Transit Accessibility and Connectivity Impacts on Transit Choice and Captivity

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Impacts of Transit Accessibility and Connectivity on Transit Choice and Captivity

Abstract

When measuring the viability of transit and automobile travel options, travelers can be classified into two groups: choice or captive users. Choice users select transit or automobile service when they view one option as superior, while captive users have only one travel option. Surprisingly, little is known about captivity effects on mode split models. This paper examines how transit service factors such as accessibility and connectivity relate to mode captivity and mode choice.

The data for this investigation comes from the Portland, Oregon 1994 Household Activity and Travel Diary Survey, the Regional Land Information System for the Portland Area, the U.S. EPA Fuel Economy Database, and the U.S. Dept. of Energy. Individual trip data were segmented into transit captive, auto captive and choice users based on information about private vehicle availability, transit connectivity and distance from a transit stop. Comparing traditional transit mode split models to captive conditions, the traditional models underestimate variation in mode choice behaviors for captive users, while overestimating the attractiveness of transit for choice users. These results indicate that better transit forecasts can result if accessibility and connectivity are used to help identify captive users. Additionally, among choice transit users, differences in travel times between automobile and transit modes does little to influence mode selection; the more important factor appears to be access to transit and out of vehicle time.

INTRODUCTION

Transit riders can be classified as belonging to one of two groups: those who use transit by choice and those who are captive users because they have no other viable option. Choice users do so because they have a realistic transit option available that connects their origin and destination at a time that meets their needs and works within the constraints of their household and life situation. Choice of transit occurs when travelers feel that the transit option is superior to other choices in terms of time, cost, convenience and comfort. In contrast, captive transit users might be bound to public transportation because of age, disability, income or family circumstances. Often, these users are taken for granted; the assumption being members of this group will always be available no matter what the transit agency does. In truth, captive transit users do have long-term options (such as moving elsewhere, eventual purchase of an automobile, etc.) that can change their status.

Similarly, those who do not use transit can be divided into two groups, those who are captive to the automobile or some other mode, and those who have options and choose the automobile because they perceive it as superior to other choices. Auto captives are people who feel they must use their car for a variety of reasons (e.g., lack of service connecting origin or destinations, scheduling limitations. need to carry large objects, etc.).

Surprisingly, little is known in detail about the differential impact of these mode captive groups on the transit modeling process. Generally, only limited information from the census, such as auto ownership and income data are used in the transit modeling process. Other data such as origin destination patterns, quality of transit access, service characteristics and household situations are seldom linked in a useful way to define transit markets**.**

OBJECTIVES:

This work will explore issues of choice and captivity to see if market segmentation between these groups can lead to better methods of forecasting and service design. Improved specification of transit markets is a preliminary step towards more accurate transit forecasting practices. The hypothesis tested here is that transit usage is highly dependant upon the circumstances of the traveler and availability of acceptable service, and that it is possible to predict transit usage with greater accuracy when these factors are incorporated into choice models.

BACKGROUND

Market share and mode split can often be misrepresented, since we have limited knowledge of what is the true population of people who have a feasible choice transit choice. Transit market share is found by a numerator that is exact (the number of transit trips completed) divided by a denominator that is usually poorly defined (the number of trips where transit is a viable option for the traveler). If the denominator is chosen to be large, by including people who cannot actively choose to use transit for whatever reason, then the market share will appear artificially low. For example, a common transit forecasting statement is that transit caries a specified percentage of trips (e.g., 1-3%) in a region. Unfortunately this number is meaningless, because transit generally provides service in only a small part of a region. Transit often does not connect all locations at all times, and may only provide adequate service in specific locations during narrow or fragmented intervals.

The Transit Capacity and Quality of Service Manual (TCQSM) provide a useful framework for understanding the transit trip decision-making process (*1*). According to the TCQSM, traveler decisions are broken into two parts. First, the user needs to decide if it is possible to use transit to achieve their trip purpose. Transit availability requires that transit be available spatially at the origin and at the destination (the user can access the stop by walking, bicycle or by using park and ride), that the user has information available to use the system and that the vehicle has temporal availability (service is available at the times required). Only when these all these conditions are met is transit an option for the user.

The manual goes on to say that if transit service is available, then the decision making process involves consideration of the comfort and convenience of transit against competing modes. Users will then consider ease of walking to a stop, service reliability, wait time, travel time and cost, security, comfort factors and amenities in the vehicle or at the stop. Measurement techniques for these factors are limited. The manual discusses passenger satisfaction surveys and various methods to measure the availability and quality of transit stops and route segments.

The Transit Level of Service software (TLOS) developed by the Florida Department of Transportation (2) provides perhaps one of the most advanced techniques for the analysis of transit access and availability of service. TLOS uses geographic information systems tools to do a detailed analysis of local street networks and transit schedules to determine a transit level of service, defined as the number of person (or job) minutes of service provided to users that fit set criteria for walking and waiting time. Actual street paths walk buffers, and service schedules are used to determine if transit service is, in fact, available to users. Such techniques allow one to quantify and visualize the mobility provided by a transit system at different times of the day and week at any location within the system's service area.

Work with the TLOS system has indicated that conventional wisdom about transit service coverage can seriously overestimate the number of individuals that have adequate transit service. Experience with these methods indicates that far fewer individuals have ‘adequate’ transit service to meet their travel needs than had been previously thought. For example, in a Tallahassee Florida case study, less that two percent of the population was found to have adequate service coverage (3). This leads to a need to rethink how transit and travel markets are defined and to develop clearer definitions of market segments for use in transit service planning.

This experience is the genesis our work. Methods are needed to understand the size of transit markets and the relationship between level of service and mode captivity. The goal of this work is to find a better way to represent the true market size for public transit. To do so should lead to better forecasts of ridership, better understanding of performance and better planning for changes in service.

TRAVEL MODE CAPTIVITY

Transit Captivity

Transit captives are usually defined as those people who do not have an automobile available for their travel and therefore have no choice but to use transit. Examples include persons without an auto in their household as well as persons who cannot use an automobile because of their age, disability, or past driving behavior. In Litman's concept of "transportation disadvantaged", people who cannot drive or do not have access to a motor vehicle, but who must make daily trips to work or school or other places can be deemed as transit captive users (*4*). Indicators that may lead to transit captivity are: households that do not own an automobile; people with significant physical disabilities that limit their ability to drive; low-income households; low-income single parents; people who are too young or old to drive; and recent immigrants from developing countries. Nationwide, about 30% of the population 5 years old or older is identified as transit-dependent; this portion of the population accounts for about 70% of all transit trips (*5*). Captive users are more likely to live close to bus stops, and on average they make transit trips that are shorter in both duration and distance but lower speed.

Rosenbloom and Fielding found women, racial minorities; immigrants, workers age 17 to 29, workers with low incomes and workers with no household cars are more likely to use transit as their principle mode for commuting to work (*6*). In households with limited access to cars, especially minority low-income households, male workers usually have the priority use of automobiles for work trips, while females are left dependent on transit for either work trips or domestic trips. Racial minorities and immigrants remain more dependent on transit even when their incomes increase substantially.

Automobile Captivity

Auto captivity refers to a situation that people must use an automobile to complete their trips because there are no feasible transit alternatives available connecting their origin and destination at their preferred time. Individuals usually consider themselves automobile dependent for reasons specifically related to the characteristics of the trip activity rather than the mode. According to research conducted by Bush, flexibility was an important issue for their mobility decisions. Inconvenience, in terms of lack of direct service, longer travel time, and loss of control over trips, was mentioned as the major impediment to using transit (*7*). Examples of factors which classify persons as automobile dependent include lack of transit service between their origin and destination at the time they need to travel, the need to make multiple stops, and the need to carry large items, and personal traits such as age and/or disability. On this last point, Rosenbloom and Waldorf found that more than 80% trips of travelers that older than 65 are made in a car, either as the driver or as the passenger; the second most important travel mode for those older travelers was walking (*8*).

Living in communities with auto-dependent transportation and land use patterns also reduces people's transport choices (*9*). Cervero found there were high levels of transit travel if both the origins and destinations were in reasonable close proximity to a station, but the densities and built environment were generally conducive to increased auto ownership and use, and reduced transport options (*10,11*). Additionally, greater availability of vehicles, abundant free parking, and cheap fuel prices all attribute to high auto ownership and use.

Captivity in Mode Choice Models

Models designed to measure choice behavior must incorporate characteristics of all the choices available to accurately forecast transit ridership. It is difficult to develop a definitions of mode dependency which are both comprehensive and can be incorporated into a specification of a transit market. By definition, mode captives often simply do not have information on the non-selected travel mode choice. This makes incorporation of captives into travel forecasts a potential source of modeling error.

Mode split models follow a logit approach and uses an S-shaped curve to show the change in mode split as one mode improves relative to another. In many cases this is done on a continuous scale without recognition of captivity. Mode split models can be modified to include a captivity factor that represents the portion of persons in a zone that are transit captives. This can provide a better representation of transit choice since it only applies the equation to those who actually have a choice rather than to the entire population. If auto and transit dependency are known they can be included as a captivity term in the model as shown in Figure 1.

Figure 1 Here

CONDITIONS FOR ACCEPTABLE TRANSIT OR AUTOMOBILE USE

For any given trip there are a number of conditions that must be met before a mode is selected. This work concentrates on trips that may have two potential modes and that use walk access at the origin and destination. The same principles can eventually be generalized to include a greater range of travel modes and a wider variety of access methods.

As shown in Figure 2, travelers determine if there is acceptable transit service available and if there is acceptable automobile service; these two decisions may take place more or less simultaneously. This results in four groups: those who have acceptable transit and automobile service (choice users), those that only have one acceptable mode available (transit captives or auto dependants) and those with no acceptable modes (non-travelers).

To use this structure, acceptable transit and automobile service need to be defined. Transit service must have: accessibility, connectivity, knowledge, usability and security to be used. Conditions for acceptable use fall into one of five general categories, as shown in Table 1.

Table 1 here

Accessibility: The user must be able to get to the origin transit stop and from the destination transit stop within a reasonable amount of time (5 minutes or ¼ mile distance is a typical standard for walking). If access to transit is by the automobile, such as in a park and ride trip, then the parking facility needs to be located somewhere on the route to the destination. Park and ride trips will also require walk access on one end of the trip

Connectivity: Service must exist between origin and destination and provide a return trip at times that match users' schedule. This can be determined directly through transit route data. In the case of auto travel, connectivity is always assumed.

Knowledge: The user must be aware that service is available between the origin and destination, or the auto user must be capable of finding a route between the origin and destination. In addition the user must have all the necessary information for scheduling the trip. For transit this may include stop locations, fare payment procedures, travel times and transfer schedules.

Usability: The user is able to physically get on and off the vehicle and is able to identify where to get off and transfer between vehicles if necessary. In addition, user is able to carry everything related to the trip on the vehicle. Usability would depend on trip purpose and traveler background information.

Security: Users must feel safe and secure in all elements of the trip, in the vehicle, while waiting and while traveling to and from the vehicle. Once a traveler meets all of these conditions for multiple modes then they become choice users.

PROJECT APPROACH AND DATA SOURCES

The ideal way to test these ideas is to have detailed data on actual travel by individuals along with an assessment of all of the personal factors (i.e., accessibility, connectivity, knowledge, usability and security) as they affect an individual's travel decision-making process. The issue then simply would be to examine how much of travel choice behavior can be explained by these personal factors and how much is based on choice variables such as travel time and trip cost. Unfortunately, data does not exist on all these factors. Our analysis concentrates on the accessibility and connectivity factors. The method used was to calibrate logit mode split models from detailed travel activity data for choice and captive users to see if segmentation into these groups provided better estimates of choice behavior. Equation 1 describes the model used in this analysis:

$$Pr(T) = Pr(TCaptive) + Pr(TChoice) +(1- Pr(ACaptive)) \qquad (1)$$

Where

Pr (T) = Probability of selecting transit compared to automobile modes of travel,
Pr (TCaptive) = Probability of user being a transit captive
Pr((TChoice) = Probability of user choosing transit as a choice user
Pr (ACaptive) = Probability of user being a auto captive

The concepts of accessibility, connectivity, knowledge, usability and security act as constraints on Equation 1, setting baselines that help to determine the correct size of the transit market by excluding captive users of transit or automobile modes.

In order to explore these ideas, analysis was conducted using information from the Portland, Oregon 1994 Household Activity and Travel Diary Survey (1994 Travel Diary), the associated Regional Land Information System (RLIS) data, the U.S. EPA fuel economy database, fuel cost data from the U.S. Department of Energy, and the transit fare schedule for 1994, provided by Portland Tri-Met, the regional transit authority for the Portland, Oregon Area. The 1994 Household Activity and Travel Diary Survey and RLIS data sets are maintained by the Portland Metropolitan Services District (Portland Metro). These data provides detailed geographic information on individual and household elements of travel choices, including surrounding land uses, local and regional employment, personal employment status, vehicle availability, bus stop locations, transit analysis zone boundaries and inter-zone travel times.

The 1994 travel diary contained information on 129,188 activities, identifying 74,399 trips across individual travelers for all modes of travel (i.e., walking and biking, transit and automobile use) over a two-day period. Of those trips, 50,623 were located within the region of interest for this analysis. For the purposes of this investigation, we focus on mode selection for work trips (i.e., commute trips or trips made for work related purposes). This is done because of the emphasis of most regional transit planning efforts toward modeling employment-related travel. Data were analyzed to determine the specific location of the both the origin and destination along with a ¼ mile (403 meter) air buffer around each end of the trip to determine if transit stops were available within sufficiently close walking distances.

Because this investigation is focused on modeling a choice behavior (i.e., choosing transit or automobile commuting behaviors), it is necessary to determine values for variables of the non-selected modes. This is particularly important when analyzing the captive auto and transit user behaviors with respect to the entire data set of travel behaviors. Network travel times for both auto and transit travel, and the transit wait, walk access and transit times (developed by Portland Metro from their EMME2 network mode) were used to estimate in vehicle travel times and out of vehicle access time between trip origins and destinations. Although these network times differ from self reported travel times; they provide information on the non-selected travel mode for captive users. Further, the using the EMME2 network times allowed for the contrasting travel behaviors under rush hour and non-rush hour conditions.

Variable vehicle costs were calculated by multiplying the trip distances by the average vehicle operating costs in the household. Average vehicle operating costs were calculated by matching the vehicles listed in the 1994 Travel Diary with the U.S. EPA Fuel Economy database to obtain the average vehicle operating cost in the household. Where no vehicles were listed in the household, the average operating cost for all known vehicles in the data set was used. Trip distances were provided using EMME2 network shortest path distance estimates between trip origins and destinations.

RESULTS

Of the 50,623 trips initially identified, 6,578 were classified as work trips, 419 of these were made by bus or rail transit. Of those, 959 did not have transit connectivity. Transit connectivity was assumed if the trip EMME2 data provided a transit travel time between the origin and destination zones of the trip. About half of the transit trips, 214 were made with no automobile available for that trip, i.e. travelers responded to the survey that they had no automobile available for that trip. These were classified as captive transit trips. About two thousand trips (1829) in this total had an automobile available, but were beyond a quarter mile airline buffer distance of a transit stop at either their origin or destination locations. These travelers are defined as captive automobile users. The remaining 3,576 travelers were defined as potential choice users of transit.

These data were used to calibrate four logit mode split models, with the dependent outcomes binary coded as 1 for selecting a transit option, or 0 for using a private vehicle. The first model was calculated for all trips, the second for captive transit trips compared to all automobile users, the third for captive automobile trips compared to all transit users, and finally a model for choice users. The purpose of this analysis was to see if market segmentation into choice and captive users provides a better way to predict transit users by comparing results from the all trips model to the segmented models.

Tables 2 and 3 here

Tables 2 and 3 and Figure 3 show the results of this analysis. Table 2 shows the results for non-rush hour trips while Table 3 uses only trips begun during the morning and evening rush hours. The first column shows the logit model for all work trips while other columns show separate models for the segmented trips. There are two transit captive models, one with all trips with connectivity included (transit captive –A) and one with only those trips within a ¼ mile air buffer included (transit captive –B). The goodness of fit of the models can be determined by looking at the pseudo-R^2 values for each model. The pseudo-R^2 is calculated as $1 – L_1/L_0$, where L_1 and L_0 are, respectively, the log-likelihood of the fully specified models described here, and a model with only constants used in place of the explanatory variables. The lower the log-likelihood (i.e., the greater the amount of variance in discrete outcomes explained) in the fully specified model, the higher the pseudo-R^2 ; thus, a higher psuedo-R^2 implies a greater amount of variance in the discrete choice outcomes explained.

Figure 3 here

As shown in Figure 3, the overall model has a pseudo-R^2 of 0.22, while the transit captive models have values of 0.34 and 0.33, the auto captive model has a value of 0.39 and the choice model has a value of 0.11. Segmentation of the trips into transit captive, auto captive and choice users presents interesting results. Once the general model is segmented with the captivity conditions, the explanatory power increases, as indicated by the trend in the pseudo-R^2 values, even in the face of constricting the number of potential observations for the model. The models for captive users give a better fit to the data while choice model behaves worse. This indicates that segmentation can improve the accuracy of transit models and once this is done, models where users have realistic choices do not work as well. This implies that traveler choice in the data we analyzed is far more constrained than had previously been thought. Situational factors such as those described in Table 1 may be at work.

Similar results were also found when rush hour trips were analyzed. The overall model has a pseudo-R^2 of 0.22, while the transit captive models have values of 0.37 and 0.36, the auto captive model has a value of 0.30 and the choice model has a value of 0.13. The auto captive model has a somewhat lower value that when all eligible trips were analyzed.

Other interesting findings also emerge as well. There is a general insignificance of in-vehicle travel times, variable vehicle costs, transit fares, and parking charges for both automobiles and transit toward explaining travel mode selection. Although increased transit fares were a deterrent in the captive auto user compared to general transit rider case, the only consistently significant explanatory variables in Table 2 are the number of vehicles in the household, and the out of vehicle access times (a composite of walking, waiting and transfer times estimated along the EMME2 network). Both of these variables behave as expected; as the number of vehicles in the household, and the out of vehicle time for transit increases, the probability of selecting transit decreases.

Findings are similar for travel started during rush hours in Table 3 (traveling either to or from employment activities), while adding new insights regarding vehicle costs and the separate aspects of out of vehicle time for transit. In both the unrestricted model and the captive transit user rush hour models, variable vehicle cost estimates played a significant role in determining transit use, as variable vehicle costs for private auto use increased, the probability of transit usage increased. For rush hour conditions, only the wait time between transit vehicles acted as a significant deterrent to transit usage; walk access times and vehicle transfer times were of no consequence. For captive vehicle users, the only significant factor was the number of vehicles in the household. Among the choice users, the trends observed in Table 2 were repeated. Variable vehicle costs and transit fares had no significant impact on the likelihood of selecting transit, while increases in out of vehicle times for transit resulted in transit being selected less often.

One possibility for the insignificance of vehicle travel times and out of pocket costs would be if variance in these explanatory factors were somehow constrained. Both Tables 2 and 3 provide summary statistics on the variables used in each model. In examining the explanatory factors for each model, constrained variance did not appear to be a major issue. The averages for observed costs and vehicle times were all within a reasonable ranges, and if constrained variance were a major issue one would expect the observed means to be several multiples larger than the standard deviation; this is not the case. Hence, the insignificance of vehicle travel times and out of pocket costs is not due to constrained variance in the data set.

CONCLUSIONS

The purpose of this paper was to describe the impact of mode captivity on transit forecasting procedures. While the issue is not fully laid to rest, some interesting clues have been uncovered. By separating the transit market into captive and choice users, the results presented here suggest traditional, undifferentiated transit forecasting models might not reflect the constraints on the decision making patterns of transit users. The patterns of pseudo-R^2 indicate that unrestricted models will underestimate the variation in travel mode choice behaviors for captive users, while simultaneously overestimating the attractiveness of transit to choice travelers. Proper market segmentation can improve the ability to predict transit use and also has the potential of improving transit planning and service design. This implies that traveler choice in the data we analyzed is far more constrained than had previously been thought.

Additionally, among travelers who do have a choice, the data analyzed shows that differences in travel times between automobile and transit modes does little to influence the choice of whether or not to use transit. The more important factor appears to be access to the transit system, and out of vehicle time spent transferring or waiting for the next available vehicle. This suggests plans to improve transit mode splits should focus on system connectivity and access rather than increasing speeds along existing routes.

By addressing the issue of viability of travel mode choice in this methodology, we have gained further insight into the issue of why traditional, non-segmented models might poorly estimate transit mode splits. The traditional models may do quite well in identifying the mode choices of travelers who are "captive" to one particular mode (either transit or private vehicle), but fall short in explaining variability in mode choices for those travelers who can realistically choose between options; more accurate forecasts are likely to develop from areas where higher percentages of the traveling population are identified as captive to one mode or another. This does not bode well for those who are involved with policies whose success is directly tied to increasing transit participation.

In particular, this research points to the need for a better understanding of how transit access can be incorporated into transit mode split models. This may be especially useful for the planning of suburban services, or, in a broader context, measuring the effectiveness of transit as a component of achieving social goals. In addition, better understandings of impacts of travel mode captivity on transit modeling will help transit agencies explain their role by providing a clarification of how these agencies deal with populations that have differential transit access. A clear methodological improvement would be the use of transit walk access buffers that followed the travel network, as opposed to the continued use of air buffers. Additionally, the framework needs to be expanded to deal with park and ride travel as well as non-work trip purposes. Future research regarding transit forecasting models will need to address these points in order to improve transit forecasting and service planning.

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ENDNOTES

1. Kittleson & Associates. TCRP Web Project 6 (Project A-15): Transit Capacity and Quality of Service Manual: Part 5, First Edition. January 1999. http://transit.kittelson.com/download.html. Accessed July 15, 2002.

2. Florida Department of Transportation, "Transit Level of Service Software Users Guide", version 3.0, 2001 http://www11.myflorida.com/transit/Pages/transitlevelofservicesoftware.htm, Accessed, July 22, 2002

3. Ausman, Jon, TLOS Demonstration, Urban Transportation Planning Short Course, Tampa, Florida, March, 2002

4. Todd Litman. Victoria Transport Policy Institute, You Can Get There From Here Evaluating Transportation Choice. Jan.5, 2001. http://www.islandnet.com/~litman/choice.pdf. Accessed July 15, 2002.

5. Steve E. Polzin, Xuehao Chu, and Joel R. Rey. Density and Captivity in Public Transit Success Observations from the 1995 Nationwide Personal Transportation Study. In *Transportation Research Record 1735*, **TRB**, National Research Council, Washington, D.C., 2000, pp. 10-18.

6. Sandra Rosenbloom, and G. J. Fielding. *Transit Markets of the Future The Challenge of Change*. TCRP Report 28. **TRB**, National Research Council, Washington, D.C., 1998.

7. Scott J. Bush. Research-Based Transit Marketing in Southeastern Wisconsin. In *Transportation Research Record 1669*, **TRB**, National Research Council, Washington, D.C., 1999, pp. 150-157.

8. Sandi Rosenbloom, and Brigitte Waldorf. Older Travelers Dose Place or Race Make a Difference? In *TRB Transportation Research Circular E-C026—Personal Travel: The long and Short of It*, 1999.

9. Gilmore Research Group. *Tri-Met Segmentation Study Descriptive Overview*. Final Report. Tri-County Metropolitan Transportation District Oregon, Aug. 1997.

10. Robert Cervero. Rail-Oriented Office Development in California: How Successful? *Transportation Quarterly*, Vol. 48, No. 1, 1994, pp. 33-44.

11. Robert Cervero. Making Transit Work in Suburbs. In *Transportation Research Record 1451*, **TRB**, National Research Council, Washington, D.C., 1994, pp. 3-11.

LIST OF TABLES AND FIGURES

TABLE 1 Conditions for Transit and Automobile Acceptability

Transit Acceptability	Automobile Acceptability
At origin	**At origin**
Service is within an acceptable walking distance. Acceptable walking pathways exist User is aware of service User can board vehicle Schedule matches user needs Service connects to destination Fare payment can be made User feels safe and secure at stop and accessing stop	User is a licensed driver who can use auto User has auto available at time of trip Auto is located within reasonable walking distance User feels safe and secure getting to vehicle
En route	**En Route**
Total trip time is not excessive Transfer points are safe and secure User can carry whatever is necessary for the trip	User knows how to find destination
At destination	**At destination**
Final destination is within an acceptable waking distance Acceptable walking pathways exist User knows where to get off User feels safe and secure from stop to final destination Service is available to return user to origin	Parking is available within a reasonable walking distance User feels safe and secure while traveling to final destination

Table 2: Mode Split Models for Captive and Choice Users of Travel Modes with Summary Statistics - Non Rush Hour Condition

	General Model (No Captivity Conditions Enforced)		Captive Transit User (No Vehicle Available) Compared to Auto Users		Captive Transit User w/ 1/4 mile Walk Access at Trip Start and End Compared to Auto Users		Captive Auto User (No Transit Access Within 1/4 Mile) Compared to Transit Users		Choice Transit User	
	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
Vehicle Network Time - Car	0.008169	0.24	-0.022956	-0.46	0.010324	0.19	-0.063854	-0.68	0.051324	1.06
Variable Vehicle Cost (Cents/Trip)	0.010288	1.10	0.007197	0.47	0.014829	0.85	0.011792	0.52	0.012841	1.00
Avg. Parking Cost (Dollars/Day	0.009862	1.57	-0.013492	-0.26	-0.015276	-0.30	0.214908	1.05	0.007984	1.26
Number of Vehicles in Home	**-1.503070**	**12.75**	**-2.440761**	**-12.88**	**-2.272361**	**-11.84**	**-2.829275**	**-5.08**	**-0.589998**	**-3.76**
Vehicle Network Time - Transit	0.005872	0.56	0.003545	0.57	0.002739	0.44	0.022114	0.96	0.013906	1.33
Transit Fare (Cents/Trip)	0.001372	0.30	0.010821	0.74	-0.007137	-0.39	**-0.021463**	**-2.12**	-0.001672	-0.10
Out of Vehicle Time - Transit	**-0.068403**	**-7.41**	**-0.054455**	**-4.44**	**-0.066670**	**-4.72**	-0.015883	-0.72	**-0.090958**	**-5.92**
Constant	0.538500	0.89	0.666410	0.81	0.714040	0.85	**3.534139**	**2.27**	**-3.04440**	**-2.23**
Log Likelihood		-573.5351		-319.877		-294.6063		-45.12247		-302.8891
Psuedo R2		0.2206		0.3430		0.3251		0.3929		0.1125
N		2835		2748		2255		504		2225

Note: Coefficients in **bold** are significant at the five percent level or greater

Model Summary Statistics

Variable	**N**	**Min.**	**Max.**	**Mean**	**Std. Dev.**
Vehicle Network Time - Car	6578	0	72.38	12.90505	9.42072
Variable Vehicle Cost (Cents/Trip)	6446	0	229.29	34.33308	30.23744
Avg. Parking Cost (Dollars/Day)	6513	0	378.00	0.5505504	9.485553
Number of Vehicles in Home	6578	0	9.00	2.107479	1.024485
Transit Fare (Cents/Trip)	6578	45	130.00	122.3875	18.00837
Vehicle Network Time - Transit	5550	0.1	122.96	26.05693	19.35662
Out of Vehicle Time - Transit	5123	0	95.20	17.95338	14.90913

Table 3: Mode Split Models for Captive and Choice Users of Travel Modes with Summary Statistics - Rush Hour Conditions

	General Model (No Captivity Conditions Enforced)		Captive Transit User (No Vehicle Available) Compared to Auto Users		Captive Transit User w/ 1/4 mile Walk Access at Trip Start and End Compared to Auto Users		Captive Auto User (No Transit Access Within 1/4 Mile) Compared to Transit Users		Choice Transit User	
	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
Vehicle Network Time - Car	-0.036225	-1.05	-0.080473	-1.50	-0.044302	-0.71	-0.09589	-1.09	-0.040058	-0.81
Variable Vehicle Cost	**0.0210674**	**2.01**	**0.039139**	**2.45**	**0.039636**	**1.96**	0.02396	0.98	0.016801	1.05
Avg. Parking Cost	0.0046521	0.83	0.006916	0.43	0.007303	0.48	0.01748	0.06	0.002526	0.43
Number of Vehicles in Home	**-1.356057**	**-9.49**	**-2.631370**	**-10.05**	**-2.608460**	**-9.33**	**-2.08866**	**-3.86**	**-0.490820**	**-2.69**
Transit Fare	-9.15E-05	-0.02	-0.006328	-1.11	-0.007993	-1.35	0.01089	0.39	0.012222	1.11
Vehicle Network Time - Transit	0.0010871	0.09	-0.004175	-0.22	-0.014570	-0.69	0.01955	0.72	0.012712	0.79
Transit Transfer Time	**-0.117189**	**-4.43**	-0.071767	-1.88	-0.083554	-1.93	-0.04904	-0.78	**-0.131109**	**-3.38**
Transit Wait Time	**-0.117984**	**-4.05**	**-0.108336**	**-2.44**	**-0.110288**	**-2.28**	-0.19637	-1.82	**-0.098100**	**-2.46**
Transit Walk Access Time	**-0.195275**	**-2.33**	-0.016508	-0.16	0.008811	0.09	0.19409	1.41	**-0.517449**	**-4.07**
Constant	**1.686267**	**2.38**	**2.07396**	**2.39**	**2.08601**	**2.31**	-1.694002	-0.50	-0.45689	-0.30
Log Likelihood		-413.9998		-190.3799		-167.6711		-40.17914		-245.8713
Psuedo R2		0.2161		0.3692		0.3645		0.2956		0.1319
N		2225		2151		1639		518		1645

Note: Coefficients in **bold** are significant at the five percent level or greater

Model Summary Statistics

Variable	N	Min.	Max.	Mean	Std. Dev.
Vehicle Network Time - Car	6578	0	72.38	12.90505	9.42072
Variable Vehicle Cost (Cents/Trip)	6446	0	229.29	34.33308	30.23744
Avg. Parking Cost (Dollars/Day)	6513	0	378.00	0.5505504	9.485553
Number of Vehicles in Home	6578	0	9.00	2.107479	1.024485
Transit Fare (Cents/Trip)	6578	45	130.00	122.3875	18.00837
Vehicle Network Time - Transit	5550	0.1	122.96	26.05693	19.35662
Transit Transfer Time	4866	0	52.01	8.254096	7.632575
Transit Wait Time	5845	0.13	30.00	7.530529	5.928689
Transit Walk Access Time	5852	1.12	22.80	4.756864	1.288732

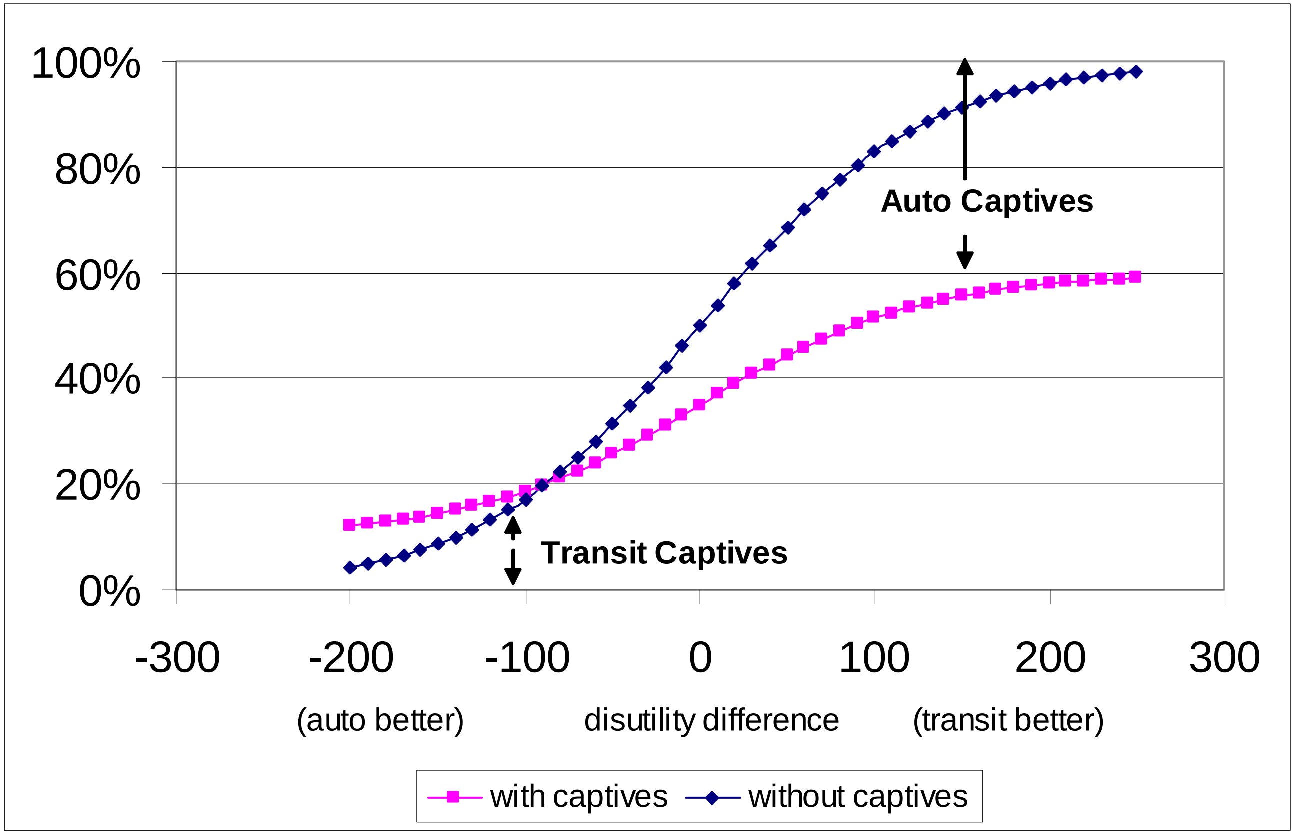

FIGURE 1 **Logit mode split with and without captivity.**

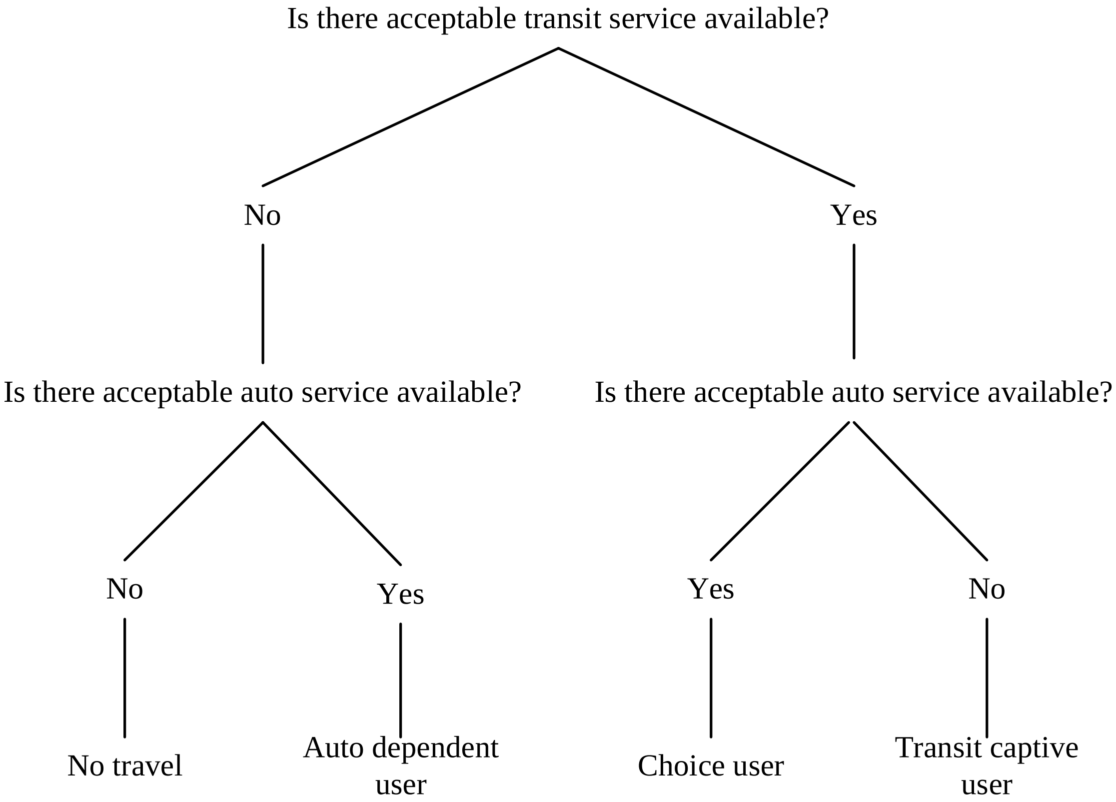

FIGURE 2 Trip decision process.

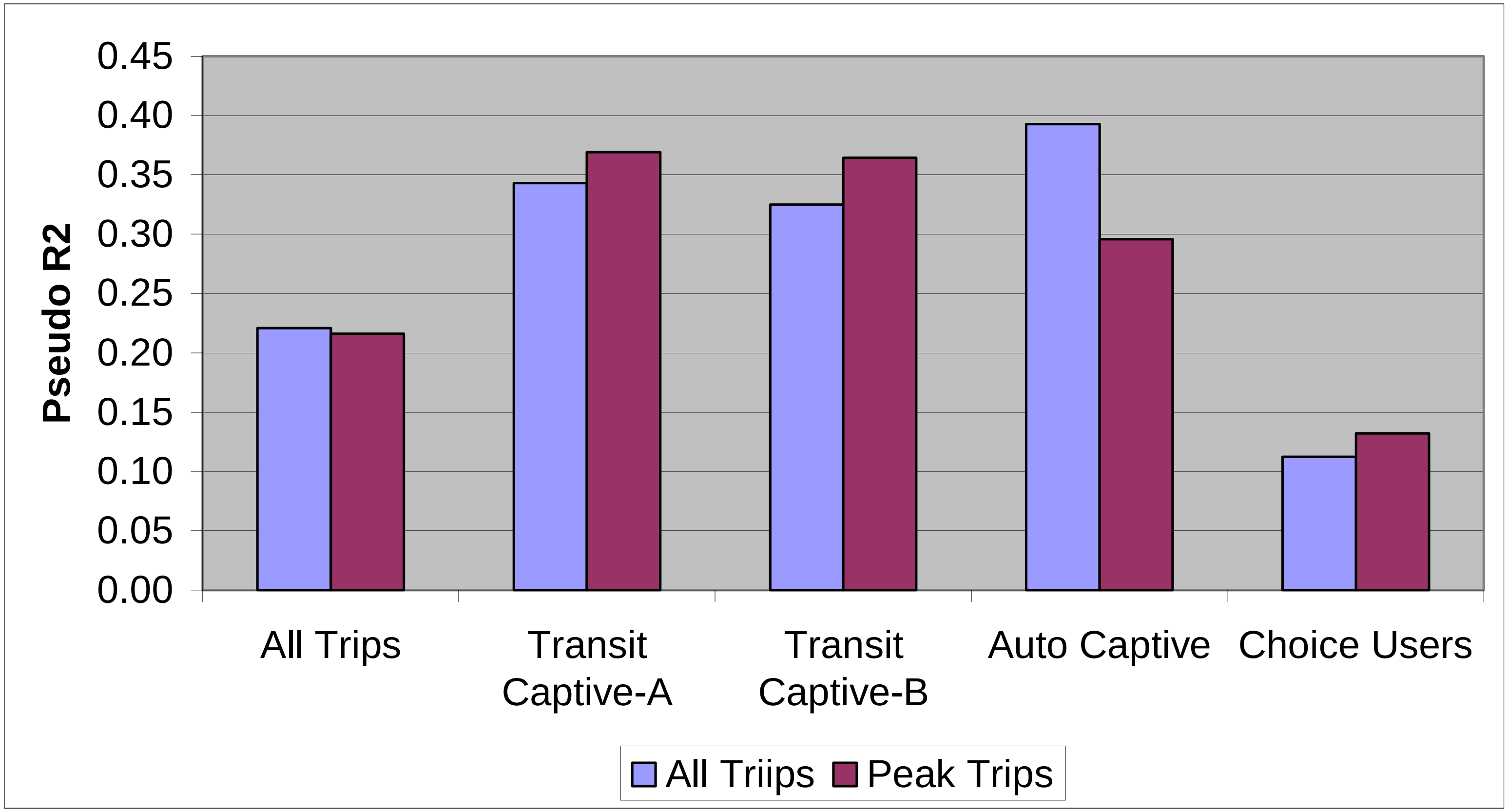

Figure 3: Logit Results