An Analysis of New Bus Rapid Transit Service and New Ridership in Lane County, Oregon

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Abstract: In economics, new products draw new consumers into the market. In this analysis, I use data from a survey of bus riders to examine the transit mode choices of individuals before a new service was introduced. In particular, I examine the change in demand for bus ridership following the introduction of the EmX Bus Rapid Transit line in Eugene, Oregon. Using survey data obtained from the Lane Transit District (LTD), I use logit estimation to analyze changes in ridership due to the introduction of the EmX line, and identify the attributes of new riders descriptively and econometrically. The results suggest that demand for bus transit has changed, based on attributes such as income, gender, car ownership, total trip length and length of time having used the LTD system.

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I. INTRODUCTION

In economics, the introduction of a new product draws new consumers into the market. These new consumers often have different preferences or attributes than previous consumers, which lead to changes in demand for the product. In this thesis, I examine the sources of new demand for a service caused by the introduction of new product variety. In particular, I consider the introduction of a Bus Rapid Transit system into a public transit system to examine the attributes of new riders on the system.

The provision of mass transportation to urban and suburban areas has become an increasingly relevant issue as populations in these two areas have grown. Transportation capacity must be expanded in order to decrease congestion. Planners must now decide how to supply public transportation to an area in the most cost effective and efficient way possible. Increasingly, Bus Rapid Transit (BRT) systems have been chosen as the preferred method of provision. The BRT Implementation Guidelines define BRT as,

> *...a flexible, rubber-tired rapid-transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image.*[1]

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[1] Levinson 2002

BRT is a transportation system designed to improve upon the speed, design and quality of traditional transportation systems. There is no one specific design for BRT; rather it is a mix of a bus system and a light rail system that is tailored to suit the needs of a particular area.[2]

Many BRT systems are now federally funded under the Federal Transit Administration's New Starts Program. Over 25 cities in the United States currently use some form of BRT in their transportation system. [3] As the program grows it is important to identify what types of riders the system attracts. This information is relevant as a general way of determining what type of public transit will work best for a particular area, and specifically in assessing whether and what form of BRT is best suited for a particular area.

The Lane Transit District (LTD) is located in Eugene, Oregon and provides public transit service to the Lane County area. The LTD system began serving Lane County in 1970 and today has an annual ridership of 11,652,909 riders.[4] In 2000, LTD opened the first line of a new BRT system. The system is called the EmX and links downtown Springfield to downtown Eugene.[5] Currently, riders are not charged a fare for riding on the EmX line. Adult bus fares on the regular LTD bus system are $1.50 per ride. In addition to the original line, LTD is currently planning to extend the reach of the EmX and create additional lines that will open beginning in 2010. One of the

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[2] Hecker, J.E. 2003.
[3] Levinson 2002.
[4] LTD. "History."
[5] LTD. "About EmX."

main goals of the EmX is to attract new riders to the bus system and increase overall ridership on the LTD bus lines.

Using a survey conducted by LTD, I provide an analysis of the types of new riders the EmX line has attracted, based on socioeconomic characteristics and bus riding habits of current bus riders. This provides planners with information regarding what factors most influence an individual's decision to ride the EmX, as well as gives them a sense of how bus ridership has changed since the introduction of the EmX line.

This information comes at an especially relevant time in EmX history. With an additional line coming into operation in 2010, planners can use information about changes in ridership caused by the new EmX line to better accommodate riders on the line as well as on the LTD bus system as a whole. This analysis applies to a specific location, but the method could be applied more generally to other BRT systems across the country. Analysis of ridership attributes in different regions using BRT would allow planners to better tailor each BRT system to a region and increase overall ridership.

This thesis begins with a background of the new BRT system in section II. The economic theory and model used are described in section III. Sections IV and V detail the data used and provides descriptive statistics and an analysis of the data. Section VI describes the empirical model used in the demand estimation. Section VII provides the results of this estimation. Finally, Section VIII presents the conclusions I have reached based on my analysis.

II. BACKGROUND

Public transportation in the United States is comprised of a number of means of transportation including buses, trolleys, light and heavy rail, commuter trains, streetcars, ferries, monorails and tramways.[6] Many cities choose to construct bus systems because of the flexibility and relatively low fixed costs of the system. In traditional bus systems, buses share lanes with other traffic and stop at station locations at given times according to a predetermined schedule. They generally do not have a very sophisticated infrastructure and have no exclusive access to right-of-way lanes or off-street facilities.[7] While the traditional system has worked well in the past, recent federal and state efforts have focused on implementing an improved version of the traditional bus system, known as the Bus Rapid Transit system, throughout the United States.

Defining the Bus Rapid Transit system is an elusive task since each system is unique to the area it serves. The Federal Transportation Administration defines Bus Rapid Transit as a "...flexible, high performance rapid transit mode that combines a variety of physical, operating and system elements into a permanently integrated system with a quality image and unique identity".[8] BRT systems are a popular public transit choice because they possess the high quality of a rail system with the flexibility of a bus system. Other reasons for BRT use include the provision of transport capacity to central business districts; quick and incremental implementation of the system; lower capital costs than rail, the ability to serve in urban and suburban areas; the ability to

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[6] Public Transportation "Facts on Public Transportation."
[7] Vuchic, V. et. al. 1994.
[8] Diaz, R. et al. 2004.

extend the reach of rail transit lines; and the ability to integrate the system into urban environments.[9]

A typical BRT system has seven major components. These components are running ways, stations, vehicles, services, route structure, fare collection and intelligent transportation systems. Improvements made to the traditional bus system to create a BRT system focus on the aforementioned components. BRT systems generally have their own right-of-way, and thus, are more efficient means of transportation; offer high-frequency all day service; are associated with a specific brand name; use off-board fare collection methods; and offer low floor boarding for easier passenger access.[10] Each BRT system is tailored to serve the needs of a specific region. Characteristics of BRT systems, therefore, vary across regions and may offer different services depending on the needs of a particular area.

Some form of BRT systems has been in operation in the United States since the 1970s.[11] The federal government, however, has only recently begun to promote the BRT as a form of mass transit. The FTA's "New Starts" program is currently the primary source of federal BRT funding. This program provides up to 80 percent of the capital costs for qualified projects. The FTA also began a demonstration program in 1999 to promote improved bus service. The program awarded $50,000 to 10 programs across the country to share information and data about their BRT projects.[12]

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[9] Jarzab, J.T. et. al.
[10] Diaz, R. et. al. 2004
[11] Federal Transit Adminstration. 2006.
[12] Hecker 2003.

The Lane Transit District (LTD) in Eugene, Oregon is one of the transit districts participating in the FTA's demonstration program. LTD decided to use the BRT system after performing a cost comparison between BRT and light rail options. LTD found that implementation of a BRT system would cost only 4% of what a light rail system would cost. In addition to cost factors, LTD also chose the EmX line for its suitability in scale and cost to a region of Eugene's size. The ability to gradually construct additional BRT lines over time allows for flexibility in the transportation system as the city grows.[13] A pilot corridor of the Eugene BRT system, called the EMX, began service in 2000. The main features of the EMX line include easy boarding, low-floor buses, smaller neighborhood feeder buses, signal priority at intersections, dedicated bus lanes, prepaid fares from bus ticket vending machines[14], passes to speed boarding and comfortable transit stations.[15]

Many previous studies have looked at the factors that affect demand for bus transit. Studies of bus transit demand find a strong relationship between trip choice and income. McLeod (1998) looks at historical data from Honolulu and finds a positive correlation between bus ridership and income.[16] Cao (2007) examines survey data from residents of Northern California and finds a positive correlation between income and an individual's decisions to drive. In addition, he also finds that age is negatively related to the decision to drive.[17] Gomez-Ibanez (1996) conducts a statistical analysis of

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[13] LTD. "EmX History."
[14] The EMX does not currently charge a fare for service. LTD intends to begin charging a fare but has yet to set a timeline.
[15] Hamm, K.P. 2008.
[16] McLeod, M.S., K. Flannely, L. Flanney, and R.W. Behnke. 1998.
[17] Cao, X., P.L. Mockhtarian, S.L. Handy. 2007.

ridership data in Boston, Massachusetts to determine how demographic factors contribute to bus ridership.[18] This study finds income to be positively correlated with public transit ridership. Kitamura (1989) looks at surveys and trip diaries from the Netherlands and finds that car ownership is correlated with car usage, and therefore a determinant of bus ridership.[19] Palma and Rochat (1999) conduct a survey of employees in Geneva, Switzerland and use the data to analyze individual characteristics associated with travel choice.[20] Their results show that a majority of bus riders are male, between 24 and 49 years old and own cars. Gebeyuhu and Takano (2007) perform a binary logit analysis of travel choice behavior using a 2004 door-to-door survey of residents of Addis Ababa. Bus ridership is estimated to be positively correlated with trip length, commute time and family size.[21] They find that bus ridership is negatively correlated with being male, age, income, wait time and number of bus transfers.

This study will go further than previous studies of bus transit demand. Although many reports have looked at bus transit demand, few have estimated how demand has changed due to the introduction of a BRT system. I will look specifically at the Lane County region and analyze ridership changes attributable to the introduction of the new EmX line.

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[18] Gomez-Ibanez, J.A. 1996.
[19] Kitamura, R. 1989.
[20] Palma, A.D. and D. Rochat. 1999;
[21] Gebeyehu, M. and S. Takano. 2007; Palma, A.D. and D. Rochat. 1999.

III. MODEL

A major goal of the EmX line is to improve transit quality and, thereby, increase ridership on the region's public transit lines.[22] To achieve this goal, transportation planners need to be aware of who is riding the bus system in order to best serve the needs of the current ridership. Estimating a ridership demand function that reveals significant differences between riders attracted by the EmX line and continuing LTD bus riders in the Lane County area can provide planners with information that better allows them to serve the transit district.

Demand emanates from individual decisions. It is common to analyze demand decisions using rational choice theory.[23] In the present context, rational choice theory posits that an individual will choose one alternative over another (e.g. bus over car) if that individual derives a greater utility from one alternative than from another. Utility is the total satisfaction an individual receives from consumption of a good or service.[24] The problem with this comparison is that utility is not observable or measurable. The most one can say about an individual's utility function is that it contains information about an individual's characteristics; about the characteristics of a particular alternative for that individual; and about any unobservable variation in the function. Given this information, one must infer an individual's utility function based on the individual's characteristics and preferences given a set of alternatives.

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[22]Hamm, K.P. 2008.
[23] See for example D. McFadden. 1996.
24 Samuelson 2005.

In a disaggregate model, decisions are driven by utility functions. Utility for a given alternative i is determined by all of the relevant characteristics of an alternative i as faced by individual n (x_{in}) and do not vary across alternatives (e.g. income); and all the relevant characteristics of individual n (r_n):

$$U = U(x_{in}, r_n) \text{ for all } i \text{ in } J_n$$

The utility function can be split into two components representing observed (V) and unobserved characteristics (e). The observed characteristics are contained in vector V which is a function of z_{in}, s_n and β. In the model, z_{in} represents a function of the observed characteristics of an alternative i faced by an individual n; s_n represents a function of the observed characteristics of individual n; and β is a vector of parameters. The unobserved characteristics are contained in an error term (e_{in}). Therefore, the utility function can be written as: $U = V(z_{in}, s_n, \beta) + e_{in}$.

The probability that an individual will choose a particular alternative (P_{in}) from a set of alternatives depends upon an individual's utility function. Probability of choosing one alternative over another is a function of the observed characteristics of an alternative i faced by an individual n (z_{in}); the observed characteristics of individual n (s_n); and a vector of parameters (β):[25]

$$P_{in} = f(z_{in}, z_{jn}, s_n, \beta) \text{ for all j in } J_n$$

[25] Train 2003.

In this equation, J_n represents the set of alternatives available to individual n (e.g. car, bus, bike, taxi, etc). In the case of transportation, P_{in} represents the proportion of times an individual chooses alternative i given the choice of all alternatives in J_n. An individual chooses a given alternative i if that particular choice yields the highest utility in J_n. Therefore, the probability that an individual chooses alternative i is the same as the probability that choice i yields a higher utility than the other alternatives in choice set J_n:

$$P_n(i) = \Pr\left(U_{in} > U_{jn}\right) \text{ for all j in } J_n$$

The utility function can be substituted into the probability equation:

$$P_{in} = \Pr\left(V_{in} + e_{in} > V_{jn} + e_{jn}\right) \text{ for all j in } J_n$$

Logit models assume that the error terms are distributed independently and identically through an extreme value distribution. The logit model manipulates the probability function to look at differences between variables:

$$P_{in} = \Pr\left(e_{jn} - e_{in} > V_{in} - V_{jn}\right) \text{ for all j in } J_n$$

In the case of multinomial logit modeling, the probability function takes the following form:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in J_n} e^{V_{jn}}}$$

It is often helpful to consider a logit model that is linear in parameters. This is modeled in the following equation:

$P_{in} = \frac{e^{\beta' x_{in}}}{\sum_{j \in J_n} e^{\beta' x_{jn}}}$ where β is a single vector of coefficients and x_{in} is a vector of attributes for alternative *i*.

This paper utilizes a multinomial logit model in its estimation. As noted earlier, a binary choice logit model is used to compare bus ridership to non-bus ridership prior to the introduction of the EmX line. The analysis is confined to identification of the import of factors for current bus riders.

IV. DATA

This analysis uses survey data from a survey of LTD bus riders conducted in 2007 by the Lane Transit District of Eugene, Oregon in conjunction with the Center for Urban Transportation. The survey was given to riders on two different bus routes on the LTD system. The survey was part of the Federal Transportation Administration's demonstration project and was intended to provide information about specific BRT impacts on various regions throughout the United States.[26] A total of 1834 surveys were filled out and returned. The survey was designed to determine what types of new riders the EmX is attracting. The survey asks questions about both individual specific characteristics as well as individual specific transportation alternative attributes. Based on the survey conducted, a number of variables were found to be useful in analyzing transportation choice.

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[26] Thole, C. and S. Hall. 2007.

As is common with most survey data, there were a number of measurement issues addressed. Specifically, each variable was reviewed to ensure that the data were recorded properly and there were no egregious outliers. There were a number of response variables that contained data that did not make sense in the context of the question and were most likely entry errors. Twelve observations of this type were found and the data for each of these entries was dropped.

Each variable from the survey relevant to the current analysis was sorted into groups based on what form of transportation an individual chose before the introduction of the EmX line. The mean of each income bracket was calculated, and that value was assigned to represent each income bracket option in the survey. Similarly, the mean number of months an individual had used LTD and the mean number of minutes in total commute time were found and used as values to represent each range option in the survey. Dummy variables were created for the gender and own car variables. The mean and standard deviation of each ordinal variable was then taken. For the ordinal variables, those for which each number in the data represents an unranked option (for example 1=student), I report the mode of the variable. The results can be seen below in Tables 1 and 2. See the Appendix for a copy of the survey questions.

Table 1. Variable Medians

Median	Car	Bicycle	Bus	Walk	Other	No Trip
How did you get to the EmX bus? (1=walk, 2=drive, 3=taxi, 4=bike, 5=dropped off, 6=transfer, 7=other)	1	4	4	1	1	5
Affiliation (1=UO student, 2=UO employee/faculty, 3=LCC student, 4=K-12 student, 5=PeaceHealth employee, 6=City of Eugene employee, 7=Group pass participant)	4	1	4	1	4.5	3
Occupation (1=student, 2=homemaker, 3=unemployed, 4=retired, 5=employed for pay outside your home, 6=employed for pay at home)	3	4	4	5	5	3
What is the main purpose of your trip? (1=work, 2=shopping, 3=school, 4=visit friends or family or recreation, 5=job seeking, 6=health or medical, 7=other)	2	2	3	3	3	3

Table 2. Mean and Standard Deviation

Mode of Transit	Car	Bicycle	Bus	Walk	Other	No Trip
Months Using LTD (1=1.5, 2=4.5; 3=8; 4=35; 5=82)	2.723 (1.618)	3.755 (1.372)	4.063 (1.023)	3.226 (1.552)	3.417 (1.666)	2.728 (1.631)
Age	36.92 (16.70)	34.07 (13.68)	35.12 (15.37)	31.22 (13.83)	32.84 (12.43)	30.15 (12.41)
Own Car (0=don't own car, 1=own car)	0.7877 (0.4101)	0.3704 (0.4874)	0.4083 (0.4918)	0.3077 (0.4651)	0.28 (0.4583)	0.4778 (0.5023)
Gender (1=female, 0=male)	0.5284 (0.5006)	0.2456 (0.4343)	0.5444 (0.4984)	0.3334 (0.4752)	0.4167 (0.5036)	0.4725 (0.5020)
Income (1=5,000; 2=12,500; 3=20,000; 4=30,000; 5=40,000; 6=52,500; 7=67,500; 8=87,500; 9=100,000)	2.784 (2.168)	1.737 (2.020)	2.007 (1.894)	1.862 (2.206)	1.8 (1.451)	2.198 (1.895)
Total Trip Time (1=3; 2=8; 3=15.5; 4=25)	2.191 (1.119)	2.138 (0.9990)	2.504 (1.129)	2.246 (1.090)	2.440 (1.227)	2.435 (1.132)
Total Trip Time (min)	2.191 (1.119)	2.138 (0.9990)	2.504 (1.129)	2.246 (1.090)	2.440 (1.227)	2.435 (1.132)
Total Time on Bus (min)	26.87 (26.55)	25.65 (13.81)	32.25 (23.94)	18.35 (20.26)	31.10 (33.32)	38.63 (37.65)
Change in Travel Time With EmX (min)	3.377 (1.778)	3.519 (3.476)	3.894 (3.476)	3.092 (1.598)	3.350 (1.899)	3.361 (1.739)
Number of Bus Trips in Week a Year Ago	2.412 (1.131)	2.582 (1.301)	2.868 (1.230)	2.523 (1.187)	2.834 (1.204)	2.522 (1.183)
Number of Bus Trips in Week	3.497 (2.015)	4.218 (2.025)	4.321 (1.845)	3.935 (1.800)	4.348 (1.921)	3.484 (2.233)
Number of Bus Trips Per Day	1.343 (2.181)	2.772 (2.584)	4.405 (3.924)	2.313 (2.569)	3 (2.859)	1.946 (2.460)
Number of Days Per Week Ride	4.157	4.655	5.120	4.508	4.36	4.641

EmX	(1.841)	(1.974)	(1.709)	(1.930)	(2.079)	(1.789)

Travel Choice Prior to EmX

Respondents were asked to identify their preferred mode of transportation prior to the introduction of the EmX line. The mode choice of each individual is used as the dependent variable in this analysis. The choices were driving oneself, riding with someone else, biking, riding the bus, walking, taking a taxi, not making the trip or some other form of transportation not included in the survey options. These choices were labeled one through eight respectively. I combined the taxi and other options to create one "other" category for use in my estimation. The frequencies of mode choice are presented in Table 3 below.

Table 3. Mode Choice Frequency

Mode of Transit	Car	Bicycle	Bus	Walk	Other	Didn't Make Trip
Number of Individuals	192	84	1,007	124	42	130
Percent of Individuals	12.2%	5.3%	63.8%	7.9%	2.6%	8.2%

V. ANALYSIS

The first step of this analysis is to determine the major differences between new riders attracted by the EmX line and riders who rode the bus prior to the introduction of the EmX line. Based on the survey results, I conducted t-tests to determine any significant differences between new and continuing riders based on the relevant variables discussed earlier. The results of these tests are presented in Table 4 below.

Table 4. T-test Results

Variable	Did not Ride Bus	Ride Bus	Total
Car Ownership	0.4031 (0.4908)	0.3645 (0.4815)	0.3819* (0.4860)
Income	3.218 (2.255)	2.834 (2.063	2.994** (2.152)
Gender	0.4262 (0.4948)	0.3893 (0.4878)	0.4059 (0.4912)
Age	33.65 (15.32)	34.167 (15.60)	33.95 (15.48)
Length of Total Commute Time	2.224 (1.217)	2.530 (1.144)	2.398** (1.185)
Length of Time Using LTD	3.068 (1.596)	4.061 (1.0257)	3.640** (1.388)

A * and ** indicate significant differences at the

*5 % significance level

** 1% significance level

These results indicate major differences between the ridership population before and after the introduction of the EmX line. In terms of demographics, new riders are more likely have higher incomes and own their own cars. Gender and age do not seem to vary significantly between the two populations.

The occupation and affiliation of the new riders is different than that of continuing LTD riders. New riders are more likely to be University of Oregon students, whereas continuing riders are more likely to be Lane Community College students. The number of riders who are students, homemakers, unemployed, K-12 students and retired has grown. The ridership population prior to the introduction of the EmX had a larger

share of people who were employed outside the home, as well as a larger share of people who were group pass participants.

Before the EmX line, many riders chose to ride the bus because they had a bus pass or did not drive. The new ridership population has a larger share of people who choose to ride the bus to avoid traffic and because they have free bus passes. The reasons the two populations ride the bus are not significantly different. The main distinction between the two groups is that a smaller share of the new ridership population is choosing to ride the bus for recreational or medical purposes.

New bus riders include a larger share of people who walk, drive and bike to the bus station and a smaller share of people who get to the bus station by transferring from another bus route. Similarly, a larger share of new bus riders bike from the bus station to reach their final destination. A smaller share of new bus riders transfer to another bus to reach their final destination.

The commute time and number of commutes for new bus riders tends to be shorter than that of continuing bus riders. The average commute time and average number of minutes of a one-way bus trip for the new ridership population is shorter than that of the older population. The older population of bus riders has experienced a much greater shortening of their commute time following the introduction of the EmX line than has the new population. New riders on average make fewer trips per day and per week on the bus than did the older population. This is true both for the period before the introduction of the EmX and after. Finally, on average new riders have been using the LTD bus system for less time than have the continuing riders.

VI. EMPIRICAL MODEL

This analysis uses a multinomial logit model to estimate the probability of riding the bus before the introduction of EmX. This allows an econometric evaluation of the differences in ridership and the attributes of new riders. Initially all the variables discussed in the previous sections were included in the logit analysis. I evaluated each variable for statistic significance and sign. Based on this evaluation, the variables included in the logit analysis were income, gender, age, car ownership, total amount of time spent on the rider's commute, and length of experience using LTD.

In the survey questions regarding total commute and length of experience using LTD, participants were asked to choose between a number of different time intervals. In order to use these data in analysis, the mid-point of each time interval was used to represent each option. The amount of time of a bus commute was measured in minutes. Length of experience using LTD was converted into the number of months.

The income variable was also measured in intervals on the LTD survey. The mid-point of each income bracket was used as the representative value for each category. These values were then used in the logit estimation.

A dummy variable was created to measure the effect of gender on current bus ridership. The variable was assigned a value of 1 if the respondent was female and 0 if the respondent was male. This variable was then used in logit estimation.

Each option listed under the survey questions regarding getting to the bus station, leaving the bus station and trip purpose was converted into a dummy variable. If the option was chosen the dummy variable was designated a value of 1, if the option

was not chosen the dummy variable was designated a value of 0. Each variable was then incorporated into the logit analysis.

In this paper, six indirect utility functions are considered. They represent transit mode indirect utility prior to the introduction of the EmX line. They are modeled as follows, where x represents all of the relevant characteristics of an alternative *i* as faced by an individual *n*, and *r* represents all of the relevant characteristics of an individual *n*:

$$U(bus) = U(x_{in}, r_n)$$

$$U(walk) = U(x_{in}, r_n)$$

$$U(drive) = U(x_{in}, r_n)$$

$$U(bike) = U(x_{in}, r_n)$$

$$U(taxi) = U(x_{in}, r_n)$$

$$U(other) = U(x_{in}, r_n)$$

The different categories of riders are analyzed based on their transportation mode choice prior to the introduction of the EmX line. The categories are drive, walk, bike, ride bus, people who did not make the trip and other. The above equations are used to model these categories.

Initially, a binary logit model is used to estimate differences in attributes between riders who rode the bus before the EmX line and those who did not. Two

probabilities, shown below, are considered: the probability that a rider used to ride the bus and the probability that he/she did not.

$$\Pr(Bus) = \frac{1}{1 + e^{X\beta(non-bus)}}$$

$$\Pr(Non-bus) = \frac{e^{X\beta(non-bus)}}{1 + e^{X\beta(non-bus)}}$$

The binary logit model compares the attributes of previous non-bus riders to continuing bus riders using the following calculation:

$$\frac{\Pr(Non-bus)}{\Pr(Bus)}$$

This binary logit estimation is performed in order to ascertain any general differences between previous bus and non-bus riders.

Binary logit estimation looks at differences between riders who used to ride the bus and those who did not. Within the category of riders who did not previously ride the bus, there are individuals who used to take a variety of forms of transit. Multinomial estimation allows one to look at differences between these individuals. Rather than focus on whether an individual rode the bus or not, multinomial estimation looks at differences between types of riders: those who used to ride the bus, bike, walk, etc. This provides a more nuanced analysis of transit demand.

In multinomial estimation, non-bus riders are separated into categories depending on what type of transit they used prior to the EmX line. These categories are driving, biking, walking, not making the trip and taking some other type of

transportation not included in the survey. In the model, each of these groups is represented as follows:

$$\Pr(Bus)=\frac{1}{1+e^{X\beta(drive)}+e^{X\beta(drive)}+e^{X\beta(bike)}+e^{X\beta(dwalk)}+e^{X\beta(other)}+e^{X\beta(notrip)}}$$

$$\Pr(Drive)=\frac{e^{X\beta(Drive)}}{1+e^{X\beta(drive)}+e^{X\beta(drive)}+e^{X\beta(bike)}+e^{X\beta(dwalk)}+e^{X\beta(other)}+e^{X\beta(notrip)}}$$

$$\Pr(Bike)=\frac{e^{X\beta(Bike)}}{1+e^{X\beta(drive)}+e^{X\beta(drive)}+e^{X\beta(bike)}+e^{X\beta(dwalk)}+e^{X\beta(other)}+e^{X\beta(notrip)}}$$

$$\Pr(Walk)=\frac{e^{X\beta(Walk)}}{1+e^{X\beta(drive)}+e^{X\beta(drive)}+e^{X\beta(bike)}+e^{X\beta(dwalk)}+e^{X\beta(other)}+e^{X\beta(notrip)}}$$

$$\Pr(Other)=\frac{e^{X\beta(Other)}}{1+e^{X\beta(drive)}+e^{X\beta(drive)}+e^{X\beta(bike)}+e^{X\beta(dwalk)}+e^{X\beta(other)}+e^{X\beta(notrip)}}$$

$$\Pr(Notrip)=\frac{e^{X\beta(Notrip)}}{1+e^{X\beta(drive)}+e^{X\beta(drive)}+e^{X\beta(bike)}+e^{X\beta(dwalk)}+e^{X\beta(other)}+e^{X\beta(notrip)}}$$

Based on theory and prior studies, it is expected that income and car ownership are negatively correlated with bus ridership. The female variable should be negatively correlated with bus ridership, as males have been shown to be generally less likely to choose public transit than females.

VII. RESULTS

Economic theory asserts that income, gender, age and car ownership are important determinants of bus ridership. As a base case, I included these variables as

exogenous right hand side variables in a simple logit analysis. The dependent variable used in the multilogit and binary logit analyses is travel mode choice prior to the introduction of the EmX line. The dependent binary logit variable has a value of one if an individual rode the bus, and zero if the rider chose some other form of transportation. Since the option of not to rider the bus has a multiplicity of different options, and since the effect of variables may be masked by this variance, a multilogit model that allows for variation in the non-bus option is useful. The six possible multilogit choices include walking, biking, driving, taking the bus, not making the trip, and choosing some other form of transportation not included in the previous choices. After estimating a logit using basic variables, I incorporate additional variables included in the survey to determine if there are any other significant differences between LTD ridership before and after the EmX line.

To account for possible endogeneity of the car ownership variable, I first predicted the value of car ownership for both the Base Case and Case 1 scenarios. I then used these predicted values in my logit estimation to avoid possible endogeneity bias. I am able to do this and avoid collinearity due to the inherent non-linear properties of the logit model.[27]

In the first stage of my estimations, I performed a binary logit estimation and analyze the difference in attributes between current bus riders who used to ride the bus prior to the EmX line, and current bus riders who chose some other form of transportation prior to the EmX line. In both cases, higher income is the only variable found to significantly affect an individual's decision of whether to ride the bus given the

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[27] See for example W.H. Greene. 2007; and J.T. Heckman. 1978. .

introduction of the EmX line. High incomes decrease the probability that a current bus rider rode the bus prior to the EmX. The results of both the base case and the added variable case are in table 5.

The next stage of my estimation consisted of analyzing the difference in attributes between current riders who chose some other form of transportation prior to the EmX line, based on what type of other transportation mode they had chosen. To do this, I separated previous non-bus riders into the following categories based on the options available in the survey: drivers, bikers, walkers, those who did not make the trip, and those who chose some other form of transportation not included in the survey options. This analysis was done using a multinomial logit model.

I first perform an estimation using only the base case variables. The marginal results of the multinomial logit estimation can be seen in Tables 6 and 7. The results show that certain attributes of current EmX riders differ depending on what type of transit mode they chose to use prior to the EmX line. An individual who owns a car is more likely to have chosen to drive or walk prior to the new bus line. Riders who previously did not make the trip are less likely to own a car than those who used to ride the bus.

As an individual's income increases, he/she is more likely to have chosen to walk, or drive prior to the new line than other individuals. Those who previously wouldn't have made the trip are likely to have lower incomes than those who previously chose to ride the bus.

Age is a significant determinant for riders who previously did not make the trip. Those who used to not make the trip tend to be younger than those who rode the bus.

Riders who previously did not make the trip are more likely to be male than riders who previously rode the bus. Riders who drove are more likely to be female than those who rode the bus. In general, current bus riders are more likely to have ridden the bus prior to the EmX line if they were women.

The transit decisions of women are more sensitive to other factors, such as income and age then males. Figure 1 below demonstrates that income does not seem to influence a male's decision to ride the bus to the extent that it influences females. Males are much less likely to ride the bus at every income level when compared to females. Similarly, as shown in figure 2, a female's choice to ride the bus is more sensitive to age than a male's decision. This corroborates with the estimation results that males are less likely to have ridden the bus prior to the EmX than females.

Figure 1

Probability of Bus and Income by Genger(median income)

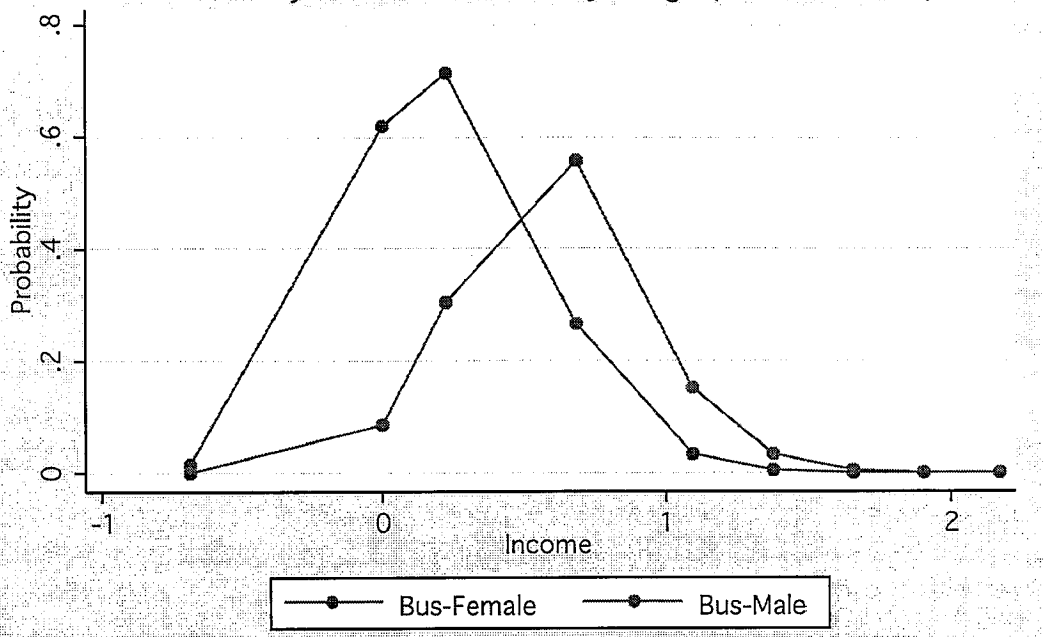
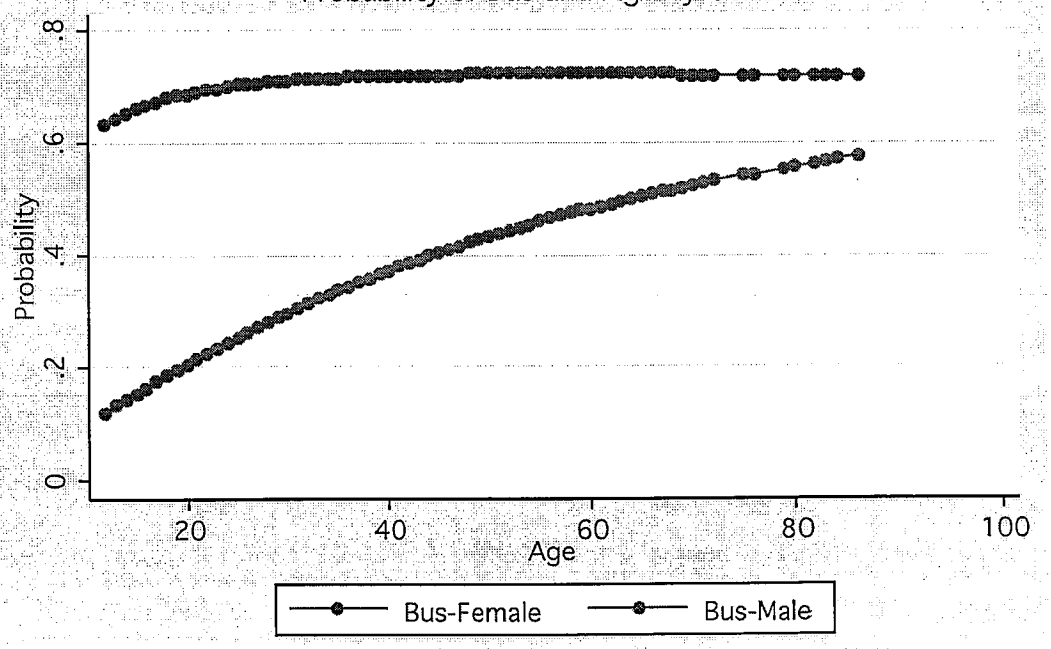


Figure 2

Probability of Bus and Age by Gender



Expanding upon the base case, I include other attributes that might be significant in distinguishing between continuing and new bus riders. The next set of variables I add to the estimation are the length of time the rider has been using the LTD bus system and the total commute length of a rider. Tables 8 and 9 show the results from my estimation of Case 1.

Income continues to be a significant determinant of whether an individual chose to drive prior to the new line. Individuals who used to drive or walk are more likely to own cars than those who rode the bus. Much like income, those who previously did not make the trip are less likely to own cars than bus riders. Drivers and walkers are more likely to own cars than bus riders. Gender also continues to be significant for all riders. Those who previously drove or walked are more likely to be female. Those who previously did not make the trip are more likely to be male than those who used to take the bus. Those who drove or walked tend to be older than those who rode the bus. Riders who did not make the trip tend to be younger than those who rode the bus. Riders who used to drive or not make the trip or choose some other form of transportation are more likely than continuing bus riders to have used the Lane Transit District bus system for a shorter amount of time than those who used to ride the bus. Riders who used to drive are more likely to have shorter commute times than continuing bus riders.

Table 5. Binary Logit Estimation

Variable	Base Case	Case 1
Own Car (Case 1)		2.922
		(3.947)
Income	-1.967	-0.714
	(1.617)	(0.779)
Age	0.131	-0.00832
	(0.177)	(0.247)
Gender	-0.305	0.293
	(0.634)	(0.301)
Length of LTD Use		0.726***
		(0.220)
Total Commute Length		0.455*
		(0.265)
Own Car (Base Case)	8.857	
	(8.003)	
Constant	-3.084	-3.770*
	(2.538)	(2.098)
Observations	1162	1119

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Base Case Multilogit Results

Variable	Car	Bike	Walk	Other	No Trip
Own Car	-17.12*	-19.66	-35.22*	4.960	36.66**
	(9.896)	(20.17)	(18.29)	(29.35)	(17.19)
Income	3.914**	3.656	6.862*	-0.982	-7.261**
	(1.995)	(4.053)	(3.674)	(5.941)	(3.495)
Gender	1.312*	0.232	1.831	-0.892	-3.127**
	(0.789)	(1.576)	(1.428)	(2.322)	(1.363)
Age	0.211	0.305	-0.0663	-0.131	-1.277***
	(0.235)	(0.421)	(0.398)	(0.617)	(0.352)
Constant	3.635	3.841	10.58*	-4.517	-10.67**
	(3.163)	(6.338)	(5.751)	(9.246)	(5.411)
Observations	1162	1162	1162	1162	1162

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7. Marginal Base Case Results

Base Case	Car	Bike	Bus	Walk	Other	No Trip
Own Car	-2.155*	-0.7017	1.399	-1.571**	0.1481	2.881**
	(1.190)	(0.7569)	(1.792)	(0.7936)	(0.6004)	(1.130)
Income	0.4933**	0.1271	-0.3177	0.302*9	-0.0306	-0.5750**
	(0.2400)	(0.1523)	(0.3623)	(0.1598)	(0.1215)	(0.2299)
Gender	0.1787*	0.0097	0.0304	0.0868	-0.0157	-0.2900*
	(0.0923)	(0.0517)	(0.1715)	(0.0737)	(0.0449)	(0.1500)
Age	0.0386	0.0145	0.0394	-0.0004	-0.0015	-0.0906***
	(0.0283)	(0.0159)	(0.0392)	(0.0178)	(0.0126)	(0.0223)
Observations	1122	1122	1122	1122	1122	1122

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Case 1 Multilogit Results

Variable	Drive	Bike	Walk	Other	No Trip
Own Car	-20.24*	-19.24	-40.14**	0.0966	34.30**
	(10.64)	(20.56)	(19.08)	(29.94)	(17.38)
Income	4.505**	3.609	7.843**	-0.0822	-6.817*
	(2.148)	(4.132)	(3.831)	(6.059)	(3.535)
Gender	1.422*	0.221	2.203	-0.488	-3.019**
	(0.849)	(1.606)	(1.489)	(2.358)	(1.378)
Age	0.424*	0.252	0.0876	-0.0622	-1.007***
	(0.257)	(0.437)	(0.424)	(0.637)	(0.361)
Length of LTD Use	-0.0234***	-0.00317	-0.0125***	-0.00614	-0.0217***
	(0.00324)	(0.00460)	(0.00466)	(0.00680)	(0.00416)
Total Trip Length	-0.369***	-0.401**	-0.292*	-0.0948	-0.0273
	(0.111)	(0.178)	(0.173)	(0.263)	(0.142)
Constant	5.705*	4.866	12.88**	-2.545	-9.835*
	(3.392)	(6.469)	(6.013)	(9.428)	(5.469)
Observations	1119	1119	1119	1119	1119

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9. Marginal Case 1 Results

	Car	Bike	Bus	Walk	Other	No Trip
Own Car	-2.209*	-0.6739	1.843	-1.675**	0.0603	2.656**
	(1.137)	(0.7876)	(1.839)	(0.7778)	(0.6385)	(1.112)
Income	0.4938**	0.1234	-0.3972	0.3248**	-0.0143	-0.5311**
	(0.2292)	(0.1581)	(0.3720)	(0.1566)	(0.1292)	(0.2263)
Gender	0.1654*	0.0083	0.0093	0.1006**	-0.0090	-0.2746*
	(0.0892)	(0.0535)	(0.1788)	(0.0791)	(0.0451)	(0.1492)
Age	0.0541**	0.0105	0.0043	0.0042*	-0.0012	-0.0719***
	(0.0275)	(0.0169)	(0.0409)	(0.0179)	(0.0136)	(0.0227)
Length of LTD Use	-0.0023***	0.0000	0.0037***	-0.0003	0.0000	-0.0012***
	(0.0032)	(0.0002)	(0.0005)	(0.0002)	(0.0002)	(0.0003)
Total Commute Length	-0.0363***	-0.0131	0.0555***	-0.0095	-0.0003	0.0038
	(0.0118)	(0.0068)	(0.0172)	(0.0072)	(0.0056)	(0.0093)
Observations	1082	1082		1082	1082	1082

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VIII. CONCLUSIONS

Introduction of a new product can change demand for the product by drawing new consumers into the market. These new consumers may have preferences and attributes that differ significantly from previous consumers. Different consumer utilities will yield a new demand curve and a changed market equilibrium. In this study, I look at how the introduction of a Bus Rapid Transit system, the EmX, has changed transit demand in Lane County.

The study uses a survey conducted by the LTD bus system in conjunction with the Federal Transit Administration to determine how ridership has change in Lane County since the introduction of the new EmX line. Based on analysis of the results of

the survey conducted by LTD, riders who began using the bus system after the introduction of the EmX line have a significantly different set of attributes than those riders who were riding the bus prior to the EmX line. A general comparison of previous bus and non-bus rider shows that current riders who did not previously choose to ride the bus are more likely to have higher incomes than those who rode the bus prior to the EmX line.

Further analysis finds differences in attributes between previous non-bus riders based on what type of transit mode they previously chose. Compared to continuing bus riders, riders who used to drive are more likely to have higher incomes, own their own cars, have shorter commute times, be male, be older and have less experience with the LTD bus system. Riders who previously biked are more likely to have shorter commute times. Those who used to walk are more likely to have higher incomes, own a car, have less experience using the LTD bus system, and have shorter commute times. Those who previously did not make the trip are less likely to own a car and more likely to be younger and have less experience using the LTD bus system than continuing riders.

Since the introduction of the EmX line, a new type of rider has begun to use the LTD bus system. This new rider is more likely to be male, have a higher income, own a car, be making shorter trips and have less experience with the LTD bus system.

Appendix

LANE TRANSIT DISTRICT CUSTOMER SURVEY (Spanish version available from the surveyor)

DEAR VALUED LANE TRANSIT DISTRICT CUSTOMER:

Lane Transit District would like information about your current trip **on EmX** to help improve
the service. PLEASE take a few minutes to complete the following survey. Please do not put
your name or other identifying marks on the survey.

Please check (☑), write out, or circle your responses as appropriate. Even if you do not complete
the survey, please return it to a surveyor or leave in your seat as you exit the bus.

Thank you for your cooperation.

1. Where did you get on this bus?

1___Eugene Station	6___Walnut Station
2___High Street Station	7___Glenwood Station
3___Hilyard Station	8___Lexington Station
4___Dad's Gate Station1	9___McVay Station
5___Agate Station	10__Springfield Station

2. Why are you riding this bus today? (*Check all that apply*)

1___Avoid traffic	4___No car available	7___Have a bus pass
2___Less expensive	5___Parking problems	8___Have free bus pass
3___More convenient	6___I do not drive	9___Other

3. What is the main purpose of your bus trip today? (*Please check only* ONE)

1 ___Work	5 ___Job seeking
2 ___Shopping	6 ___Health or medical
3 ___School	7 ___Other (Specify): _____
4 ___Visit friends or family or recreation	

4. How did you get to this EmX bus?

1 ___Walked --How many blocks? ___	5 ___Dropped off
2 ___Drove	6 ___Transfer ed from bus route

3 ___Taxi # or name _____

4 ___Bike 7 ___Other (Specify): _____

5. Where will you get off this bus?

1___Eugene Station
2___High Street Station
3___Hilyard Station
4___Dad's Gate Station
5___ Agate Stat ion
6___Walnut Station
7___Glenwood Station
8___ Lexington Station
9____ McVay Station
10___ Springfield Station

6. How will you get to your final destination? (*Please check only* ONE)

1 ___Walk --How many blocks? ___

2 ___Drive

3 ___Taxi

4 ___Bicycle

5 ___Will be picked up

6 ___Transfer to bus route

or name _____

7 ___ Other (Specify): _____

7. How long will that take you to reach your final destination?

1___1-5 minutes
2___6-10 minutes
3___11-20 minutes
4___Longer

8. Approximately how many minutes will this entire one-way bus trip take from the beginning to the end of your trip when you get off the last bus? _____Total minutes

9. Has your travel time changed with the EmX?

1___15+ minutes faster

2___11-15 minutes faster

3___6-10 minutes faster

4___1-5 minutes faster

5___About the same

6___Slower

10. Before the EmX opened, how did you make this trip?

1___Drove
2___Rode with someone else
3___Bicycle
4___Rode LTD bus route # ___
5___Walked
6___Taxi
7___Didn't make trip
8___Other (specify): _____

11. Are you? (check all that apply)
    1___UO student
    2___UO employee/faculty
    3___LCC student
    4___K-12 student
    5___ PeaceHealth employ
    6___ City of Eugene employee
    7___ Group Pass participant

12. How many separate bus trips will you make today?
    (*i.e., going to work is one trip; going from work to home is a second trip*)
    1___ 1 trip 2___ 2 trips 3___ 3 trips 4___ 4 trips 5___ Other (Specify):_____

13. In the past seven days, how many days have you ridden on an LTD bus (including the bus today)?
    1 2 3 4 5 6 7

14. Last year at this time, how many days per week were you riding the LTD buses?
    0 (None) 1 2 3 4 5 6 7

15. How many days per week do you usually ride on the EmX
    0 (None) 1 2 3 4 5 6 7

16. How long have you been using LTD service?
    1___Less than 3 months
    2___3 to 6 months
    3___6 months to 1 year
    4___1 to 5 years
    5___More than 5 years

17. In general, how would you rate each of the following aspects of **EmX** bus service?

Please circle the number that best reflects your opinion		Very	Good	Fair	Poor	Very
a.	Hours of service	5	4	3	2	1
b.	Frequency of the bus (how often buses run)	5	4	3	2	1
c.	Convenience of the bus (where buses go)	5	4	3	2	1
d.	Dependability of the bus (on time performance)	5	4	3	2	1
e.	Wait time at station/stop for the bus	5	4	3	2	1
f.	Travel time on this bus	5	4	3	2	1
g.	Cost of riding the bus (value for what you pay)	5	4	3	2	1
h.	Availability of bus information/maps at stations	5	4	3	2	1
i.	Availability of seats on bus	5	4	3	2	1
j.	Personal safety on bus	5	4	3	2	1
k.	Personal safety at stops	5	4	3	2	1
l.	Quality of bus shelters/stops	5	4	3	2	1

m.	Smoothness of ride on vehicles	5	4	3	2	1
n.	Ease of getting on and off vehicles	5	4	3	2	1
o.	Location of bus signage	5	4	3	2	1
p.	Ease of identifying bus service	5	4	3	2	1
q.	Wheelchair securement on vehicles	5	4	3	2	1
r.	Accessibility of vehicles to handicapped	5	4	3	2	1
s.	Operator courtesy	5	4	3	2	1
t.	Operator driving competence	5	4	3	2	1
u.	Cleanliness of buses	5	4	3	2	1
v.	Cleanliness of shelters	5	4	3	2	1
w.	Amenities provided at the shelters (benches, trash bins, etc.)	5	4	3	2	1
x.	Your overall satisfaction with this route	5	4	3	2	1
y.	Your overall satisfaction with LTD	5	4	3	2	1
z.	Availability of bike racks	5	4	3	2	1
aa.	The look/design of the new vehicles used for EmX	5	4	3	2	1
bb.	Additional door in the middle of the bus	5	4	3	2	1
cc.	Doors on both sides of the bus	5	4	3	2	1
dd.	Level boarding onto the bus	5	4	3	2	1
ee.	Connectivity to other bus service	5	4	3	2	1
ff.	Parking cost/availability	5	4	3	2	1

18. What are the most important reasons you ride the EmX?

_____

_____

_____

Please tell us a little about yourself. All replies are strictly confidential.

19. How old are you? _____

20. Do you own a car or other motor vehicle, or have regular daily access to one?
    1___Yes 2___No
    If yes, what is the total number of cars or other motor vehicles owned or leased by your household? (*Circle a number.*) 1 2 3 4 5 or more

21. Are you female or male? 1___Female 2___Male

22. Please check all of the following that apply to you. Are you:

1___Student	4___Retired
2___Homemaker	5___Employed for pay outside your home
3___Unemployed	6___Employed for pay at home

23. What is your total annual household income (**before taxes**)?

1 ___Less than $10,000	4 ___$25,000 to $34,999	7 ___$60,000 to $74,999
2 ___$10,000 to $14,999	5 ___$35,000 to $44,999	8 ___$75,000 to $99,999
3 ___$15,000 to $24,999	6 ___$45,000 to $59,999	9 ___$100,000 or more

24. What is your home zip code?_____

25. If you have any other comments or suggestions about the bus service, please write them in below:

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE!

PLEASE RETURN IT TO THE BUS DRIVER, SURVEYOR, OR LEAVE IT ON YOUR SEAT TO BE PICKED UP.

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