Quantifying of the economic and environmental impacts deriving from Brazilian's highways state of conservation

Daniela Bacchi Bartholomeu[1]
José Vicente Caixeta Filho[2]

ABSTRACT

Due to the importance of the road transportation for the Brazilian economy related to its participation in the matrix of load transport, to its high share in the fossil fuels consumption (diesel) and in the CO_2 emissions, this study evaluated if highways in better state of conservation imply in economic and environmental benefits. The economic benefits were related to the evaluation of the following parameters: fuel consumption, duration of the trip and expenses on vehicle maintenance. The environmental benefits were related to the CO_2 emissions reduction. They were collected primary data related to the performance observed in trucks (Volvo FH12 truck, manufactured in 2004), during a total of 48 trips along highways with different infrastructure conditions. The results showed the existence of economic and environmental benefits deriving from trips in routes with better infrastructure and a gain in energy efficiency, resulting in less fuel consumption and lower levels of CO_2 emissions.

Keywords: Road load transportation; Economic benefits; Environmental benefits; CO_2 emissions

Primary Topic: Transportation Sector Modeling
Secondary Topic: Climate Change, Kyoto and Post-Kyoto Issues

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[1] Ph.D in Applied Economics and Researcher at CEPEA - ESALQ/USP, Brazil. Email: dbbartho@esalq.usp.br.

[2] Professor – Department of Economics, Management and Sociology - ESALQ/USP, Brazil. Email: jvcaixet@esalq.usp.br.

1 INTRODUCTION

The road transport model presents some positive characteristics, such as flexibility, availability and velocity. By the other hand, there is also a series of limitations when compared to alternative models: lower productivity and energetic efficiency, higher levels of pollutant emissions and lower indexes of safety.

In Brazil, the road model accounted for more than 60% of the total amount transported along the 1990's. Unfortunatly, in Brazil there isn't a sufficient supply of infra-structure for the road transport, in terms of extension as well as in terms of quality of roads. Consequently, the poor conservation of roads impacts negatively on the economy, and generates an "anti-economy" process, that is, investments in maintenance services neglected at the adequate time result in increases of future expenses on reworks and on additional costs for the road users.

The heavy dependency of road transport on fossil fuels turns this type of transport into an important energy consumer. From 1996 on, the entire number of trucks sold in the domestic market ran on diesel. As a consequence, the sub sector "transport" accounted for roughly 40% of CO_2 emissions of the "energy" sector in Brazil in 1994, according to Comunicação Nacional (BRASIL, 2004), being the road model responsible for almost 90% of this total.

This scenario underscores the importance to seek for option to reduce the consumption of fossil fuels by the road model, lowering, consequently, its share in the Brazilian emissions of CO_2 and of the Brazilians emissions as a whole. The search for alternatives which result in energy saving generates positive multiplying effects, through the reduction of dependency on fossil fuels and of CO_2 emissions.

Considering that after the commitment period of the Kyoto Protocol (from 2008 to 2012) the emissions reduction targets for countries have not been defined yet, it is crucial to Brazil to identify and analyze the possibilities to mitigate its emissions.

The aim of this paper is to quantify and value the economics and environmental impact due to diferents road conservation conditions. The considered economic parameters were related to the fuel consumption, to the time of trip and to maintenance expense of the vehicle in the studied routes. The environmental parameter is the carbon dioxide emission. Therefore, it is expected to individuate alternatives to obtain higher energetic efficiency, supporting practices for sustainable transport.

2 THE ROAD TRANSPORT IN BRAZIL

In 2004, the road model represented 61.1% of the national load transport matrix, moving 485 billions of tons per kilometer – TKU; the rail model had a share of 20.7% and the river model 13.6%. The remaining models accounted for 4.6% of the transport matrix (CONFEDERAÇÃO NACIONAL DOS TRANSPORTES - CNT, 2005b). According to CNT (2005b), in 2004, roughly 665 millions of tons were transported on the roads.

The excessive dependency of the Brazilian transport on the road model is clear when it is studied the share of this model in the transport matrix in other countries of large continental dimensions. In the United States, the road share in the load transport represents 26%; in Australia it is 24%, and in China, it accounts only for 8% (CEL; CNT, 2002).

As a consequence of this heavy dependency, the transport productivity in Brazil is 22% lower than that of USA, the energetic consumption is 29% higher than that of the USA, and the emission of pollutants, measured in grams of carbon monoxide released per ton/kilometer of transport production, is 2.6 times higher than that of the USA (CEL; CNT, 2002).

Besides these distortions, the insufficient supply of transport infra-structure, in terms of extension as well as in terms of quality of the roads, has a negative impact on the model performance. As for extension, considering as basis the availability factor, measured as "total road kilometers per territorial space (in km^2)", the supply of roads in Brazil is equivalent to 69% of that from China; 55% of that from Canada; 45% of that of Mexico, and 6% of that from the USA (CEL; CNT, 2002).

Brazil has 1.6 millions of road kilometers, out of each only 196 thousand kilometers (or 12% of the total) are paved. The non-paved parcel (1.4 millions of kilometers), 90.7% are municipal roads; 8.3% state and 1% federal (CNT, 2005b).

According to CNT (2005a)[3], 54.6% of the roads extension are found in "Deficient", or "Poor" or "Terrible" state of conservation (Table 1).

Table 1 – Pavement conditions of Brazilian Roads (2005)

Pavement	Total Extension		State Management		Outsourced Management	
	km	%	km	%	km	%
Optmal	26,295	32.1	17,592	24.6	8,703	82.9
Good	10,916	13.3	10,070	14.1	846	8.1
Deffcient	24,551	30.0	23,875	33.4	676	6.4
Bad	14,029	17.1	13,757	19.3	272	2.6
Terrible	6,153	7.5	6,153	8.6	-	-
Total	81,944	100.0	71,447	100.0	10,497	100.0

Source: CNT (2005a)

It is important to point out the qualitative unbalance of the regions. In the comparative analysis of the general condition of the roads researched on in 2005, the Northeast shows around 31.2% if its roads extension in terrible state of conservation, while in the South, this percentage drops down to 4.1%. These numbers rank the Northeast as the number one region with roads in the worst state of conservation, a fact that hinders its development as well as the possibilities of a more effective economic integration with the other regions of the country.

The poor state of road conservation has a direct impact on the economy. Reports of the Economic Commission for Latin America – CEPAL and of World Bank estimate that the bad road infra-structure in Latin America is linked to damages to the tune of 2% of the GDP (IRF and GTZ[4], 1996 apud SENNA et al., 1998).

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[3] The tenth issue of the Road Research CNT assessed 100% of the paved federal road system, the main routes are under state management, besides roads under management of concessionaires in all states of the country, totaling 81.944 kilometers.

[4] International Road Federation – IRF; Deutusche Gesellschaft Für Technische Zusammenarbeit - GTZ. Concessiones en Argentina. **Reforma**: Conservação Vial, Santiago de Chile, n. 1, Jul. 1996.

According to Lee, 1996 apud Senna et al. (1998, p. 76), the delay of the necessary investments to minimize the needs of the sector generates an anti-economy process, in which for each dollar saved in conservation services at appropriate moment, results in an increase of around three dollars in future expenses with reworks and additional costs of operation of up to three dollars for road users.

A degraded road represents an increase of 58% in the consumption of fossil fuels; of 38% in vehicle maintenance costs; of 50% in the number of accidents and up to 100% in the time spent on the trips (Magazine CNT, 2001, p. 1).

As documented by Lima (2006), in Brazil, the diesel accounted for 16.8% of the total cost of a truck in 1996, increasing its participation to 31.8% in 2004. According to this study, around 55% of all diesel consumed in Brazil in 2004 was destined to road transport, which means 21.7 billion liters and $32.3 billion Reals.

The dependency of the heavy-vehicle fleet on fossil fuels highlights the relevant position that road transport takes in terms of CO_2 emissions. From 1996, diesel is the fuel that represents the entire truck sales in Brazil[5].

The brazilian truck fleet registered at the National Registration of Road Transport - RNTRC until June 2006 had reached 1.5 million vehicles (ANTT, 2006).

3 ENERGY CONSUMPTION AND CO_2 EMISSIONS IN BRAZIL

In Brazil, as well as in worldwide terms, transport is responsible for a large part of consumption of petroleum derivates and it has shown a growing tendency compared to other productive sectors.

In 2004, total energy consumption in Brazil was 191.1 millions of tep; petroleum derivates were accounted for almost 50% of this consumption and diesel was accounted for 17% of the total energy consumption. The diesel consumption increased 37% between 1994 and 2004, reaching 32.6 millions of tep (BRASIL, 2005).

Within the transport sector, the road model accounted for 27% of the total energy consumption in Brazil in 2004 and for 92% of the final energy consumption of the transport sector. Between 1994 and 2004, the increase of energy consumption by the road model was 39.2%, reaching a consumption of 47.3 billions of tep.

It should be highlighted the dependency of the sector in relation to petroleum derivates. In 2004, the transport accounted for more than 60% of the total consumption of petroleum derivates, followed by energetic sector (16%).

According to BEN (Brasil, 2005), the energy consumption of road transport increased from $34,025 \times 10^3$ tep in 1994 to $47,370 \times 10^3$ tep in 2004, that is, an increase of 39.2% in the period. Diesel oil was the energy source most consumed, accounting for roughly 52% of the total. The growth rate of diesel consumption in the period was 42.4%.

Finally, the transport sector has been increasing the diesel oil consumption along the years, resulting basically from the consumption of the road model, which accounts for 92% of the diesel consumption of the sector.

As for CO_2 emissions, the sub-sector “transport” alone accounted for 40% of the CO_2 emissions of the energy sector and for 9% of the total carbon dioxide emissions in Brazil in 1994. The road model accounted for almost 90% of the emissions of the transport sub-sector.

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[5] In the year 2000 alone, sales of trucks that run on gasoline reached the number of 117.

Besides that, the road model showed a higher emission increase between 1990 and 1994 (around 17%), outnumbering the average growth rate for the transport sector (15%); on the other hand, the amount released by the rail model dropped by 21%.

Therefore, in spite of the transport sector being the second largest energy consumer, it is the number one in CO_2 emissions as a result of the high participation of fossil fuels as energy source. Once the deforestation and burning rates tend to lower along the years, it is to verify an increase of the relative participation of transport in the Brazilian carbon dioxide emissions.

4 MATERIAL AND METHODS

4.1 Primary data collecting

The required data were collected from the carrying out of measurement trials, through the following up of trips in trucks equipped with on-board computers. The installation of the on-board computer *(Blue Bird)* in the trucks, the data collecting, the process of decodifying the results and the submission of data obtained on the trips remained under the responsibility of Netz Engenharia[6].

The *Blue Bird* supplies information about the trip performance (such as average speed, maximum speed, percentage of time the driver remained above the speed limit, among other), important to establish a reference of the data directly obtained for each trip (such as trip duration, fuel consumption, load weight, among others).

As a whole, it was carried out 48 trips by Volvo FH12 trucks (manufacturated on 2004) in 4 distinct routes classified according to the pavement state of conservation, taking as a basis the results from the Road Research (CNT, 2005), as shown in Table 2.

Table 2 – Classification of routes studied

Route	% Excelent or Good[a]	Classification[b]	N° Vehicle	Travel/ Vehicle	Total Travel	Travel Period
(a) Cubatão – Campinas (198 km)	100%	“Better(1)”	3	4	12	March 2005
(b) Ribeirão Preto – Bauru (205 km)	100%	“Better(2)”	3	4	12	January 2005
(c) São Paulo – Goiânia (951 km)	64%	“Worse(1)”	3	4	12	March 2004
(d) São Paulo – Feira de Santana (1.790 km)	48.9%	“Worse(2)”	3	4	12	April 2006

[a] Taking as a basis the results from the Road Research (CNT, 2005).
[b] Adopted in this study.

On all trips the same control conditions were preserved, that is, the same load, the same time of the trip, the same weather conditions and the same drivers. In all cases, the truck traveled with its full load capacity, respecting each type of vehicle/implement.

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[6] Netz Engenharia. Information available at: <http://www.netz.com.br>.

On each trip, besides the date supplied by the *Blue Bird,* it was also registered the fuel consumption, used as *proxy* to quantify emissions.

4.2 Valuing of environmental and economics benefits

The considered economic parameters were related to the fuel consumption (l/100 km), to the time of trip (h/100 km) and to the expense with maintenance of the vehicle (R$/100 km) in the studied routes.

It was carried out the statistical analysis of fuel consumption from the experiments made. The test of hypothesis considered the difference between the two averages admitting that the variances are unknown, but supposedly different (Hoffmann, 1991), which alters the number of degree of freedom, taking a more detailed analysis. It was aimed to reject the null hypothesis that the average consumption is equal to routes in different state of conservation, based on random and independent samples. The alternative hypothesis tested was that the average values observed on the routes in a worse state of conservation are higher than the average obtained on better routes.

It was supposed that better pavement condition must imply lower values of average fuel consumption, average time of trip, expense with maintenance of the vehicle and CO_2 emissions. As a result, there is a benefit (economic and environmental) from trips in highways in better conditions of conservation.

a) Benefit with fuel consumption

It was supposed that the fuel consumption is related to the highway state of conservation. The fuel consumption by trucks in routes with different state of conservation was calculated from primary data collected.

The benefit with fuel consumption (*Bc*) is the subtraction between the average consumption from roads in good states of conservation and roads in bad states of conservation. The value of benefit with fuel consumption (*Bc*) is calculated from Eq. 1.

$$VBc = Bc \times P \tag{1}$$

where:

VBc = value of benefit (economy) with fuel consumption resulting from a trip on road with better infra-structure (R$/100 km);

Bc = benefit resulting from a reduction of average fuel consumption (l/100 km); and

P = average diesel price in Brazil in May/2006 (R$ 1.915)[7].

b) Benefit with trip time

The trip time was considered as a function of different states of conservation too. The private benefit from a reduction in the time of trip (*Bt*) is given by the subtraction of the values (average time in roads in bad state of conservation - average time in roads in good state of conservation). Roads in worse conditions reduce the average speed of the vehicles; consequently, the number of trips is reduced and the fixed cost for trip is increased (depreciation, remuneration of the capital, insurances and licensing etc.).

In this way, when the time in the analysis is considered, it must be included:

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[7] Agência Nacional do Petróleo - ANP. Home-page: http://www.anp.gov.br/doc/petroleo/ relatorios_precos/2006/Diesel_2006.pdf.

- the direct impact from the driver wage (R$ 7.52/h[8]); and
- the indirect impact from the fixed costs of a trip. The more time the truck be in movement, more the fixed costs are diluted in the trips (R$ 26.20/h in July/2006[9]).

Therefore, the *VBt* is figured according to Eq. (2).

$$VBt = Bt\ (M + CF) \tag{2}$$

where:

VBt = value of benefit (economy) with trip time resulting from a trip on road with better infra-structure (R$/100 km);
Bt = benefit resulting from a reduction of average trip time (h/100 km);
M = hour wage paid to driver (R$/h); and
CF = transport fixed costs.

c) Benefit with vehicle maintenance expense

The operational cost of the trucks is strongly affected by the state of conservation of the pavements.

The annual expense with the truck maintenance is calculated as the distance covered in a trip multiplied for the average cost of vehicle maintenance. So, the value of the benefit (*VBm*) is the subtraction between the average expense of maintenance in highways in bad state of conservation and the average expense of maintenance in highways in good state of conservation, according to Eq. 3.

$$VBm = Bm\ x\ CVMe \tag{3}$$

where:

VBm = value of benefit (economy) with vehicle maintenance expense from a trip on road with better infra-structure (R$/100 km);
Bm = benefit resulting from a reduction of average cost vehicle maintenance (18.7%); and
CVMe = average variable cost estimated by ESALQ-LOG in july/2006 (R$ 1.43/km).

The benefit (*Bm*) was calculated from Reis (2006), that verified the road condition impact on a Scania 4x2 maintenance cost. According to that study, a “deficient” road increases the maintenance costs in 18.7% when compared with the results from a “good” road. In this sense, this percentage was adopted on this research.

d) Total benefit economic

The value of total benefit economic - *VBET* is given by the sum of economics benefits calculated before (Eq. 4).

$$VBET = VBc + VBt + VBm \tag{4}$$

where:

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[8] SINDICATO DAS EMPRESAS DE TRANSPORTES DE CARGAS E LOGÍSTICA NO ESTADO DO RIO GRANDE DO SUL – SETCERGS. **Convenção coletiva de trabalho 2005**. Home-page: <http://www.sinecarga.org.br/documentos/aconv2006.doc>.

[9] ESALQ-LOG. Home-page: <http://sifreca.esalq.usp.br>.

VBc = value of benefit (economy) with fuel consumption resulting from a trip on road with better infra-structure (R$/100 km);
VBt = value of benefit (economy) with trip time resulting from a trip on road with better infra-structure (R$/100 km);
VBm = value of benefit (economy) with vehicle maintenance expense from a trip on road with better infra-structure (R$/100 km);

e) Environmental benefits: reduction of negative externalities regarding emissions.

The environmental variables refer to carbon dioxide emissions deriving from road length in different state of conservation.

The estimates of GEE released by heavy road transport are restricted to the emissions of diesel oil combustions, once the load transport is predominantly done on diesel (Brasil, 2002b). Besides that, it was adopted a premise that the combustion is complete, that is, all carbon of the fuel is converted into carbon dioxide (it was disregarded CO and NMVOC, which are converted into carbon dioxide in the atmosphere). It was disregarded the N_2O e CH_4 emissions, as it was adopted by Álvares and Linke (2003) and suggested by the *GHG Protocol* (2005).

It was adopted the carbon dioxide emission factor from diesel 2.75kg/l, an average value suggested by Brasil (2002b) and Bartholomeu (2001) that corresponds to a general estimate which considers the average characteristics of the diesel supplied in Brazil.

The environmental benefit (Be) is equivalent to a reduction of negative externality (emissions level) resulting from investment in road repairs. Be should be estimated through the subtraction of values obtained (average of CO_2 emissions on roads in poor state of conservation – average of CO_2 emissions on roads in good state of conservation).

In order to appraise this benefit (VBe), it was considered the average price of carbon ton for the MDL projects under the scope of the Kyoto Protocol[10], US$ 10,00/t CO_2e. In this market, however, it is observed a certain prices variation of the carbon ton traded, as a result of some factors. One of them corresponds to the type of bilateral trading between the parts involved and, consequently, the value agreed between them. Besides that, the carbon price also depends on the project status and the involved risks. MDL projects at more advanced phases in the approval cycle and, mainly, with carbon credits obtained, will certainly have higher prices for the ton of CO_2 equivalent, once the risks are reduced.

The VBe is figured from the Eq. (5).

$$VBe = Be \times RCE \times TC \tag{5}$$

where:
VBe = value of benefit (externality) with CO_2 emission resulting from a trip on road with better infra-structure (R$/t.100 km);
Be = benefit resulting from a reduction of CO_2 average reductions (kg CO_2/t.100 km);
RCE = price of CO_2e ton (US$/t); and

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[10] There are other markets that trade carbon, such as the European market - European Union's Emissions Trading Schene - EU ETS – and the Chicago exchange market - Chicago Climate Exchange - CCX -, where prices around US$ 18.00/t and US$ 3.50/t, are being practice, respectively (MÜLLER, 2006).

TC = exchange rate (R$ 2.30/US$ 1.00).

In fact, however, the *VBe* should not reflect reliably the reductions of negative externalities, once, in adopting the price of carbon ton under the scope of the Kyoto Protocol, the other indirect benefits to humankind aren't being considered. Thus, in valuing the externalities it should also be taken into consideration indirect benefits to the global and local environment, to the community directly involved (near roads) and to the society as a whole, due to its contribution to mitigate GEE emissions and, consequently, to the negative impacts on global warming.

However, there is an unknown fact, on the part of the scientific community, regarding the dimension of the impacts and, consequently, of its monetary values, making it difficult to obtain a value closer to the externality. Thus, the appraisal of reduction of negative externalities related to the reduction of transport emission should be considered as conservative in this study.

5 RESULTS

5.1 Economic Benefits

This section presents the results related with economic benefits.

a) Benefit with fuel consumption

It was done a statistical analysis of the data collected, presented on Table 3. It is observed that the data were rather consistent, in through the low dispersion in relation to the average, resulting in a small variance. Besides that, the average value approaches the mode. The best routes resulted in a saving of 5.07% in the fuel consumption.

Table 3 – Statistical analysis of the data collected on fuel consumption (l/100 km)

Route	Average	Standard deviation	Mode
a) Cubatão - Campinas (*Better(1)*)	44.94	1.50	44.64
b) Ribeirão Preto – Bauru (*Better(2)*)	44.34	0.62	44.05 and 44.84
c) São Paulo - Goiânia (*Worse(1)*)	45.04	0.87	45,04
d) São Paulo – Feira de Santana (*Worse(2)*)	47.15	0.82	47.17; 47.39 and 47.85

Source: Research results.

Table 4 presents different results of the hypothesis test. In majority of cases, the null hypothesis is rejected in favor of the alternative hypothesis, * $P<0.05$, that is, the average consumption in the routes in worse state of conservation is higher the average consumption observed in routes in better conditions. Only in the first case the null hypothesis isn't rejected.

Table 4 – Test of hypothesis results for the average fuel consumption

Route	Variable t' obtained	Liberty degree (g)	Value t_0
Better(1)/Worse(1)	0.209	18	2.101
Better(2)/Worse(1)	2.300	20	2.086
Better(1)/Worse(2)	4.481	17	2.110

Better(2)/Worse(2)	9.490	20	2.086

Source: Research results.

The benefits with fuel consumption and its valuation are presented on Table 5. The route (b) - "*Better(2)*" was the most efficient, resulting in a lower average consumption around 1.3%, 1.6% and 6.3% than the rote (a), (c) and (d), respectively.

Once the benefit was positive in all the cases studied (Table 5), the results indicate that better roads imply lower fuel consumption.

Table 5 – Benefits with fuel consumption

Route	Benefit (l/100 km)	Value of Benefit (*VBc*) - R$/100 km
Better(1)/Worse(1)	0,10	0,20
Better(2)/Worse(1)	0,71	1,35
Better(1)/Worse(2)	2,21	4,23
Better(2)/Worse(2)	2,81	5,38

Source: Research results.

b) Benefit with trip time

When time was analyzed, the hypothesis test wasn't consistent, since it indicated that the null hypothesis couldn't be rejected (Table 6).

Table 6 **–** Test of hypothesis results for the average fuel consumption

Route	Variable t' obtained	Liberty degree (g)	Value t_0
Better(1)/Worse(1)	2.352	21	2.080
Better(2)/Worse(1)	-3.449	20	2.086
Better(1)/Worse(2)	4.145	19	2.093
Better(2)/Worse(2)	-3.728	20	2.086

Source: Research results.

The data indicate that the trip time can be influenced by exogenous variables (like speed limits, police fiscalization, etc.). These influences are more important to determine the time of trip than the road state of conservation. Consequently, routes (c) and (d), classified as "worse", resulted lower trip time than the route (b), as can be seen at Table 7.

Table 7 – Benefit with trip time

Route	Benefit (h/100 km)	Value of Direct Benefit (VBt_d) - R$/100 km	Value of Indirect Benefit (VBt_i) - R$/100 km	Value of Benefit (*VBt*) - R$/100 km
Better(1)/Worse(1)	0.06	0.45	1.57	2.02
Better(2)/Worse(1)	-0.08	-0.63	-2.20	-2.83
Better(1)/Worse(2)	0.08	0.59	2.06	2.65
Better(2)/Worse(2)	-0.07	-0.49	-1.71	-2.20

Source: Research results.

c) Benefit with vehicle maintenance expense

The maintenance expense was based on study realized by Reis (2006). According to his results, a “deficient” road increases the maintenance expenses in 18.7% when compared with trips on “good” highways.

Considering the CVMe equal R$ 1.43/km, the value of benefit is R$ 26,69/100 km.

d) Total Benefit

When the parcial economic benefits are summed, the *VBET* is founded. To each 100 km traveled by a Volvo 2004, the *VBET* is between R$ 25.21 and R$ 33.57, as illustrated on Table 8.

Table 8 – Value of Parcial and Total Economic benefits (R$/100 km)

Route	Value of Fuel Consumption (*VBc*)	Value of time trip (*VBt*)	Value of vehicle maintenance expense (*VBm*)	Value of Total Economic Benefit (*VBET*)
Better(1)/Worse(1)	0.20	2.02	26.69	*28.91*
Better(2)/Worse(1)	1.35	-2.83	26.69	*25.21*
Better(1)/Worse(2)	4.23	2.65	26.69	*33.57*
Better(2)/Worse(2)	5.38	-2.20	26.69	*29.87*

Source: Research results.

5.2 Environmental benefits

If pavement conditions of route (c) became equivalent to those of routes (a) or (b), each ton transported at each 100 kilometers would result in an emission level of 6.7 and 45.7 gCO_2 lower, respectively. This difference increases when the road condition becomes more precarious and, therefore, the environmental benefit for unit of weight and distance becomes more evident. In the case of the route that connects Sao Paulo to Feira de Santana, there would be an average reduction of 162.2 gCO_2/t.100 km in case it were in good conditions.

Table 9 illustrates the benefits related with emissions reduction from trips on good state of conservation.

Table 9 – Benefits of CO_2 emissions, in kg CO_2/t.km and in R$/100 km.

Route	Environmental Benefit (kg CO_2/t.100 km)	Value of Benefit (*VBe*[a]), in R$/100 km
Better(1)/Worse(1)	0.007	0.01
Better(2)/Worse(1)	0.046	0.04
Better(1)/Worse(2)	0.143	0.14
Better(2)/Worse(2)	0.182	0.18

Source: Research results.

In order to estimate the value of the environmental benefit, it is necessary to verify the emission reduction potential, which is related to the routes in the other states, excluding the state of Sao Paulo, whose roads are in the best state of conservation in

Brazil. Thus, a route that starts in Sao Paulo must have the destination to another state and vice-versa, it cannot have the origin and destination within the state of Sao Paulo. Supposing that such cases account for 60% of all loads transported by roads[11] and that this parcel corresponds to 291 billion of TKU transported in 2004, the aggregate value of the estimated environmental benefit would be R$ 6.3 million per year. This volume corresponds to 0.08% of the necessary resource to recover the national road system released by CNT (2005b)

6 CONCLUSIONS

The results obtained confirm the hypothesis the routes in better conditions of conservation result in economic and environmental benefits. In spite of the differences in the magnitudes reached, it was identified reductions of fuel consumption, pointing to an improvement in the energy efficiency observed during the trips when the option was to use roads in better condition of pavement.

It was founded a reduction between 0.22% and 6% of the average fuel consumption, depending on the routes considered, when the vehicle used in the research traveled in routes in better state of conservation. However, it was possible to note that others exogenous variables have more influence on trip time than the road state of conservation.

The hypothesis tests applied show statistical significance in the cases involving comparisons between average fuel consumption on routes with different conditions of conservation, rejecting the hypothesis that they are equal, in favor that the average consumption on better roads is lower than that verified in worse routes. In the case of the time of travel, however, the hypothesis tests didn't show statistical significance.

Besides that, routes in better pavement conditions reduced emissions between 0.1 gCO_2/t.km and 1.8 gCO_2/t.km, that is, reductions from 0,01% to 0,2% in the negative externalities related to emissions.

It is important to emphasize that in the figures carried out, however, it was not considered the indirect benefits caused by the emissions reductions, once it is not known the impact of mitigating measures and, consequently, its monetary values, underestimating its potential.

Therefore, it is concluded that investments in infra-structure that improve the conservation conditions of roads generate private and environmental benefits, which in turn, present different impacts on the values of the benefits.

In addition, the reduction of individual fuel consumption, when spread to the entire road transport sector, causes an expressive drop in the national diesel oil consumption, contributing favorably not only to the reduction of the importation of this fuel, but the Brazilian balance trade as well. The average reduction of fuel consumption verified was 5.06% (considering aggregate experiment), which would be equivalent to, considering data from Lima (2006), a drop of 1.10 billion liters consumed in the year of 2004 and to an economy of R$ 1.63 billion.

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[11] According to the Economic Development Index of Transport (Fundação Instituto De Pesquisas Economicas – FIPE; CNT, 2005), in 2004, almost 37% of loads transported on roads were concentrated in the state of São Paulo (they had origin and destination within that state).

It is expected that the results assist policies (via public or private agents, or even involving partnerships between both – the so-called Public – Private Partnerships) that aim the improvement of the efficiency of the road transport, especially from the economic and the energy efficiency points of view.

Besides these aspects, it is also important that the country find sustainable solutions that reduce the carbon dioxide emissions considering current indefinitions regarding the commitments emissions targets for Brazil after 2012 (considering the Kyoto Protocol).

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