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Policy implications and analysis of the determinants of travel mode choice: an application of choice experiments to metropolitan Costa Rica

FRANCISCO ALPIZAR
CATIE, Costa Rica

FREDRIK CARLSSON
Department of Economics, Gothenburg University, Sweden.
E-mail: fredrik.carlsson@economics.gu.se

ABSTRACT. In this paper we study a group of policies aimed at discouraging the use of private transportation during peak hours, both directly and indirectly, by increasing the attractiveness of the only available substitute, the bus. This is done using a choice experiment constructed to find the answer to the following basic question: Given fixed house-to work structures and no working hour flexibility, by how much is the choice of travel mode for commuters to work sensitive to changes in travel time, changes in costs for each mode and other service attributes? This information is then used to identify the most suitable combination of policies dealing with air pollution and congestion in the typical developing country context of metropolitan Costa Rica. We also provide estimates of the value of travel time as a measure of the potential benefits gained from reduced congestion.

1. Introduction

The last 20 years have been characterized by a dramatic increase in the urban populations of most developing countries. Even small countries like the ones in Central America now have metropolitan areas that surpass one million inhabitants. This increase, in combination with a lack of urban planning and an inefficient transportation system, causes problems of decreased air quality and traffic congestion in urban environments. Pollution is associated with a wide variety of health problems, deterioration in buildings, acid rain, and global warming. Traffic congestion further complicates matters since it not only imposes high costs in terms of lost time and high stress, but also increases emissions by decreasing the speed of travel.

The main objective of thus study is to contribute to the design of policies dealing with the problems of congestion and air pollution in the urban context of a typical developing country. We study the determinants of the

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choice of transport mode for work trips in the short run, where we treat the number of trips as exogenously given. This is done with a choice experiment conducted on car commuters. These commuters are responsible for the worst congestion and pollution during peak hours, and at the same time are the ones who can most easily switch to public modes of transportation. Our argument is that a mode switch from car to bus can increase the efficiency of the transport system in two basic ways: (i) a more efficient use of the available infrastructure by transporting a higher number of individuals per unit of physical area, potentially reducing congestion and travel time, and (ii) a more efficient use of the environment by less emissions per commuter and, if congestion is reduced and travel speed increases, less emissions in general.

These arguments are subject to many qualifications; particularly, they depend on the average number of passengers per bus and the environmental performance of buses compared to cars. Our view is that there are many dimensions of a sustainable strategy to manage transport, including for example minimum requirements on the environmental performance of buses. We explore a combination of policies aimed at increasing the cost of private transportation (increased fuel and parking costs) and improving public transportation (reduced travel time, subsidized fares, and improved quality of the service). The joint implementation of these policies aims at reducing congestion and pollution, especially during peak hours, by restraining demand for private transportation while providing a suitable substitute. Currently the Costa Rican Transport Ministry is involved in a program to improve and restructure the public transportation system. One aim of this program is to achieve a reduction in congestion and pollution originating from urban transportation. Therefore, our survey is also a test of the ability of such a system to detract customers from private transportation. To our knowledge this is the first mode choice study conducted in Costa Rica.

2. Environmental regulation of transport in a developing country context

Environmental policies require strong and stable institutions, adequate legislation, and effective monitoring and enforcement. Many developing countries have weak institutions and unclear legislation, and in many cases there is a weak political commitment to environmental goals, which means that resistance to environmental measures is more likely to be successful. In addition, uncertainty about the permanence of environmental regulations causes additional incentive problems (O'Connor, 1999; Eskeland and Jiménez, 1992). It may therefore be important to revise the perspective of environmental regulations by emphasizing their short-run effects, and identifying ways of reducing the potential resistance against the policies (Calfee and Winston, 1998; Harrington *et al.*, 1998).

Regulation of private transportation, intended to reduce congestion and pollution, requires a number of policies that can, more or less, mimic the properties of the first-best solution.[1] Furthermore, public transportation is often regulated in terms of fees, routes, number of departures, and other

[1] See for example de Borger *et al*. (1996), Eskeland and Devarajan (1996), and Fullerton and West (2002).

characteristics. Decision makers therefore need information regarding which of these characteristics are most relevant to travelers.

Policies aimed at decreasing private transportation by means of increased costs include fuel taxes, parking fees, and road tolls in city centers. The last two are particularly relevant for tackling congestion, since they directly raise the cost of entering the city (Small, 1992; Willson and Shoup, 1990). Fuel taxes have been successful in reducing fuel demand in many countries, although public perception about them is negative (Sterner, 1994; Thomson, 1998). One way to reduce the political opposition to such measures is to provide a suitable system of public transportation. The design and quality of the public transportation system is thus an important factor itself in decreasing the use of private transportation.

An increase in the cost per trip for cars is expected to have two effects in the short run. First, there will be a reduction in the overall number of trips and second there will be a substitution towards public transport.[2] In the case of trips to work, we expect the first effect to be small since most trips have to be made. A substitution from private to public transportation is expected to have two further effects: (i) a reduction in congestion levels, which has a direct effect on emissions, and (ii) if the new passengers can be accommodated by the existing bus journeys, then passengers per bus trip would increase, and emissions per passenger would be lower. In metropolitan Costa Rica, buses run during peak hours with an average load of approximately two-thirds of their capacity, so a marginal mode switch is not expected to raise the number of bus journeys required to cope with the increase in demand (Ministry of Public Infrastructure and Transport, 1999). In cities where buses run with full loads, the number of bus trips might increase due to increased demand. In this case, the net benefit of a mode switch might not necessarily be positive and will depend on the performance of the bus fleet.[3]

3. Urban transport in Costa Rica

Almost half of the population and most of the economic and governmental activity in Costa Rica is located in the metropolitan areas of San José, Alajuela, Cartago, and Heredia. The city of San José, the capital, shows signs of a collapse in its transport infrastructure,[4] particularly during the peak hours of the morning. (7–9 a.m.) and the evening (5–8 p.m.). The roads linking the other cities to San José have also reached severe congestion levels. Most inhabitants of metropolitan Costa Rica are exposed daily to high pollution levels, with road transportation contributing more than 80 per cent of the total air pollution in metropolitan San José (Alfaro, 1999). A survey conducted by the Ministry of Health identified respiratory and

[2] In the long run, drivers can buy smaller and more fuel efficient cars, or even move closer to work in response to more expensive travel.

[3] Metropolitan Costa Rica is in a process of renewing the bus fleeet, resulting in an improved environmental performance of the public transport.

[4] Although approximately 70 per cent of all trips are made using the bus mode the number of car commuters surpasses the capacity of the available infrastructure.

pulmonary illnesses as the most common causes for visiting the public health hospitals (Ministry of Health, 1997).

Government reactions have mostly been limited to the provision of new infrastructure. Unfortunately, the capacity of the additional infrastructure is overburdened sometimes even before its construction is completed, in an extreme example of the so-called 'law of highway congestion'. In addition, this focus on infrastructure provision has further encouraged car use.

In recent years there have been some attempts to tackle the problem of air pollution, mostly by using command and control measures to reduce the amount of emissions per kilometer. As of 1995, all new cars are required to have a catalytic converter, and lead was eliminated from fuels in 1996. Also in 1996, the government introduced emissions standards for all vehicles. These standards were not very strict and there is little evidence that this policy has had any effect on emissions (Pujol, 1996; Jiménez, 1997). The tax structure for importing and owning a car has had perverse effects on the generation of pollution (Echeverría and Solórzano, 2000). Since 1986, older cars face an import tariff of 30 per cent, whereas new cars paid a 100 per cent tariff. The impact of this policy was dramatic. By the end of 1997, 72 per cent of the car fleet for private use was more than ten years old (RECOPE, 1999). In the last years the government has tried to reduce this distortion despite opposition from the affected parties. In addition, the yearly road tax is based on the value of the car, implying relatively higher taxes for newer, more fuel-efficient, cars.

Car ownership and fuel consumption have been increasing at high rates. Between 1989 and 1999, the car fleet grew at an average rate of 7.6 per cent per year,[5] with gasoline and diesel use increasing at an average rate of 10.4 per cent and 7 per cent per year, respectively. In the same period, per capita GDP increased, on average, 2.2 per cent per year (Proyecto Estado de la Nación, 1999). The main factors behind this development are most likely the declining real price of fuel, the perverse tax structure for car ownership, and the lack of an adequate system of public transportation. As of 1999, real prices on all fuels were slightly lower than in 1988, with an average yearly growth of 0.02 per cent in that period.

On the other hand, the public transportation system is underdeveloped. The government has paid little attention to its quality and service. Many times companies operating similar routes are competing for passengers along the same street, with most routes leading all the way to the center of the capital (that is, a radial system). This has resulted in deteriorating levels of service. Fares have been determined by the regulatory authority based on basic operating costs with little attention to the quality and type of service provided. Now, the Ministry of Transportation is aiming at restructuring the routes into a trunk and feeding system. Furthermore, companies face higher standards regarding the vintage of buses. The new

[5] The car fleet doubled from 1978 to 1988 and doubled again from 1988 to 1998. Approximately 75 per cent of the fleet is for private use (RECOPE, 1999). According to a recent local newspaper survey, 47 per cent of all households own at least one vehicle.

program also provides economic incentives to bus companies that comply with the new regulations. Bus fares will be linked to an evaluation of the service. If the project becomes a reality, it will imply better buses and better quality of service, less congestion due to fewer buses in the city center, and potentially shorter travel times. As mentioned in the introduction, our survey is also a test of the ability of such a system to attract new customers away from private transport.

4. Mode choice experiments

In order to evaluate the potential impact of different polices on the substitution between private and public transportation, information regarding traveler preferences for the attributes of the transport system is needed. Since some of the attributes of interest do not exist today, it is not possible to rely only on revealed preference data for that purpose. Therefore, we conduct a mode choice experiment evaluating traveler preferences for different attributes of both private and public transportation. The basic idea behind a mode choice experiment is to create a hypothetical situation and elicit the preferences of commuters for different attributes, through their choice of mode of transport in each of those situations.

In this paper we apply a general type of model called Random Parameter Models, where taste variation among individuals is explicitly treated (see, for example, Bhat, 2000; Train, 1998). We assume a linear latent indirect utility function U, consisting of a systematic and a stochastic part

$$U_{iqt} = \alpha_{iq} + \gamma_i s_q + \beta_{iq} x_{iqt} + \epsilon_{iqt} \tag{1}$$

Where α_{iq} captures an intrinsic preference of individual q for alternative i, $\gamma_i s_q$ captures systematic preference heterogeneity as a function of sociodemographic characteristics (s_q), x_{iq} is the vector of K attributes (including costs) for alternative i, and ϵ_{iq} is a stochastic component that reflects observational deficiencies arising from unobservable components, measurement error and/or heterogeneity of preferences. In choice experiments, the respondents face a sequence of such decisions, where each decision set (indexed by t) contains different profiles of the alternatives. The probability that individual q chooses alternative i in a choice situation t, conditional on β_q, is given by

$$P_q(it|\beta_q) = P\{(\alpha_{iq} + \gamma_i s_q + \beta_{iq} x_{iqt} + \epsilon_{iqt}) > (\alpha_{jq} + \gamma_j s_q + \beta_{jq} x_{jqt} + \epsilon_{jqt}) \; \forall \, j \in A_t\} \tag{2}$$

The vector of coefficients β_q is assumed to vary in the population, with probability density given by $f(\beta \mid \theta)$, where θ is a vector of the true parameters of the taste distribution. In this simple form, the utility coefficients vary across individuals, but are constant across the choice situations for each individual. This reflects an underlying assumption of stable preference structures for all individuals (Train, 1998). An important element of these Random Parameter Models is the assumption regarding the distribution of each of the random coefficients. We use two alternative formulations. The first assumption is a normal distribution, that is that the coefficient for the k-attribute is given by $\beta_k \sim N[b_k, w_k]$. However, a coefficient might then be negative for some individuals and positive for others. For most of the attributes it is more reasonable to expect that all respondents have the same coefficient sign. A more reasonable assumption would be that the coefficients are log-normally distributed

$$\beta_{kq} = \pm \exp(b_k + v_{kq}) \tag{3}$$

where the sign of coefficient β_k is determined according to expectations, b_k is constant and the same for all individuals, and v_{kq} is normally distributed across individuals with mean and variance equal to 0 and σ^2_k, respectively. The coefficient has the following properties: (a) median = $\exp(b_k)$, (b) mean = $\exp(b_k + \sigma^2_k/2)$, and (c) standard deviation = $\exp(b_k + \sigma^2_k/2)(\exp(\sigma^2_k) - 1)^{0.5}$. For a more detailed treatment of preference heterogeneity, see, for example, Bhat (1998, 2000).

5. The mode choice survey

The population used in the survey is individuals with work that have access to a car, and that are living and working in the metropolitan area of San José. The reason is that we want to ensure that the respondents can actually make a choice, in the short run, between private and public transportation. This sampling strategy excludes the low-income segments of society, since they cannot afford to own a car. As pointed out by a referee, changes in the costs of driving a car and in the attractiveness of the bus might have an impact on car ownership and long-run car use. Since we do not sample potential car users, we are unable to measure this impact. Still, we believe that the short-run situation of transportation in Costa Rica is not viable with the current size of the private car fleet, and we decided therefore to focus on current car owners. Hence, we can only hypothesise that the policies we study also can reduce the incentives for households without a car to buy a car in the future. We also focus on work trips since they, in particular, contribute to congestion problems at peak hours. In our experiment the length and destination of work trips is assumed to be fixed. Additionally, the timing of the trips is assumed to be exogenous, that is we do not allow the commuters to adjust their schedule in response to the hypothetical situation presented in the experiment. This assumption is required in order to maintain a higher control of the experiments. If not, we would have to make the mode choice decision a function of the chosen departure time. Since in Costa Rica there is very little work-hour flexibility, both in the public and private sector, and given that peak hours start early in the morning, we do not believe this addition will greatly improve our results. In addition, we note that the hypothetical mode choice situations do not depend on congestion levels.[6] Finally, we restrict the sample to work trips with an origin and destination within the metropolitan area, in order to restrict the analysis to the urban bus system. One limitation of our analysis is that it is partial in nature. For example, our estimates of cost elasticities cannot be regarded as the overall price elasticity of transport demand for metropolitan San José. Even in the short run, individuals can

[6] For discussions on commuter's scheduling adjustments to changes in congestion, see Small (1982), Arnott, de Palma, and Lindsey (1993).

adjust to higher costs per car trip by carpooling and reductions in non-work trips, among other possibilities. All these factors hint to larger effects of the policies that we analyze.

A survey company with more than ten years of experience conducted the survey between 1 September and 30 October 2000. All interviews were personal interviews where the enumerator read the questions aloud. The respondents were visited at their homes after office hours. The National Institute of Statistics has divided the metropolitan area into 5,700 segments, of which 43 were randomly selected for this survey. The questionnaires were then randomly assigned to each of these segments. The field supervisor would then decide which houses to survey in each locality. If the person at the door did not meet our criteria, the house next door was surveyed. A total of 602 questionnaires were completed, and the statistical error was 4 per cent.

Table 1 presents some descriptive statistics. The average income in Costa Rica was 160,000 colones[7] per month in 1999, whereas the average income of the 10th decile was around 600,000. Our sampled income distribution seems to fit this description, given the exclusion of low-income and rural families from our sample. The gender composition of our sample is simply a reflection of our sampling strategy, which required the respondent to be currently employed. Of particular interest is the high number of respondents who usually use the car to go to work. A large share of the respondents also stated that they sometimes need the car in their line of work.

The questionnaire consisted of three parts. The first part contained questions regarding their present work trips. The second part of the survey contained the choice experiment. Before the actual experiment was conducted, the enumerator carefully explained each of the attributes in the choice experiment. The respondent also received a written summary of the attributes. The last part of the survey contained questions regarding the respondent's socio-economic status and debriefing questions regarding the choice experiment.

Discussions with experts, several focus groups, informal tests of the questionnaire and a formal pilot study conducted by the survey company preceded the final design of the experiment and the survey. These intended to get a broad picture of the real problem of transportation in metropolitan Costa Rica. They also aimed at identifying the relevant alternatives, their attributes, and realistic attribute levels. Two important conclusions were the need to customize some of the attributes, particularly travel time and cost per trip, and the possibility of restricting the number of alternatives to only two: car and bus. All of the attributes selected are factors that a policy maker can affect, directly or indirectly, and they were all regarded as relevant based on the information from focus groups. Local newspapers have been discussing the need for a solution to the problem of public and private transportation. Different alternatives have been discussed and described, in particular the program for increasing the quality of bus services. This gave extra realism to our survey.

[7] IUSD corresponds to approximately 300 colones.

Table 1. *Sample statistics*

Variable	*Frequency*	
Income in colones	0–200,000	31.6%
	200,001–400,000	40.3%
	400,001–600,000	18.3%
	600,001–800,000	5.7%
	800,001+	3.5%
Gender	Male	77.2%
	Female	22.8%
Usual travel mode	Car	90.7%
	Bus	9.3%
Car needed at work	Yes	39.9%
	No	60.1%

The selected attributes for the car alternative are: (1) operating costs, (2) travel time per trip, and (3) parking cost. The selected attributes for the bus alternative are: (1) travel time, (2) bus fare per trip, (3) punctuality, (4) distance to bus stop, (5) frequency of departures, and (6) comfort and security. These attributes and their levels are presented in table 2.

The cost per trip and travel time for the car alternative, and travel time by bus, were customized to the current situation and the actual levels are thus not presented in table 2.[8] Questions regarding the distance to work, type of fuel used, and the travel time by car were asked at the beginning of the survey. The enumerator then filled in the relevant information in the choice experiment. The cost per car trip in colones was calculated based on conversion tables, which included the percentage increase in gasoline price. The punctuality attribute was defined such that it was not related to frequency of departures. For a high frequency service, one could argue that punctuality is not important. Nevertheless, it was explained that delays in the bus imply that for at least 15 minutes there was no bus stopping, irrespective of the frequency of departures. The Program for Quality Improvement, currently under study by the government, was carefully described. If this program were implemented, it would bring an increase in the quality of the service, including more comfortable buses, and higher security both onboard and at improved bus stops.

The choice situations were constructed with a linear D-optimal design using SAS (see, for example, Kuhfeld, 2001). The eight attributes were combined into 24 choice sets. These where then divided into three groups of eight choice situations, again using a D-optimal criterion. Consequently,

[8] The best way to customize travel time for the bus option would have been to define percentage increases relative to the car alternative. The results from focus groups and the pilot study made us fear that this would be too demanding for the enumerators and respondents. The levels chosen, in terms of absolute differences, were the most reasonable ones, based on the results of focus groups. The average travel time for trips to work by bus and car are 60 and 25 minutes, respectively, for the individuals in our sample.

Table 2. *Attributes and attribute levels*

Attribute	*Levels*
Travel cost car, per trip	i. Same as today, ii. 25% increase, iii. 40% increase
Bus fare, per trip	i. 50 colones, ii. 100 colones
Parking cost	i. Free parking, ii. 400 colones per day
Travel time: Car	i. Same as today
Bus	i. Same time as car, ii. 20 minutes longer than car, iii. 30 minutes longer than car, iv. 40 minutes longer than car
Punctuality	i. The bus is always on time, ii. The bus sometimes is more than 15 minutes late
Distance to bus stop	i. 10 minutes, ii. 15 minutes, iii. 20 minutes
No. of departures	Every i. 5 minutes, ii. 10 minutes, iii. 15 minutes
Comfort and security	i. Same as today, ii. The Program for Quality Improvement is implemented

each respondent answered eight choice sets. In each choice set they were to choose between going to work by car or by bus.

Since task complexity, learning, and fatigue effects are mentioned as criticisms of choice experiments we conduct a test of the stability of preferences, following Carlsson and Martinsson (2001). This test consisted of surveying half of the respondents with the choice sets in the order {A,B} and the other half in the order {B,A}.[9] A test for stability was performed by comparing the preferences estimated for the choices in subset A, when it was given in the sequence {A,B}, with the preferences obtained when the choices in subset A were given in the sequence {B,A}. This can be tested in a likelihood ratio test between the pooled model of the choices in subset A and the separate groups. A similar test can be performed for subset B. If the pooled model cannot be rejected, we can reject the hypothesized presence of the effects mentioned above. Based on the standard MNL, the hypothesis of stable preferences cannot be rejected.[10]

The survey also included debriefing questions, mainly intended to identify respondents who did not like (protestors) or did not understand the experiment. Of all 602 interviewed individuals, 3.8 per cent (23 individuals) expressed a negative perception or understanding of the experiment. These questionnaires are excluded from the estimations presented in the next section.

6. Results

We estimate two Random Parameter Logit models (RPL), in addition to the multinomial logit model. The two RPL models are: one with the attributes independently normally distributed and one with the attributes

[9] 'A' refers to the original first four choice sets, and 'B' to the original last four choice sets in each experiment.

[10] The statistics are equal to 12.65 and 7.77 respectively; the statistic is χ^2-distributed with 13 degrees of freedom.

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independently lognormally distributed. In both RPL models the cost attributes are kept fixed for several reasons: (i) we wish to restrict the cost variables to be non-positive for all respondents, hence a normal distribution is not recommended; (ii) a lognormal distribution, which restricts the sign of the variable, can result in extremely high values-of-time estimates, since values of the cost attribute close to zero are possible (Revelt and Train, 1998); and (iii) the distribution of the marginal value of time is simply the distribution of the time attribute.

The attribute 'distance to the bus stop' was consistently insignificant and caused problems with convergence for some models, and was therefore dropped from the analysis.[11] Both specifications include a mode specific intercept for car; in the normal specification the coefficient is fixed, while normally distributed in the model with lognormally distributed attributes.[12] Further, a variable capturing state dependence or inertia is included. This variable is a dummy variable equal to one if the respondent usually uses the car when traveling to work. In both random parameter models, this fixed state dependence variable could not be rejected in a likelihood ratio test. Furthermore, a number of individual characteristics are included as fixed coefficients. These are (i) *need car*, indicating whether the respondent sometimes needs his/her own car in the line of work, (ii) the respondent's *income*, and (iii) the respondent's *age*.

In table 3 we present the results for the three estimated models. The models were estimated with simulated maximum likelihood (see Revelt and Train, 1998; Train, 1999), based on Halton draws and 500 replications, using Limdep 7.0.2.

Columns 3 and 4 give the estimated coefficients for the model with the attributes normally distributed and columns 5 and 6 for the model with attributes lognormally distributed. The last two columns in the table present the estimated median and mean of β_k for the lognormal distribution. Note that the attributes are alternative specific; this implies that for the MNL model and the normal RPL model, the coefficients correspond to the parameters of the utility functions for *each* of the two alternatives. For the lognormal RPL, the mean and median of the corresponding parameters of the utility functions are given in columns 7 and 8. For example, the negative parameter for *Cost car* indicates that an increase in this item will reduce the utility of going by car, and hence the probability of choosing the car to commute. The two RPL models have a substantially higher

[11] This variable was not significant in the pilot study either, although it was mentioned several times during the focus groups. We tried to change the explanation of this attribute in order to have individuals make a trade-off with this characteristic. There are several explanations why this attribute turns out to be insignificant. First, the respondents may actually not see this attribute as important, or the choice experiment may have been too difficult and therefore many respondents chose not to focus on all attributes, including the distance to the nearest bus stop. Second, it may not have been thought of as credible that the government could actually change the distance to the bus stop by changing the routes.

[12] The model with normally distributed attributes did not converge when we included a normally distributed intercept.

Table 3. *Econometric results*

	MNLogit	*RPL (normal)*		*RPL (lognormal)*			
	Coeff.	*Coeff.*	*Coeff. Std.*	*Coeff.*	*Coeff. Std.*	*Median*	*Mean*
Constant Car	0.098	−1.427	Fixed	−0.488	2.594	−0.488	
	(0.235)	(0.740)[c]		(0.814)	(0.266)[a]	(0.814)	
Time (minutes): Car	−0.023	−0.032	0.066	−3.221	(0.430)	−0.040	−0.044
	(0.004)[a]	(0.019)[b]	(0.011)[a]	(0.496)	(0.467)	(0.020)[b]	(0.016)[a]
Time (minutes): Bus	−0.017	−0.053	0.043	−3.187	0.988	−0.042	−0.067
Cost (colones): Car	(0.003)[a]	(0.006)[a]	(0.006)[a]	(0.151)	(0.208)[a]	(0.006)[a]	(0.018)[a]
	−0.001	−0.003	Fixed	−0.003	Fixed		
	(0.0003)[a]	(0.090)[a]		(0.0008)[a]			
Cost (colones): Bus	−0.001	−0.002	Fixed	−0.002	Fixed		
	(0.002)	(0.249)		(0.002)			
Parking (dummy)	−0.190	−0.214	1.446	−1.935	1.522	−0.144	−0.460
	(0.075)[b]	(0.151)	(0.204)[a]	(0.607)	(0.313)[a]	(0.088)[c]	(0.490)
Punctuality (dummy)	0.639	1.111	1.864	−0.495	1.325	0.610	1.468
	(0.076)[a]	(0.181)[a]	(0.228)[a]	(0.253)	(0.181)[a]	(0.154)[a]	(0.701)[b]
No. of departures	0.031	0.006	0.240	−3.225	1.053	0.040	0.069
(units)	(0.011)[a]	(0.030)	(0.030)[a]	(0.646)	(0.456)[b]	(0.026)	(0.019)[a]
Quality program	0.054	0.171	0.357	−2.928	1.386	0.054	0.140
(dummy)	(0.075)	(0.132)	(0.312)	(1.458)	(0.447)[a]	(0.078)	(0.289)
	Non-random socio-demographic characteristics						
State dependence	1.755		4.300		4.266		
	(0.111)[a]		(0.518)[a]		(0.555)[a]		
Need car at work	0.553		0.791		1.043		
	(0.081)[a]		(0.307)[a]		(0.348)[a]		
Income	0.041		0.067		0.050		
	(0.011)[a]		(0.041)[c]		(0.046)		
Age	−0.081		−0.094		−0.146		
	(0.035)[b]		(0.139)		(0.154)		
Log-likelihood	2226		1695		1662		
Pseudo R^2	0.31		0.47		0.48		

Notes:
Standard errors in parentheses.
[a] Significant at 1% level.
[b] Significant at 5% level.
[c] Significant at 10% level.

pseudo-R^2 compared to the MNL model. The MNL is a restricted version of the two RPL models, in which all the coefficients are deterministic. In a likelihood ratio test we can reject the restrictions imposed by the MNL model.[13] The two RPL models give similar results in terms of the significance of coefficient and standard deviations estimates.[14] The only differences are that the mean coefficient for *Number of departures* is insignificant in the normal model while significant in the lognormal model, that the estimated standard deviation for *Travel time* by car is only significant in the normal model, and finally that the estimated standard deviation for the *Quality program* is only significant in the lognormal model. Most of the standard deviations are significant, reflecting heterogeneity in the underlying preference structure. Since the estimated standard deviations are large relative to the estimated mean coefficients in the RPL model with normal distribution, there is a relatively high probability that a respondent has the reverse sign of the preference for an attribute. This is perhaps not a desirable feature of the model and, as such, a justification for preferring the lognormal model.

In the lognormal model, all attributes except the *Bus fare* and the *Quality program* for the bus, and *Parking* for the car have significant mean effects.[15] The relative importance of the level-of-service attributes is revealed by the estimates of the mean in columns (3) and (8) for the normal and lognormal models, respectively, for those attributes that share the same unit of measurement. For example, *Punctuality* has relatively a much higher mean effect on the utility derived from a bus trip than the *Quality program*.

For the car mode, *Travel time* and *Cost per trip* are the significant determinants of the mode choice. It is surprising that *Parking cost* is not significant, given our discussion in section 2. A possible explanation for this result is that the levels presented in the experiment might have been regarded as too low. The definition of the levels for the parking attribute proved to be an evasive task throughout the construction of the experiment. Although parking in the city can be regarded as free, there is an informal system of car-watchers who charge a fee for their service. For the bus mode all attributes except for the *Cost per trip* and the *Quality program* are significant determinants of the mode choice, although *Number of departures* is not significant in the normal model. This indicates that the important characteristic of the bus mode is the overall travel time.

[13] For the RPL (normal) and RPL (lognormal) models, the test statistics are 1062 which is χ^2-distributed with 6 degrees of freedom, and 1128 which is χ^2 with 7 degrees of freedom, respectively.

[14] The significance of the constant term (b_k) in the lognormally distributed coefficients is not reported since the only reasonable test of significance for this parameter is a test of negative infinity. In any case, the standard errors of these estimated coefficients are small compared to the parameters.

[15] For large samples, and under quite general conditions, the sample mean of a sequence of random variables converges to a normal distribution even though the parent distribution is not normal. A one-tail t-student test can therefore be applied on the means to test the hypothesis $\beta^{mean} = 0$, versus $\beta^{mean} > 0$.

An important variable is the state dependence variable, which is highly significant. This variable captures a strong inertia in the use of the car for those individuals already using it, and it has important policy implications. Another way in which we model heterogeneous preferences is by including socio-demographic characteristics. As expected, those individuals who sometimes need the car at work are more likely to choose the car mode in the choice experiment. In the MNL model, both the income and the age of the respondent are highly significant. This significance is reduced in the RPL models. The positive coefficient for income indicates that higher-income individuals are less likely to take the bus, since they experience a higher cost of traveling time.

7. Analysis of results

In this section we explore the responsiveness of modal choice to changes in the attributes. We calculate the aggregate elasticities and marginal effects for each attribute and estimate the value-of-time for each mode. The estimates of the value-of-time provide information about the potential gains for the travellers from the policies. These benefits may actually be as important as the benefits from reduced emissions.

Since the two different RPL models give similar elasticities and marginal effects, we only report the results for the model with the attributes having a lognormal distribution. The aggregate elasticities are computed as a weighted average of the individual elasticities using the choice probabilities as weights, and the marginal effects are also weighted by the choice probabilities[16] (see Ben-Akiva and Lerman, 1985; Bhat, 1998). Table 4 reports the estimated elasticities and marginal effects. The elasticities are the percentage change in choice probability for a percentage change in the corresponding attribute, and the marginal effects are the marginal change in choice probability for a marginal change in the corresponding attribute.[17]

The elasticities and marginal effects are generally low, mainly due to the effect of state dependence and the limited adjustment to the policies permitted in our study, due to the assumptions of given number of trips and fixed origin and destination. This is expected, and is in line with other similar studies (see, for example, Bhat, 1998, 2000; Swait and Eskeland, 1995). Travel time for bus and car have the highest elasticities and marginal effects. A hypothetical 10 per cent decrease in average travel time by bus (corresponding to an average reduction of 6 minutes) would reduce the probability of car use by 1.36 per cent.

The elasticity and marginal effect of the cost per car trip is much higher than the elasticity and marginal effect of the cost per bus trip, and parking cost is less important than costs per car and bus trip. Punctuality and frequency of the bus service both have a larger impact on the choice of mode than the Quality Improvement Program. This is also an indication of the

[16] Since the marginal effects are probability weighted they will not in general sum to one.

[17] Parking, punctuality, and quality are dummy variables, so the reported elasticities and marginal effects are only approximations.

Table 4. *Average elasticities and marginal effects (times 100) for the car and bus modes. RPL model with lognormal distribution*

	Average elasticities		*Average marginal effects*	
	Direct (car)	*Cross (bus)*	*Direct (car)*	*Cross (bus)*
Increase in travel time for the car mode	−0.093	0.319	−6.854	8.282
Increase in cost per car trip	−0.064	0.219	−4.613	6.027
Increase in parking costs for car	−0.020	0.069	−1.516	1.673
	Cross (car)	*Direct (bus)*	*Cross (car)*	*Direct (bus)*
Decrease in travel time for the bus mode	−0.136	0.468	−9.855	12.813
Decrease in cost per bus trip	−0.014	0.049	−1.055	1.239
Increase in punctuality	−0.059	0.202	−4.280	5.461
Increase in frequency	−0.047	0.161	−3.524	3.964
Increase in quality	−0.006	0.022	−0.467	0.551

importance of travel time, since frequency and punctuality have an impact on overall travel time.

Our analysis allows us to reach several conclusions from a policy-making perspective. First, the model shows an important inertia in travel behavior. The car mode has several advantages in terms of comfort, travel route timing, flexibility, and safety, among others, and our results confirm that breaking the travel pattern of a car user is difficult. A reduction in travel time for the bus mode emerges as the most important element in a program aimed at attracting commuters towards public transport and away from the private mode. Consequently, measures such as exclusive bus lanes, faster and more accurate connections, and traffic light priority, can have an impact on the use of private transport. On the other hand, subsidized bus fares seem to have very low effectiveness according to our analysis. Subsidies should instead be linked to better service, particularly regarding punctuality and frequency of departures, which further reduce overall travel time. Alternatively, the low direct elasticity of bus fares indicates the feasibility of creating a bus system that is more expensive, but faster and with better service, which would target the middle-class travelers sampled in our study. Of the monetary incentives that could be used to discourage private transportation, increases in parking costs at work do not seem to be as effective as expected. Its mean effect is not significantly different than zero, and the elasticity of car use with respect to parking costs is correspondingly very low. Due to the reasons mentioned in the previous section, we prefer not to draw a strong conclusion from this result. On the other hand, contrary to public perception, increases in cost per car trip do have an effect on modal substitution, although this effect is rather small.

Finally, the (average) marginal value of time is calculated as the ratio of the coefficient for travel and the coefficient of travel cost by car. The value of time is related to the value of working time for individuals traveling to work. In our sample, the average wage per hour is around 2,000 colones. Table 5 reports the estimated average marginal values of time for all three models. The confidence intervals are based on 9,000 replications of the Krinsky–Robb (1986) method.

Due to the assumption of a lognormal distribution, the estimated mean value of time is higher in the lognormal model compared to the normal model, in particular for the value of time when traveling by bus. Furthermore, the confidence intervals are very large, in particular for the lognormal model. The willingness to pay for reduced travel time in both modes is high, around 40–50 per cent of the average hourly wage in our sample. This is in line with many previous studies (Small, 1992; Bhat, 1998), although some studies have found rather low values of time using choice experiments (see, for example, Calfee and Winston, 1998). In the Random Parameter Models, the willingness to pay for reduced travel time is higher for the bus mode than for the car mode. This result is expected since the disutility of the time spent traveling by bus is likely to be higher. These results show that reductions in travel time due to reduced congestion can have substantial benefits for our sample population. However, we also find that the estimated value of time is sensitive to the econometric specification.[18]

8. Conclusion

In general, the results indicate that mode substitution is sensitive to the characteristics and performance of each mode. In particular, travel time for both modes and travel cost for car are the most important determinants of mode choice. Our estimates of elasticities and marginal effects are rather small. This is in line with other studies, and is partly the result of their short-run perspective. Since the aim is to determine which characteristics are more relevant to achieving a switch from private to public modes of transportation, we rather concentrate on the relative importance of each attribute. We therefore conclude that a program aimed at reducing congestion and pollution during peak hours should focus on increasing the cost of private transport and providing faster and more reliable public transport.[19] The possibility of separating public transport by creating a parallel service that provides a more expensive but faster service, is one potential alternative to detract customers from private transportation. As mentioned, the Costa Rican Ministry of Transport is currently redesigning the system of public transportation. Our study sheds light on the most important features required by that system if it is to attract travelers from

[18] Bhat (2000) also finds that the estimates of value of time is sensitive to the econometric specification, while Bhat (1998) and Calfee *et al*. (2000) finds little evidence of sensitivity of the estimates of value of time with respect to econometric specification.

[19] This conclusion is contingent on the excess capacity of the current fleet and the environmental performance of new additions to this fleet. Given the discussion in section 2, we believe a mode switch from private to public commuting will actually reduce emissions.

Table 5. *Average value of time, 90% confidence interval*

	MNL	*RPL (normal)*	*RPL (lognormal)*	
			Mean	*Median*
Value of time in bus	949	1005	1394	856
(col/hour)	(602–4640)	(666–1820)	(795–3109)	(536–1715)
Value of time in car	1291	614	908	827
(col/hour)	(534–2806)	(27–1878)	(441–3171)	(291–2952)

private modes. Specifically, emphasis has to be put on measures intended to reduce travel time, for example by designing routes and exclusive bus lanes, and more frequent and reliable departures. Contrary to popular beliefs, comfort on board seems to be a much less relevant characteristic for commuters to work.

Finally, our estimates of the willingness to pay for reduced travel time in both modes show that potentially large benefits can be obtained from a program aimed at reducing congestion, although a study of the net social value of such a program would be required.

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