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Modeling the Determinants of Automobile Ownership in Developing Cities: The Case of Monterrey, Mexico

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MODELING THE DETERMINANTS OF AUTOMOBILE OWNERSHIP IN DEVELOPING CITIES: THE CASE OF MONTERREY, MEXICO

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Abstract

This article develops a behavioral model to examine the impacts of socioeconomic and demographic variables on auto ownership in a developing city using Monterrey, Mexico as a case study. The importance of accessibility of the competing mode, namely, public transit on auto ownership was also examined. Multinomial logit was used to estimate the probability of auto ownership utilizing data from 1991 and 1993 surveys. Constructing the model proved difficult due to high correlations between several variables.

Results confirm the important role that income (wages) plays in determining the probability of vehicle ownership and income elasticities were within the normal ranges. Home ownership, household size, and number of adults per household also had a large impact on the probability of auto ownership. The significance of household wages, household size and the number of adults in the household increased as the level of auto ownership increased. Generalized cost variables, zonal densities and the use of locational variables failed to demonstrate that accessibility by public transit had any impact on auto ownership. This conclusion may have been primarily due to inadequate time and cost data and requires further investigation.

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MODELING THE DETERMINANTS OF AUTOMOBILE OWNERSHIP IN DEVELOPING CITIES THE CASE OF MONTERREY, MEXICO

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1. INTRODUCTION

Developing cities have experienced a large increase in the levels of auto ownership over the past three decades (Button et al, 1991; Spencer and Madhavan, 1989). The increase in the absolute number of cars continues to put pressure on government budgets to provide more road infrastructure. One of the main reasons for the increase in auto ownership levels is the growth in income levels in developing cities (Button et al, 1991; Khan and Willumsen, 1986). As a result, the current upward trend in car ownership levels can be expected to continue, although at a slower pace at the higher income levels. A better understanding of the determinants of auto ownership is imperative for better coping with and managing auto growth.

A review of the transportation literature clearly reveals the relatively small number of behavioral transportation models for developing cities, particularly in academic journals. The lack of data has precluded the development of such models in many cities; and even when data are available, they tend to be inaccurate and inconsistent (Button et al, 1993). Given the lack of behavioral transportation models, it seems unlikely that the impacts of transportation policies are accurately predicted or estimated in many cities in developing countries.

The main objective of this article is to design a behavioral auto ownership model that sheds some light on auto ownership behavior and on how rates of ownership are expected to change with changes in socioeconomic and demographic variables in developing cities using Monterrey, Mexico as a case study. Results of the model are briefly compared to those of auto ownership models from other cities, and behavioral differences are discussed.

The rest of the article is arranged as follows. Section 2 provides a brief background of the levels and growth rates of auto ownership in Monterrey, Mexico. Section 3 presents the data sources, and Section 4 presents the elements of the discrete choice auto ownership model developed in this study for the city of Monterrey. In Section 5, results of preferred models and alternative specifications are discussed and the main differences are analyzed. Section 6 compares the model results to the findings of other studies. The elasticity of vehicle ownership with respect to household wages is also discussed in this section. Section 7 presents the summary of the article and its main conclusions.

2. AUTO OWNERSHIP IN MONTERREY, MEXICO

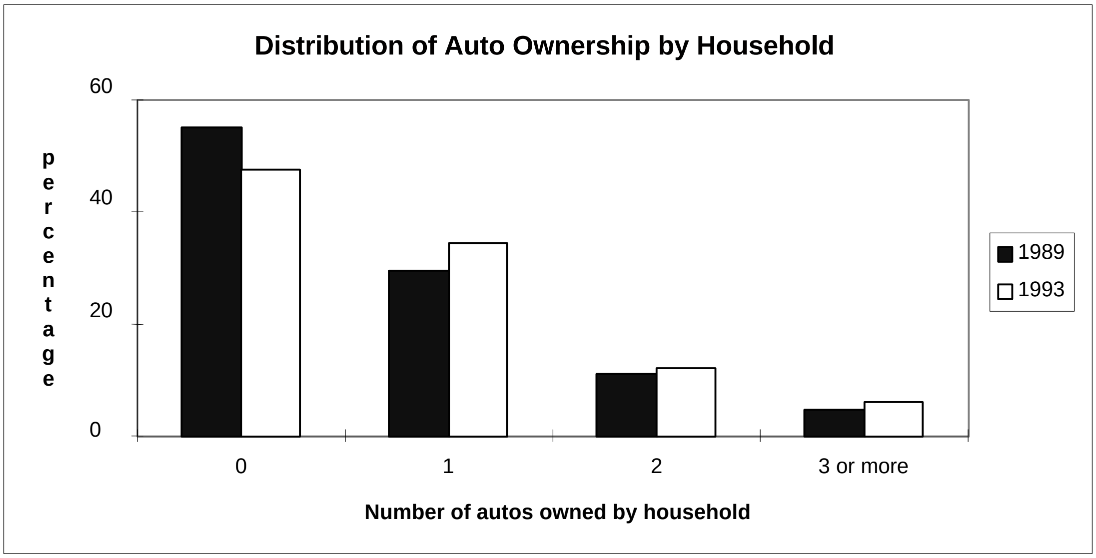
The percentage of vehicle-owning households in the Monterrey Metropolitan Region (MMR) increased from 45% in 1989 to 52.5% in 1993 (see Table 1 and Figure 1). This represents a 7.5 percentage-point increase over only a four-year period. The 1993 data also suggest that the mean number of vehicles owned by a household is approximately 0.82, up from 0.67 in 1989. This represents a growth rate of 22 % in the average number of vehicles per household over the four-year period or an annual growth rate of 5.2 percent.[1] The rate of growth falls within that of many developing cities. For example, Cevero (1990) uses data showing that the annual growth rate in per capita auto ownership in Jakarta from 1980 to 1988 was 5.1%, and that for Manila from 1982 to 1988 was 5.5%.

Table 1
Distribution of Automobiles Owned by Households
Monterrey Metropolitan Region

Number of Vehicles	1989	1993
0	55.0%	47.5%
1	29.5%	34.3%
2	11.0%	12.2%
3 or more	4.5%	6.0%
Total	100%	100%
Average level	0.67	0.82

Source: The household surveys conducted by MSCT in 1989 and 1993.

Figure 1



Although income growth in Mexico was slow in the early 1990's, growth prospects were favorable for the mid 1990's until the devaluation of the Mexican currency in 1995. Notwithstanding the short run impacts of the currency devaluation on the Mexican economy, it is reasonable to expect an increase in income levels in Mexico, particularly as a result of the North American Free Trade Agreement (NAFTA). One can also expect Monterrey, being the second largest industrial center in Mexico, to enjoy higher-than-average growth rates as the city stands to gain more from NAFTA than the rest of Mexico given its proximity to the United States. The anticipated increases in income can be expected to further increase auto ownership in MMR. Moreover, the population projections of 5 million for MMR by the year 2000 are likely to contribute to the overall increase in the number of vehicles.[2]

[1] The difference in means is statistically different from zero at the 5% level.

[2] Population projections for MMR are obtained from Consejo Estatal Del Transporte, (1992).

3. DATA[3]

The main data sources include: 1) three home surveys conducted by the Monterrey State Council for Transportation; MSCT (Consejo Estatal Del Transporte) in 1993, 1991 and 1989. 2) the 1990 census conducted by Mexico's National Institute for Geographic and Informatic Statistics (Instituto Nacional De Estadistica, Geographia E Informatica-INEGI). 3) computer simulations of trip times and distances obtained using the two software packages employed by MSCT for analyzing auto and transit policies. These packages are TRANPLAN and VIPS respectively. 4) Additional reports and data obtained through interviews and discussions with staff members of MSCT.

INEGI has divided the Monterrey Metropolitan Region into 785 census tracts based on socioeconomic characteristics. MSCT aggregated the 785 census tracts into 293 transportation zones.[4] In the 1993 home survey, 3013 homes representing 85 census tracts and 81 transportation zones were visited and a representative of the household was interviewed. The homes were selected using stratified random sampling. First census tracts with similar socioeconomic characteristics were grouped together, then homes were randomly selected from these tracts. The number of homes visited from each group of census tracts was proportional to the total number of homes in the group. Interviewers asked a household representative about demographic and socioeconomic characteristics of all members of the household including age, gender, education, occupation, wage, etc. The interviewer also asked for information on vehicle ownership, and on trips made by each household member on the day prior to the interview. Trip data included origin and destination of trip, mode used, trip time broken down by walk, wait and in-vehicle times for transit, trip cost, and frequency of trips per week.

The 1991 home survey included 1997 homes. Unlike the 1993 survey, the method of selection of the sample is not clear. The 1991 survey collected information on demographic and

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[3] All data used are based on surveys conducted well before the currency devaluation of 1995. Accordingly, the general conclusions arrived at are not affected by the devaluation and in principle may be transferable to other developing cities.

[4] Actual number of transportation zones used by MSCT is 303. Of these, 10 zones are "gates" to the region reflecting the main points used by intercity travelers to enter, or exit from, the region.

socioeconomic variables similar to that collected in the 1993 survey but had less detailed information on trips made. The data in this survey were used to estimate a second auto ownership model and to compare its results to those obtained from the model estimated using 1993 data. The 1989 survey had interviewed approximately 23000 homes and covered all transportation zones. Unfortunately interviewers did not gather any information on income levels or the different components of travel time and cost. Thus, the results could not be used to estimate a behavioral auto ownership model. Data from this survey were used above to determine the growth rates in auto ownership from 1989 to 1993. Computer-simulated trip times, distances and money costs obtained from MSCT were used to develop and test different measures of accessibility.

4. MODEL SPECIFICATION

Several different auto ownership models are developed and tested for the Monterrey Metropolitan Region using cross sectional data from the 1993 and 1991 home surveys. Multinomial logit is used to estimate the probabilities of certain levels of vehicle ownership by a household. The household is assumed to have four options: no vehicles, one vehicle, two vehicles, and three-or-more vehicles. The probability for level of ownership (i) by household (n) is estimated as follows:

$$P_n(i) = \frac{e^{\beta_i \mathbf{X}_{in}}}{\sum_{j \in C_m} e^{\beta_j \mathbf{X}_{jn}}}$$

where C_m is the choice set reflecting level of auto ownership. It consists of zero, 1, 2, and 3-or-more vehicles; $\mathbf{X}_{jn}$ is the vector of explanatory variables for choice level j by household n; & β_j is the vector of coefficients for choice level j.

Three broad categories of explanatory variables are used. The first two deal with the economic and demographic characteristics of the household respectively. The third deals with the availability, cost, and convenience of competing transport modes.[5] Table 2 presents the means and medians for some of the main explanatory variables used in the analysis.

Economic Variables: These variables typically include attributes such as household wealth and income. The wealthier the household, the higher is the probability and level of ownership. Since wealth is difficult to measure, household income is the more-frequently used measure. Two variables from this category are tested.

1. The first variable is ***total weekly (monthly) wages per household***: This variable is used for lack of other variables that better represent household wealth or income. It does not capture other income sources, such as savings and pensions. Weekly wages are used in the 1993 model and monthly wages in the 1991 model instead of annual wages because the latter are not always available in the data sets.

   Table 2 shows that the average wage per month has increased from 1,451 current new pesos in 1991 to 2,449 current new pesos in 1993, an increase of approximately 10% per year over and above the inflation rate.[6] This increase may seem somewhat high given that growth rates in real income over the same period in Mexico were only 3.0 % per year. But one should keep in mind that Monterrey, being the second largest industrial center in Mexico is very likely to be growing faster than the national average. Nevertheless, various unofficial estimates suggest that inflation in Monterrey from 1991 to 1993 was higher than the national average reported by the International Monetary Fund. If this proved to be the case, the reported increase in per capita income would be lower.

[5] Variables dealing with the direct cost of vehicle ownership and use such as vehicle price, taxes on ownership and use, and gasoline costs hardly vary from one area to another in Monterrey and were hence not considered. Also data on parking costs were not available for Monterrey.

[6] Inflation rate over the two years was taken at 39% based on International Monetary Fund (1994). This estimate is for the whole country.

Table 2
Basic Statistics for Explanatory Variables used in Auto Ownership Model
Monterrey Metropolitan Region

<table>
<tr><th rowspan="2">Variable (per household)</th><th colspan="2">Mean</th><th colspan="2">Median</th></tr>
<tr><th>1991</th><th>1993</th><th>1991</th><th>1993</th></tr>
<tr><td>Monthly wages in new pesos[1]</td><td>1,454</td><td>2,449</td><td>1,000</td><td>1,520</td></tr>
<tr><td>Persons</td><td>5.1</td><td>4.5</td><td>5</td><td>4</td></tr>
<tr><td>Permanent Workers[2]</td><td rowspan="2">1.8</td><td>1.3</td><td rowspan="2">2</td><td>1</td></tr>
<tr><td>Occasional Workers[2]</td><td>0.4</td><td>0</td></tr>
<tr><td>Age of Principal Worker</td><td>n.a.</td><td>38</td><td>n.a.</td><td>35</td></tr>
<tr><td>Persons 5-19 years old</td><td>1.5</td><td>1.3</td><td>1</td><td>1</td></tr>
<tr><td>Adults (19-60 years old)</td><td>2.8</td><td>2.8</td><td>2</td><td>2</td></tr>
</table>

1. Monthly estimates for 1993 are based on reported weekly wages.
   Wages for both 1991 and 1993 are in current new pesos.

2. In the 1991 survey, workers are reported in one category. Occasional workers are hired on a job-by-job basis whenever there is one available.

n.a. not applicable. Ages for 1991 are reported in six 10-year brackets only.

Source: The household surveys conducted by MSCT in 1991 and 1993. Method of selection of 1991 sample is not clear.

2. The second variable from this category is ***home ownership***: Home ownership can be also interpreted as a measure of wealth and is expected to have a positive impact on vehicle ownership. This variable takes the value 1 if the home is owned by one of its residents; and 0 otherwise.

Household Demographic Variables: These variables include the number, age, and gender of persons in a household; and the gender, age and occupation of the principal household worker. The composition of household members is also important. For instance, the presence of infants in the family might increase the probability of ownership. The gender of the principal worker is sometimes used to explain differences in ownership behavior. In some cultures, higher vehicle ownership is associated with a female principal worker, while in others it is associated with a male principal worker. In choosing from this large menu of variables, one should be aware of the multicollinearity that is likely to exist between many of these variables if included in the same model. The following variables are examined:

1. ***Size of household:*** The larger the number of persons per household for a given income level, the less is the income per capita. Consequently, one would expect that the greater the number of persons per household for a given income level, the lower is the probability and level of ownership.

2. ***Number of workers per household:*** In models that control for the size and income of the household, one would expect higher probabilities of ownership to be associated with households that have a larger number of workers because more work trips may require more autos. The 1993 data included two types of workers: permanent and occasional. The latter is presumed to include workers hired on a job-by-job basis whenever there is one available (for example certain construction workers). The category is believed not to include part-time workers.[7]

3. ***Age of principal worker:*** Principal worker in the household is defined as the highest wage-earner. For the 1991 model, actual ages are not available; instead, six 10-year age brackets are used.

4. ***Gender of the principal worker:*** The variable takes the value 1 if the principal worker is female; 0 if it is male.

5. ***Number of persons under five years*** per household.

6. ***Number of persons between the ages of 5 and 19 years*** per household.

7. ***Number of adults*** (persons between the ages of 19 and 60 years) per household.

Variables Measuring Characteristics of Competing Modes: This category deals with the availability, cost and convenience of alternative transport modes. Ideally it should include variables that reflect the availability, extensiveness, accessibility, convenience and frequency of

[7] The Spanish name for this category of employment is *'eventual'*.

public transit service, the automobile’s main alternative. Examples of these variables are the availability of bus stops close to the household, the number of blocks to bus stops, time it takes to get to work by the competing mode, and the number of transfers associated with a trip by the competing mode.

Accessibility is typically measured as a composite index of travel time or travel distance between the household residence and the different locations of employment, education, recreation, etc. In this study, crude indices were developed based on zone-to-zone data and not door-to-door travel time and distance.

a) One index tested was the average distance by auto from the zone to which the household belongs to all other zones.

b) Another index tested was travel distance from zone of residence to zone of employment of principal worker.

c) Zone population density was also considered. Accessibility may sometimes be indirectly captured by measuring 'neighborhood' population densities. The hypothesis is that the less dense a certain area is, the less likely it will have frequent public transit service, if any at all. Consequently, lower-density neighborhoods are expected to be associated with higher levels of vehicle ownership.

d) Since data on many of the trip attributes mentioned above are not readily available or reliable, an attempt has been made to capture some of these location-specific characteristics of competing modes by testing 6 locational dummy variables--a variable for each municipality (except the municipality of Apodaca, which is used as a reference). Two points need to be emphasized. First, these municipalities are quite large and varied so some of the location-specific characteristics of the household or the neighborhood may be lost due to aggregation at the level of the whole municipality. This is particularly true of the municipality of Monterrey which is much larger in terms of area and number of households than any of the other municipalities. The second point is that these locational variables may also capture certain socioeconomic aspects that are not fully represented in the model. For example, it is very likely that they will reflect the wealth of the municipality since we are only using household wages and home ownership to express wealth. They may also capture differences in parking costs between municipalities, assuming there are any.

5. MODEL RESULTS

Tables 3 and 4 present the results for two preferred multinomial logit models for 1993 and 1991 respectively. Four alternative model specifications using 1993 data are presented in Tables A1.1 and A1.2 in Appendix 1, while five alternative specifications using 1991 data are presented in Tables A2.1 and A2.2 in Appendix 2. The results of the preferred models are analyzed and compared to the results from the alternative model specifications.

5.1 Preferred Models

Tables 3 and 4 show that most of the coefficients of the preferred models have the expected signs and are statistically significant at either the 5% or 10% levels. Table 5 presents the elasticities for the different explanatory variables used in the preferred models. The table shows that household wages, and the number of persons and adults per household have a large impact on the probabilities of ownership. Other demographic variables (number of workers and gender of principal worker) have little impact on auto ownership. The results are discussed in more detail below.

The preferred model for 1993 uses somewhat different explanatory variables than those used in the 1991 preferred model. Ideally one would like to use the same variables in both preferred models--the one estimated using 1993 data and the one estimated using 1991 data--to allow for a complete comparison between the results of the models. This was not possible due to problems of definition and high correlations between variables. For instance, while the 1991 household survey asked about the number of workers in the household, the 1993 survey inquired about the number of permanent workers and the number of occasional workers in the household. As discussed later, the impact of the number of permanent workers on vehicle ownership is different from that of the number of occasional workers. Including both types of labor in one category may result in a loss in the overall explanatory power of the model and one would not be able to analyze the different impacts of the different types of employment on vehicle ownership.

Table 3
Multinomial Logit Estimates for Household Vehicle Ownership
Monterrey Metropolitan Region, *1993*

(Preferred Model)

Choice set: zero vehicles, 1 vehicle, 2 vehicles, 3 or more vehicles		
Explanatory Variable	***Coefficient***	***Asymptotic t statistic***
HOUSEHOLD OWNS ONE VEHICLE		
Constant	-1.1213	-7.12
Total weekly wages per household	0.001884	11.23
Permanent workers per household	-0.11518	-2.13
Occasional workers per household	-0.35711	-5.37
Home ownership (1 if owner, 0 otherwise)	0.36014	2.40
Gender of principal worker (1 if female, 0 otherwise)	-0.35294	-3.28
HOUSEHOLD OWNS TWO VEHICLES		
Constant	-3.8943	-11.00
Total weekly wages per household	0.002996	16.78
Permanent workers per household	-0.14770	-1.98
Occasional workers per household	-0.49567	-4.39
Home ownership (1 if owner, 0 otherwise)	1.1058	3.24
Gender of principal worker (1 if female, 0 otherwise)	-0.43523	-2.39
HOUSEHOLD OWNS THREE-OR-MORE VEHICLES		
Constant	-7.2238	-8.38
Total weekly wages per household	0.003385	18.44
Permanent workers per household	0.18067	1.98
Occasional workers per household	-0.31773	-1.94*
Home ownership (1 if owner, 0 otherwise)	2.2728	2.71
Gender of principal worker (1 if female, 0 otherwise)	-0.42808	-1.59**

Summary Statistics

Number of Observations	2,925
L(0): Log-likelihood (slopes=0)	-3,164
L(β): Log-likelihood (at maximum)	-2,764
ρ^2: [1 - L(β)/L(0)]	0.13

* not statistically significant at the 5% level, but statistically significant at the 10% level.
** not statistically significant at the 10% level.

Source: Estimation carried out in this study using 1993 household survey data.

Table 4
Multinomial Logit Estimates for Household Vehicle Ownership
Monterrey Metropolitan Region, *1991*

(Preferred Model)

Choice set: zero vehicles, 1 vehicle, 2 vehicles, 3-or-more vehicles

Explanatory Variable	*Coefficient*	*Asymptotic t statistic*
HOUSEHOLD OWNS ONE VEHICLE		
Constant	-1.1374	-5.88
Total monthly wages per household	0.000839	11.37
Persons per household	-0.07750	-2.18
Adults (ages 19-60 years) per household	-0.08995	-1.68*
Home ownership (1 if owner, 0 otherwise)	0.24985	1.70
HOUSEHOLD OWNS TWO VEHICLES		
Constant	-4.0570	-10.57
Total monthly wages per household	0.001353	15.64
Persons per household	-0.26193	-4.01
Adults (ages 19-60 years) per household	0.25347	2.96
Home ownership (1 if owner, 0 otherwise)	0.92166	2.94
HOUSEHOLD OWNS THREE-OR-MORE VEHICLES		
Constant	-7.0771	-8.25
Total monthly wages per household	0.001474	15.46
Persons per household	-0.42364	-3.49
Adults (ages 19-60 years) per household	0.65978	4.51
Home ownership (1 if owner, 0 otherwise)	1.6730	2.18

Summary Statistics

Number of Observations	1,743
L(0): Log-likelihood (slopes=0)	-1,763
L(β): Log-likelihood (at maximum)	-1,501
ρ^2: [1 - L(β)/L(0)]	0.148

* not statistically significant at the 5% level, but significant at the 10% level.

Source: Estimation carried out in this study using 1991 household survey data.

Table 5
Elasticities of Vehicle Ownership
Monterrey Metropolitan Region

Elasticity of probability of level of vehicle ownership with respect to:	**Prob. of owning one**		**Prob. of owning 2**		**Prob. of owning 3-or-more vehicles**	
	93	91	93	91	93	91
Household wages	0.42	0.59	1.10	1.34	1.34	1.52
Persons per household	n.a.	-0.13	n.a.	-1.08	n.a.	-1.92
Adults per household	n.a.	-0.23	n.a.	0.73	n.a.	1.87
Workers per household						
Permanent workers	-0.07	n.a.	-0.11	n.a.	0.30	n.a.
Occasional workers	-0.05	n.a.	-0.10	n.a.	-0.04	n.a.

n.a.: not applicable.

Source: Elasticities are estimated at the means based on the multinomial models presented in Tables 3 and 4 as follows:

$$h_i^x = x(b_i^x - \sum_{j \in C_n} P_j b_j^x)$$

where:

h_j^x is the elasticity of the probability of owning i vehicles with respect to variable X.

j is the level of ownership and belongs to the ownership set C_n which contains the elements 1, 2 and 3 or more.

b_j^x is the coefficient of variable X used to estimate the probability of owning j vehicles.

P_j probability of ownership level j.

Another problem was that the number of workers and the number of persons per household were very highly correlated. This prevented the use of both variables in the preferred models as the inclusion of both would result in one of the variables having the wrong sign and in lowering the statistical significance of both. Due to the inability to include both variables--number of persons and number of workers--in the same model, the variable that had a higher statistical significance and contributed more to the overall explanatory power of the model was used. In the 1991 model, number of persons was used; and in the 1993 model, two variables for the number of permanent and occasional workers were used. Not using identical variables in both models implies that one should be cautious when comparing the results of the two models. The importance and impact of each of the explanatory variables on auto ownership is discussed below.

***Household Wages*:** This variable is by far the most statistically significant of all explanatory variables tested. In both 1991 and 1993 models, it is statistically significant at the 1% level and its coefficient is positive indicating an increase in vehicle ownership probabilities the higher household wages are.[8] The models indicate that wages play a larger role in determining the probability of ownership as the level of ownership increases. The size of the wage coefficient, and the wage elasticity increase as we move from the equation determining the probability of owning one vehicle to the next determining the probability of owning two vehicles and finally to the equation determining the probability of owning three-or-more vehicles. (Wage elasticities are discussed in Section 6.) This holds for both 1991 and 1993 models. Moreover, in the 1993 model, the statistical significance of income as an explanatory variable increases at the higher levels of ownership as demonstrated by the increase in the value of the asymptotic t statistic for the household wage variable as we move from the one-vehicle equation to the multiple vehicle equations.

Home Ownership: The dummy variable for home ownership is statistically significant at the 10% level in all equations and at the 5% level in all but one equation, and has a relatively large coefficient in both 1991 and 1993 models. Its coefficient has the expected positive sign indicating that higher probabilities of vehicle ownership are associated with higher probabilities

[8] The large difference in the size of coefficients for 1993 and 1991 can be partly explained by the use of weekly wages for 1993 and monthly wages for 1991, and partly by the inflation rate between 1991 and 1993. Multiplying the coefficient of monthly wages in the 1991 model by 4 to find its weekly equivalent, and dividing by the estimated rate of inflation of 39%, we end up with closer values to the wage coefficients obtained from the 1993 model. If indeed the rate of inflation was higher than the estimated 39% during the early 1990s, the adjusted wage coefficients for 1991 would be even closer to those of 1993.

of home ownership. If a median home is owned by one of its residents, the probabilities of owning one, two, and three-or-more vehicles are estimated to be 42%, 8% and 1.5% respectively. If the home is not owned by one of its residents, the probabilities drop to 36%, 3% and 0.2% respectively. An interesting result is that the probability of owning one vehicle is only slightly affected (in relative terms) if the home is not owned by one of its residents. However, at the higher ownership levels, the probability of ownership drops substantially if the home is not owned by one of its residents. Also, the statistical significance of the variable increases at the higher levels of ownership.

Number of persons per household: Using 1991 data, this variable is significant at the 5% level for all three equations. It has a negative sign implying that the probabilities of vehicle ownership would be lower the larger is the number of persons in the household. This can be explained by the fact that for a given household income, per capita income will be lower the larger is the size of the household; and the lower per capita income, the lower is the probability of vehicle ownership. The increase in the magnitude of the coefficient of the variable and its elasticity as we move from the one-vehicle equation to the two-vehicle and three-or-more vehicle equations suggests that household size, similar to household wages, plays a larger role in predicting the higher levels of vehicle ownership.

Interestingly, the absolute value of the elasticity of the probability of owning three-or-more vehicles with respect to the size of the household (-1.92) is larger than that with respect to income (1.52). A 10% increase in the size of the household will result in a 19.2% decrease in its probability of owning three-or-more vehicles. The net impact of household size does not appear to be that large when one considers that a 10% increase in the number of *adults* in the household will result in an 18.7% increase in the probability of owning three-or-more vehicles--basically offsetting the impact of household size.

Size of household was not used as an explanatory variable in the preferred model estimated using 1993 data because of the high level of correlation between number of workers and number of persons per household. When size of household and number of workers per household were included in the same model, both household size and household permanent workers were statistically insignificant at reasonable levels in the 1993 model. Estimating a model with household workers but not persons gave more satisfactory results than a model estimated using persons but not workers. Results of an alternative model specification using size of household, but not number of workers, are presented in Appendix 1.

Number of adults (persons between the ages of 19 and 60 years) per household: In the 1991 model, this variable is statistically significant at the 10% level in the equation used to estimate the probability of owning one vehicle, and at the 5% level for the second and third equations. The negative sign of the coefficient in the one-vehicle equation and its positive sign in the latter two equations are plausible. As the number of adults in the household increases, the probability of owning just one vehicle would drop while that of owning multiple vehicles would increase.

As expected, the variable plays a larger role in explaining ownership behavior for the three-or-more vehicle household than it does for the lower levels of ownership. The coefficient for the three-or-more vehicle equation is more than twice as large as its equivalent for the two-vehicle equation; and it is more statistically significant. Moreover, the elasticity of the probability of owning three-or-more vehicles with respect to adults is the second highest in the entire model after the elasticity with respect to all household members; a 10% increase in the number of adults in the households results in an 18.7% increase in the probability of owning three-or-more vehicles. The importance of the elasticity of this variable and its implication become clear as young household members become adults. Since the total number of household members has not changed, household size will have no impact and the probability of owning multiple vehicles will rise due to the increase in the number of adults in the household. The variable had no statistical significance, however, in the 1993 model when used in conjunction with the number of workers, and was consequently excluded from the preferred model.

Number of workers per household: In the model estimated using 1993 data, two types of workers were represented: permanent and occasional (workers hired on a job-by-job basis whenever there is one available). With one exception, both variables are negatively associated with the probabilities of ownership in all equations. The exception is the number of permanent workers in the equation used to estimate the probability of owning three-or-more vehicles, where its coefficient has a positive sign. The negative sign can be easily explained by the fact that household persons are not included in the 1993 model, and that number of workers is capturing the impact of household size. Consequently a larger number of workers per household represents less per capita income and is associated with lower levels of ownership. When both number of persons and number of permanent workers are included in the same model, the coefficient of permanent workers has a positive sign but is statistically insignificant at reasonable levels.

The positive relationship between permanent workers and the probability of owning three-or-more vehicles is interesting and a little more challenging to explain. The variable, household workers, captures two effects in the model. It captures the effect of household size which means that an increase in household workers results in less per capita income and a lower probability of ownership. But the increase in household workers leads to an increase in work trips and may result in higher probabilities of ownership. It is likely that the second impact outweighs the negative impact of lower per capita income; hence resulting in a net positive relationship between household workers and the probability of owning three-or-more vehicles.

The size of the coefficient of occasional workers is about 3 times that of the coefficient of permanent workers in the first two equations but the elasticities of both variables at the means are quite similar and low. However, the impact of the two variables on owning three-or-more vehicles is different but is still small. While a 10% increase in the number of occasional workers would result in a negligible decrease (0.04%) in the probability of owning three-or-more vehicles, the same percentage increase in the number of permanent workers would result in a 3% increase in that probability.

In the 1991 model, where no distinction is made between permanent and occasional workers, the number of workers per household was not statistically significant when used in conjunction with the number of household members (Model 4, Table A2.1, Appendix 2). Results of models estimated using number of workers, but not household size, were quite similar to results of models estimated using household size and not number of workers. The former model, however, had slightly less overall explanatory power.

Gender of principal worker: Results from the 1993 model indicate that the level of auto ownership is higher if the principal worker in the household is male. A dummy variable used to determine the impact of the gender of the principal worker in the household on auto ownership is statistically significant at the 5% level for the equations estimating the probability of owning one vehicle and two vehicles, and significant at the 11% level for the equation estimating the probability of owning three-or-more vehicles. The variable is statistically insignificant in the 1991 model and is therefore excluded.

5.2 Alternative Model Specifications

Tables A1.1 and A1.2 in Appendix 1 present four of the alternative 1993 models that were tested, while Tables A2.1 and A2.2 in Appendix 2 present five of the alternative 1991 models. The alternative models presented in the appendices test two main issues: measures of accessibility of competing modes, and the use of different combinations of demographic variables.

Accessibility of Competing Modes: The preferred models do not include measures of accessibility by public transport because no measures performed adequately. Two types of measures were tested: one using trip time and distance data and a second using broader and rather indirect measures such as residential densities and municipal dummy variables. The two measures are discussed below.

Access by Public Transit: In theory, better access by public transit should result in lower probabilities of automobile ownership. One of the main difficulties associated with testing this hypothesis was finding reliable data that could be used to construct an index that captures the attributes of 'better' transit service, such as quality, monetary cost, speed, comfort, reliability, frequency, etc.

Some accessibility indices based on generalized cost were tested but none proved to be satisfactory. Crude indices were developed based on zone-to-zone data and not door-to-door travel time and distance. The average distance by auto from the zone to which the household belongs to all other zones was tested as a possible index. Another index tested was based on travel distance and peak travel time from the zone to which the household belongs to all other zones. Both indices proved to be statistically insignificant and yielded the wrong sign. The lack of accurate and reliable data on the location of employment for all household members, or just for the highest wage-earner, contributed to the difficulty of finding and using a direct and significant measure of transit access.

***Indirect Measures of Accessibility*:** Residential density was also tested as a proxy for public transit service. High population densities may be correlated with high levels of public transit service and therefore associated with low automobile ownership. The variable, however, proved statistically insignificant.

Another indirect measure tested was the use of municipal dummy variables. Tables A1.2 and A2.2 in Appendices 1 and 2 respectively present the preferred multinomial models for 1993 and 1991 re-estimated using locational dummy variables for the place of residence. The dummy variables were utilized to capture some of the accessibility characteristics of a particular location. Initially a locational dummy variable for each municipality was tested (except Apodaca which is used as a reference) but the variables for Santa Catarina and Escobedo did not perform adequately and were also excluded from the alternative multinomial specifications. Locational variables were used for the municipalities of Monterrey, Guadalupe, Garza Garcia and San Nicolas.

The municipal dummy variables increased the overall explanatory power of the models, but only slightly. In the 1993 model, all dummy variables except that for San Nicolas were statistically insignificant in the first equation, used to estimate the probability of owning one vehicle. For the second and third equations, all four variables were statistically significant at the 10% level or better. Their coefficients had positive signs indicating a higher probability of owning two-or-more vehicles by a household in any of these four municipalities than by a household in the three excluded municipalities. In the 1991 model, the coefficients of the four locational variables had positive signs, and were statistically significant at the 10% level or better for the first two equations. In the third equation, estimating the probability of owning three-or-more vehicles, all dummy variables were statistically insignificant at the 10% level, with the exception of Garza Garcia, whose locational dummy variable was significant at the 5% level.

Table A1.3 presents the probabilities of ownership estimated at the means for households in the different municipalities on the basis of Model 4 in Table A1.2. Table A1.3 shows a large variation in the probability of ownership from one municipality to another. For example, the probability of owning two-or-more vehicles is about 5% for a household in Apodaca, Escobedo, or Santa Catarina, but rises to about 16% for a household in San Nicolas and to 35% for a household in Garza Garcia. These estimates are used only to give orders of magnitude of the difference in probabilities and should probably not be used for any forecasts given that city-wide means are used and not municipality means. The latter values can not be estimated on the basis of the selected sample.

The coefficients for the dummy variables differ greatly between the 1991 and the 1993 models, a fact which reduces confidence in these variables and makes it difficult to interpret their coefficients. It is possible that these variables capture socioeconomic characteristics that are not represented in the model and not just accessibility characteristics. An example of a socioeconomic variable that is not explicitly represented is wealth. One can argue that the relatively large size of the coefficient for the Garza Garcia locational variable may be explained by the wealth of the municipality rather than by the lack of access to public transit.

Finally, including the locational dummy variables in the preferred models had very little impact on the coefficients of most of the other explanatory variables. In both 1993 and 1991 multinomial models, the wage coefficients and their significance hardly changed, although both show some slight decrease as one would expect. The largest impact of the locational variables was on household workers, both permanent and occasional. For the first and second equations, the value of the coefficient of permanent workers dropped by approximately 9% and 25% respectively and ceased to be significant at the 5% level. In the third equation, the value of the coefficient was about 39% higher than in the preferred model and its significance increased. The coefficient of occasional workers in the third equation was about 43% lower than in the preferred model and the variable ceased to be statistically significant.

The above results show that there might be some modest gains to including the municipal locational variables in the preferred model because they may crudely capture some accessibility features. However, the fact that their coefficients are not robust and they are highly correlated with household workers makes the interpretation of the results quite difficult and led to their exclusion from the preferred models.

Demographic Variables: Several alternative combinations of demographic variables were tested since these variables are closely related and often strongly correlated. Models 1 for 1993 and 1991 in Tables A1.1 and A2.1 respectively include a wage variable only and are intended to provide a base line to compare the impact of other demographic variables. The coefficient of household wages shows a slight change when other variables are introduced but remains the most significant. Moreover, the explanatory power of estimated models does not increase much when other variables are added.

In models estimated using 1993 data, the high correlation between the size of the household and its number of permanent workers prevented the use of both variables in the same model. Models 2 and 3 for 1993 in Table A1.1 include as explanatory variables household size but not household workers, and workers but not size respectively. When included separately, each of the two variables generally had the same directional impact on auto ownership. An increase in the number of persons or workers is associated with lower probabilities of owning one-or-two vehicles but higher probabilities of owning three-or-more vehicles. This finding was consistent with the results of the preferred 1993 model.

The positive sign of the coefficient of household size in the equation estimating the probability of owning three-or-more vehicles can be explained in the same way the positive sign of the coefficient of permanent workers in the 1993 preferred model was explained. The increase in probability of ownership resulting from a larger demand for trips outweighs the decrease in the probability of ownership resulting from the decline in per capita income. In the preferred 1991 model, however, the impact of household size on vehicle ownership was negative in all three equations suggesting that the impact of lower per capita income dominated the impact of the increased demand for trips in all three equations.

To further explore the correlation between household size and workers, and whether it is possible to include both, three models were estimated using 1991 data: Model 2 using household persons only, Model 3 using workers only, and Model 4 using both variables. Table A2.1 in Appendix 2 presents the results of the three models. Similar to the preferred 1991 model, in Model 2, household size had the expected negative signs. The variable was statistically significant for the two equations estimating the probabilities of owning one, and two, vehicles but statistically insignificant for the third equation. Substituting household size by workers in Model 3, we end up with very similar results to those of Model 2. The variable, household workers, had negative signs and was statistically significant for the equation estimating the probability of owning one vehicle but statistically insignificant for the other two equations.

When household size and workers are included in the same model, one would expect household size to have a negative sign in all equations reflecting the negative relationship between lower per capita income and the probability of vehicle ownership. Also one would have expected the probability of vehicle ownership to increase as the number of workers in the household increased. Alternative Model 4 presents different results. For the first equation, both variables were statistically significant at the 5% level, and both had negative signs. In the second equation, both signs were still negative and the coefficient of workers was statistically insignificant; and in the third equation both variables were statistically insignificant and their coefficients had the wrong signs. The inability to successfully include household size and workers in the same model has precluded a clearer understanding of the impacts of these variables.

Various other combinations of permanent and occasional workers, total number of persons, and persons in different age brackets were tested. Other demographic variables such as the age of the principal worker in the household (highest wage-earner) were tested but proved to be statistically insignificant at the 10% level in all 1993 and 1991 specifications and were consequently not included in any of the models presented.

6. RESULTS OF OTHER STUDIES

Despite an abundance of automobile ownership models in the literature, only a few of these models are for developing countries. Button et al (1993) suggest that one of the main reasons for this is the difficulty in establishing a reliable database. Furthermore, only a few of these models are estimated using multinomial logit which makes it more difficult to compare their results with those from Monterrey. Since income is the most important variable in determining auto ownership levels, it is discussed first and then followed by a discussion of other variables.

6.1 Income

Table 6 presents the elasticities of auto ownership from Monterrey. Two types of elasticities are presented: the elasticity for the probability of a household owning at least one vehicle (one, two, and three-or-more) and the elasticity for the number of vehicles owned. The elasticity of the number of vehicles owned is derived from the probabilities in the multinomial logit model in order to compare the Monterrey results with studies elsewhere that use number of vehicles as the dependent variable. Table 7 presents the results from other studies in developed and developing countries. Of particular interest are Tanner's (1983) analysis of a number of industrialized countries and Button and colleagues' (1993) cross-sectional study of over 60 low-income developing countries.

Every study of developing or developed countries agrees that rising incomes increase vehicle ownership. Table 6 shows that in Monterrey, the estimated elasticity of vehicle ownership with respect to income is between 0.70 (in the 1993 model) and 0.87 (in the 1991 model).[9] These figures are fairly comparable to estimates from studies of other developing countries with similar income levels, as shown in Table 7. For example, Button et al (1993) divide developing countries into five categories based on their income and auto ownership levels. The elasticity for

[9] Although estimates of elasticities for 1991 and 1993 are relatively close, one would have expected elasticities estimated using 1993 data to be slightly higher than those using 1991 data. The expectation stems from evidence from developing countries that responsiveness of auto ownership to income increases as income levels increase.

Category 5 countries, to which Monterrey belongs, is 0.95. Table 7 also shows that the elasticities for industrialized countries tend to be generally higher than those for developing countries. This can be explained by the fact that elasticities are low at the low income and ownership levels and then increase as income and auto ownership levels rise.

Table 6
Wage Elasticities of Vehicle Ownership
Monterrey Metropolitan Region

A) Elasticity of the Probability of Level of Vehicle Ownership with respect to Household Wages estimated at the means:[1]

	1993	**1991**
Probability of owning one vehicle	0.42	0.59
Probability of owning two vehicles	1.10	1.34
Probability of owning three-or-more vehicles	1.34	1.52
B) Elasticity of vehicle ownership with respect to the wage rate:[2]	0.70	0.87

C) Elasticity of the Probability of Level of Vehicle Ownership with respect to Household Wages estimated for different wage levels:[3]

	Mean (US$ 612)	**0.5 * Mean (US$ 306)**	**1.5 * Mean (US$ 918)**
Probability of owning one vehicle	0.42	0.32	0.28
Probability of owning two vehicles	1.10	0.66	1.30
Probability of owning three-or-more vehicles	1.34	0.78	1.66

1. Elasticities of probabilities are estimated at the means based on the preferred models presented in Tables 3 and 4 using the same equation in Table 5.

2. Elasticity of level of ownership is estimated on the basis of the elasticities of probabilities. First, level of vehicles was estimated using the probabilities at the means. Second, new probabilities were estimated on the basis of the elasticities. Finally, new levels of vehicles were estimated on the basis of the new probabilities.

3. Mean values for variables other than the wage rate were used in all estimates.

Table 7
Income Elasticities of Auto Ownership
(Other Studies)

	Elasticity	
	Vehicle [1]	***Auto***
1. Silbertson (1970) using 1964 international cross sectional data- dependent variable was per capita ownership in a linear model: [2]		
Industrialized Western European countries	1.27	1.06 - 1.28
Eastern European countries and USSR [3]		14.8 - 17.7
Cyprus, Greece, Malta, Portugal, Spain & Turkey	2.89	3.15 - 3.77
Australia, New Zealand, Canada & USA	0.91	0.77 - 0.92
Latin American countries	1.72	1.90 - 2.27
Israel, Japan & South Africa	1.71	2.89 - 3.46
2. Tanner (1983) using international time series data from 1958 to 1980- dependent variable was per capita ownership in a linear model:		
Western countries, Australia and New Zealand		1.1 - 3.7
3. Tanner (1983) using international time series data from 1958-60 and from 1978-80- dependent variable was per capita ownership in a log-log model.		
Western countries, and Japan (1958 - 1960)		1.89 - 2.85
Western countries, and Japan (1978 - 1980)		0.38 - 0.77
4. Cundill (1986) using 1981 cross sectional data- dependent variable was probability of household ownership in a quasi logistic model. [4]		
Kenya		1.09
5. Khan and Willumsen (1986) using international time series data from 1971 to 1975- dependent variable was per capita ownership in a log-log model.		
10 industrialized and 8 developing countries		1.32
6. Button et al (1993) using international pooled data from 1968 to 1987- dependent variable was per capita ownership in a log-log model. Elasticities were estimated for the five categories of countries shown below:		
a) less than 0.002 cars per person.		0.53
b) 0.01 > cars per person > 0.002 & per capita GNP < US$450.		0.73
c) 0.01 > cars per person > 0.002 & per capita GNP > US$450.		0.89
d) 0.02 > cars per person > 0.01.		1.12
e) greater than 0.02 cars per person.		0.95

Notes:

1. 'Vehicles' include autos, trucks and buses.
2. Elasticities are estimated on the basis of the coefficients derived by Silbertson (1970), and on the mean values of gross national product (net material product) and auto ownership rates for each of the six categories.
3. Elasticities are based on net material product. The high elasticities are primarily due to the very low levels of auto ownership (0.006 per capita).
4. Elasticity based on equi-probability income (income at which probability of ownership is 50%).

Table 6 (Section C) shows that in Monterrey the elasticity of the probability of auto ownership with respect to the wage rate increases as the level of income rises up to a certain level than starts declining, a finding also consistent with the results of other studies. For example, Button et al (1993), in a cross-sectional study of over 60 low-income countries, find the responsiveness of auto ownership to income to increase as income and ownership levels increase. On the other hand, Tanner (1983), in a study of industrialized countries, finds the responsiveness to drop as ownership levels rise. The results of both studies can be easily reconciled once we recognize that the elasticity increases as income and auto ownership levels increase up to a certain point, then starts dropping once countries begin approaching high levels of ownership. Similar to the case of Monterrey, the countries in Button's study had a per capita GNP less than US$3,000 and had low ownership levels, whereas Tanner's sample included industrialized countries with relatively high per capita incomes and ownership levels.

Table 6 also shows that an increase in the wage rate will increase the probability of owning multiple vehicles more than it would increase the probability of owning a single vehicle. There are two possible reasons for the lower elasticities at the lower ownership levels. First, a household may or may not consider the first car to be a luxury good, but the second car is likely to be more of a luxury good, and the third even more so. As a result, the elasticity with respect to the wage rate is higher at high ownership levels. Second, for a representative (median) household, the probability of owning multiple cars is much lower than the probability of owning a single car. Consequently, a small absolute change in the probability of owning 3-or-more vehicles, say from 3% to 4%, constitutes a 33% change, whereas a similar absolute change in the probability of owning one vehicle from 45% to 46% represents a 2% change and the probability of ownership at this level is considered less responsive to changes in the wage rate.

6.2 Other Variables

Persons/Adults per Household: Both the Monterrey study and other studies generally agree that the elasticity of auto ownership with respect to the number of adults per household is positive if one controls for the size of the household (for example Said, 1992; Tanner, 1981). Tanner (1981) found the strength of the relationship to increase at the higher income levels, a finding also consistent with the Monterrey model.

Yong (1993) in an analysis of Singapore, used household size instead of number of adults and found a positive relationship between auto ownership and household size in a binomial model of auto ownership. This finding is inconsistent with the results of the preferred Monterrey model estimated using 1991 data where household size is negatively correlated with auto ownership. The difference may be explained by the fact that the Singapore model used household workers in conjunction with household size, while the Monterrey model does not use both due to the high correlation between the two variables. In the Singapore model, the variable, household workers had a negative sign, while household size had a positive sign. One might have thought, however, that household size would have had a negative sign since a larger household implies less per capita income and a lower probability of ownership. One would have also expected the coefficient of household workers to have a positive sign because an increase in the number of workers would lead to more work trips and possibly an increase in the demand for vehicles.

Workers per Household*:* Few studies of auto ownership have used the number of workers as an explanatory variable and even in these studies, there appears to be none that makes a distinction between permanent workers and occasional workers. Evidence regarding the impact of the number of workers on auto ownership seems inconclusive. Portland Transportation Department (1991) developed a multinomial auto ownership model for Portland, Oregon, and found a positive relationship between auto ownership and the number of workers per household. Yong (1993) developed a binomial model for auto ownership in Singapore and found a negative relationship between auto ownership and the number of workers per household.

Gender of Principal Worker: This is a culture-specific variable whose impact may vary from one county to another. For example, Yong (1993) finds ownership to be higher in Singapore among households where the principal worker is female while in Monterrey vehicle ownership is higher among households with a male principal worker.

Residential Density*:* Evidence from the Monterrey study does not support the hypothesis that higher residential densities are associated with higher levels of public transit service and lower levels of vehicle ownership. Silbertson (1970), in a study using international cross sectional data, found population densities to be positively associated with auto ownership but the relationship was statistically insignificant. In another study, using international cross sectional data, Khan and Willumsen (1986) found population density to be positively associated with auto ownership in a linear model but statistically insignificant in log-linear and semi-log specifications. Pearman and Button (1976), in a model developed to examine regional differences in ownership behavior found population density to have no explanatory power.

Accessibility: The failure of measures of accessibility used in the Monterrey model to be significant could be attributed to the inaccuracy of available data as is often the case in developing countries. However, a number of studies, mainly on industrialized countries, have demonstrated the impact of access on auto ownership. For example, Golob and Burns (1978), using data from the Detroit area in the USA, found that auto ownership is sensitive to travel time by automobile and public transit. Button and Pearman (1980), in a study of West Yorkshire in the United Kingdom, found that households living in areas which enjoy 'good' access by public transport tend to own fewer cars.

7. SUMMARY AND CONCLUSIONS

The multinomial auto ownership models estimated in this study show that wages play the most significant role in determining the probability of vehicle ownership in Monterrey, Mexico. Home ownership, household size, and number of adults per household are also important variables in determining ownership behavior. The importance of household wages, household size and the number of adults in the household in determining auto ownership increased as the level of auto ownership increased. The analysis also demonstrates that the number of household workers and gender of principal worker in the household have little impact on auto ownership. These results are generally in agreement with the results of other studies of auto ownership.

The significance of accessibility by public transport was tested using indices of generalized cost, zonal densities, and dummy variables for the household location. All variables tested failed to contribute to the understanding of ownership behavior. The locational dummy variables may have contributed to a slightly better estimation of probabilities of auto ownership but their coefficients were far from robust and were difficult to interpret.

Accessibility is an issue of both interest and importance because it may provide policy-makers with an understanding of the likely tradeoffs between better public transit service and levels of vehicle ownership. The insignificance of variables measuring accessibility in this study may have more to do with the relatively poor quality of data than with the significance of accessibility as a determinant of auto ownership. A number of studies, mainly on industrialized countries, where data are generally more accurate, have demonstrated the impact of access on auto ownership. Another possible reason for the failure of travel time and cost to have any explanatory power is the use of zone-to-zone travel time and cost, and not door-to-door travel time and cost. The use of zone-to-zone travel times and distances estimated from the urban transportation planning simulation model for Monterrey meant that all intrazonal variations were ignored. The use of reported data did not always prove satisfactory either. The importance of accessibility by competing modes clearly needs further investigation.

APPENDIX 1
ALTERNATIVE MULTINOMIAL MODEL SPECIFICATIONS
USING 1993 DATA

Table A1.1
Multinomial Logit Estimates for Household Vehicle Ownership
Monterrey Metropolitan Region, 1993

Choice set: zero vehicles, 1 vehicle, 2 vehicles, 3-or-more vehicles

Explanatory Variable		**Model 1**	**Model 2**	**Model 3**
HOUSEHOLD OWNS ONE VEHICLE				
Constant		-0.9919	-0.7543	-0.8316
		(-14.07)	(-6.87)	(-10.46)
Total weekly wages per household		0.00156	0.00166	0.00188
		(12.03)	(12.13)	(11.25)
Permanent workers per household		n.a.	n.a.	-0.1351
				(-2.52)
Occasional workers per household		n.a.	n.a.	-0.3731
				(-5.65)
Persons per household		n.a.	-0.0636	n.a.
			(-2.79)	
HOUSEHOLD OWNS TWO VEHICLES				
Constant		-3.145	-2.82	-2.905
		(-28.01)	(-15.04)	(-21.5)
Total weekly wages per household		0.00264	0.00273	0.00298
		(18.02)	(17.87)	(16.78)
Permanent workers per household		n.a.	n.a.	-0.1714
				(-2.34)
Occasional workers per household		n.a.	n.a.	-0.5003
				(-4.47)
Persons per household		n.a.	-0.0797	n.a.
			(-2.16)	
HOUSEHOLD OWNS THREE-OR-MORE VEHICLES				
Constant		-4.694	-5.39	5.091
		(-28.16)	(-17.39)	(-22.03)
Total weekly wages per household		0.00306	0.00314	0.00360
		(19.9)	(19.67)	(18.40)
Permanent workers per household		n.a.	n.a.	0.1594
				(1.80)*
Occasional workers per household		n.a.	n.a.	-0.3030
				(-1.87)*
Persons per household		n.a.	0.1234	n.a.
			(2.55)	
Summary Statistics				
Number of Observations	2,925			
L(0): Log-likelihood (slopes=0)	-3,164			
L(β): Log-likelihood (at maximum)		-2,810	-2,799	-2,782
ρ^2: [1 - L(β)/L(0)]		0.112	0.115	0.121

Values in parentheses are asymptotic t statistics
n.a. not applicable
not statistically significant at the 5% level, but significant at the 10% level

Table A1.2
Multinomial Logit Estimates for Household Vehicle Ownership
Monterrey Metropolitan Region, *1993*

Model 4: Preferred Model using Locational Dummy Variables

Choice set: zero vehicles, 1 vehicle, 2 vehicles, 3-or-more vehicles

	Coefficient	*asymptotic t statistic*
HOUSEHOLD OWNS ONE VEHICLE		
Constant	-1.1836	-6.479
Total weekly wages per household	0.00181	10.816
Permanent workers per household	-0.10533	-1.929*
Occasional workers per household	-0.33545	-5.003
Home ownership (1 if owner, 0 otherwise)	0.36344	2.396
Gender of principal worker (1 if female, 0 otherwise)	-0.36490	-3.353
Locational Variables		
Monterrey (1 if Monterrey, 0 otherwise)	-0.05951	-0.510**
Guadalupe (1 if Guadalupe, 0 otherwise)	0.00916	0.072**
Garza Garcia (1 if Garza Garcia, 0 otherwise)	0.41045	1.055**
San Nicolas (1 if San Nicolas, 0 otherwise)	0.61093	4.192
HOUSEHOLD OWNS TWO VEHICLES		
Constant	-4.7830	-11.406
Total weekly wages per household	0.002832	15.824
Permanent workers per household	-0.11035	-1.469**
Occasional workers per household	-0.42338	-3.748
Home ownership (1 if owner, 0 otherwise)	1.1199	3.309
Gender of principal worker (1 if female, 0 otherwise)	-0.49774	-2.718
Locational Variables		
Monterrey (1 if Monterrey, 0 otherwise)	0.95673	3.739
Guadalupe (1 if Guadalupe, 0 otherwise)	0.76623	2.790
Garza Garcia (1 if Garza Garcia, 0 otherwise)	2.3176	4.930
San Nicolas (1 if San Nicolas, 0 otherwise)	1.5072	5.313
HOUSEHOLD OWNS THREE-OR-MORE VEHICLES		
Constant	-8.1383	-8.716
Total weekly wages per household	0.003168	17.169
Permanent workers per household	0.25066	2.718
Occasional workers per household	-0.1821	-1.108**
Home ownership (1 if owner, 0 otherwise)	2.1490	2.629
Gender of principal worker (1 if female, 0 otherwise)	-0.42959	-1.591**
Locational Variables		
Monterrey (1 if Monterrey, 0 otherwise)	0.95281	2.184
Guadalupe (1 if Guadalupe, 0 otherwise)	0.81621	1.744*
Garza Garcia (1 if Garza Garcia, 0 otherwise)	3.0276	5.010
San Nicolas (1 if San Nicolas, 0 otherwise)	1.7309	3.686

Summary Statistcs

Number of Observations	2,925
L(0): Log-likelihood (slopes=0)	-3,164
L(β): Log-likelihood (at maximum)	-2,721
ρ^2: [1 - L(β)/L(0)]	0.14

* not statistically significant at the 5% level, but significant at the 10% level.
** not statistically significant at the 10% level.

Table A1.3
Probabilities of Ownership for Different Municipalities
Monterrey Metropolitan Region, 1993

	Probability of owning:		
	one vehicle	**two vehicles**	**three-or-more vehicles**
Apodaca, Escobedo & Santa Catarina	46%	4%	1%
Monterrey	41%	11%	2%
Garza Garcia	38%	25%	10%
Guadalupe	43%	9%	2%
San Nicolas	53%	13%	3%

Source: Probabilities are estimated on the basis of Model 4 in Table A1.2

APPENDIX 2
ALTERNATIVE MULTINOMIAL MODEL SPECIFICATIONS
USING 1991 DATA

Table A2.1
Multinomial Logit Estimates for Household Vehicle Ownership
Monterrey Metropolitan Region, *1991*

Choice set: zero vehicles, 1 vehicle, 2 vehicles, 3-or-more vehicles

Explanatory Variable		Model 1	Model 2	Model 3	Model 4
HOUSEHOLD OWNS ONE VEHICLE					
Constant		-1.5323	-1.008	-1.981	-1.102
		(-15.26)	(-6.17)	(-8.82)	(-5.63)
Monthly wages earned by household		0.00080	0.00084	0.00089	0.00088
		(11.30)	(11.53)	(11.50)	(11.33)
Persons per household		n.a.	-0.111	n.a	-0.0883
			(-4.00)		(-2.84)
Workers per household		n.a.	n.a.	-0.2385	-0.1494
				(-3.56)	(-1.99)
Home ownership		n.a.	n.a.	n.a.	0.2536
(1 if owner, 0 otherwise)					(1.72)*
HOUSEHOLD OWNS TWO VEHICLES					
Constant		-3.826	-3.28	-3.62	-3.961
		(-22.63)	(-11.57)	(-15.07)	(-10.21)
Monthly wages earned by household		0.00133	0.00137	0.00140	0.00139
		(15.91)	(15.98)	(15.62)	(15.38)
Persons per household		n.a.	-0.1122	n.a.	-0.1236
			(-2.42)		(-2.32)
Workers per household		n.a.	n.a.	-0.1519	-0.0524
				(-1.483)**	(-0.45)**
Home ownership		n.a.	n.a.	n.a.	0.9274
(1 if owner, 0 otherwise)					(2.98)
HOUSEHOLD OWNS THREE-OR-MORE VEHICLES					
Constant		-5.552	-5.586	-5.606	-6.944
		(-20.96)	(-11.39)	(-12.82)	(-8.00)
Monthly wages earned by household		0.00144	0.00149	0.00152	0.00152
		(15.79)	(15.99)	(15.61)	(15.48)
Persons per household		n.a.	-0.00867	n.a.	0.0305
			(-0.11)**		(0.35)**
Workers per household		n.a.	n.a.	-0.0425	-0.0406
				(-0.25)**	(-0.21)**
Home ownership		n.a.	n.a.	n.a.	1.683
(1 if owner, 0 otherwise)					(2.21)
Summary Statistics					
Number of Observations	1,743				
L(0): Log-likelihood (slopes=0)	-1,763				
L(β): Log-likelihood (at maximum)		-1,535	-1,525	-1,528	-1,515
ρ^2: [1 - L(β)/L(0)]		0.129	0.135	0.133	0.141

Values in parentheses are asymptotic t statistics
n.a. not applicable
* not statistically significant at the 5% level, but significant at the 10% level.
** not statistically significant at the 10% level.

Table A2.2
Multinomial Logit Estimates for Household Vehicle Ownership
Monterrey Metropolitan Region, *1991*

Model 5: Preferred Model Using Locational Dummies

Choice set: zero vehicles, 1 vehicle, 2 vehicles, 3-or-more vehicles

Explanatory Variable	**Coefficient**	**asymptotic t statistic**
HOUSEHOLD OWNS ONE VEHICLE		
Constant	-1.4518	-6.28
Monthly wages earned by household	0.000829	11.12
Persons per household	-0.0770	-2.15
Adults (ages 19-60 years) per household	-0.0928	-1.72*
Home ownership (1 if owner, 0 otherwise)	0.2360	1.59**
Locational Variables		
Monterrey (1 if Monterrey, 0 otherwise)	0.3144	1.85*
Guadalupe (1 if Guadalupe, 0 otherwise)	0.345	1.86*
Garza Garcia (1 if Garza Garcia, 0 otherwise)	0.870	2.30
San Nicolas (1 if San Nicolas, 0 otherwise)	0.642	3.28
HOUSEHOLD OWNS TWO VEHICLES		
Constant	-4.927	-9.69
Monthly wages earned by household	0.00132	15.01
Persons per household	-0.2562	-3.89
Adults (ages 19-60 years) per household	0.2533	2.93
Home ownership dummy (1 if owner, 0 otherwise)	0.9191	2.91
Locational Variables		
Monterrey (1 if Monterrey, 0 otherwise)	1.055	2.79
Guadalupe (1 if Guadalupe, 0 otherwise)	0.755	1.80*
Garza Garcia (1 if Garza Garcia, 0 otherwise)	1.799	3.23
San Nicolas (1 if San Nicolas, 0 otherwise)	1.125	2.71
HOUSEHOLD OWNS THREE-OR-MORE VEHICLES		
Constant	-7.760	-7.54
Monthly wages earned by household	0.00141	14.51
Persons per household	-0.3936	-3.14
Adults (ages 19-60 years) per household	0.6588	4.36
Home ownership dummy (1 if owner, 0 otherwise)	1.757	2.26
Locational Variables		
Monterrey (1 if Monterrey, 0 otherwise)	0.5988	0.92**
Guadalupe (1 if Guadalupe, 0 otherwise)	0.3318	0.44**
Garza Garcia (1 if Garza Garcia, 0 otherwise)	2.554	3.30
San Nicolas (1 if San Nicolas, 0 otherwise)	0.0366	0.05**

Summary Statistics

Number of Observations	1,743
L(0): Log-likelihood (slopes=0)	-1,763
L(β): Log-likelihood (at maximum)	-1,482
ρ^2: [1 - L(β)/L(0)]	0.159

* not statistically significant at the 5% level, but statistically significant at the 10% level

** not statistically significant at the 10% level.

REFERENCES

Button, K. J., Ngoe, N. and Hine, J. (1993) Modeling Vehicle Ownership and Use in Low-Income Countries. *Journal of Transport Economics and Policy* 27(1), 51-65.

Button, K. J., Hine, J. and Ngoe, N. (1991) Car Ownership Forecasts for Low-Income Countries. *Traffic Engineering and Control* 33(12), 666-70.

Button, K. J. and Pearman A. (1980) Long Term Influences on the Pattern of Car Ownership." *Transportation Policy Decision Making* 1, 301-311.

Cundill, M. A. (1986) Car Ownership and Use in Kenya. Department of Transport, TRRL Research Report 48. *Transport and Road Research Laboratory*, Crowthorne.

Golob, T. F. and Burns, L. D. (1978) Effects of Transportation Service on Automobile Ownership in an Urban Area. *Transportation Research Record* 673, 137-45.

International Monetary Fund (1994) *International Financial Statistics* XLVII.

Khan, M. A. and Willumsen L. G. (1986) Modeling Car Ownership and Use in Developing Countries. *Traffic Engineering and Control* 27, 554-60.

Monterrey, Mexico. Consejo Estatal Del Transporte (1992) *Sistema Integral de Transporte Colectivo para el Area Metropolitana de Monterrey*. Monterrey, Nuevo Leone, Mexico. April.

Pearman, A. D. and Button, K. J. (1976) Regional Variations in Car Ownership. *Applied Economics* 8, 231-3.

Said, G. M. (1992) Modeling Household Car Ownership in the Gulf States: The Case of Kuwait. *Journal of Transport Economics and Policy* 26(2), 121-38.

Silbertson, A. (1970) Automobile Use and the Standard of Living in East and West. *Journal of Transport Economics and Policy* 4(1), 3-14.

Spencer, A. H. and Madhavan S. (1989) The Car in Southeast Asia. *Transportation Research A* 23A, 425-37.

Tanner, J. C. (1983) International Comparisons of Car and Car Usage. Department of the Environment and Transport, TRRL Laboratory Report 1070. *Transport and Road Research Laboratory*, Crowthorne.

Yong, P. S. (1992) *Housing Markets and Urban Transportation: Economic Theory, Econometrics and Policy Analysis for Singapore*. McGraw-Hill.