles.

As mentioned, knowing that in 2012 there were 128,882 motorcycles registered in Curitiba (13% of the city's total vehicle fleet), and assuming that 12,000 are dedicated to delivery (4,000 registered but the more realistic figure of 12,000 was explained above), then around 10% of motorcycles can be estimated to be employed in delivery. From

Table 1, 2388 accidents in the city were ascribed to motorcycle, and therefore 240 accidents per year can be estimated to be involved in delivery by motorcycles.

Using the information from the bikers union (Ciclo Iguaçu, 2014) explained above, an estimate 3% of all deliveries were done by bicycle. Assuming as before 12,000 deliveries done by motorcycles, we have an estimation of 360 deliveries by bicycle, which represents a ratio motorcycle to bicycle of 33 times. Since the ratio of accidents in the total use of motorcycles vs. bicycles in Curitiba was 5.4 times (see paragraph below Table 1), it is concluded that delivery by bicycle may involve much less accidents than delivery by motorcycles. This is in agreement with comments from the fire department (FIREMAN, 2014), given above, regarding the more violent collisions occurring with motorcycles related to their speed.

From Table 3, the cost of a bicycle dedicated to delivery is 14% of that of a motorcycle. Besides this benefit, the maintenance of the bicycle is 25% of that of the motorcycle, which amounts to R$ 1,800, a significant sum compared to the Brazilian gross minimum wage of R$ 724.

As seen in Table 3, the operational cost carries also the cost for fuel of R$ 8.75 daily, which in a year implies R$ 3,194. This amount is very significant and accounts annually for 57% of the cost of the vehicle. Adding fuel and maintenance for the motorcycle, operational costs are above the cost of the vehicle in only 13 months. Therefore, it can be assume the economical effectiveness of bicycles for city delivery businesses.

In spite of these advantages for bicycles there are also disadvantage indicators. One is the limited load to 8 kg compared to 20 kg by motorcycles, and the other is the high cost of the safety equipment, that should be added to the cost of bicycles, which is R$ 150 against R$38 for motorcycles (see Table 3).

Finally, the environmental account presents advantages for the use of the bicycle due to emissions to air from fossil fuels needed in the motorcycle.

We thus conclude that delivery transport by bicycles is a logistic practice with several advantages, especially considering the trade-off between economical development, environment and social issues. The indicators analysed in this work showed that this means of delivery reaches better extra organizational effectiveness to satisfy social demands in the urban territory.

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