

# **A CHOICE MODEL FOR COLLECTIVE PASSENGER TRANSPORTATION IN BRAZIL: AIR X HIGHWAY**

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## **Abstract**

Public intercity passenger transportation in Brazil has been strongly affected by low cost airline prices and by people's increasing income. The regulatory system allows operators from different modes to serve the same route. In this context, the potential competition has been increased, with some disadvantages for highway transportation. This study estimates the total cost of passenger transportation (internal and external) in Brazil. For a 677 km trip, the passenger-kilometer cost obtained was US\$ 0.1387 traveling by airplane, and US\$ 0.0955 by bus, in Brazil. These costs were parameterized considering consumer income and the distance of the trip. A statistical function  $d=5800y-1,88$  was generated, showing the efficient choice when a passenger has to decide between traveling by airplane or by bus.

**Keywords:** Air transportation, Highway transportation, Multi-mode competition.

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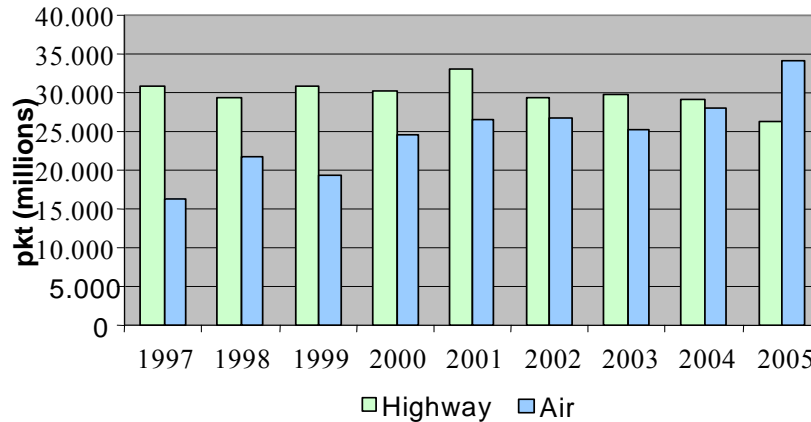
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## 1. INTRODUCTION

In Brazil in recent years, passenger air transportation has grown significantly, whilst highway transportation has remained more stable, as shown in Figure 1, drawn up with

data from the National Land Transportation Agency (ANTT) and the National Civil Aviation Agency (ANAC). The data for coach transportation excludes trips under 75 km.



Source: ANTT for highway transportation and ANAC for air transportation.

**Figure 1 – Development of passengers-kilometer transported (pkt) in interstate highway passenger transportation and domestic air transportation**

Data presented in the form of the development of the number of passengers-kilometer transported (pkt) (which corresponds to the sum of paying passengers transported multiplied by the total number of kilometers covered), shows the alteration in passenger transportation composition in recent years, with an increased pkt in air transportation.

This study presents the potential competitive conditions between collective passenger air and land transportation in Brazil, considering the consumer route and income. To this end, the economic theory has been looked into for an optimum choice model that explains the relationship between income levels and the

choices that maximizes consumer utility. This analysis is important at a time when pricing by low cost airlines offers this service to consumers in lower income brackets. Likewise, the gradual increase in income amongst Brazilians also pushes the market to a new point of equilibrium, changing the country's passenger transportation matrix, with important consequences for public transportation policy.

The neoclassical economic theory shows that consumers make choices in order to maximize utility, subject to budgetary restriction. According to Varian (2003), optimal consumer choice depends on income and the

price of goods, all other conditions remaining the same.

$$\frac{\Delta x_1}{\Delta y} > 0 \tag{1}$$

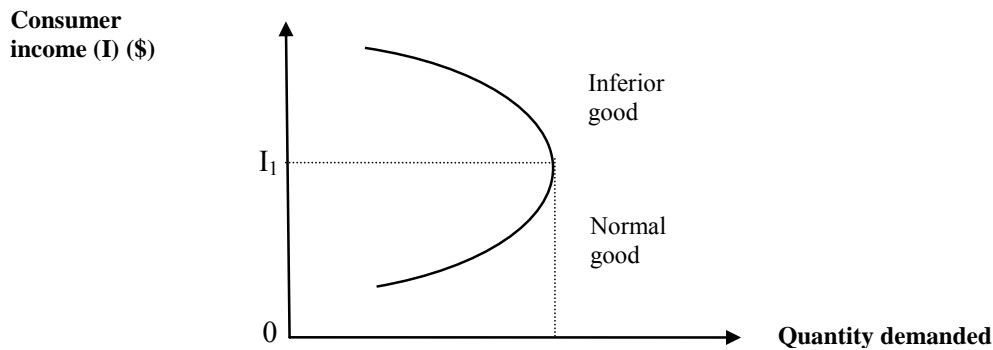
Assuming economic goods prices to be constant, it can be stated that consumer income variations affect demand in different ways. For some types of goods, income variation causes changes in the quantity demanded by the same direction, defining a positive relationship between income and demand. Goods whose demand presents this behavior are called *normal* goods. Otherwise, when demand goes inversely to income change, goods are called *inferior*.

For an *inferior good* ( $x_2$ ) the change in quantity demanded happens in the opposite direction to the income variation ( $y$ ):

$$\frac{\Delta x_2}{\Delta y} < 0 \tag{2}$$

Assuming that  $x_1$  is a *normal good*, the variation in quantity demanded always happens in the same direction as the income variation ( $y$ ):

One and the same economic good may behave as a *normal good* or as an *inferior good* for different income levels, since income variations modify consumer purchasing power and, as a result, consumer choices. This behavior is shown by the Engel Curve:



Source: Varian, 2003.

Figure 2 – Engel Curve

Applying this theory to passenger transportation, it can be stated that for a certain income bracket (0;  $I_1$ ) passenger transportation by coach can be considered as a

normal good, with demand increases as income increases. However, for persistent increases in income, this same economic good shall behave as an *inferior good*. This occurs

because of the substitution of the highway mode by the air mode, decreasing demand for coach travel, when consumer income exceeds a certain limit ( $I_1$ ). This individually variable limit is also closely related to the distance to be covered, besides other variables.

### 3. METHODOLOGY

This study investigates the conditions under which there may be competition in land (coach) and air collective passenger transportation services.

To this end, it was used as a reference a survey that had been developed by Levinson *et al.* (1996) at the University of California to estimate total pkt cost for intercity passenger transportation by land and by air on a specific route in the United States (São Francisco to Los Angeles) covering 677 kilometers.

To apply that study to Brazilian conditions, it was necessary to estimate collective passenger transportation costs in Brazil that could be compared with the US model. The main adaptations necessary for the Brazilian case considered:

a) correction of the highway transportation values which, in the study by Levinson *et al.* (1996), focused on automobile transportation, and which in the Brazilian case refer to coach transportation,

b) difference between US consumer income and Brazilian consumer income, and

c) difference in coach and airplane occupation rates in the two markets.

#### 3.1 Model for Brazil

The choice model presented here was based on a study developed at the University of California and considers a 677 km route used to transport passengers with an income equal to the average income in Brazil adjusted by the Purchasing Power Parity. This section aims to generalize the results in a parameterized manner based on distance ( $d$ ) and income ( $y$ ) of the population served.

It was necessary to adopt the following parameters:

- a) Number of passengers per airplane: 98
- b) Number of passengers per coach: 28
- c) Price of airplane: US\$ 60,000,000
- d) Price of coach: US\$ 150,000
- e) Average speed of airplane: 900 km/h
- f) Average speed of coach: 70 km/h.

To carry out analysis from the Brazilian standpoint, this study adapts the American study and, from indicators based on income and trip distance, determines the mode with the maximum economic return that would be one which is more efficient.

The main variables differentiating the results obtained by the American study and this study, which uses data from the transportation

sector in Brazil, are the cost of time and the density of the path covered. The cost of traveling time is strongly related to the user's income, whilst the density of the path is measured by the vehicle occupation rate. The sections that follow present the necessary adaptation for the theoretical model to the Brazilian case.

### 3.1.1 Infrastructure cost

The adaptation for highway mode considered that a coach burdens the infrastructure twenty times more than an automobile, but transports an average of 28 passengers, whilst automobiles, in the American case, transport 1.5 passengers. The results are estimate by  $US\$ 0.012 \times 1.5 / (28) = 0.0129$ . For the air mode it was used the same American cost.

### 3.1.2 Capital and Maintenance Cost

This is the cost of investment in capital to acquire and maintain vehicles. To determine the pkt cost for air transportation in Brazil, a traffic density of 58% was used, whilst in the United States it was 68%. The estimated cost for the coach considered a base value for airplane acquisition in the American study with the due adjustments because of the difference in cost between the airplane and the coach, the difference in the passenger transportation capacity, and the difference in speed between the means. The calculation formula is the cost per air pkt  $\times$  (airplane pax/coach pax)  $\times$  (coach price /airplane price)

$\times$  (airplane speed / coach speed), which equals  $US\$ 0.0710 \times (98/28) \times (US\$ 150.000/US\$ 60,000,000) \times (900/70) = 0.0080$ .

### 3.1.3 Operating Cost

Data from the IBGE-PAS – (Brazilian Institute of Geography and Statistics – Annual Services Survey) (IBGE, 2005) shows that the total operating cost for regular air transportation companies was R\$ 5,299,428,000 billion in 2004, whilst the pkt number for the same mode was 27 billion (ANTT, 2006). The average pkt cost in the air transportation was approximately R\$ 0.20. However, once this value includes taxes, labor contributions and so on, a reduction of 50% was applied, obtaining a cost of R\$ 0.10 per pkt. Adopting a rate of R\$ 3.00 per US\$ 1.00, the figure US\$ 0.034 per pkt is attained, which must be adjusted to the Brazilian occupation rate ( $0.034 \times (0.68/0.58) = US\$ 0.0399$ ).

Also according to the IBGE-PAS, total regular non-urban highway passenger transportation cost in 2004 was R\$ 2.261.350.000, whilst according to the ANTT (2006) the pkt number for the same mode in that year was 29.222.000.000. So the pkt cost of coach transportation was R\$ 0,077. Discounting taxes, as in the air mode example, an economic cost of R\$ 0,038, per

pkt is obtained, or US\$ 0.012, considering an exchange rate of R\$ 3.00 to the US dollar.

#### 3.1.4 Cost of Negative Externalities:

##### Accidents

Evaluation of external costs resulting from accidents is not negligible, with the most commonly used methods taking into consideration analysis of costs that can be avoided through accident prevention measures, or using production or consumption loss evaluation techniques. In the study developed by Levinson *et al.* (1996), costs attributed to negative externalities in accidents were US\$ 0.0004 per pkt for air transportation and US\$ 0.02 per pkt for automobile transportation. For the Brazilian case, adjustments were made regarding the different occupation rates for automobiles and coaches, assuming that the claim for Brazilian coaches is equivalent to that for automobiles in the United States. The result was obtained through  $US\$ 0.002 \times 1,5 / (28) = 0.0011$ .

##### 3.1.5 Congestion

The impact of congestion on transportation costs is estimated through the use of traffic flow models. In these models, the flow speed on a certain highway is considered to be a function of the density of vehicles in circulation. This impact includes higher fuel consumption, higher exhaust emissions, and also the loss of users' time from longer trip duration.

The monetary evaluation of loss of time is usually done through measuring the time lapsed multiplied by the time for all the users affected. In the Californian study, the cost of congestion in the air transportation mode is US\$ 0.0017, whilst for automobile transportation it is US\$ 0.0046, per pkt. These values stem from acceptance of a uniform time value for all users equal to US\$ 10/hour. In an European Union survey, a value of €5/hour was used (European Commission, 2006).

To estimate this cost, adjustments were made regarding the different occupation rates for automobiles and coaches. In addition, it was – randomly – considered that a coach causes three times more impact than an automobile:  $US\$ 0.0046 \times 3 \times 1.5 / (28) = US\$ 0.0007$ .

##### 3.1.6 Noise Cost

The nuisance caused by noise is difficult to measure. Methods have used devaluation of property in noisy areas, the cost of treating noise-related diseases, and the cost of mitigating measures. According to Levinson, the cost of noise in air transportation is US\$ 0.0043, per pkt, whilst for automobiles it is US\$ 0.0045. In the Brazilian case, adjustments were made regarding the different occupation rates for automobiles and coaches, considering that noise for a coach is twice as loud as that for an automobile:  $US\$ 0.0045 \times 3 \times 1,5 / (28) = 0.0005$ .

### 3.1.7 Atmospheric Pollution

Part of the atmospheric pollution is caused by means of transportation. In the Levinson survey, air transportation presented a cost of US\$ 0.0009 per pkt, whilst for the highway mode (automobile) the pollution cost was US\$ 0.0031. In the Brazilian case, the difference was applied between automobile and coach occupation, and it was accepted that coaches consume twice as much fuel as automobiles in the USA:  $US\$ 0.0031 \times 2 \times 1.5 / (28) = 0.0003$ .

### 3.1.8 User Cost

These costs are related only to personal automobile transportation, and hence do not fall within the scope of this study.

### 3.1.9 Time Value

The opportunity cost for time for one individual can be inferred from how much this individual is prevented from producing, using a per capita average product. The product per capita in the USA adjusted by the Purchasing Power Parity was approximately US\$ 42,000 in 2006 (World Bank, 2007) and in Brazil it was US\$ 8,400 (World Bank, 2007). The hourly cost was approximately five times greater in the USA than in Brazil. Hence, in this study an average value per hour in Brazil that was

accepted could be compared with the hour rate used in the American study - randomly adopted to be US\$ 10 - was US\$ 2. It must also be considered there are differences in travel time between an automobile and a coach. To estimate the time for the automobile passenger in Brazil, a multiplier of 1.5 was adopted to adjust this value to the cost of time. After that, the difference in the income between the countries was considered. The result was obtained by  $US\$ 0.1 \times 1.5 / 42 \times 8.4$  corresponding to US\$ 0.03 pkt per automobile, in Brazil. For transportation by coach, it was considered that the value of time was twice than that by automobile ( $US\$ 0.03 \times 2 = 0.06$ ). For traveling by airplane, the value for California - US\$ 0.0114 per pkt - corresponds to US\$ 0.0023 per pkt in Brazil, only taking into account the difference in the income.

The results are the first approach to the total cost (external and internal) in transportation for Brazilian conditions, as shown in Table 1.

**Table 1 – Comparison between long term average cost in California and Brazil (US\$/pkt) for a 677 km route**

Cost Category	In California		In Brazil	
	Air	Automobile	Air	Coach
1 Infrastructure	0.0182	0.0120	0.0182	0.0129
2 Investment cost	0.0606	0.0000	0.0710	0.0080
3 Operating cost	0.0340	0.0000	0.0399	0.0120
4 Negative externalities: accidents	0.0004	0.0200	0.0004	0.0011
5 Negative externalities: congestion	0.0017	0.0046	0.0017	0.0007
6 Negative externalities: noise	0.0043	0.0045	0.0043	0.0005
7 Negative externalities: air pollution	0.0009	0.0031	0.0009	0.0003
8 User vehicle cost	-	0.0860	-	-
9 Time cost	0.0114	0.1000	0.0023	0.0600
<b>TOTAL</b>	<b>0.1315</b>	<b>0.2302</b>	<b>0.1387</b>	<b>0.0955</b>

Source: Levinson et al. (1996), for the California data. Values for Brazil were estimated by the authors.

Note that the cost per pkt for highway transportation in Brazil is significantly lower than in the USA, mainly because the US model was developed for automobiles and the Brazilian model for coaches. This involves greater dilution of fixed costs because of the number of passengers, which is greater in coaches. Another important reason is the difference in consumer income that heavily influences passenger time cost.

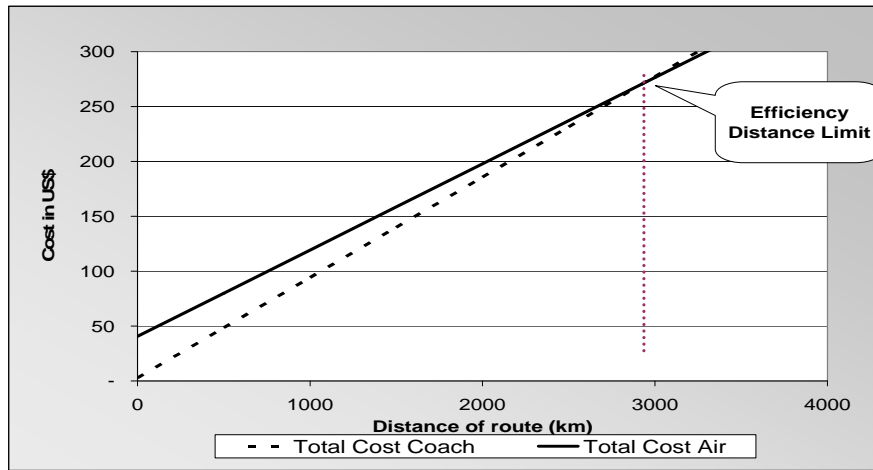
Each of the eight total cost categories was parameterized according to its theoretical behavior for each mode of transportation. Each cost component may, thus, be *variable*, because of income and distance, *constant*, or *fixed*, or even have one *fixed part* and another *variable part*. The parameterization model is shown in Chart 1.

**Chart 1 - Parameterization of cost categories for income and distance variations**

Cost Category	Parameterization	
	air	coach
1 Infrastructure	fixed per trip	proportional d
2 Investment cost	1/2 fixed; 1/2 pptl. d	1/2 fixed; 1/2 pptl. d
3 Operating cost	pptl. d	pptl. d
4 Negative externalities: accidents	fixed trip, pptl. y	pptl. d*y
5 Negative externalities: congestion	fixed trip, pptl y	pptl. d*y
6 Negative externalities: noise	fixed trip, pptl. y	pptl. d*y
7 Negative externalities: air pollution	pptl. d	pptl. d
8 User vehicle cost	N/A	N/A
9 Time cost	pptl. d*y	pptl. d*y

Source: Elaborated by the authors.

Applying the parameterization to the costs shown in Table 1, the result was that for income of US\$ 2.00 per hour and with the distance varying, total cost would behave as in Figure 3a below. This income is assumed to be equivalent, in Brazil, to hourly per capita income used by Levinson et al.. On the other hand, making income flexible and fixing distance (d) at 677 km, the results shown in Figure 3b were achieved.



**Figure 3a - Total cost of modes varying distance for y = US\$ 2.00**

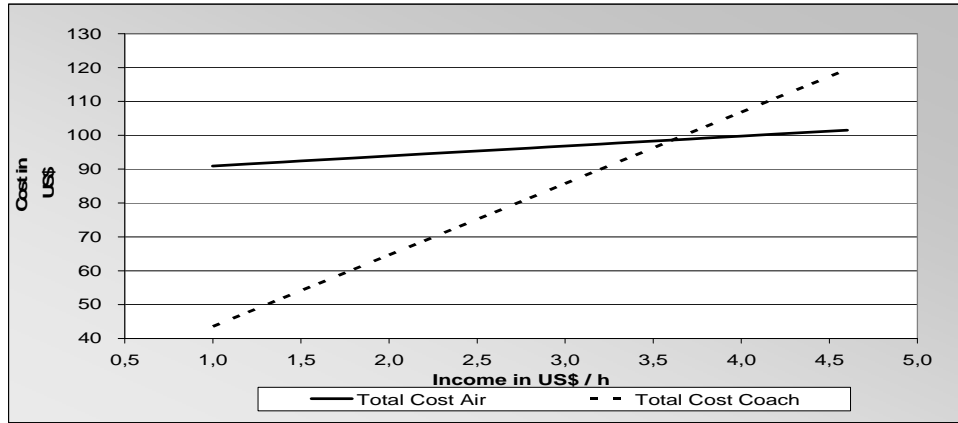


Figure 3b - Total cost of modes varying income for d = 677 km

Figure 3a shows that for an average income of US\$ 2.00 per hour, what is known as the “efficiency distance limit” is approximately 2,900 km. For this distance, it makes no difference if the passenger travels by air or highway. Longer distances are more efficient by air, whilst coaches are recommended for shorter routes. On the other hand, fixing the distance at 677 km, the income for which it makes no difference to consumers whether they travel by coach or airplane is approximately US\$ 3.6

per hour. For lower incomes, land transportation maximizes efficiency so as the air transportation for higher incomes. Dealing simultaneously with income and distance data, the income effect is obtained on the efficiency distance limit. For each level of income regions are estimated in which each mode is preferable when comparing costs, as shown in Figure 4:

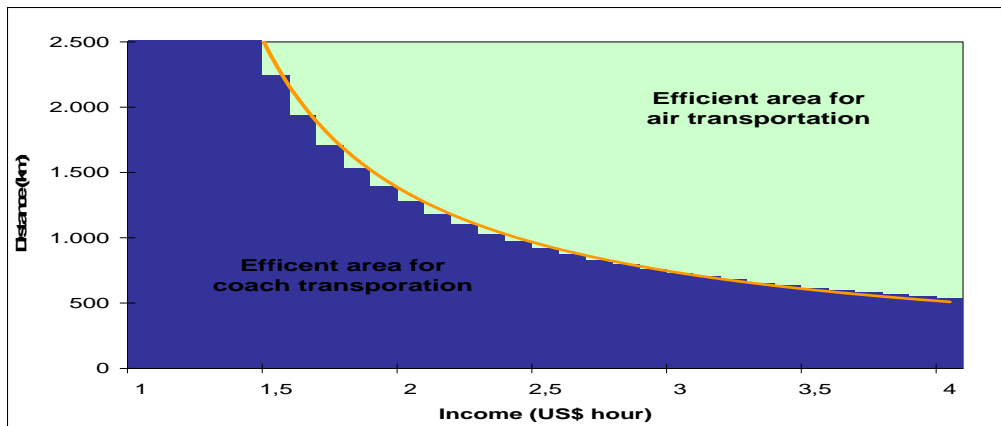


Figure 4 - Regions for maximum return based on the distance and the income

Figure 4 shows the income limit for varying distances, determining when the mode considered behaves as a normal good and when it behaves as an inferior good according to the microeconomic theory. For example, it can be noted that taking the distance of 1,000 km, highway transportation behaves as a normal good up to an income of approximately US\$ 2.3 per hour. For higher incomes, it behaves as an inferior good and demand for it begins to fall. It was generated a statistical function to model the borderline for choice of mode presented in the chart above that is equal to  $d = 5800y^{-1.88}$ .

#### 4. CONCLUSIONS

The study shows the competitive potential between air and coach modes in passenger transportation in Brazil, when considering only the distance traveled and the income of the consumer. The basic premise is that consumers view to maximize their utility, seeking the most efficient mode of transportation.

The results obtained in this study are still preliminary and are based on comparisons with the American model, as well as some estimates for the Brazilian case. Other studies are recommended in order to improve their accuracy. The statistical function was obtained considering the costs presented here, so other more specific costs will result in

another function, obviously. Even the results are preliminary; analysis shows the importance of both modes in serving passenger demands. The advantages of coaches are clear for short distances in providing capillarity, and the large geographical coverage of the transportation system as a whole. The disadvantages of coaches are related to the high time cost for long distance trips, and the natural obstacles on the highway infrastructure when considering hilly topography, excessively high or low temperatures, and issues related to the lack of safety on some stretches of Brazilian roads.

To satisfy users' needs, the transportation system is expected to offer a set of access solutions between regions, serving different preferences and market segments. The model achieved aids in forecasting demand for both modes, considering estimated increases in consumer income. It must be noted that the lower the income for a region, the greater the importance of coach transportation. On the other hand, the growth in Brazilian consumer income and low airfares indicate increased demand for air transportation, with consequences for airport capacity. Such a change could lead to an alteration in the country transportation matrix, such as the result of changes in consumer preference,

requiring public policies more attuned to the national economy as a whole and to the transportation system scenario in particular. More recently, some changes were observed in the demand for both means of transportation with a marginal advantage for coaches. This is supposed to be due the two accidents which occurred with airplanes in Brazil. Even so, it is expected that once the condition of increasing consumer's income and decreasing prices in air transportation still prevails, the scenario is highly positive for air transportation.

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