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Forecasting Mobile Ticketing Adoption on Commuter Rail

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Abstract

Several commuter rail systems are beginning to accept mobile payments, in which tickets are purchased and validated on smartphones. Mobile payments may improve the rider experience while reducing costs and simplifying the fare collection process for rail operators. Before investing in this new ticketing technology, rail operators want to understand rider demand for mobile tickets. To assess the potential adoption of mobile payments, stated preference data from an onboard survey on two commuter rail lines (Worcester and Newburyport/Rockport) in the greater Boston area were analyzed. Binary logit was then used to forecast adoption on all commuter rail lines. Based on this model, 26 percent of commuter rail riders in Boston are very likely to adopt mobile ticketing.

Introduction

Commuter rail services typically use conductor-validated or proof-of-payment fare collection systems. In conductor-validated schemes, such as Boston's commuter rail, riders either prepay or buy tickets from conductors onboard. To prepay, passengers purchase tickets at windows, vending machines, or local retailers. Passengers then present tickets to conductors onboard trains for validation. In proof-of-purchase systems, riders must carry a valid ticket with them and are subject

to random inspection (Multisystems, Inc. 2003). Typically, these two types of fare collection are used in barrier-free rail systems.

While these types of fare collection are common in suburban commuter rail services, there are a few noteworthy drawbacks. First, it can be expensive to install equipment and operate the ticketing facilities needed for prepayment in rail stations. Second, ticket windows and onboard fare collection typically involve a large number of cash transactions. This can inconvenience customers who prefer credit or debit payments, particularly if electronic payments are not accepted at ticket windows or onboard trains. There are also significant risks associated with operators handling high volumes of cash, such as theft or fraud.

Although many heavy rail systems in urban centers have transitioned to smartcard fare collection systems (Fleishman et al. 1998; Multisystems, Inc. 2003; Hong 2006; Acumen Building Enterprise, Inc. 2006), most suburban commuter rail networks do not accept contactless smartcard payments. One reason for this is high capital and operating cost projections for previously ungated rail systems; this includes installing gates or validation systems and maintaining fare equipment distributed over extensive geographic areas. Additionally, installing a smartcard system—particularly with barriers—involves a significant change in customer experience for most conductor-validated or proof-of-payment fare collection systems. For these reasons and others, commuter rail operators have struggled to adopt smartcard fare collection systems.

As an alternative strategy, many commuter rail operators are now considering mobile payments for fare collection. Mobile payments would enable riders to purchase tickets directly on their smartphones with a credit card, debit card, or other electronic payment. This option may improve the customer experience by replacing prepayment at ticket windows or vending machines, which typically require some amount of waiting in line, thereby saving travel time. Furthermore, mobile payment with credit and debit cards can help reduce the number of cash transactions at ticket windows and onboard trains. Finally, mobile purchases may provide rail operators with valuable planning data that are currently not available in cash-based systems (i.e., disaggregate origin and destination information). In light of these advantages, several commuter rail systems are beginning to implement mobile payment fare collection systems.

Objective

Given interest in mobile payments, this research aimed to assess the level of demand for mobile payments by train riders. Stated preference survey data from two commuter rail lines in the greater Boston area were used in a discrete choice modeling framework to predict mobile payment adoption by riders. This model was then used to forecast demand for mobile payments on the entirety of Boston's commuter rail network.

Since most commuter rail operators do not yet accept mobile payments, there is limited information about the potential size of the market. Furthermore, other commuter rail operators may not have the resources to conduct detailed customer research to assess rider demand for mobile payments in their region. Therefore, this study also aimed to develop a simple methodology that other regional rail operators can use to estimate mobile ticketing adoption in their region. This methodology assumes that other operators have recent travel survey data, including rider demographics.

Background on Mobile Payments

Mobile payments enable riders to purchase tickets directly on their smartphones using a credit card, debit card, or other electronic payment. This transaction occurs in real-time over a cellular network and is then processed like a standard credit or debit transaction. Passengers may be required to activate their ticket before it is valid for travel. Operators then have several validation options, such as visually inspecting the smartphone ticketing screen or scanning a ticketing barcode with a hand-held device. This model of validation for mobile payments is applicable to commuter rail systems that rely on conductor-validated or proof-of-payment fare collection schemes.

Several commuter rail systems in the United States are moving toward mobile ticketing, and they are in different stages of assessment, procurement, testing, and implementation. Long Island Rail Road (LIRR) conducted a pilot program in which passengers could purchase mobile tickets for travel to a golf tournament and reported that approximately 20 percent of riders used mobile tickets to travel to the event (Mian 2012). Metro North Railroad (MNR) in New York and Connecticut recently tested mobile tickets with railroad staff, and the Metropolitan Transportation Authority (MTA) issued a request for proposals to move forward with mobile ticketing (MTA 2013). Similarly, Virginia Railway Express (VRE) in northern Virginia is in a procurement process for mobile ticketing (VRE 2013). Several transit agen-

cies with proof-of-payment fare collection systems are also implementing mobile payment systems, including TriMet in Portland (TriMet 2013) and DART in Dallas (DART 2012).

Despite the interest in mobile ticketing by regional rail operators throughout the country, there is very little literature pertaining to mobile payments for commuter rail fare collection. Most prior research has focused on mobile payments using near-field communications (NFC) technology and its application to urban bus and subway systems (Dorfman 2007; Quibria 2008; NFC Forum 2012). Consequently, additional research could provide significant insight for commuter rail operators considering mobile ticketing systems; the following analysis begins to fill this gap in the literature.

Background on Commuter Rail in Boston

This study analyzes the new mobile ticketing pilot program on commuter rail in Boston (Moskowitz 2012). The commuter rail is operated by the Massachusetts Bay Commuter Rail Company (MBCR) under contract with the Massachusetts Bay Transportation Authority (MBTA 2012). This operation includes fixed-schedule, daily service on 14 lines serving downtown Boston via two central city stations (North Station and South Station). It is the fifth largest commuter rail system in the United States based on the number of unlinked passenger trips (APTA 2011).

Boston's commuter rail has a zone-based fare policy, and both period passes (monthly) and pay-per-ride (single or multi-ride) tickets are available. Fare collection is administered through a conductor-validated system. Riders can prepay for tickets in rail stations at vending machines or at ticket windows, although many outlying stations lack ticketing facilities. Commuting riders can also purchase tickets through pre-tax employer programs, with participating companies in greater Boston distributing tickets directly to corporate program customers. Once onboard, conductors validate single- and multi-ride tickets using a hole-punch, and monthly passes are simply shown to conductors as flash passes. Passengers also have the option of purchasing single-ride tickets from the conductor onboard with cash at a higher price (MBTA 2012).

In late 2006, the Massachusetts Bay Transportation Authority (MBTA) launched the CharlieCard smartcard and magnetic stripe fare collection system on MBTA buses, subway, and light rail (Ryan 2007). The only part of the CharlieCard system that integrates with commuter rail is monthly passes; the backside of the com-

Commuter rail flash pass has a magnetic stripe ticket that can be used for free transfers onto MBTA subway trains and buses.

Over the past six years, there has been significant interest in expanding the CharlieCard system to commuter rail (Goodison 2007). Due to various constraints—most importantly, cost—this has not happened. The MBTA originally invested more than \$150 million in the CharlieCard system for subway, bus, and light rail. When proposals for expansion to the commuter rail estimated more than \$70 million in costs, the MBTA chose to pursue an alternative strategy.

In early 2012, the MBTA announced a one-year pilot program for mobile ticketing on commuter rail. This program has minimal upfront costs; the company contracted out the provision of the mobile ticketing platform for 2.8 percent of ticket sales (Moskowitz 2012). The pilot program officially launched in November 2012, and riders on all commuter rail lines are now able to purchase single- and multi-ride tickets via Android and iPhone smartphones. Monthly passes are also available as mobile tickets, but they currently do not include free transfers to MBTA bus or subway (MBTA 2013).

Riders who participate in the pilot program can purchase mobile tickets for their selected journey (see left screen in Figure 1) using a credit or debit card (see middle screen in Figure 1). Riders then activate their tickets before boarding, and once onboard, conductors can validate mobile tickets by visually inspecting them (see right screen in Figure 1). For further validation, tickets include a barcode that can be scanned to ensure fare compliance.

While the MBTA was planning the mobile ticketing pilot program, it worked in coordination with researchers (authors Brakewood and Rojas) to conduct detailed customer research about the potential adoption of mobile ticketing in Boston, which is described in the following paragraphs.

Selection Origin & Destination

Purchase Ticket

Display Active Ticket



Figure 1. Demonstration screenshots of commuter rail mobile ticketing application

Data Collection

The authors and a small group of graduate students conducted a short onboard survey to collect data for this analysis. An onboard sampling method was selected to ensure that only those in the target population (commuter rail riders) were reached. The survey was administered on three weekdays in June 2012 during the AM and PM peak periods (approximately 6:30–10 AM and 4–7:30 PM). Because ridership on the commuter rail is highly peaked in the commuting direction (inbound in the AM, outbound in the PM), the off-peak direction (outbound in the AM, inbound in the PM) was also sampled, so that both peak and off-peak riders could be included in the analysis. A total of 12 different train trips were sampled; 6 were outbound trips and 6 were inbound trips. Once onboard the trains, teams of two or three distributed paper surveys to as many riders as possible.

Line Selection

Due to manpower constraints, all commuter rail lines could not be sampled. Instead, two representative lines were selected for this analysis: the Worcester and Newburyport/ Rockport lines. These lines were selected to best represent the

population of commuter rail riders as a whole. Three factors influenced this selection: geography, ridership levels, and diversity of ridership.

The first factor, geography, was defined based on the terminal stations in downtown Boston. Two large commuter rail stations serve as the terminus for most commuter rail trips (North Station and South Station). Differences in service provision—particularly ticketing facilities at these two locations—could impact adoption of mobile ticketing. The first line that was selected (Newburyport/Rockport) terminates at North Station, and the second line (Worcester) ends at South Station.

Second, only high ridership lines were considered to maximize the response rate during the data collection process. Both of the selected lines have average weekday boardings of approximately 17,000–18,000 (cumulative counts for the Newburyport and Rockport branches), which makes them two of the highest ridership lines within the overall commuter rail network (MBTA 2010).

Third, the diversity of rider income levels and ethnicities from previous survey results was considered. This factor was hypothesized to impact the level of technology adoption and, therefore, the potential for mobile ticketing adoption. The Worcester line has relatively high levels of demographic diversity, whereas the Newburyport/Rockport line has a relatively homogenous ridership (CTPS 2011).

Data Collection Constraints

Although standard procedures for survey research were followed, there were a few constraints on the data collection process. First, there was no mail-back option for the survey. Riders were instructed to complete as many questions on the survey as possible during their commute, but some surveys were left incomplete because the rider alighted the train. Additionally, since the survey was administered only in English, a very small number of riders (less than 10) declined participation because they did not speak English. Last, for most of the sampled trips, the data collection process did not extend to the outlying terminal station. There are very few commuter rail trips with boardings and alightings between the outermost stations based on previous survey results (CTPS 2011). Therefore, it is reasonable to assume that additional data collection efforts between these stops would not have had a significant impact on the results.

Total Responses

Overall, 914 surveys were collected during the fieldwork period, and 903 were deemed sufficiently complete for the following analysis. Sufficient completeness meant that the respondent answered the questions up to and including the stated

preference mobile ticketing question (question 18 on the survey instrument). Table 1 shows the number of completed surveys collected on each line during each time period. The paper surveys were coded by the authors, and a sample of 5 percent was cross-checked for any data entry errors.

Table 1. Commuter Rail Surveys by Time Period and Line

Date	Day	Time	Line	Inbound Surveys	Outbound Surveys	Total Surveys	% of Total*
June 12, 2012	Tues	AM	Worcester	75	62	137	15%
June 12, 2012	Tues	PM	Newburyport	36	153	189	21%
June 13, 2012	Wed	AM	Newburyport	123	17	140	16%
June 13, 2012	Wed	PM	Worcester	81	160	241	27%
June 14, 2012	Thurs	AM	Worcester	89	2	91	10%
June 14, 2012	Thurs	PM	Rockport	33	72	105	12%
Total				437	466	903	100%

*Percentages rounded to the nearest whole number.

Survey Content

The survey instrument contained four questions designed to capture topics relevant to the use of mobile ticketing. First, the survey included a question about the adoption of information and communications technologies that could be used to access mobile ticketing applications, particularly smartphones. Second, the use of mobile payments for other retail transactions (i.e., Starbucks) was investigated using a revealed preference question. Then, after a brief description of mobile payments on the commuter rail, a stated preference survey question was posed to assess the likelihood of participants adopting mobile ticketing. This was followed by a question that probed the respondents' opinions about mobile payments (i.e., reasons for preferring mobile purchases or not).

Statistical Analysis

A high-level statistical analysis was performed on the four key questions that pertained to mobile ticketing, and the results are summarized in Table 2. This table contains the exact wording used for each of the four questions in the survey instrument, including the description of the stated preference question for mobile ticketing.

Table 2. Commuter Rail Mobile Ticketing Survey Results

Question*	Answers – All Respondents		Worcester		Newburyport/ Rockport		All Respondents	
	Count	%**	Count	%**	Count	%**	Count	%**
Total respondents	469	100%	434	100%	903	100%	903	100%
Which devices/technologies have you used in the past 30 days? ***	403	86%	402	93%	805	89%	882	98%
• Computer (laptop/desktop) or tablet	461	98%	421	97%	882	98%	688	76%
• Cell phone (includes smart phone)	356	76%	332	76%	688	76%	635	70%
• Smartphone (iPhone, Android, Blackberry, other)	317	68%	318	73%	635	70%	3	0%
• Text messaging	0	0%	3	1%	3	0%		
• Did not answer								
How often do you use a smartphone to make purchases (i.e., iTunes, Android Market/Play, Starbucks)?	238	51%	210	48%	448	50%	268	30%
• Never	143	30%	125	29%	268	30%	130	14%
• Sometimes (monthly)	58	12%	72	17%	130	14%	52	6%
• Often (weekly)	27	6%	25	6%	52	6%	5	1%
• Always (every day)	3	1%	2	0%	5	1%		
• Did not answer								
Later this year, commuter rail riders will be able to purchase and display tickets on their smartphones. How likely are you to use your smartphone to buy your commuter rail ticket?	135	29%	107	25%	242	27%	171	19%
• Very likely	93	20%	78	18%	171	19%	135	15%
• Somewhat likely	72	15%	63	15%	135	15%	69	8%
• Neutral	35	7%	34	8%	69	8%	275	30%
• Somewhat unlikely	130	28%	145	33%	275	30%	11	1%
• Very unlikely	4	1%	7	2%	11	1%		
• Did not answer								
How do you feel about making mobile purchases on your smartphone?	122	26%	134	31%	256	28%	45	5%
• I regularly make mobile purchases.	21	4%	24	6%	45	5%	110	12%
• I make mobile purchases but don't like it.	58	12%	52	12%	110	12%	211	23%
• I worry about making mobile payments.	119	25%	92	21%	211	23%	65	7%
• I do not currently make mobile purchases but I am open to it.	38	8%	27	6%	65	7%	207	23%
• I had not previously considered making mobile payments.	108	23%	99	23%	207	23%	9	1%
• I don't have a smartphone.	3	1%	6	1%	9	1%		
• Did not answer								

* Wording exactly as appeared on survey questionnaire.

** All numbers and percentages rounded to nearest whole number.

*** Riders could select all that apply.

As can be seen in Table 2, riders were first asked what devices/technologies they have used in the past 30 days, which included different types of smartphones. This question is crucial to forecasting the potential mobile ticketing market size, since riders without smartphones will be unable to participate in the MBTA's mobile ticketing initiative. The results show that approximately 76 percent of riders use smartphones, and the most popular smartphone is the iPhone. As a basis for comparison, approximately 55 percent of U.S. mobile subscribers own smartphones as of June 2012 (Streams 2012). These high adoption rates suggest that mobile ticketing is well suited for Boston's commuter rail.

Next, riders were asked how often they use a smartphone to make purchases (i.e., iTunes, Android Market/Play, Starbucks). Fifty percent of riders make mobile purchases once a month or more. Among the 50 percent who do not make mobile purchases, almost half do not use smartphones.

Then, the survey instrument informed riders that they would be able to purchase and display tickets on their smartphones later this year, and they were asked how likely they are to use their smartphone to buy a commuter rail ticket. A total of 29 percent of Worcester riders and 25 percent of Newburyport/Rockport riders indicated that they are very likely to use mobile ticketing. These riders are likely to be early adopters of mobile ticketing. Similarly, 20 percent of Worcester riders and 18 percent of Newburyport/Rockport riders indicated that they are somewhat likely to use mobile ticketing, whereas 22 percent of Worcester riders and 23 percent of Newbury/Rockport riders said they were neutral or somewhat unlikely to use mobile ticketing. This second group of riders may eventually use the technology, but it is doubtful that they will be early adopters. Last, 28 percent of Worcester riders and 33 percent of Newburyport/Rockport riders indicated they were very unlikely to use mobile ticketing.

Finally, riders were asked how they feel about making mobile purchases on their smartphones, which is intended to gauge rider attitudes towards mobile ticketing. The majority of riders stated that they already make mobile purchases (including those who do not like it) or are open to doing so (55% of Worcester riders and 58% of Newburyport/Rockport riders). Others were worried about making mobile purchases or had never even considered it (20% of Worcester riders and 18% of Newburyport/Rockport riders). These results show that if agencies aim to increase adoption rates, they must consider how to attract this demographic. The remaining 23 percent of riders on both the Worcester and Newburyport/Rockport lines said they did not have smartphones to make mobile purchases.

One additional caveat should be made about the statistics presented in the previous two paragraphs. All respondents were able to answer the questions pertaining to mobile ticketing for commuter rail and their feelings about mobile purchases, regardless of whether or not they currently use a smartphone. Sixteen respondents (1.7% of 903 total surveys) said they were “very likely” to use mobile ticketing, but answered the previous question by stating that they had “not used a smartphone in the past 30 days.” While this answer appears to be counterintuitive, six of these respondents had used a tablet (iPad, Kindle) in the past 30 days, and therefore, they may have assumed that mobile ticketing options would be available on these devices. Additionally, 2 of these 16 respondents answered the last question by saying “I do not currently make mobile purchases, but I am open to it.” One possible explanation is that these riders may be considering purchasing a smartphone/tablet in the future, which is a logical conclusion since the adoption rates of these devices are rapidly growing. Finally, the remaining 8 of 16 respondents may have answered the mobile ticketing question in error, but this is a relatively low error rate for a sample of more than 900 participants.

Forecasting Analysis

To estimate the probability that a respondent will choose to adopt mobile ticketing, the survey data were used in a discrete choice modeling framework. This model was then used with a sample enumeration forecasting technique to estimate the total percentage of commuter rail riders who are likely to adopt mobile ticketing.

Specification and Estimation of the Discrete Choice Model

The first step in this analysis was to specify a discrete choice model. The coefficients of the parameters in the model allow for interpretation of the extent to which socioeconomic characteristics of the respondent relate to choice of mobile ticketing versus existing fare media. This is different from discrete choice models commonly discussed in the transit fare policy literature that are based on ticket price (Hong 2006; Zureiqat 2008). Instead, this modeling framework rests on the assumption that mobile tickets are inherently different from the existing fare media (namely paper tickets). This framework was recently applied to the demand for open payment systems (Brakewood 2010; Brakewood and Kocur 2011).

A binary logit model (Ben-Akiva and Lerman 1985) was specified in which the choice set was those who stated they were “very likely” to use mobile ticketing versus everyone else, who were assumed to continue using existing fare media. This modeling framework was selected because those who responded “very likely”

will presumably be early adopters of mobile ticketing, and will therefore have the highest likelihood of participating in the MBTA pilot program.

The open source software package BIOGEME was used for estimation of this discrete choice model (Bierlaire 2010). The independent variables available for this analysis included socioeconomic and travel characteristics of the respondent, which were selected because they aligned with variables available for the forecasting exercise based on previous system-wide survey results (discussed in the following paragraphs). The data from both sampled lines were pooled for this analysis, and the sample size was reduced from 903 to 651 because many survey participants did not complete the demographic questions (namely income and ethnicity). After assessing multiple specifications using these independent variables, the binary logit specification shown in Table 3 was selected as having the most explanatory power while conforming to the constraints above.

Discussion of the Binary Logit Model

The following conclusions can be drawn from the results of the binary logit model. The negative alternative specific constant (-2.94) for mobile ticketing indicates that, all else being equal, the existing fare medium is the preferred alternative. Additionally, the relatively large magnitude of this constant compared to the other coefficients indicates that there is a high level of unexplained preference between the two alternatives.

The first independent variable, age, demonstrates that individuals below age 45 are more likely to adopt mobile ticketing, which is indicated by the positive coefficients of the other age variables. Examining the magnitude of the coefficients reveals that as age increases, the respondent is less likely to use mobile ticketing.

Conversely, the coefficients for household income show that as income increases, the likelihood of using mobile ticketing increases. This is shown by the positive coefficients for income, which has a reference group of the lowest household incomes.

For ethnicity, minority groups are somewhat less likely to use mobile ticketing than Caucasian riders, as demonstrated by their negative coefficients. It should be noted that “Hispanic” was asked separately from ethnicity, and the positive coefficient of the “Hispanic” variable indicates that they are more likely to adopt mobile ticketing than non-Hispanic riders.

Frequency of travel and gender were not statistically significant, as indicated by *t*-statistics of less than 1.5.

Last, the overall goodness of fit of the model is moderately low. An adjusted Rho-squared of 0.16 suggests that the independent variables have a somewhat limited relationship with fare medium intention.

Table 3. Binary Logit Results

Very Likely to Use Mobile Ticketing			
<i>Category</i>	<i>Independent Variable</i>	<i>Coefficient</i>	<i>T-statistic</i>
	Alternative Specific Constant	-2.94	-5.81
Age	Age 45 and older (reference)	-	-
	Age 35 to 44	0.39	1.42
	Age 25 to 34	1.25	5.07
	Age 24 and under	1.27	4.17
Annual Income	Less than \$39,999 (reference)	-	-
	\$40,000 to \$49,999	0.83	1.92
	\$50,000 to \$74,999	0.96	2.34
	\$75,000 or more	1.23	3.27
Ethnicity	Caucasian (reference)	-	-
	Asian	-0.03	-0.12
	African American	-1.17	-1.62
	Other	-1.16	-1.94
Hispanic	Not Hispanic (reference)	-	-
	Hispanic	0.75	1.46
Travel Frequency	1 day or less per week (reference)	-	-
	2 to 4 days per week	0.36	0.96
	5 days per week	0.21	0.61
	6 to 7 days per week	0.89	1.37
Sex	Female (reference)	-	-
	Male	0.17	0.9
Summary Statistics	Number of observations	651	
	Initial log likelihood	-451.24	
	Final log likelihood	-365.38	
	Likelihood ratio test	171.72	
	Rho-Squared	0.19	
	Adjusted Rho-Squared	0.16	

Forecasting

After estimating the discrete choice model, a forecasting analysis was conducted using sample enumeration to predict the adoption of mobile ticketing on the entire commuter rail network. The data used in the forecasting exercise are from the Central Transportation Planning Staff (CTPS) commuter rail survey conducted in 2008–2009. This system-wide survey asked questions pertaining to travel behavior and demographic information needed for the Boston area travel demand model; questions about technology adoption were not asked. Therefore, the forecasting analysis was constrained by the questions available from this system-wide survey.

CTPS provided the authors with the raw data from this system-wide survey for all commuter rail questions pertaining to gender, age, ethnicity, household income, and frequency of travel. The total sample size of the CTPS dataset was 12,960 respondents, but this was reduced to 10,407 because some respondents did not answer all of the demographic questions (namely household income). The CTPS dataset included a weight for each respondent to assure system-wide representativeness. Weights were not used in the sample enumeration calculation. Once the sample enumeration was performed, the probability that each rider would use mobile ticketing was then weighted by the original value provided by CTPS, and these weighted probabilities were aggregated to determine the total adoption rate on the commuter rail network. **The results of this analysis reveal that approximately 26 percent of commuter rail riders are very likely to adopt mobile ticketing.**

Modeling Constraints and Areas for Improvement

This analysis aimed to provide a simple methodology to forecast mobile ticketing adoption. Initially, an ordinal logit specification including all mobile ticketing preference levels was tested, but the goodness-of-fit was extremely low, implying that levels of preference other than “very likely” were not reliable indicators of intention. Therefore, the simple binary logit model was selected for presentation in this paper.

To improve this analysis, more sophisticated methodologies could be used. For example, the discrete choice model could include more complicated specifications, such as nesting the stated mobile ticketing intention question within the revealed preference of past mobile purchase behavior. Such a model might add insight into the behavior of riders considering adoption of mobile ticketing but, unfortunately, it would not permit forecasting given the datasets available for this specific analysis. Furthermore, other commuter rail operators who have only standard travel

survey information would not be able to easily adapt more sophisticated discrete choice models to forecast mobile payment adoption in their regions. In summary, the discrete choice methodology presented in this paper should be treated as a simple forecasting approach, and future research could aim to improve the model specification.

Additionally, this modeling approach relies completely on stated preference data about mobile ticketing. Because stated intention does not always align with actual behavior, this analysis could be improved in the future by combining the dataset with actual adoption information that could become available within the year.

Last, this forecasting method assumes that all fare types will be included in the mobile ticketing pilot program; similarly, it assumes that the corresponding fares will not be raised or lowered. At this time, the pilot program does not include monthly passes with free transfers, although it is anticipated that this will be added in the future. Additionally, the pilot program does not have plans for distribution of tickets purchased through corporate pass programs. Based on the survey results, approximately 30 percent of Worcester and 42 percent of Newburyport/Rockport riders purchase their tickets through pre-tax employer programs. Because of this constraint, the actual adoption of mobile ticketing in the commuter rail pilot program is likely to be lower than the forecasted results.

Conclusions

This research demonstrates significant potential for adoption of mobile ticketing on the commuter rail network in Boston. The onboard survey data revealed that there are high levels of technology use by riders, with approximately 76 percent of riders using smartphones and 50 percent making mobile purchases at other merchants. Mobile ticketing offers these riders a more convenient purchase method than prepayment at ticket windows or vending machines and is less problematic (for both the customer and operator) than onboard cash transactions. Furthermore, it is a low cost option for the MBTA and other rail operators to capitalize on existing infrastructure—the widespread adoption of smartphones among their riders—rather than installing gates or validation systems over extensive geographic areas.

To assess the potential adoption of mobile payments, stated preference data from an onboard survey on two MBTA commuter rail lines in the greater Boston area were analyzed. Binary logit was used to forecast adoption on the entire rail network, and the results showed that approximately 26 percent of all commuter

rail riders stated that they are likely to adopt mobile ticketing. Considering the dearth of research about the potential size of the market, this forecast should help the MBTA and other agencies make informed decisions regarding mobile ticketing. Moreover, the survey data provided important information concerning rider attitudes towards adoption of mobile ticketing, offering rail operators additional statistics. In light of this research and the widespread adoption of smartphones, mobile ticketing appears to be a compelling alternative to traditional ticketing methods, and its adoption by rail operators and utilization by riders are likely to increase in the near future.

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Engaging Transit Riders in Public Awareness Programs

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Abstract

In the aftermath of the September 11, 2001, terrorist attacks, the transit industry emerged as a leader in leveraging the value and power of the public's "eyes and ears" to promote system security. Although a public awareness program is widely viewed as a core component of a transit agency's system security plan, efforts to assess whether the messages are reaching transit riders and to identify obstacles to participation have been limited. This paper highlights strategies and tactics to engage transit riders in public security awareness programs based on interviews with transit agency representatives, the analysis of transit rider survey data, and transit rider focus groups.

Introduction and Background

The transit industry emerged as a leader in leveraging the value and power of the public's "eyes and ears" to promote system security in the aftermath of the September 11, 2001 terrorist attacks. In 2002, New York's Metropolitan Transportation Authority (MTA) launched the first transit security awareness and public engagement campaign under the tag line "If You See Something, Say Something™." This was followed by the U.S. Department of Transportation Federal Transit Administration's (FTA) release of the Transit Watch Program in 2003. Transit Watch was developed in partnership with the American Public Transportation Association (APTA), the Community Transportation Association of America (CTAA), the Amalgamated Transit Union (ATU), and the U.S. Department of Homeland Security.

ty's (DHS) Transportation Security Administration (TSA), and designed to provide transit agencies with technical assistance and tools to encourage transit employees and their riders to report suspicious packages and behavior. Ready-to-use templates allowed transit agencies to customize materials for their own systems while maintaining consistent messaging across the industry.

By 2005, more than 200 agencies had implemented some form of public awareness materials (Shaw 2011), and TSA had identified public awareness and preparedness campaigns as a priority area to provide the essential foundation for effective security programs. An updated version of Transit Watch was released in 2006. In 2010, the DHS licensed the use of MTA's "If You See Something, Say Something™" slogan for its anti-terrorism efforts in surface transportation and other key sectors.

The Transportation Systems Sector-Specific Plan contained in an Annex to the National Infrastructure Protection Plan (U.S. Department of Homeland Security 2010) outlines goals and objectives for continuously improving the risk posture of U.S. transportation systems. The implementation of security awareness campaigns specifically supports the following goal and corresponding objective outlined in the plan:

Goal 1: Prevent and deter acts of terrorism using, or against, the transportation system.

Objective: Increase vigilance of travelers and transportation workers. The travelling public and transportation workers can serve as force multipliers to Federal, State, and Local law enforcement.

Although a public awareness program is widely viewed as a core component of a transit agency's system security plan, there has been little formal evaluation of these efforts.

Edwards, Haas and Rohlich (2010) attempted to explore the effectiveness of transit security awareness campaigns in the San Francisco Bay area. However, they found that none of the agencies interviewed actively sought to measure the effectiveness of their security awareness efforts.

In theory, an evaluation of the effectiveness of surface transportation security initiatives, including public awareness campaigns, can provide meaningful information from which to determine whether strategies are achieving the intended results and to target any needed improvements (U.S. Government Accountability Office 2010). In practice, a one-to-one relationship between a security measure and a specific terrorist event is rare. The absence of a terrorist attack could mean either that

security was effective as a deterrent or that no attack was ever contemplated. In addition, determining whether it is the preventive security measures by themselves that have deterred a terrorist attack apart from the array of other actions and policy instruments, including the destruction of terrorist organizations, is virtually impossible (Jenkins 2011).

Although the impact of public awareness campaigns on preventing and deterring acts of terrorism against public transportation cannot be calibrated, agencies can evaluate whether their efforts have increased rider vigilance. This paper shares findings and recommendations from a collaborative research effort conducted by three National Transportation Security Center of Excellence (NTSCOE) institutions: the Mineta Transportation Institute (MTI) at San José State University; the Center for Transportation Safety, Security and Risk at Rutgers University; and Tougaloo College. The research explored whether security awareness messages are reaching transit riders and identified obstacles to participation.

Research Methodology

This article summarizes key findings from research conducted for the National Transportation Security Center of Excellence. Phase I, completed in August 2011, focused on the engagement of transit riders in awareness campaigns in collaboration with the Metropolitan Atlanta Rapid Transit Authority (MARTA). The findings indicated that existing security awareness campaigns were reaching transit riders; however, additional strategies could be implemented to enhance the impact of campaign materials, remove obstacles to reporting, and build positive relationships between an agency and all its customers (Haider et al. 2011).

Phase II, completed in June 2012, and was conducted in conjunction with the Greater National Capital Region (NCR) Transit Security Working Group's 2011 transit security awareness campaign. The Maryland Transit Administration (MTA) served as the project manager. The design and structure of the campaign was consistent with many of the recommendations developed by the research team as a result of the Phase I findings. The Phase II research identified opportunities to enhance the effectiveness of public security awareness campaigns and documented best practices and lessons learned from the NCR 2011 transit security awareness campaign (Haider et al. 2012).

The research plan incorporated a mix of study methods including the following:

- Interviews were conducted with marketing and security/police personnel from each agency participating in the campaign to establish a context for the research.
- An analysis of MTA's 2010 and 2011 annual Customer Ridership Study (CRS) was conducted to identify potential shifts in rider perceptions that could be attributed to the campaign.
- Transit rider focus groups were conducted in Baltimore County and Montgomery County, Maryland and Washington, DC.

The CRS collects data from approximately 2,200 to 2,500 transit riders each year regarding their travel habits, needs, perceptions, and levels of satisfaction with MTA services overall (Maryland Marketing Source 2012). Both the 2010 and the 2011 CRS asked general questions about personal safety; specific questions regarding security awareness campaigns were added to the 2011 study at the recommendation of the research team.

Transit rider focus groups conducted in Atlanta as part of Phase I provided valuable insights into the opinions, perceptions, and behavior of frequent transit riders relevant to improving the effectiveness of public awareness campaigns. To expand upon this knowledge and provide a basis of comparison, additional groups of NCR transit customers were conducted. A total of 88 people who were generally representative of the riding public in the area based on ridership and demographic factors participated in the groups. The following topics were explored:

- Riding behaviors
- Situational awareness
- Awareness of communications
- Perceptions of transit security
- Willingness to engage in public awareness campaigns
- Reactions to NCR campaign materials

NCR 2011 Public Security Awareness Campaign

The 2011 NCR campaign ran from July through December 2011; however, printed materials such as bus cards remained posted until they were damaged or replaced by other advertising. The components were designed to build upon the success-

ful “If You See Something, Say Something™” tag line through innovative concepts, message continuity, sustainable instructional information, and improved public participation. The campaign components were organized in two levels, allowing regional partners the flexibility to select tools that enhanced their existing transit security efforts and that could be effectively implemented at their agencies (Integrated Designs, Inc. 2012). In addition, all materials were available in English and Spanish.

Level One included:

- Access to a main campaign website (www.securetransit.org)
- Radio advertising on 20 stations
- Cinema advertising including on-screen messages and a lobby stand-up display with information cards in six theaters
- Collateral and Information Materials
 - 4" x 9" Informational card
 - Wallet card
 - Currency jackets
 - Coffee sleeves
- On-site transit events at major train stations
- Transit station decals

The campaign website provided information on what to look for, who to tell, and how an individual can help; links to transportation security resources, such as TSA press releases; and a DHS “If You See Something, Say Something™” television spot.

Level Two offered participating agencies a “menu” of artwork that could be installed locally. The menu included:

- Print advertisements
- Interior car cards
- Exterior bus signage (transit kings/queens and transit tails)
- Platform posters
- Window decals

- Bus wraps
- Kiosk posters

The agencies actively involved in the campaign included:

- Washington, DC
 - Washington Metropolitan Area Transit Authority (WMATA, also known as Metro)
 - Maryland
 - Maryland Transit Administration (MTA)
 - Montgomery County Ride On (Ride On)
- Virginia
 - Virginia Railway Express (VRE)
 - Fairfax Connector
 - The Potomac and Rappahannock Transportation Commission (PRTC)
 - Arlington Transit (ART)

These agencies range in size from WMATA, the nation's fourth largest system, to ART, the nation's 272nd largest system based on unlinked passenger trips. Table 1 shows the relative size of the agencies involved in the campaign based on average weekday unlinked passenger trips and total unlinked passenger trips (American Public Transit Association 2011).

Experience with public awareness programs, the resources available to invest in these efforts, and the level of involvement in the NCR campaign varied based on agency size and operating area. A key advantage of the regional initiative was that the smaller agencies could benefit from Level 1 mass marketing activities that, under other circumstances, would be too costly. For example, all riders were able to access the campaign website, www.securetransit.org, to get more information and the radio advertising covered all jurisdictions in the region. In addition, although most of the events were held at Metrorail stations, those selected had high volumes of customers transferring from one of the smaller agency's services to Metrorail.

Table 1. Overview of NCR Agencies

State	Agency	2009 Average Weekday Unlinked Passenger Trips	2009 Total Unlinked Passenger Trips	National Rank Based on 2009 Total Unlinked Passenger Trips	Transit Modes
DC	WMATA (Metro)	1,460,135	435,858,900	4	Bus, heavy rail, paratransit
MD	MTA	417,773	123,697,400	10	Bus, light rail, heavy rail, commuter rail, paratransit
MD	Ride On	97,043	29,739,300	47	Bus
VA	Fairfax Connector	33,139	9,576,600	101	Bus
VA	VRE	15,681	3,868,000	160	Commuter rail
VA	PRTC	12,200	3,179,200	185	Bus
VA	ART	5,296	1,537,100	272	Bus

Findings and Recommendations

Campaign materials reflected the diverse transit ridership in both Atlanta and the NCR. In-system advertising, including posters, car cards, and announcements, were the primary components of the public awareness campaigns. The MTA CRS revealed that more than 70 percent of transit riders attributed their increased awareness of how to respond if they see something suspicious to posters and signs they had seen while riding transit and other information provided at MTA locations (Greenberg et al. 2012). Feedback from the focus groups indicated that transit riders' daily experiences dealing with the transit system, individual employees, and other riders had the most significant impact on their likelihood to report suspicious activity. For the most part, these experiences varied by ridership patterns such as mode, frequency, and time of day rather than race, age, gender, etc.

Addressing Barriers to Reporting

Public awareness efforts are a form of social marketing focused on motivating transit riders to voluntarily modify their behavior to help prevent terrorism and other criminal acts. The goal is to prepare riders to act when they see something suspicious. In addition to overcoming inertia, the research revealed the reasons why people cannot or do not make reports. They include:

- Lack of trust in the transit agency and its employees
- A reluctance to report something that could be nothing
- Anticipated inconvenience
- Communication challenges

The tendency to plan and implement public awareness activities in isolation from other agency issues and operations limits their potential to effect real change. If riders believe an agency and its employees are concerned for their welfare and trying to meet their needs, they are more likely to respond to requests for support and cooperation. During the focus groups, several participants echoed this perspective by questioning why they should help the transit agency by reporting suspicious activity when many transit employees, including police, station agents, and bus drivers, did not treat them with respect. Some had even attempted to report situations and felt rebuffed by employees. The CRS data also revealed that riders' willingness to report suspicious activities increased with their overall satisfaction with MTA (Greenberg et al. 2012).

Indeed, the U.S. Department of Justice's (DOJ) "Guidance for Building Communities of Trust" (Wasserman 2010) cites lack of trust as one of the greatest obstacles faced by American policing and has a direct impact on the ability to address issues of crime, disorder, and the prevention of terrorism. The document provides advice and recommendations on how to initiate and sustain trusting relationships, particularly with immigrant and minority communities that support meaningful sharing of information, responsiveness to community concerns and priorities, and the reporting of suspicious activities and behavior that may legitimately reflect criminal enterprise or terrorism precursor activities. The basic construct is that active engagement results from positive relationships and that the level of engagement will not improve until inherent problems in the relationship are addressed.

For those who might be willing to respond to an agency's request to report suspicious activity in theory, what happens in practice can be influenced by several other factors. For many, doubt will serve to paralyze their actions by fueling their ability to rationalize away the suspicious activity they may be witnessing with a variety of plausible explanations. The doubt can come from many sources such as the level of perceived terrorist threat or lack of confidence in knowing what activity is, indeed, legitimately suspicious. However, whatever its origin, it leads to a reluctance to report something that "could be nothing." A London Metropolitan Police

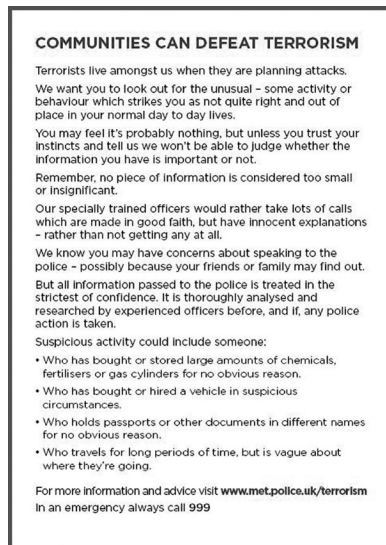
security awareness campaign launched in February 2012 attempts to address this obstacle. The campaign includes radio advertisements, posters, and flyers with the tag line “It’s probably nothing but ...” and encourages the public to give specially trained police officers the opportunity to be the judge. Figures 1 and 2 illustrate the front and back of a campaign flyer (London Metropolitan Police 2012).

Figure 1.
Front of London
campaign flyer



The flyer is a vertical rectangular poster with a black background and white text. At the top right, it features the URL 'met.police.uk/terrorism' and a small logo for 'TERRORISM HOTLINE'. The main headline is 'IT'S PROBABLY NOTHING, BUT...' in large, bold, white capital letters. Below this, smaller white text reads: 'IF YOU SEE OR HEAR SOMETHING THAT COULD BE TERRORIST RELATED, TRUST YOUR INSTINCTS AND CALL THE CONFIDENTIAL ANTI-TERRORIST HOTLINE. OUR SPECIALLY TRAINED OFFICERS WILL TAKE IT FROM THERE.' The phone number '0800 789 321' is prominently displayed in a large, bold font, with the tagline 'YOUR CALL COULD SAVE LIVES' underneath. At the bottom, there are four logos: 'METROPOLITAN POLICE TOTAL POLICERS', 'CITY OF LONDON POLICE WWW.LONDONPOLICE.COM', 'METROPOLITAN POLICE', and a small signpost icon.

Figure 2.
Back of London
campaign flyer



The back of the flyer has a white background with black text. The title 'COMMUNITIES CAN DEFEAT TERRORISM' is centered at the top. The text below explains that terrorists live amongst us and encourages the public to look out for unusual behavior. It states that the police will take information in good faith, even if it seems insignificant. A list of suspicious activities is provided, including buying large amounts of chemicals, hiring vehicles in suspicious circumstances, holding multiple passports, and long-term travel without clear destinations. The flyer concludes with the website 'www.met.police.uk/terrorism' and the emergency number '999'.

COMMUNITIES CAN DEFEAT TERRORISM

Terrorists live amongst us when they are planning attacks. We want you to look out for the unusual – some activity or behaviour which strikes you as not quite right and out of place in your normal day to day lives.

You may feel it's probably nothing, but unless you trust your instincts and tell us we won't be able to judge whether the information you have is important or not.

Remember, no piece of information is considered too small or insignificant.

Our specially trained officers would rather take lots of calls which are made in good faith, but have innocent explanations – rather than not getting any at all.

We know you may have concerns about speaking to the police – possibly because your friends or family may find out. But all information passed to the police is treated in the strictest of confidence. It is thoroughly analysed and researched by experienced officers before, and if, any police action is taken.

Suspicious activity could include someone:

- Who has bought or stored large amounts of chemicals, fertilisers or gas cylinders for no obvious reason.
- Who has bought or hired a vehicle in suspicious circumstances.
- Who holds passports or other documents in different names for no obvious reason.
- Who travels for long periods of time, but is vague about where they're going.

For more information and advice visit www.met.police.uk/terrorism
In an emergency always call 999

Service delays or being required to “stick around” to answer questions, were also cited by focus group participants as negative consequences from reporting something. Metrorail riders—who have endured station closures and service delays because of “suspicious packages” that turned out to be discarded or forgotten items—were particularly sensitive to this concern. In addition, one well-meaning participant who had reported something to a station agent was detained until police arrived and interviewed him. By the end of the ordeal, the person felt he was being treated like a suspicious person rather than appreciated for taking the time to make the report.

Finally, even if the aforementioned obstacles could be overcome, the challenges associated with actually making the report come into play. To consummate a report, a person needs to know how to safely reach someone who can receive the report. The majority of focus group participants in both Atlanta and the NCR expressed a preference for telling an easily-accessible police officer or transit employee if they saw something suspicious. Many lamented that, often, especially in the heavy rail environment, police and other employees are not present on the trains or station platforms. The perception was that police tended to be clustered at station entrances. Several participants were familiar with emergency call buttons to reach the train operator and/or emergency phones in the stations, but many were not, and some questioned the reliability of these communications mechanisms.

Calling in a report also presented challenges. Most focus group participants were not aware of the number they should call and indicated that they would most likely rely on 911. In both Atlanta and the NCR, riders were instructed to call a 10-digit number. The majority of participants felt these numbers were too cumbersome to remember, even if they included a mnemonic like the Virginia Terrorism Hotline, 877-4VA-TIPS. Spotty cell phone coverage along the rail right-of-way, particularly underground and in tunnels, and the fear of suffering retaliation, if overheard, were also major concerns. The value of being able to text in a report was organically raised in every focus group. Offered as a solution to many of the issues discussed, it was viewed as a safe and convenient way to make a report. Subsequent to the completion of the research, several transit agencies outside the study areas implemented this option.

Improving Public Awareness Campaigns

Armed with an understanding of the market and the factors that influence an individual’s willingness to engage, public awareness program planners can move forward with designing campaign messages, selecting communication tools,

identifying performance measures, and ensuring that internal groups that will be impacted by campaign activities or responsible for receiving customer reports are prepared to support the initiative. These can be daunting tasks, but planners have the advantage of being able to learn from prior and existing transit industry efforts.

Campaign Messages

Public awareness campaigns should communicate the following in ways that will resonate with transit riders:

- *What to look for* – The research clearly indicates the importance of educating transit riders on what could be considered suspicious.
- *What to do when they see it* – Straightforward and simple directions (i.e., call or text a certain number, inform a transit employee, etc.) regarding what to do when a suspicious activity or package is spotted are critical.
- *What's in it for them* – There was resonance among riders with the message that “we’re all in this together.” It is important to stress the idea that reporting a suspicious activity or package is for self-preservation, as well as the safety of others.
- *Not to hesitate* – Similar to the concepts conveyed in the London campaign, public awareness campaigns need to be responsive to the natural hesitation of riders to “second guess” their instincts as to whether a certain situation is, indeed, suspicious.

A review of public awareness campaign pieces from around the country reveals a tendency to either omit one or more of the above in the quest for brevity or to include too much detail in order to cover all the bases.

It is important to use both text and graphics to communicate the message and strategically match the design of campaign components to the environments in which they will be placed. For example, materials placed in areas where transit riders will be rushing through should contain as little text as possible since they will not have the time or inclination to stop and read them. Conversely, materials posted in vehicles or places where people are waiting for vehicles can include more text since many people may actually pass the time by reading them.

The creative components of a campaign should reflect the character, idiosyncrasies, and realities of the markets in which they will be placed. Many commonalities were revealed among focus groups participants in Atlanta and the NCR, but

reactions to sample campaign materials varied. However, some basic constructs became evident that will start the design effort off in the right direction:

- Promote single, simple, doable behaviors one at a time.
- Remind and motivate transit riders to be vigilant; do not scare them.
- Reflect the diversity of transit riders.
- Depict situations and scenarios that are realistic and relevant to area transit riders.
- Provide visual examples of what to look for.
- Use color or other graphic design techniques to catch the viewer's eye.
- Limit the amount of text by communicating the message in a clear and concise manner.
- Do not overly complicate the instructions for making a report; use a single, easy-to-remember telephone number and feature it prominently in the copy.
- Encourage riders to program the telephone number for making reports into their cell phones.
- Select a limited number of themes/approaches and create different versions of it to maintain interest and reinforce the message.
- Link messages through the use of the same logo, slogan, tagline, and/or other device.

Although it can be tricky, the use of humor seemed to garner the attention of many focus group participants and was memorable. Featuring "success stories" that highlight the value of reporting to the riding public also appeared appealing. It was viewed as a way to reinforce the notion that one person can make a difference and overcome the stigma of being a "snitch."

Pre-testing different ideas or creative executions is an important step that should not be ignored. The feedback obtained will help the development team choose the most effective approaches, and more importantly, raise red flags regarding an option that could offend some people.

Communication Tools

A wide variety of communication tools is available to transmit public security awareness messages. Tables 2 and 3 summarize the research team's findings rela-

tive to the communication tools available to transit agencies and the benefits and challenges associated with each. The selection of communication tools should be based on ridership demographics, organizational realities, and resource constraints. A best practice in the NCR campaign was to offer regional agencies a menu of options, allowing them to choose the communication tools that “fit” with their operations and contractual agreements regarding system advertising.

Table 2. Internal Communication Tools

Tools	Benefits	Challenges
Agency website	Increasingly the #1 source used by the public to find information about public transportation. Low or no incremental cost. Information can be updated quickly and easily.	Content should be updated frequently to maintain interest.
Existing printed materials (newsletters, rider guides, schedules, transit passes, fare cards)	Riders refer to these documents frequently and may carry them throughout their trip. Lower incremental cost.	Competition among a variety of public information requirements for limited space on materials. May be produced in mass quantities, which will limit ability to update easily.
Brochures, flyers, seat-drops	Ability to provide more detailed information. Can be retained for future reference.	Many customers will discard without reading.
Interior vehicle advertising	Riders more likely to read while confined to vehicle. Riders can refer to advertisement if they observe suspicious behavior while onboard. Cost-effective in reaching target market.	Must be engaging to break-through advertising “clutter.” Depending on agency’s contractual arrangements, advertising space may be controlled by third party and limited and/or costly.
Exterior vehicle advertising	High visibility.	Depending on an agency’s contractual arrangements, advertising space may be controlled by third party and limited and/or costly. More likely to be viewed by non-riders.
On-board announcements	Low cost. Most likely to be remembered by riders if repeated frequently. Very cost effective for reaching transit riders.	Message content should be short and varied to maintain interest. Repetition may be irritating to some customers.

Table 2. Internal Communication Tools (cont'd.)

Tools	Benefits	Challenges
In-station advertising	Cost effective in reaching target market.	Depending on agency's contractual arrangements, advertising space may be controlled by third party and limited and/or costly. Must be engaging to break through advertising "clutter." Message content should be limited as most riders will view while quickly passing through station.
Station announcements	Most likely to be remembered by riders if repeated frequently. Very cost effective for reaching transit riders.	Competition with other required announcements. Message content should be short be varied to maintain interest. Repetition may be irritating to some customers.
Platform/bus stop advertising	Message content can be more detailed since riders will be waiting for train/bus to arrive. Riders can refer to advertisement if they observe something suspicious. Cost-effective in reaching target market.	Must be engaging to break through advertising "clutter." Depending on an agency's contractual arrangements, advertising space may be controlled by third party and limited and/or costly.
Variable message sign postings	High visibility. Very cost-effective in reaching target market.	Limited message capability. Competition among a variety of public information requirements for limited space on signs.
Station events	Personal exchange of messages is impactful. Event staff can distribute handouts (i.e., brochures and/or promotional materials). Ability to foster dialogue with customers and answer questions.	Some riders will be resistant to engaging with event staff because they are focused on getting where they need to be. Can be expensive to execute depending on staffing requirements and costs.
Promotional items	Particularly appealing to some market segments. Items can be selected that will reinforce an overall security message (i.e., flashlights, whistles) or will be carried on person while riding public transit.	Limited imprint space. Expensive. Some may view as a waste of taxpayer dollars.

Table 3. External Communication Tools

Tools	Benefits	Challenges
Press releases	Ability to provide more detailed information. Can generate free media coverage. Effective method for publicizing special events or “success stories.”	Media coverage not guaranteed. Limited control over ultimate content published.
Social media (e.g. Facebook, Twitter)	Popular communications forum, especially for certain market segments. Information can be updated quickly and easily.	Must be monitored and have staff assigned to stimulate ongoing dialogue and respond to rider posts in a timely manner
Outreach efforts (e.g., community meetings, special events)	Personal exchange of messages is impactful. Staff can distribute handouts (i.e. brochures and/or promotional materials). Ability to foster relationships with key market segments.	Time/labor intensive. The audience may include a high percentage of non-riders
Print advertisements	Ability to provide more detailed information. Allows riders to “digest” materials at their own pace.	Expensive. Audience will include a high percentage of non-riders. Must be engaging to break through advertising “clutter.”
Radio advertisements/public service announcements (PSA’s)	Non-traditional approach that may reach people who tune out messages while riding transit. If memorable, may stimulate word-of-mouth promotion of message. PSAs could be cost-effective if free or reduced rate media available.	Paid advertising is expensive. Audience will include a high percentage of non-riders. Must be engaging to break through advertising “clutter.”
Television advertisements/public service announcements	Message can be communicated verbally and non-verbally. Non-traditional approach that may reach people who tune out messages while riding transit. Depending on media buy, can result in high visibility of the message. If memorable, may stimulate word-of-mouth promotion of message. PSAs could be cost effective if free or reduced rate media available.	High production costs. Paid advertising is very expensive. Audience will include a high percentage of non-riders. Must be engaging to break through advertising “clutter.”

Table 3. External Communication Tools (cont'd.)

Tools	Benefits	Challenges
Non-traditional target marketing (i.e., theatre advertising, coffee sleeves, cash jackets)	Non-traditional approaches may reach people who tune out messages while riding transit. Provides alternatives for short reinforcement type messages such as tag line/phone number printed on a coffee sleeve. Conversely, options such as theatre advertising allow for a more targeted approach to exposing an audience to television-type advertisements. Can target efforts based on rider demographics and/or relatively small geographic areas so it can be more effective in reaching riders than other external tools.	Requires research and planning to maximize effectiveness. Can be relatively expensive.
Venue marketing (i.e., stadium advertising)	Non-traditional approach that may reach people who tune out messages while riding transit. Can target efforts based on rider demographics to increase effectiveness in reaching riders. Can be effective in reaching occasional riders that use public transit to get to/from special events like football games, etc. Potential partnership opportunities with venue management.	Must be engaging to break through advertising “clutter.” Can be relatively expensive. Selection of venues needs to be based on ridership patterns to maximize effectiveness.

The primary audience for public security awareness programs should be regular transit riders since they are more likely to spot something out-of-the-ordinary. Therefore, internal communications tools ought to comprise the majority of the effort. Communicating with riders when they are about to choose between alternative, often competing, behaviors (i.e., being alert or tuning out, reporting something or ignoring it) is key. These “just-in-time” messages can include both primary campaign executions and simple reminders.

External tools can complement internal efforts and reach riders when they are not expecting it. However, they must be well researched and budgeted to ensure that the “media buy” is sufficient enough to be impactful on the target audience(s). The research revealed that although radio can be a viable method for targeting specific demographics, it may not effectively reach transit riders. Many riders reported that they listen primarily to the radio while driving; however, they are not in their cars for long periods of time since they use public transit.

Finally, although outside the scope of this research effort, a recently released Transit Cooperative Research Program (TCRP) report, “Uses of Social Media in Public Transportation,” suggests that a potentially powerful tool for enhancing the effectiveness of public awareness campaigns, especially among minorities, could be social media. It cites Pew Center research in reporting that minority Americans are more likely than white Americans to believe that government use of electronic communications helps keep citizens informed. Nearly one-third of African Americans and Hispanics said it was “very important” for government agencies to post information and alerts on social networks compared to only 17 percent of white Americans (Bregman 2012). Indeed, a large percentage of focus group participants were technology savvy and indicated that they relied on their smart phones and computers to access information about public transit. Many transit agencies are experimenting with social media and weighing the benefits of various applications versus the resource requirements associated with ongoing maintenance and monitoring. The report did not include any public awareness campaign examples. However, social media’s ability to connect with transit riders and measure their responses using built-in statistics or numerous free and fee-based third-party applications makes it an option worth exploring.

Conclusion

Despite the widespread implementation of public awareness programs in the transit industry, there are little data assessing the effectiveness of these efforts. Evaluation can be a difficult and complex task, but performance measures are essential to the prudent allocation and management of available resources. Investments in identifying a baseline level of awareness and facilitating the systematic tracking of customer responses to campaign elements will yield significant returns in terms of more informed decision-making. By understanding the current level of awareness and the relative effectiveness of campaign messages and communication tools, program managers can set reasonable expectations and determine what they need to do to meet them.

It is important to understand that a public awareness campaign involves much more than developing posters and brochures. Two critical factors that influence transit riders’ willingness to report are the ease at which they can make a report and their perceptions of how they will be treated by agency employees. The need for safe and reliable reporting mechanisms such as easy access to transit personnel, easy-to-dial telephone numbers, and electronic forms of communication (i.e., via text message) was repeatedly mentioned in the focus groups. In addition, partici-

pants recounted situations where they had tried to report a security concern only to receive a negative reaction from a transit employee. An implementation plan that stresses the important role employees play in the success of the initiative is needed. Specific strategies will vary by agency, but communication and training are essential components. Employees that interact with the public should be informed about what the public is being told, when, and how, as well as how to appropriately respond to customers reports with interest and respect.

Finally, ongoing research into the role of social media in promoting transit security awareness and the impact of recently implemented mobile applications that address major barriers to reporting should be pursued.

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Evaluating Public Transportation Local Funding Options

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Abstract

This report describes and evaluates 18 potential local funding options suitable for financing public transportation projects and services. They are evaluated according to eight criteria, including potential revenue, predictability and sustainability, horizontal and vertical equity, travel impacts, strategic development objectives, public acceptance and ease of implementation. This is a somewhat larger set of options and more detailed and systematic evaluation than most previous studies. This study discovered no new options that are particularly cost-effective and easy to implement; each has disadvantages and constraints. As a result, its overall conclusion is that a variety of funding options should be used to help finance the local share of public transit improvements to ensure stability and distribute costs broadly.

Introduction

High-quality public transit can provide various economic, social, and environmental benefits, including direct user benefits and various indirect and external benefits. Residents of communities with high-quality transit tend to own fewer motor vehicles, drive less, and spend less on transport than they would in more automobile-oriented locations. Governments and businesses can save roadway and parking facility costs. It can support economic development. Appropriate public transit investments can provide positive economic returns: under favorable conditions transit investments provide savings and benefits that more than offset costs (Litman 2010). As a result, public transit service improvements are an important component of many jurisdictions' strategic transport plans (Buehler and Pucher 2010).

Although federal and state/provincial funds often help finance transit improvements, additional local funding is generally needed. Several previous studies identify and evaluate potential public transit funding sources, but most consider only a relatively limited set of options and evaluation criteria. This report evaluates 18 potential local funding options according to 8 criteria, including potential revenue, predictability and sustainability, horizontal and vertical equity, travel impacts, strategic development objectives, public acceptance and ease of implementation. This is a somewhat larger set of options and evaluation criteria than considered in most previous studies. Much of this analysis can be applied to any type of transportation improvement, not just public transit.

Literature Review

This section summarizes several recent studies of potential transportation and public transit funding options.

“Primer on Transit Funding: FY 2004 through FY 2012” (APTA 2012) describes existing U.S. public transit funding, including federal and state grant programs and various regional and local funding sources, including general fund, gas tax motor vehicle, rental car sales tax, vehicle registration fees, bond proceeds, general sales tax, and interest income.

“Local and Regional Funding Mechanisms for Public Transportation” and its online “Regional Funding Database” (TCRP 2009) provides an extensive list of local and regional funding sources that are or could be used to support public transit, plus guidance on factors to consider when evaluating and implementing these options. Table 1 summarizes the funding options identified. It evaluates them based on revenue yield (adequacy and stability), cost efficiency, equity across demographic and income groups, degree to which beneficiaries pay, political and popular acceptability, and technical feasibility.

The “Guide to Transportation Funding Options” (UTCM 2010) by the Texas Transportation Institute’s University Transportation Center for Mobility provides information on various transit funding options.

Table 1. U.S. Local and Regional Public Transport Funding Options

Traditional Tax- and Fee-Based Transit Funding Sources	Common Business, Activity, and Related Funding Sources	Revenue Streams from Projects (Transportation and Others)	New “User” or “Market-Based” Funding Sources
<ul style="list-style-type: none"> • General revenues • Sales taxes • Property taxes • Contract or purchase-of-service revenues (school/universities, private organizations, etc.) • Lease revenues • Vehicle fees (title, registration, tags, inspection) • Advertising revenues • Concessions revenues 	<ul style="list-style-type: none"> • Employer/payroll taxes • Vehicle rental and lease fees • Parking fees • Realty transfer tax • Corporate franchise taxes • Room/occupancy taxes • Business license fees • Utility fees/taxes • Income taxes • Donations • Other business taxes 	<ul style="list-style-type: none"> • Transit-oriented development (TOD)/ joint development • Value capture/ beneficiary charges • Special assessment districts • Community improvement districts/ community facilities districts • Impact fees • Tax-increment financing districts • Right-of-way leasing 	<ul style="list-style-type: none"> • Tolling (fixed, variable, dynamic; bridge/roadway) • Congestion pricing • Emissions fees • VMT fees

Source: TCRP 2009

“Finding Solutions to Fund Transit: Combining Accountability and New Resources for World-Class Public Transportation” (IPIRG 2007) identifies and evaluates various public transit funding options and evaluated them according to seven principles: market efficiency, low collection costs, reliability, diversity, “fare increases are self-defeating,” budget accountability and community participation. It evaluated general sales taxes, dedicated gasoline taxes, car rental taxes, registration fees, tire taxes, weight-based vehicle registration fees, vehicle battery taxes, weigh-mile truck fees, road tolls, development impact fees, stormwater fees, real estate transfer taxes and parking taxes.

“Financing Sustainable Urban Transport” (Sakamoto Belka and Metschies 2010) provides information on available options for financing urban transport improvements, particularly in developing countries. It identifies various funding options and evaluates them based on administrative levels, potential revenues, efficiency, equity, environmental objectives, stability, political acceptability and administrative ease. It provides numerous examples and case studies from around the world.

“The Move Ahead: Funding ‘The Big Move’” (TBoT 2010) describes and evaluates potential options for funding The Big Move, a 25-year, \$50 billion regional transport infrastructure program. Each option is evaluated based on technical feasibility

ity, projected revenue, predictability, sustainability and durability of the revenue, administrative cost and complexity, impact on travel behavior, and social equity and fairness.

“Financing Transit Systems through Value Capture: An Annotated Bibliography” (Smith and Gihring 2003) summarizes numerous studies concerning the impacts transit service has on nearby property values, and the feasibility of capturing a portion of the incremental value to finance transit improvements.

Evaluation Criteria

This section describes the eight criteria used to evaluate funding options.

Potential Revenue

This refers to the amount of money that an option can be expected to generate, based on various assumption about how it is implemented. Some funding options have natural constraints; for example, there are limits to the amount of money transit agencies can generate through advertising and station rents, but, in most cases, maximum potential revenues reflect assumptions about how an option is implemented and what is politically acceptable.

Predictability and Stability

Funding predictability and stability are desirable for planning and budgeting purposes. Some funding options fluctuate from year to year, while others are more predictable and stable. These evaluations are based on a general understanding of funding options, which may be modified in a particular situation.

Equity Analysis

One of the most common issues raised in public consultations is a desire that transport funding be equitable—that is, the distribution of costs and benefits should be considered fair and appropriate. Transport equity can be defined and measured in various ways that may lead to different conclusions concerning what is equitable (Litman 2002). There are two major categories:

- Horizontal equity refers to the distribution of impacts between people with similar wealth, needs and abilities. It assumes that similar people should generally be treated equally and implies that people should “get what they pay for and pay for what they get” unless subsidies are specifically justified.
- Vertical equity refers to the distribution of impacts between people who differ in wealth, ability, or need. It generally assumes that costs should be smaller

and benefits greater for people who are physically, economically or socially disadvantaged. Policies that do this are called progressive, and those that impose higher costs on disadvantaged people are called regressive.

Equity analysis can consider various types of impacts and group people in various ways. For example, road pricing is generally considered regressive, since a given toll represents a larger portion of income to lower-income than to higher-income motorists. However, lower-income people tend to own fewer cars and drive less than wealthier people, particularly on major urban highways that are candidates for tolling. Lower-income people tend to rely more on alternative modes and can benefit directly if congestion pricing reduces delay for rideshare vehicles and buses. As a result, road pricing may be less regressive than other roadway funding options (such as general taxes) and may be progressive overall if it leads to improvements to alternative modes, such as increased investment in cycling facilities and transit services.

Horizontal equity requires that program costs be borne by beneficiaries. Public transit service improvements can provide various benefits to users (internal benefits) and society (external benefits). Some benefits result from the service improvements themselves; others result only if the improves reduce automobile travel or stimulate more compact development (Banister and Thurstain-Goodwin 2011; CTOD 2011; Litman 2011). These include benefits to:

- Transit users, from improved convenience and comfort, financial savings, increased safety, and improved public fitness and health
- Motorists, from reduced traffic and parking congestion, improved mobility for non-drivers (which reduces chauffeuring burdens), improved traffic safety, and emission reductions
- Taxpayers, from road and parking facility cost savings, improved safety, and increased public health
- Businesses, from congestion reductions, parking cost savings, improved employee safety and fitness, and, in various ways, high-quality public transport tends to support regional economic development
- Residents (regardless of how they travel), including parking cost savings, improved mobility for non-drivers, increased safety, reduced pollution, and improved public fitness.

Travel Impacts

This refers to the effects an option has on how and how much people travel and the degree that this supports or contradicts strategic transport planning objectives, such as reducing automobile travel and increased use of alternative modes. These are estimated based on our understanding of price impacts on travel activity (Litman 2004, 2013).

Strategic Development Objectives

This refers to the effects an option has on the type and location of development in a community and whether this supports or contradicts strategic planning objectives, such as objectives to encourage more compact, accessible development and discourage sprawl. These are estimated based on our understanding of tax and price impacts on development patterns.

Public Acceptability

Public preference and the acceptability of specific funding options can be determined through surveys and public consultations. Such preferences can vary depending on the group surveyed, how questions are phrased, and how funding options are structured and implemented. For example, the public acceptability of a fuel tax increase may depend on existing fuel tax levels, when they were last raised, and how revenues are used.

These impacts can vary significantly, depending on specific conditions and assumptions. Equity impacts are particularly subjective, depending on how equity is defined and impacts measured. As a result, analysis assumptions should be clearly described and, if possible, the public consulted to ensure that all perspectives are represented. For example, it may be useful to use public surveys and focus groups to explore the perceived fairness and acceptability of various potential funding options in a community (Earthvoice Strategies 2012; Quay Communications Inc. 2012).

Ease of Implementation

This refers to a revenue option's transition (initial implementation) and transaction (ongoing collection) costs. These are estimated based on assumptions about how it will be implemented and what is required to do this.

Analysis

This section describes and evaluates 18 potential public transit funding options.

Fare Increases

In most urban transit systems, current adult fares average \$2–\$3 per trip or \$50–\$80 for a monthly pass, with discounted (concession) fares for youths, older adults, and people with disabilities. It is possible to increase all fares, selected categories, or change price structures, for example, to include higher fares for longer-distance trips or for special services such as light rail or express commuter buses.

- **Potential Revenue** – The price elasticity of transit ridership with respect to fares is usually -0.2 to -0.5 in the short run (first year), and increases to -0.6 to -0.9 over the long run (5–10 years) (Litman 2004; McCollom and Pratt 2004; Wardman and Shires 2011). This suggests that a 10 percent fare increase typically increases revenue 5–8 percent over the short run and 1–4 percent over the long-run. As a result, rising fare increases revenue, but less than proportionately (raising fares 10% provides less than 10% increased revenue), and revenue gains tend to decline over time. These impacts tend to vary depending on the types of riders and types of services. Transit-dependent users and peak-period travelers tend to be less price-sensitive than discretionary travelers (people who could travel by automobile) and off-peak travel.
- **Predictability and Stability** – As previously described, the additional revenues from fare increases can be difficult to predict with precision and tend to decline over time.
- **Horizontal Equity** – Since transit services are subsidized, fare increases can be considered horizontally equitable (users pay for the services they receive). However, automobile travel imposes significant external costs, particularly under urban-peak travel conditions, including road and parking subsidies, traffic congestion, accident risks, and pollution damages imposed on others (Litman 2009). Under urban-peak travel conditions, transit subsidies are often smaller than the subsidies that would be required to accommodate additional automobile travel on the same corridor. Described differently, to the degree that shifting travel from automobile to public transport is considered a sacrifice that benefits other people, fare increases can be considered horizontally inequitable because they double-charge transit users.
- **Vertical Equity** – Since public transit provides basic mobility and many users are lower-income, fare increases tend to be regressive and vertically inequitable.

This regressivity varies depending on specific factors, such as transit user incomes and price structures.

- Travel Impacts – Fare increases tend to reduce public transit travel and shift travel to automobile. They, therefore, tend to contradict planning objectives to reduce automobile travel.
- Strategic Development Objectives – Transit fare increases may reduce the relative attractiveness of transit-oriented locations, such as downtowns and transit station areas.
- Public Acceptance – Although there is general support for the user pay principle, surveys and focus groups indicate opposition to large fare increases, to keep public transit affordable to lower-income users and encourage transit use.
- Ease of Implementation – Fare increases are easy to implement.
- Legal Status – Most public transit agencies or local governments have the legal ability to increase fares.
- Examples – Most transit agencies regularly increase fares.

Discounted Bulk Transit Passes

Public transit agencies can sell transit passes to a group, such as all students at a college or university (called a “U-Pass program”), all employees at a worksite, or all residents of a neighborhood. They are often designed to be revenue neutral; the additional transit service costs are at least offset by the additional revenues. For example, if standard monthly passes are priced at \$80 and used for 40 average monthly trips, the transit agency can sell \$40 discounted passes to a group of students that average 20 monthly trips or \$20 to a group of residents that average 10 monthly trips.

- Potential Revenue – Potential revenues depend on the scope of these programs, which could add hundreds, thousands, or tens of thousands of new users. However, this also tends to increase transit service costs.
- Predictability and Stability – Contracts for such services tend to be for one or more years, so transit agencies can generally plan for the additional revenue and ridership on an annual basis.

- Horizontal Equity – Such passes tend to create cross-subsidies from those participants who seldom or never ride transit to those who ride more than average, although they may benefit from reduced congestion and accident risk.
- Vertical Equity – Since physically- and economically-disadvantaged people tend to ride transit more than average and benefit most from financial savings, and since such programs tend to increase total transit service (for example, allowing increased frequency), this strategy tends to support vertical equity objectives.
- Travel Impacts – This tends to increase transit ridership and reduced automobile travel, although impacts will vary depending on specific circumstances.
- Strategic Development Objectives – This can increase the attractiveness of transit-oriented locations.
- Public Acceptance – There is often high public acceptance of such programs, since they make transit more affordable and encourage transit ridership. U-Pass programs often receive high levels of student support, but neighborhood programs tend to receive less.
- Ease of Implementation – Once a price structure is established implementation is relatively easy.
- Legal Status – Most transit agencies have the legal ability to negotiate discounted fares for particular groups.
- Examples – Many colleges and universities have U-Pass programs that provide transit passes to all students and sometimes staff at a campus (Brown, Hess and Shoup 2003). Boulder, Colorado, offers such a pass to residential neighborhoods, called the Neighborhood Eco Pass (Boulder 2013).

Property Taxes

Most municipal governments collect property taxes. In many jurisdictions a portion of property taxes are dedicated to public transit.

- Potential Revenue – It is possible to increase property taxes by virtually any amount, but large tax increases are politically difficult and there are many demands on these tax revenues.
- Predictability and Stability – Property taxes are relatively stable.

- **Horizontal Equity** – To the degree that public transit improvements increase nearby property values or provide other savings and benefits to nearby residents and businesses (congestion reductions, parking cost savings, household savings, emission reductions, etc.), property tax funding can be considered horizontally equitable.
- **Vertical Equity** – Property ownership tends to increase with income, and lower-income residents tend to qualify for various property tax discounts and exemptions, so this tax tends to be relatively progressive with respect to income. However, even poor people bear a portion of these taxes through rents, and property taxes are burdensome to some lower-income home owners.
- **Travel Impacts** – Property taxes have few direct travel impacts.
- **Strategic Development Objectives** – Large property tax differences may cause development to shift between jurisdictions, but transit taxes are relatively small and usually applied region-wide so impacts are likely to be minimal.
- **Public Acceptance** – Although property taxes are widely used to finance public transit and tend to be considered a default funding source (the source used if other options are not feasible), there may be resistance to significant increases in this tax.
- **Ease of Implementation** – Since transit property taxes are already collected in most jurisdictions they would be relatively easy to increase.
- **Legal Status** – In some jurisdictions, state/provincial legislation or voter approval is required to raise property tax rates.
- **Examples (TCRP 2009; UTCM 2010)** – Many transit agencies rely on property taxes.

Regional Sales Taxes

Many jurisdictions (particularly in the U.S.) rely significantly on sales taxes to finance public transit. Variations include special taxes on particular transactions such as hotel room and vehicle rentals.

- **Potential Revenue** – A regional general sales tax could generate virtually any amount of revenue. Revenues from taxes on sales of particular products tend to be modest.

- **Predictability and Stability** – Moderately stable. Sales taxes tend to fluctuate more than property taxes.
- **Horizontal Equity** – To the degree that public transit benefits consumers, sales taxes can be considered horizontally equitable, although the relationship is indirect (people and businesses that benefit most do not necessarily pay more sales taxes).
- **Vertical Equity** – Sales taxes are regressive and, therefore, tend to be vertically inequitable.
- **Travel Impacts** – Sales taxes do not directly affect travel activity.
- **Strategic Development Objectives** – Large sales tax differences may cause development to shift between jurisdictions, but transit taxes are relatively small and usually applied region-wide so impacts are likely to be minimal.
- **Public Acceptance** – Mixed. Although there tends to be opposition to most tax increases, sales taxes are among the most often applied to fund transportation programs, including public transit improvements, indicating a moderate degree of public acceptance.
- **Ease of Implementation** – In jurisdictions that already apply sales taxes, there is minimal cost to increasing such taxes to fund public transit. Where no sales taxes are currently applied, implementation costs would be moderate.
- **Legal Status** – In many jurisdictions, state/provincial legislation or voter approval is required to raise sales tax rates.
- **Examples** – Sales taxes are the most common dedicated source of transit funding in the U.S. (IPIRG 2007). According to the Federal Transit Administration’s National Transit Database, after federal funds, sales taxes comprised the largest source of revenues for capital spending (38%) and the second largest source of operating expenses (27%) after fares (32%). In 2008, more than two-thirds of Los Angeles County voters approved Measure R, a referendum that established a special 0.5 percent sales tax dedicated to rapid transit and some road infrastructure (METRO 2011).

Fuel Taxes

Special fuel tax can be collected in a jurisdiction to fund public transit. In some cases a portion of existing fuel tax revenue is dedicated to public transit programs without increasing fuel tax rates.

- Potential Revenue – Assuming residents average 500 gallons of annual fuel consumption, each cent per gallon of taxes generates \$5. Although fuel price increases reduce demand (a 10% price increase typically reduces fuel consumption 2–4% in the medium-run), a few cents per gallon to fund transit generally have minimal impact (Litman 2013; Wardman and Shires 2011).
- Predictability and Stability – Fuel tax revenue is moderately stable. It tends to fluctuate more than property taxes.
- Horizontal Equity – To the degree that motorists benefit from public transit improvements due to reduced traffic and parking congestion and reduced need to chauffeur non-drivers, and to the degree that automobile travel imposes external costs on non-drivers, fuel taxes can be considered to increase horizontal equity.
- Vertical Equity – Fuel taxes are regressive, but this regressivity is reduced if public transit improvements provide a more convenient and affordable alternative to driving. Described differently, of all possible fuel tax uses, transit improvements are relatively progressive if they improve affordable mobility options.
- Travel Impacts – Fuel tax increases tend to reduce automobile travel and encourage use of alternative modes, although typical transit funding taxes are small and so would have minimal impact. Travel impacts depend on whether the transit tax is in addition to, or a portion of, existing fuel taxes.
- Strategic Development Objectives – Fuel tax increases tend to encourage more compact, multimodal land development, although the effects of this are likely to be minimal.
- Public Acceptance – In general, fuel tax increases tend to be unpopular. However, surveys and focus groups indicate moderate support to fuel tax increases that are dedicated to transportation improvements.
- Ease of Implementation – Implementation is relatively easy and in jurisdictions where fuel taxes are already collected.
- Legal Status – Fuel tax increases often require state or provincial approval.
- Examples – At least 12 U.S. states have local option transit gasoline taxes (TCRP 2009). Such taxes are also common in Canada (TBoT 2010).

Vehicle Levy

A vehicle levy is an additional fee for registering vehicles in the region.

- Potential Revenue – Although vehicle levies can be any size, most are \$20–\$60 annually per vehicle, only a portion of which is dedicated to public transit, so their total transit revenue is small to moderate. High levies can motivate some motorists to register their vehicles in other jurisdictions.
- Predictability and Stability – Stable.
- Horizontal Equity – As previously discussed, to the degree that motorists benefit from public transit improvements due to reduced traffic and parking congestion and reduced need to chauffeur non-drivers, and to the degree that automobile travel imposes external costs on non-drivers, a vehicle levy can be considered to increase horizontal equity. However, since vehicle fees do not reflect use (fees are the same for vehicles driven high and low annual mileage), this fee poorly reflects the external costs imposed by a particular vehicle.
- Vertical Equity – This fee tends to be regressive, particularly because lower-income motorists tend to drive their vehicles lower annual mileage and so pay more per kilometer than higher income motorists on average.
- Travel Impacts – Higher vehicle fees may marginally reduce vehicle ownership and use, but impacts are likely to be small.
- Strategic Development Objectives – No significant impacts.
- Public Acceptance – According to survey and focus group responses, vehicle levies have less public acceptance than other transportation-related revenue options.
- Ease of Implementation – Where vehicle registration fees are already collected an additional levy to fund transportation or public transit programs is easy to apply. Implementation costs are much higher if a special fee collection system must be established.
- Legal Status – In most jurisdictions, this would require state/provincial legislation and support.
- Examples – In the United States, 33 states and 27 local jurisdictions have vehicle registration fees that help finance transportation improvements, which often includes public transport (IPIRG 2007). Vehicle registration fees help finance public transport in many Canadian jurisdictions (TBoT 2010).

Utility Levy

This is a special transit levy applied to all utility accounts in the region.

- Potential Revenue – Small. Although such a levy could be any size, they are usually \$10–\$40 annual per meter, or \$5–\$20 per capita.
- Predictability and Stability – Stable.
- Horizontal Equity – Similar to a property tax, a utility levy charges residents.
- Vertical Equity – A utility levy is likely to be relatively regressive, since it is a flat fee per household.
- Travel Impacts – No significant impacts.
- Strategic Development Objectives – No significant impacts.
- Public Acceptance – According to survey and focus group responses, utility levies have low public acceptance. It had the greatest level of opposition of all options presented.
- Ease of Implementation – Relatively easy to implement.
- Legal Status – Would generally require state/provincial legislation.
- Examples (TCRP 2009) – Some jurisdictions have local government utility taxes. TransLink receives a hydro levy of \$1.90 per month from each electric utility account within its service region, which generates approximately \$18 million annually (TBoT 2010).

Employee Levy

This is a levy paid by employers (often only larger employers) located in a transit service area.

- Potential Revenue – Small to moderate potential revenues, depending on the number of employees covered and the level of the levy.
- Predictability and Stability – Stable.
- Horizontal Equity – Can be considered fair to the degree that commuters create traffic congestion and create demand for public transit.
- Vertical Equity – The ultimate incidence of this fee is difficult to predict. It may substitute for wages, reduce total employment, or shift employment location if a large levy is applied just in the urban core.

- Travel Impacts – Travel impacts are likely to be small.
- Strategic Development Objectives – If applied only in an urban core, it may discourage downtown employment and encourage sprawl.
- Public Acceptance – Uncertain.
- Ease of Implementation – Would probably involve moderate implementation costs, similar to other business taxes and fees.
- Legal Status – May require state/provincial legislation.
- Examples (TBoT 2010; TCRP 2009) – In France, the Versement Transport (Transport Levy) taxes employers with more than nine staff to help finance local public transport services. A special 0.6 percent payroll tax is collected from most employers in the Portland and Eugene, Oregon, regions to help finance public transport services.

Road Tolls

Tolls are user fees for driving on a particular road or bridge or in a particular area. A variation is High Occupancy Tolls (HOT) lanes, which are free for use by high occupant vehicles (buses and carpools) but require a fee for use by single-occupant vehicles. Congestion pricing refers to tolls that are higher during peak periods to reduce traffic congestion.

- Potential Revenue – Although revenues are theoretically large if widely applied, most proposals only toll a minor portion of roads and vehicle travel, resulting in modest total revenues. For example, if 20 percent of commuters pay \$1.00 per trip (\$2.00 for a round-trip commute), revenues would average about \$50 per capita.
- Predictability and Stability – Once established, revenues would probably be moderately stable, but may decline over the long run as travelers take tolls into account when making longer-term decisions (such as where to live).
- Horizontal Equity – Tolls are generally considered vertically equitable, because they charge users directly for the congestion and roadway costs they impose, but they are often criticized as unfair if they only apply to a few roadways.
- Vertical Equity – Tolls are often criticized as regressive, since a given toll represents a higher portion of income for poorer than wealthier motorists, but overall regressivity depends on the incomes of actual road users, the quality

of travel options on that corridor and how revenues are used. Tolls are often progressive compared with other funding options, such as using general taxes to finance roads and public transit services.

- Travel Impacts – Road tolls tend to reduce affected automobile travel and traffic congestion, particularly if implemented with public transit improvements.
- Strategic Development Objectives – Mixed. If applied only in central areas, tolls may encourage more dispersed development, but if applied broadly and implemented with improvements to other modes, they may encourage compact development.
- Public Acceptance – There is often public opposition to tolls, particularly on existing roadways, although surveys indicate some acceptance if revenues are used to support popular road and public transport improvements.
- Ease of Implementation – Although there are many possible ways to implement road tolls, including new technologies that reduce costs; implementation is likely to be expensive, particularly if implemented by a single region.
- Legal Status – Road tolling usually requires state/provincial legislation.
- Examples (TBoT 2010; TCRP 2009) – London, Singapore, and Stockholm apply congestion tolls for driving on urban roads during peak periods. New York City uses bridge toll revenue to finance both highways and public transit services

Vehicle-Km Tax

This is a form of road pricing that charges motorists per kilometer traveled. It could vary by vehicle type, such as higher fees for higher polluting vehicles.

- Potential Revenue – Potentially large.
- Predictability and Stability – Moderate. Similar to fuel taxes.
- Horizontal Equity – Similar to fuel taxes. To the degree that motorists benefit from public transit improvements, and to the degree that automobile travel imposes external costs on non-drivers, vehicle-kilometer fees can be considered to increase horizontal equity.
- Vertical Equity – Likely to be regressive. However, to the degree that public transit improvements reduce the need to drive, this regressivity is reduced.

- Travel Impacts – Vehicle-kilometer fees tend to reduce automobile travel and encourage use of alternative modes, including public transit.
- Strategic Development Objectives – Vehicle-kilometer fees tend to encourage more compact, multi-modal land development.
- Public Acceptance – In general, vehicle-kilometer fees tend to be unpopular.
- Ease of Implementation – Would have high implementation costs since it would require a special system to measure annual vehicle travel in a region.
- Legal Status – Would generally require federal state or provincial legislation and support.
- Examples (Huang, et al, 2010; TBoT 2010) – Vehicle-kilometer fees have been proposed in many jurisdictions, but so far have only been implemented for freight trucks. For example, in Germany freight trucks are charged a fee of €0.09 to €0.14 per kilometer based on their emissions levels and number of axles

Parking Sales Taxes

This is a special tax on parking transactions (when motorists pay directly for parking).

- Potential Revenue – Small to moderate. Only a minor portion (probably 5–10%) of parking activity is priced. It could encourage more businesses to provide free parking to employees and customers.
- Predictability and Stability – Moderate to low stability.
- Horizontal Equity – As with other vehicle use fees, it can be considered horizontally equitable to the degree that transit improvements benefit motorists and to the degree that motor vehicle travel imposes external costs.
- Vertical Equity – Since this fee applies only when parking is priced, it is probably less regressive than other vehicle fees.
- Travel Impacts – By marginally increasing parking fees it may slightly reduce vehicle trips, but by increasing the value to users of parking subsidies and reducing commercial parking profitability, it may reduce the total portion of parking that is priced (Litman 2013; Wardman and Shire 2011).
- Strategic Development Objectives – Because this fee primarily applies in downtowns and other major commercial centers, it may discourage compact development.

- **Public Acceptance** – There is often public opposition to parking fees. Survey and focus group responses indicate moderate support for this option.
- **Ease of Implementation** – Implementation costs are likely to be small to moderate. It may require new accounting requirements for commercial parking operators.
- **Legal Status** – Requires provincial or state legislation and support.
- **Examples (Litman 2012; TBoT 2010)** – Many U.S. jurisdictions levy a parking surcharge. Chicago assesses a flat parking surcharge rather than a percentage charge on daily, weekly, and monthly parking, with charges ranging from \$0.75–\$2 for daily parking, \$3.75–\$10 for weekly and \$15–\$40 for monthly parking.

Parking Levy

This is a special property tax on non-residential parking spaces throughout the region.

- **Potential Revenue** – Potential revenue is large. Assuming that there are one to two qualifying parking spaces per capita, a \$50 per space annual tax could generate \$100 annually per capita.
- **Predictability and Stability** – Relatively stable, although revenues could decline slightly over time if property owners are allowed to reduce their parking supply.
- **Horizontal Equity** – Like a fuel tax, this can be considered fair to the degree that motorists benefit from public transit improvements or to the degree that parking facilities or automobile travel impose currently uncompensated external costs.
- **Vertical Equity** – The ultimate incidence of this tax is difficult to predict and will vary depending on specific conditions. It will mainly be borne by commercial property owners (residential parking is exempt), and so may marginally increase retail prices, increase parking pricing, and reduce wages. Costs may be reduced if property owners are allowed to reduce their parking supply. To the degree that public transit improvements reduce the need to drive, any regressivity is further reduced.
- **Travel Impacts** – This tax may reduce parking supply and encourage property owners to price parking, which can reduce vehicle travel (Litman 2013;

Wardman and Shire 2011). Travel impacts, therefore, depend on its magnitude, how it is applied, and the flexibility of local parking requirements.

- Strategic Development Objectives – This tax encourages reduced parking supply and therefore more compact development.
- Public Acceptance – Surveys and focus groups indicate relatively high support for parking taxes. Vancouver region experience indicates possible opposition from suburban businesses.
- Ease of Implementation – This tax would have relatively high implementation costs, since it requires adding a new field to property records, but once established, ongoing costs are likely to be modest.
- Legal Status – May require state or provincial legislation.
- Examples (IPIRG 2007; Litman 2012) – Melbourne, Perth, and Sydney all impose levies on city center non-residential parking spaces to encourage use of alternative modes and fund transport facilities and services. Small businesses are exempted. TransLink implemented a parking levy in 2006, but this was subsequently rejected by the provincial government.

Expanded Parking Pricing

This involves the expansion of where and when public parking is priced, such as metering currently unpriced on-street parking spaces in urban neighborhoods and charging for off-street parking at public facilities such as for government employees and at schools and parks. This is best implemented as part of a comprehensive parking management program that also includes better pricing systems, user information and enforcement practices.

Potential Revenue – Small to moderate. In most urban areas there are many unpriced publically-owned parking facilities that could be priced, although motorists will avoid using priced parking if possible. Currently only 1–2% of non-residential parking activity is priced, which probably averages \$20–40 annual per capita. If this can be tripled to 3–6% it would generate an additional \$40–\$80 annual per capita.

- Predictability and Stability – Relatively stable.
- Horizontal Equity – Like a fuel tax, this can be considered fair, since these valuable spaces are currently provided free to motorists, and to the degree

that automobile travel imposes currently uncompensated external costs, and to the degree that motorists benefit from public transit improvements.

- Vertical Equity – Mixed. Lower-income households tend to own fewer vehicles and drive less than higher-income households, so overall impacts will vary depending on specific conditions, including lower-income vehicle ownership rates and the quality and price of transport and parking options.
- Travel Impacts – Parking pricing encourages people to reduce their vehicle ownership and use.
- Strategic Development Objectives – Mixed. If implemented as part of an integrated parking management program, efficient parking pricing can reduce the total number of parking spaces needed in an area and total vehicle travel, supporting more compact development. However, if parking is priced in a few major commercial areas it may favor suburban commercial areas, encouraging sprawl.
- Public Acceptance – Mixed. Motorists and businesses often oppose parking pricing, although the concept of user paid parking is gaining support as a way to reduce parking problems and generate local revenues.
- Ease of Implementation – Parking pricing tends to have relatively high implementation costs to install and operate pricing systems, plus additional transaction costs to motorists.
- Legal Status – Many jurisdictions already price public parking.
- Examples (Litman 2012; TCRP 2009) – Many communities price a portion of on-street and publically-owned off-street parking spaces.

Development Cost Charges or Transportation Impact Fees

These are fees on new development to help fund infrastructure costs (MRSC 2010). Transportation or traffic impact fee are sometimes dedicated to roadway improvements, so policy changes may be required to allow them to be spent on public transit improvements.

- Potential Revenue – Small to moderate. Since it applies only to new development, it depends on the amount of development occurring in the region.
- Predictability and Stability – Is highly variable depending on how it is applied and the amount of qualifying development that occurs.

- Horizontal Equity – To the degree that new development increases demand for public transit or that developers benefit from high-quality transit service, it can be considered equitable.
- Vertical Equity – Uncertain. Although wealthier people tend to purchase more new housing, this fee will increase the costs of all new development and so will tend to increase rents and reduce housing affordability.
- Travel Impacts – If the charges discourage more compact, infill development, they may increase sprawled development and therefore automobile travel.
- Strategic Development Objectives – If the charges discourage more compact, infill development, they may increase sprawled development.
- Public Acceptance – Surveys and focus groups indicate relatively high support for development fees.
- Ease of Implementation – Implementation costs are minimal since development fees are already collected in most jurisdictions.
- Legal Status – Most municipalities governments and many region governments have a legal ability to collect such fees, although the use of such funds is often restricted to specific infrastructure, which may exclude public transit facilities and services.
- Examples (IPIRG 2007; TCRP 2009) – Many jurisdictions collect development or traffic/transportation impact fees.

Land Value Capture

This is a special property tax imposed in areas with high-quality public transit, intended to recover a portion of the increased land values provided by transit and to help finance the service improvements. It is sometimes called a transit benefit district tax (TRILLIUM Business Strategies 2009).

- Potential Revenue – Moderate to large over the long-run.
- Predictability and Stability – Difficult to predict, but stable once development occurs.
- Horizontal Equity – Considered horizontally equitable to the degree that

high quality public transit provides an extra increase in land values and development revenues.

- Vertical Equity – Impacts depend on how the tax is structured and development conditions. It tends to capture value from developers and property owners, but some of the tax may be passed on to residents, and it can reduce housing affordability in transit-oriented developments (TODs), which is regressive.
- Travel Impacts – Depends on details. If such a tax discourages development around transit stations it could reduce transit ridership and TOD.
- Strategic Development Objectives – Mixed. May discourage some TOD, but it could encourage more concentrated development near transit stations.
- Public Acceptance – Surveys and focus groups indicate relatively high support for land value capture.
- Ease of Implementation – May require special analysis and legislation to determine the most appropriate tax structure.
- Legal Status – In some jurisdictions, state or provincial legislation and support would be required.
- Examples (TBoT 2010) – Land value capture in the form of transit benefit districts is used in some U.S. cities including Miami, Los Angeles, and Denver.

Station Rents

This involves collecting revenues from public-private developments on publically-owned land in or near transit stations.

- Potential Revenue – Probably small. It depends on the transit agency's ability to obtain and develop land around transit stations and the demand for such building space.
- Predictability and Stability – Revenues are difficult to predict, but, once established, may be relatively stable.
- Horizontal Equity – Considered horizontally equitable to the degree that it captures the value of proximity to high quality public transit.
- Vertical Equity – Impacts depend on development conditions. It can be an opportunity for a community to raise additional revenue from businesses and higher income residents, but if rents are structured to maximize revenue

it may reduce housing affordability in accessible locations (i.e., lower-priced housing in TODs), which is regressive.

- Travel Impacts – Uncertain. If this increases TOD, it may help reduce total vehicle travel.
- Strategic Development Objectives – Uncertain. It may increase or discourage TOD, depending on how development and rents are structured.
- Public Acceptance – Surveys and focus group responses indicate relatively high support for station rents.
- Ease of Implementation – Some station development may be relatively easy, but maximizing this revenue option may involve some effort and risks.
- Legal Status – Most transit agencies have the legal ability to develop stations, but may require state or provincial approval to condemn land for station development.
- Examples – Larger transit agencies with significant space in terminal and station facilities may enter into concession agreements (an income-generating strategy similar to leasing) with a variety of commercial and retail enterprises (TCRP 2009). For example, TransLink has established a Real Estate Division that is responsible for acquiring, managing and disposing of its properties in a manner that optimizes revenue, reduces capital costs, and supports strategic development goals such as station-area development (TransLink 2011).

Station Air Rights

This involves selling the rights to build over transit stations (Tompkins 2010).

- Potential Revenue – Depends on demand for such development. There are generally few sites where such development is feasible, so total potential revenues are probably modest.
- Predictability and Stability – Uncertain. Depends on demand for such development.
- Horizontal Equity – Considered horizontally equitable to the degree that it captures the value of proximity to high quality public transit.
- Vertical Equity – Impacts depend on specific conditions. It can raise revenue from businesses and higher income residents, but if structured to maximize

revenue it may reduce housing affordability in accessible locations (i.e., lower-priced housing in transit-oriented developments) which is regressive.

- Travel Impacts – Uncertain. If this increases TOD, it may help reduce total vehicle travel.
- Strategic Development Objectives – Uncertain. It may increase or discourage TOD, depending on how development and rents are structured.
- Public Acceptance – Surveys and focus groups indicate relatively high support for revenue-generating station area development.
- Ease of Implementation – Some station air rights development may be relatively easy, but maximizing this revenue option may involve some effort and risks.
- Legal Status – Most transit agencies probably have the legal right sell or rent station-area air rights.
- Examples (Tompkins 2010) – The Toronto Transit Commission has investigated options for selling air rights at the York Mills subway station, the Eglinton/Yonge bus terminal, the Sheppard/Yonge station bus terminal, and land adjoining the Spadina station (Hall 2002).

Advertising

Most transit agencies collect revenues from transit vehicle, stop, and station advertising.

- Potential Revenue – Although expanding transit service and increasing transit ridership should allow more advertising, even doubling or tripling of revenue would provide relatively small additional revenue.
- Predictability and Stability – Relatively unstable.
- Horizontal Equity – No clear impact.
- Vertical Equity – No clear impact.
- Travel Impacts – No clear impact.
- Strategic Development Objectives – No clear impact.
- Public Acceptance – Surveys and focus groups indicate relatively high support for advertising. However, there may be public opposition to particular advertising methods or materials.

- Ease of Implementation – Since most transit agencies already sell advertising, expansion is relatively easy.
- Legal Status – Already widely used.
- Examples (TCRP 2009) – Most public transit agencies generate revenue from advertising.

Options Summary

Table 3 summarizes the 18 funding options evaluated in this review.

Table 3. Potential Public Transport Funding Options

Name	Description	Advantages	Disadvantages
Fare increases	Increase fares or change fare structure to increase revenues	Widely applied; is a user fee (considered equitable).	Discourage transit use. Is regressive.
Discounted bulk passes	Discount passes sold to groups based on their ridership	Increases revenue and transit ridership	Increases transit service costs and so may provide little net revenue
Property taxes	Increase local property taxes	Widely applied; distributes burden widely	Supports no other objectives; considered regressive.
Sales taxes	Special local sales tax	Distributes burden widely	Supports no other objectives; regressive
Fuel taxes	Additional fuel tax in region	Widely applied; reduces vehicle traffic and fuel use	Considered regressive
Vehicle fees	Additional fee for vehicles registered in region	Applied in some jurisdictions; charges motorists for costs	Does not affect vehicle use
Utility levy	Levy to all utility accounts in region	Easy to apply; distributes burden widely	Small, regressive, and supports no other objectives
Employee levy	Levy on each employee within a designated area or jurisdiction	Charges for commuters	Requires collection system; may encourage sprawl if only in city centers

Table 3. Potential Public Transport Funding Options (cont'd.)

Name	Description	Advantages	Disadvantages
Road tolls	Tolls on some roads or bridges	Reduces traffic congestion	Costly to implement; can encourage sprawl if only applied in city centers
Vehicle-Km tax	Distance-based fee on vehicles registered in region	Reduces vehicle traffic	Costly to implement
Parking taxes	Special tax on commercial parking transactions	Applied in many cities.	Discourages parking pricing and downtown development
Parking levy	Special property tax on parking spaces throughout region	Large potential; distributes burden widely, encourages compact development	Costly to implement; opposed by suburban property owners
Expanded parking pricing	Increase when and where public parking facilities (such as on-street parking spaces) are priced	Moderate to large potential; distributes burden widely, reduces driving.	Costly to implement; May discourage downtown business activity.
Development or transport impact fees	Fee on new development to help finance infrastructure, including transit improvements	Charges beneficiaries	Limited potential
Land value capture	Special taxes on property that benefit from the transit service	Large potential; charges beneficiaries.	May be costly to implement; may discourage TOD
Station rents	Collect revenues from public-private development at stations	Charges beneficiaries	Limited potential
Station air rights	Sell rights to build over transit stations	Charges beneficiaries	Limited potential
Advertising	Additional advertising on vehicles and stations	Already used	Limited potential; sometimes unattractive

Conclusions

Public transit service improvements are an important component of many regions' transportation system improvement plans. High-quality public transit services can provide various economic, social, and environmental benefits, including direct user benefits and various indirect and external benefits.

Implementing transit improvements often requires additional funding. Although federal, state, or provincial funding may be available, new local funding is generally needed. Based on a detailed review of existing literature, this study identified 18 funding options, including some that are widely used and others considered innovative and used only in a few jurisdictions.

These potential funding options were evaluated against eight criteria. Evaluation results can vary depending on perspective and assumptions. Equity analysis is particularly subjective depending on how equity is defined and impacts measured. From some perspectives, it is most equitable to generate transit funding from a narrowly-defined group of beneficiaries, such as users of a new transit service, employers who generate commute trips, or owners of transit station area properties. However, high-quality public transit tends to provide multiple, dispersed benefits, including external benefits to people who do not currently use the service but benefit from reduced traffic and parking congestion, improved safety, reduced need to chauffeur non-drivers, energy conservation and emission reductions, and increased regional economic development. Public transit improvements tend to provide a broader scope of benefits than highway expansion, so a wider range of funding options can be justified for the sake of horizontal equity (i.e., beneficiaries pay).

Widely-used public transit funding sources include fares, property taxes, sales taxes, fuel taxes, advertising, and station rents. There is potential for increasing revenues from these options, although fare increases contradict other planning objectives. Fuel tax increases and expanded parking pricing (more frequently charging motorists for using public parking facilities, particularly on-street parking in urban neighborhoods) are particularly appropriate because they also encourage fuel conservation and more efficient transport, in addition to raising revenues. However, these taxes and fees are considered burdensome and regressive (their actual regressivity depends on the quality of transport options available, and so is reduced by public transit service improvements) and so should be implemented gradually.

The options that seem most acceptable to the public (development and transportation impact fees, station rents, advertising) tend to generate modest revenue.

Economists are particularly enthusiastic about congestion pricing, but it tends to be costly and politically difficult to implement, and total revenues are often modest since tolls are only collected on a small portion of total vehicle travel.

Three new revenue options with significant potential deserve more consideration: parking levies (special property taxes on non-residential parking spaces throughout the region), vehicle levies (an additional fee on vehicles registered in the region) and employee levies (a levy on each employee, often only collected from larger employers). These could generate relatively large amounts of revenue, distribute costs broadly, and have a logical connection to transit improvements (high-quality transit benefits motorists, businesses, and employees). A parking levy applied to all non-residential parking spaces in a region would disperse the financial burden and support strategic planning objectives by encouraging more compact development and more efficient parking pricing. These three options have moderate implementation costs, more than increasing existing transit funding options, but less than road tolls or vehicle-kilometer fees.

Where feasible, development and transportation impact fees, station rents, and air rights can be used to generate funds, but their revenues will vary depending on future demand for transit-area development, and so are difficult to predict and are likely to be modest in most cases.

Land value capture taxes and levies should also be considered. They should be structured to avoid discouraging TOD (they should not be too high or geographically concentrated), and it may be best to defer their implementation for a few years until station-area demand rises sufficiently. It is particularly appropriate to create local area benefit districts around transit stations where modest special levies and parking pricing revenues are used primarily to finance local improvements such as station amenities, streetscaping and special cleaning, and security services, rather than financing system-wide transit services.

This research discovered no new funding options that are particularly cost-effective and easy-to-implement. Each option has disadvantages and constraints. As a result, this study's overall conclusion is that a variety of funding options should be used to help finance the local share of public transit improvements to ensure stability (so total revenues are less vulnerable to fluctuations in a single economic sector or legal instrument) and distribute costs broadly. Public transit improvements often provide widely dispersed benefits that can justify widely dispersed funding sources. Even people who do not currently use public transit benefit from reduced conges-

tion, increased public safety and health, improved mobility option for non-drivers, regional economic development, and improved environmental quality.

Additional research is recommended to better understand the impacts of these options. Revenue options that are implemented should be structured to maximize benefits and minimize problems. Taxes and levies should be designed to support other regional planning objectives, including increased transit ridership, reduced automobile traffic, economic development, energy conservation, compact development, and greenspace preservation and affordability.

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Ballot Box Planning: Rail Referenda Implementation

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Abstract

Metropolitan areas in the United States frequently finance new rail lines with local option taxes, and, as a result, rail plans and associated taxes often come before voters as ballot measures. Existing research finds that rail ballot measures are more likely to pass when taxes are linked to specific projects and planning has broad stakeholder involvement. Such studies, however, have not examined to what extent agencies implement voter-approved projects. This research fills this gap and finds the interrelated variables of ballot measure provisions, campaign supporters and strategies, and planned rail projects contribute to varied progress toward implementation in Denver, Houston, and Miami. In addition, a fourth variable, transit agency capacity, is critical for implementation and for securing federal support. Because electoral strategies may contribute to or mitigate implementation challenges, rail and regional advocates should weigh the long-term consequences of ambitious rail plans and consider transit agency capacity.

Introduction

Local option taxes are becoming a more common tool for transportation investment (Goldman and Wachs 2003), sometimes providing funds for rail expansion. Taxes or even just rail plans may require voter approval. Research on transportation ballot measures has focused on factors associated with ballot measure passage and voter

support (Beal, Bishop, and Marley 1996; Hannay and Wachs 2006; Peterson, Kinsey, Bartling and Baybeck 2008; Werbel and Haas 2002) or how to “win” votes. Strategies to pass transportation measures include designing them in collaboration with powerful stakeholders (Werbel and Haas 2002) and connecting new taxes to specific projects (Beal, Bishop, and Marley 1996). But, successful passage of a ballot measure is only one step in the process to actually build a rail system. Existing studies have not examined the importance of and variance in rail implementation, after the passage of ballot measures. To understand resulting transportation infrastructure, we need to understand more than what makes ballot measures more or less likely to pass. When and how does “winning” at the ballot box lead to construction of associated rail systems?

Using a comparative case study approach, this research explores to what extent voter-approved rail plans have been implemented in Denver, Houston, and Miami. None of the plans is fully implemented, but progress toward implementation varies significantly, from 48 miles under construction in Denver to 2.4 miles completed in Miami. To explain this variation, the research describes the importance of ballot measure provisions, campaign support and strategies, rail plans, and agency capacity. In these cases, plans designed to be winnable ballot measures are not fully feasible plans, although the feasibility varies, and decisions made to win votes appear to have important repercussions for implementation. Given the limited implementation of voter-approved plans, rail advocates should consider the potential political fall-out of partial implementation before advancing ambitious plans at the polls. At the same time, as the discussion of the Denver case will demonstrate, building support for a ballot measure can cement advocacy coalitions.

Transportation Votes and Rail Implementation

Infrastructure investment often relies on local options taxes. Goldman and Wachs (2003, 20, emphasis added) explain: “Local option taxes have become the levers by which communities ensure that *favored* but *expensive* projects are built.” Levying such taxes may require voter approval. Studies of transportation tax ballot measures identify a range of factors that correlate with or contribute to passage; two are most relevant for this study. First, support and involvement across different sectors, including business, are associated with passage of transportation measures (Haas and Estrada 2011; Werbel and Haas 2002). The second factor is “detailed earmarking of funds in the expenditure plan” (Beal, Bishop, and Marley 2006, 74)—in other words, specific projects. Not surprisingly, voters located near planned projects were more likely to support new taxes in three elections in Sonoma County, California (Hannay and Wachs 2006) and for monorail funding in Seattle (Peterson,

Kinsey, Bartling, and Baybeck 2008). In short, broad support, including business, and specified projects may correlate with passage of local taxes and approval of transportation infrastructure. The existing research, however, has stopped on election day, without reviewing how the design of and support for ballot measures and rail projects set the stage for rail implementation.

Even if implementation is rarely complete, there is significant variability in whether and how transit agencies may make substantial progress toward building envisioned plans. Rail systems do not appear as soon as citizens cast their votes in support, of course. Rather, implementation is a multi-year and multi-stakeholder process that faces challenges, especially cost overruns (see Flyvbjerg 2007; Laverny-Raftner 2010; van Wee 2007). This research explored why three regions have disparate progress toward implementing rail plans adopted by ballot measure, thereby linking research on rail implementation and ballot measures.

Case Studies

We selected regions that exemplify where metropolitan transformation is both most challenging and possible—fast-growing southern and western metropolitan areas. The nation's fast-growing regions in the Sunbelt and Mountain West present great challenges for transformation to more sustainable urban forms, because their development patterns are typically auto-oriented. Fast growth can contribute to change, however, since growth is a critical factor for rail-associated land use change (see Giuliano 2004). Thus, understanding rail ballot measure implementation in fast-growth regions—where sustainability is possible but challenging—is especially important for researchers and policy-makers.

A comparative case study approach allows insight into complex processes (Yin 2003), and the selected cases provide varied progress toward implementation. Denver's transit agency has the most rail infrastructure in construction (48 miles). Houston's transit agency is laying down 22 miles of light-rail, but Miami's transit agency has completed the only 2.4 miles it will build out of the 89 miles of heavy-rail planned. The contrasting progress occurs alongside important similarities. First, the cases share the characteristics of fast-growth regions discussed above. As Table 1 shows, the population of each metropolitan statistical area grew significantly more than the United States population between 1990 and 2000.¹ Second, rail-plan votes occurred during a limited time period (2002–2004). In the following case

¹ 1990 and 2000 population totals were adjusted to 2010 MSA boundaries by totaling the population of the counties included in each 2010 MSA.

study accounts, the ballot measure, associated campaign support and strategies, planned rail projects, and implementation progress are described. We then summarize the trends across the cases and conclude with implications for practice and research..

Table 1. Metropolitan Population and Growth

	1990	2000	Change 1990–2000	2010	Change 2000–2010	Change 1990–2010
Denver MSA	1,675,127	2,196,028	31%	2,543,482	16%	52%
Miami MSA	4,056,100	5,007,564	23%	5,564,635	11%	37%
Houston MSA	3,767,335	4,715,407	25%	5,946,800	26%	58%
U.S.A	248,709,873	281,421,906	13%	308,745,538	10%	24%

Source: U.S. Census Bureau 1990, 2000, 2010 Decennial censuses

Fieldwork was part of the larger project that examines transportation investment in regions with fast population growth. Data collection was qualitative. During 2009 and 2010, we made at least two visits and conducted at least 35 semi-structured interviews in each region. Interviewees included actors from state, regional, county and local government, businesses and business associations, and community and civic organizations. Interviews were supplemented with document review, including media coverage and agency documents.

Table 2. Overview of Case Studies

City	Ballot Measure	Campaign Support & Strategy	Rail Projects	Agency Capacity	Implementation
Denver	0.4 cent sales tax	Regional, strong business role	122 mi. light/commuter rail	High	48 mi. under construction
Houston	Authorized 73 mi. rail, bonds for only first 22 mi.	Houston mayor, transit agency & urban core developer	22 mi. light rail financed, 73 approved	Moderate	16 mi. under construction
Miami	0.5 cent sales tax	County mayor led outreach	89 mi. heavy rail	Low	2.4 mi. constructed

Denver

Denver's transit agency—the Regional Transit District (RTD)—is currently building 48 miles of 122 miles planned. In 2004, voters approved a 0.4 percent sales tax for the rail and transit plan. Mayors and business leaders across the region led a well-funded campaign for this extensive *regional* rail system. The high-capacity transit agency has begun construction on three lines and secured over a billion dollars from the Federal Transit Administration (FTA), but full build-out would require about a billion more dollars in revenue.

Following an unsuccessful ballot measure for rail in 1997, several of the region's mayors began to work in earnest for rail and thereby lay the groundwork for the successful ballot measure campaign. Mayors across the region had formed the voluntary Metro Mayors Caucus (MMC) in the 1990s. With business elites, they established a new organization—the Transit Alliance—to educate the public and press for rail regionally. The mayors found capable and forceful partners in the private sector, not only among developers, land owners, and engineering firms that would benefit directly from transit but also among the broader business elite, who viewed livability as an important component of the metro area's national and international competitiveness.

The first success for the coalition came in 1999, when it helped win voter approval of bonds for two rail lines. Subsequently, the Colorado Department of Transportation and RTD collaborated on a combined highway-rail expansion along corridor southeast of downtown Denver.

Table 3. Denver Rail Timeline

1983	Transit agency begins receiving sales tax revenue
1994	First rail line opens
1997	Ballot measure for tax increase and rail rejected at polls
1999	Ballot measure approves bonds for rail and road projects
2004	Voters approve 0.4% sales tax to support expanded rail system
2010	RTD enters into public-private partnership agreement for three lines
2012	Groundbreaking for Northwest line (6 mi)
2013	Projected opening of West Line

Following this success, a coalition of area mayors, the RTD board, elite and minority businesses, and organized labor crafted a ballot measure and associated rail

plan in 2004. The measure asked voters to approve 0.4-cent sales-tax increase for a regional rail system. The transit plan, called FasTracks, reflects the regional reach of the transit agency's board and the coalition. As depicted in Figure 1, the five proposed lines stretch from the central business district to the west, northwest, north, and east and from the Tech Center toward the newly-developing Fitzsimons medical campus in Aurora. Extensions were also included on three existing lines. Oiled by a \$3 million campaign budget, the coalition overcame the opposition of the governor and a weakly-organized and poorly-funded "no" campaign to win 58 percent voter approval.

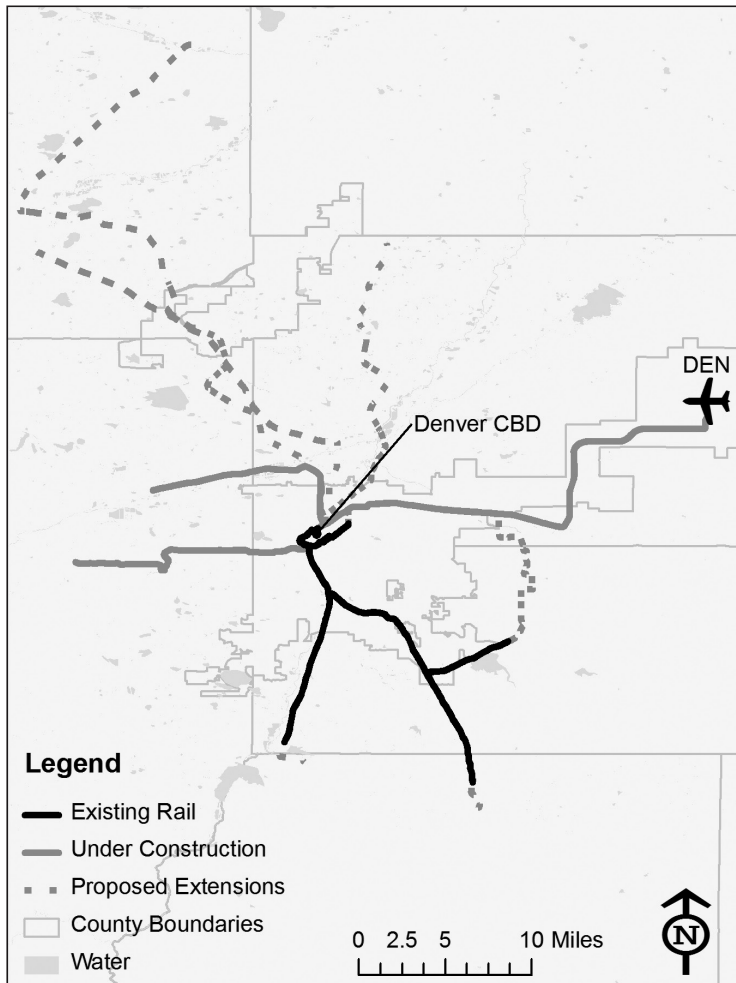


Figure 1. Denver rail system

The Regional Transit District has substantial capacity. Since 1983, the agency has received revenue from a 0.6 percent sales tax levied within its service district. The district and board, like the FasTracks plan, are regional in scope. RTD serves eight counties and its board members are directly elected by district. By the time of the sales tax increase, the agency already operated two rail lines, which opened in 1994 and 2000 (the latter finished under budget and ahead of schedule).

As is typical, fares and other fees do not cover the full cost of service. RTD's total revenue, however, has been sufficient for a balanced budget. From 2008 to 2010, its net assets grew from \$1.9 billion to \$2.2 billion (RTD n.d.). As a total share of operating funds (22%) and in absolute numbers (\$85.6 million), the agency has allocated more to general administration than the two agencies profiled in the following case studies (authors' calculations from FTA 2012).

The ability of the RTD to secure federal grants has further strengthened its capacity. FTA, through a competitive program (New Starts), provided the majority of funds for RTD's two existing lines. The same competitive program will pay for significant, albeit smaller, shares for the three new lines closest to completion: the West LRT line and the Gold and East commuter rail corridors. In total, the FasTracks' budget relies on \$1.3 billion of New Starts funds. All federal funds (including New Starts awards) account for just under a quarter of the rail expansion's financial plan (RTD 2011). In addition, RTD applied to FTA's pilot public-private partnership program (Penta-P program). FTA selected the commuter rail lines as one of three pilot projects. The commuter rail lines have a design-build-operate-maintain contract, an innovative strategy that could result in cost savings for the transit agency. Although the Penta-P program has largely not succeeded in easing the process for receiving competitive federal funds (GAO 2009), RTD's application and selection show ongoing federal partnership.

Implementation is substantial, but full build-out of the system is not assured, due to cost increases and revenue shortfalls. As of early 2012, the cost estimate for full build-out was \$7.8 billion (RTD 2012), approximately 166 percent of the \$4.7 billion estimated at the time of the vote (authors' calculations based on RTD 2011, 5). Revenue has fallen short, and RTD has adjusted its sales tax projections (2005–2035) from \$13.7 to \$8 billion (RTD 2011). The Metro Mayors Caucus pledged support for a 2012 ballot measure to increase sales tax by another 0.4 percent. RTD's approved agency financial plan (RTD 2011) would allow for full build-out by 2020 (four years after original date), assuming passage of this 0.4 percent sales tax increase in 2012. The RTD board, however, later voted not to bring a sales tax increase to the ballot

box in 2012. The dynamics are continually unfolding, and some are questioning whether remaining planned lines are the most effective rail investments for the region (*Longmont Times Call* 2012).

Houston

In Houston, the Metropolitan Transit Authority (“Metro”) is building three light-rail lines (16 miles) and may construct two more. These five lines are part of a 73-mile rail system that voters approved through a 2003 ballot measure; yet, the measure gave the transit agency bonding authority only for the first five lines and avoided the potentially contentious issue of sales tax distribution. While two lines are still possible—in addition to the three under construction—civic leaders no longer seriously discuss most of the 73-mile system. Houston mayors, an urban developer, and the transit agency itself have been the major champions behind rail. Given the centralized political power in the local government and business arenas, a handful of players could negotiate what would appear in a rail ballot measure, as well as the CBD-orientation of the associated rail system.

Houston’s transit agency, Metro, designed the rail expansion plan in 2003. At that time, the agency was building its first rail line, running south from downtown to the Astrodome. In April 2003, Metro released a draft plan with 41 miles of rail, but some unserved communities demanded rail investment. The agency released another plan with 55 miles of rail and then a final plan—“METRO Solutions”—with even more rail (73 miles). Metro even was explicit that rail additions were due to community requests (Perez 2003).

The rail plan faced two central challenges. Voter approval was required, because local rail foes—a long-standing presence in Houston—had successfully backed a measure that mandates voter approval for rail expansion. Second, the allocation of the Metro district sales tax would be contentious. Metro has received a 1 percent sales tax since 1978, but a more recent provision requires the agency to sub-allocate 25 percent to the service district’s counties and cities. The initial plan relied on receiving the full 1 percent after 2009, when the sharing requirement was scheduled to sunset.

Elite rail-backers anticipated that municipalities and business leaders would oppose the sunset of the municipal sales tax share. Municipalities and business leaders would not want to lose the revenue that local governments were using for general mobility investments, including roadway improvements. Resistance on the tax sharing issue would mean that the rail initiative could trigger wide-spread

opposition. Ed Wulfe, a developer and supporter of rail for the urban core, took on the task of forging a rail plan that business stakeholders would support (Williams 2003).

Then Mayor Lee Brown and Wulfe met with the Greater Houston Partnership (the area's chamber of commerce), Metro officials, and a former mayor and rail foe (Bob Lanier) to broker a measure that would appear on the ballot. Houston business leaders typically have been deeply involved in pivotal decisions for the city (Gainsborough 2003). The compromise ballot measure plan included 73 miles, but authorized bonds only for the first 22 miles, the first component to quell opposition. This phase one system is depicted in Figure 2. Second, more importantly, it extended the allocation of sales tax to municipalities, until a future unspecified referendum (that would happen in 2012). The mayor of Houston appoints the majority of members on the Metro board, and Mayor Brown successfully pressured his appointees to approve the compromise measure which then went to voters (Williams 2003). The Greater Houston Partnership endorsed the measure but did not actively campaign to support it.

Rail champions wielded significant resources, but faced opposition from U.S. Congressmen Tom DeLay and Culberson and a well-funded, anti-rail political action committee (PAC). Combined, the pro- and anti-PACs spent just under \$3 million (Wall 2003). The pro-rail campaign was primarily elite-led and targeted young voters, those who had moved from other regions, citizens concerned about urban quality of life, and minorities (Wulfe interview). Metro conducted extensive outreach and education, explaining that a yes vote would not result in more taxes. It spent about \$3 million on education (Wall 2003), but it is banned from campaigning per se. Voters narrowly approved the light-rail system of 73 miles and bonds for the first five lines.

Despite some missteps, Metro's capacity has rebounded, and the agency has secured millions of federal dollars to build rail. At the time of the METRO Solutions vote (2003), Metro appeared financially healthy and was constructing the area's first rail line without state or federal assistance. Since 1978, the agency has had dedicated revenue stream—a 1 cent sales tax (although one-quarter of that tax currently goes to municipalities as discussed above).

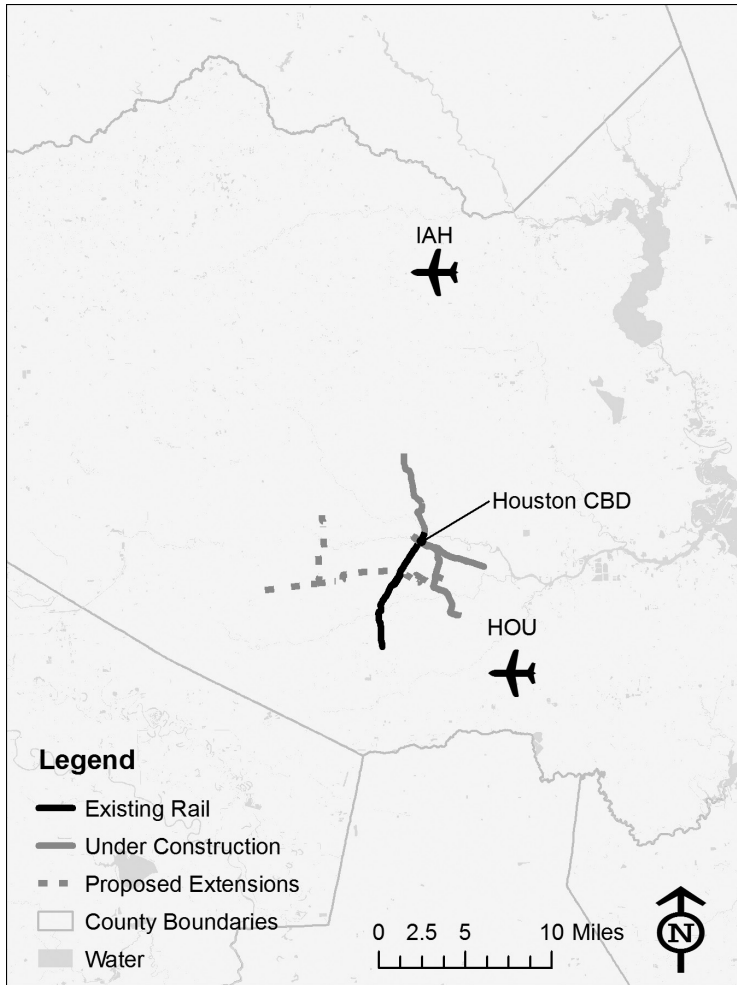


Figure 2. Houston rail system

Table 4. Houston Rail Timeline

1978	Metro (transit agency) starts receiving one cent sales tax
2003	Voters approve ballot measure for 73 miles and bond authority for 22 miles
2004	First rail line opens (Red/Main Street line)
2011	FTA finalizes agreement for \$900 million to support construction of two rail lines
2012	Voters approve measure to continue distributing METRO tax to municipalities
2014	Scheduled opening of North, East End and Southeast lines

The public has held somewhat negative perceptions of the agency, and Metro management has made missteps. The *Houston Chronicle* reported some Metro staff as suffering from “arrogant intractability,” and some interviewees similarly expressed frustration with the agency’s forcefulness and lack of transparency. Under the tenure of Frank Wilson, the Metro CEO who was appointed soon after the rail vote, a Metro contract for European light-rail vehicles violated the FTA’s “Buy America” rules. Wilson, however, did advance a potentially cost-saving implementation model, a multi-line, design-build contract.

Furthermore, for several years following the ballot measure, Metro operated on a deficit. It borrowed to pay the share of sales tax due to the cities, thereby creating \$167 million of short-term debt. As a candidate, Mayor Parker criticized Wilson’s leadership of Metro and asserted the agency had not been transparent, including on the financial prospects for implementation of some lines (Snyder 2010). After taking office, Parker appointed new board members, who negotiated Wilson’s departure in 2010. Under the subsequent CEO, Metro has responded to the FTA’s Buy America concerns, increased transparency, and adopted a more cautious tone about finances and building the last two lines of the first phase. The new CEO ended the practice of borrowing to pay the funds due to cities, comparing the practice to a family living on credit cards (Snyder 2010).

Houston’s Metro has secured millions in federal funds for its METRO Solutions rail plan. In November 2011, Metro and FTA signed an agreement for \$900 million that will support build-out of Houston’s North and Southeast LRT lines. If the \$1.4 billion-University Line goes forward, Metro will request \$700 million for it. Like Denver’s RTD, Metro was selected as one of three agencies in the FTA’s pilot program for public-private partnerships.

Implementation progress is notable, but much of the rail plan has an uncertain or dubious future. Metro predicts opening the three light-rail lines under construction (16 miles) in 2014. The future for the next two lines, however, remains uncertain at best. Costs are higher than anticipated. For example, the Southeast and North corridors—just 11 miles—will cost \$1.6 billion, more than double the initial estimated costs for all 22 miles. Like Brown, subsequent mayors (Bill White and Anise Parker) control the majority of Metro’s board seats and until 2012 continued to advance Metro Solution’s light-rail lines. In that election cycle, voters approved (by more than three quarters) a measure that continues to divert Metro sales tax

to local governments. The measure also prohibits use of Metro sales tax for rail expansion, until at least 2024. The new rules do allow Metro to receive up to 81 percent (up from 75%) of the sales tax, which can still fund debt payments and bus operations. Mayor Parker and the Metro board supported the measure, explaining it would help re-balance investment between rail and bus. Critics suggested Parker and the board supported it to mute suburban opposition to rail (Rhor and Begley 2012). Thus, the future of the last two urban core lines appears uncertain at best, while the remaining rail lines (of the 73 miles approved by voters) have disappeared from debate.

Miami

In 2002, voters in Miami-Dade County approved a ballot measure that authorized a 0.5 cent sales tax for transit. The plan, which included 89 miles of heavy rail, offered investments for a wide range of constituents, but few stakeholders led its development or pushed for its passage. The county's transit agency struggles with capacity issues, but has built and opened a 2.4-mile rail spur to the airport. The rail spur is and will be the only implementation of the pledged investments, as the transit agency and metropolitan planning organization have struck the other rail investments from future plans.

The plan originated in the office of then County Mayor, Alex Penelas. His 2002 "low-key" campaign (Viglucchi 2002) was likely a response to a failed 1999 sales tax initiative that citizens perceived as elite led. The county did, however, already have rail service: a 22-mile heavy rail line and a downtown monorail circulator. Penelas' office conducted broad outreach. At numerous community meetings, constituents identified the transportation investments they wanted. Community groups, however, did not lead the campaign nor deliberate together for a realistic plan.

Following outreach, the mayor's office then developed and released the "People's Transportation Plan." It had something for almost everyone—older adults, municipalities, bus riders, and the many neighborhoods slated for rail investment. The plan allocated 20 percent of the tax revenue to the county's municipalities for public works. Older adults would receive free transit passes. Miami-Dade Transit (MDT) would extend Metrorail hours and add bus routes. The combination of service improvements and decreased fare revenue alone would strain the transit agency's budget. The plan called for more: eight heavy-rail lines (89 miles) throughout the county that would add to the existing Metrorail system. Heavy rail is typically more costly than light-rail. For instance, among recently-completed projects

that received FTA grants, the average cost of heavy rail per mile was \$175 million, and the average for light-rail was \$74 million per mile.²

This plan did not reflect that MDT had limited financial and institutional capacity. As a county agency, the bulk of MDT's operating subsidies come from Miami-Dade County. Rather than having a dedicated funding stream prior to the vote (as agencies in the other case studies did), the County Commission controls subsidies for and the budget of MDT amid an ever-changing political and fiscal environment.³

The transit agency was already operating with a deficit (\$23.9 million) at the time of the 2002 ballot measure (Lebowitz 2008). In other words, it lacked sufficient financial capacity to operate its existing services. Its financial struggles, however, were not part of the dialogue on the rail plan and sales tax increase, but have since garnered more attention. FTA identified MDT's poor, long-term fiscal capacity as reason *not* to award it expansion funds in 2009.⁴

Implementation has been and will be minimal. There are far from sufficient funds for the service, let alone the capital, expansions in the plan. Only 2.4 miles of rail will be implemented from the 2002 transit plan. In 2004, the County Manager and the Aviation Department secured assent from the County Commission to proceed with a Metrorail spur to the airport, rather than projects prioritized in the rail plan. Using \$100 million in state funds and \$426 million from the sales tax, the transit agency built this two-mile branch from the existing Metrorail to the airport's intermodal center (Figure 3). It opened in July 2012.

In 2009, recognizing the fiscal distress of the transit agency and infeasibility of rail implementation, the Miami-Dade Board of County Commissioners voted to redirect the sales tax to the transit agency's general fund. Following this, the transit agency and metropolitan planning organization removed the other heavy rail lines from their official plans.

² Authors' calculations based on New Starts projected completed from 2003–2007 (FTA 2008). Reconstruction of lines, double-tracking, commuter rail, and bus rapid transit were not included in calculations. Completed heavy-rail (n=3) and light-rail (n=10) projects were included. The average is based on a small set of projects but a substantial share of U.S. rail projects completed in that period.

³ In a study of a transit agency faced with similar year-to-year budgeting, Jones, Mock and Cearley (2006, 27) note the toll that annual budgeting demands: "CATA [Little Rock's transit provider] became engrossed in a year-to-year struggle to maintain even minimal transit services."

⁴ Later, in November 2010, FTA suspended MDT's formula funds due to concerns about the proper use and documentation of grants, as well as potential discrepancies between recorded farebox revenue and cash on hand (Chardy 2010). In July 2011, FTA released \$62.5 million in formula funds—amid fears of emergency service cuts—and soon thereafter \$72.6 million in stimulus funds (Brannigan, Chardy, and Haggman 2011).

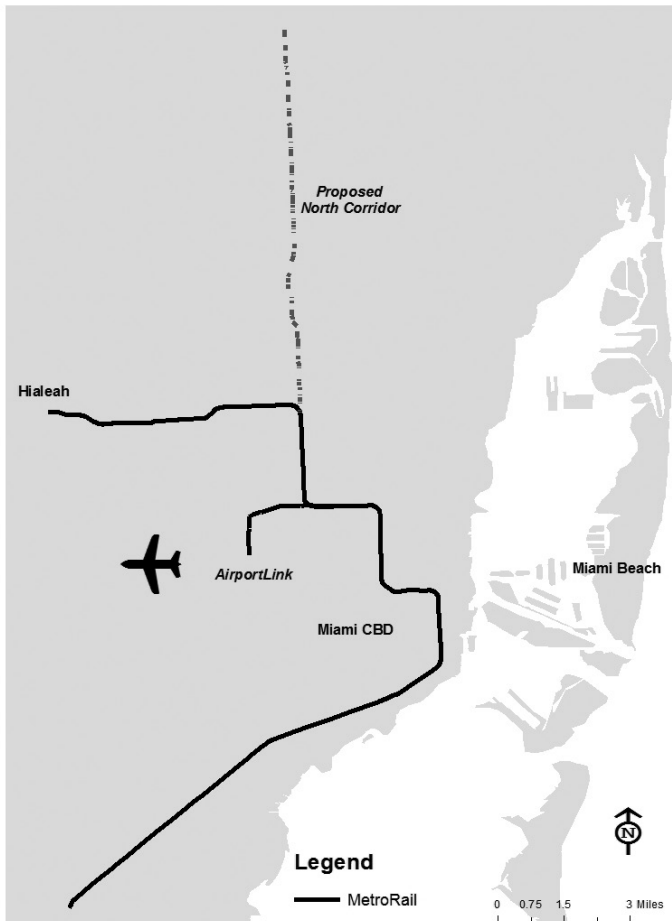


Figure 3. Miami rail system

At best, the plan was overly ambitious for a 0.5 percent sales tax, and, at worst, a “bait and switch” (*Miami Herald*, 2009). The plan reduced revenue and offered benefits for many county constituents, all funded by a half-cent sales tax. But, in fact, the transit agency would receive an effective rate of 0.4 cents, given the municipal allocation. While one state-level employee attributed financial woes to rising production costs, another state-level interviewee explained the plan may never have been realistic:

Not so much the mileage, because they did have, all these transit lines had already been identified through their transitional study... I don't think there was enough money being generated in order to do it, because heavy rail is very expensive.... I think a lot of people were pretty skeptical about the ability to deliver.

Indeed, the costs for the only rail project that will be implemented increased significantly from projected costs, from an estimated cost of \$67 million per mile in 2002 to a cost of \$220 million per mile in 2009.⁵

Table 5. Miami Rail Timeline

1999	1 cent sales tax ballot measure fails
2002	Voters approve 0.5 cent sales tax for transit expansion
2004	County Commission approves construction of 2.4-mile spur from existing Metrorail to airport
2009	County Commission votes to move sales tax to transit agency's general fund
2009	Miami-Dade MPO and MDT release plans without rail expansions
2012	Miami-Dade Transit opens airport rail service

Discussion

The case studies demonstrate that the provisions of the ballot measure, campaign support and strategies, the rail plan, and transit agency capacity affect implementation. In the case studies, implementation progress ranges from a meager 2.4 of 89 miles of heavy rail proposed in Miami to at least 48 of 122 miles in Denver. Houston's implementation progress falls in the middle, with 16 miles under construction. Several factors identified in the literature on referenda passage—multi-stakeholder involvement and specified projects—may contribute to plans that include so much rail that full implementation becomes infeasible. This section first discusses the interrelated variables of ballot measure provisions, rail plans, and campaign supporters and strategy, depicted in Figure 4. Then we discuss transit agency capacity and its relationship to federal assistance.

⁵ Authors' calculations. Costs and mileage from Lebowitz series in *Miami Herald*, <http://www.miamiherald.com/multimedia/news/transit/index.html>.

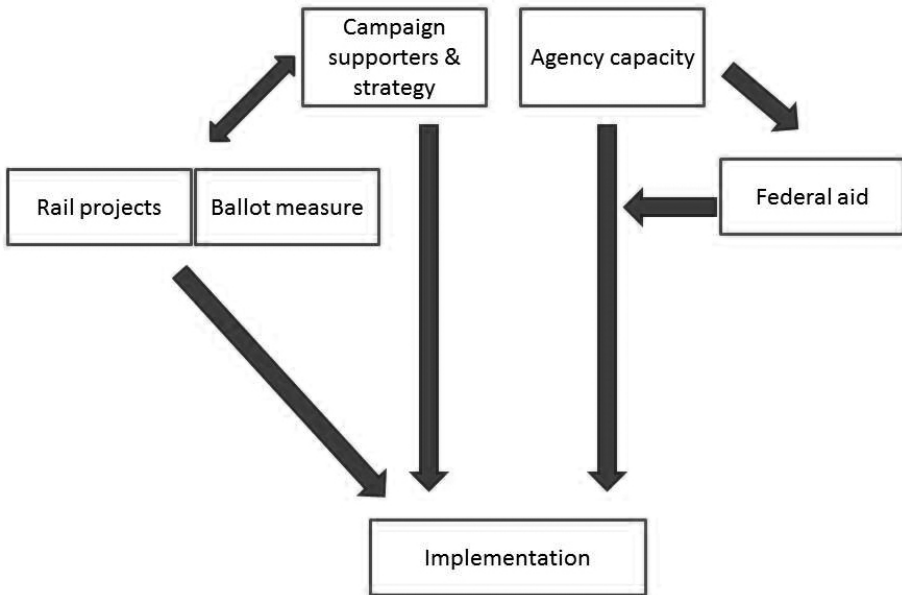


Figure 4. Implementation of ballot-box rail plans

Denver-area mayors and business elites are a powerful force behind rail. Their partnership, as well as the transit agency, reaches across the region. A regional plan reflects the geographic dispersal of key supporters. Much of the rail promised is going forward, but the full plan—with expansive extensions across the region—would require additional revenue.

To appease communities, Houston’s Metro added miles and miles to its rail plan. Meanwhile, city-based elites reduced the ballot measure’s funding authorization to neutralize opposition. Thus the ballot measure reflected a dual strategy to attract votes and quell opposition. As Houston voters dominate the Metro service area and its mayor controls the majority of board seats, the plan did not need to attract regional support. Phase one lines serve the urban core. Ongoing mayoral support and Metro leadership has led to groundbreaking on three lines, but current funds and the political climate may halt further implementation.

Intense outreach resulted in a Miami-Dade People’s Transportation Plan that offered something for everyone in the county. This campaign strategy, based on promises of extensive operating and capital enhancements, was especially infeasible due to the existing deficit, increased operating expenses, decreased revenue, and the especially high cost of heavy rail. The County Mayor led the outreach and

campaign, without broad based or regional involvement. Furthermore, the ballot measure required sub-allocation of 20 percent of the revenue, further reducing funds for implementation. Only 2.4 of 89 miles will be built.

In addition to these three interrelated variables, transit agency capacity significantly affects the extent of rail implementation. The varied capacities of implementing agencies are tied to conditions that pre-date each region's rail vote. MDT—burdened by ongoing operating deficits—appears to have the least capacity. Both Denver's RTD and Houston's Metro had dedicated revenue for more than a decade prior to the ballot measures discussed. Metro has a substantial planning and outreach staff, but recently doubts about implementation of all five (phase 1) lines have surfaced. There have also been several missteps by management. RTD's capacity seems most robust, and the agency has allocated the largest amount and share of funds to general administration (authors' calculations from FTA 2012 for 2009).

Competitive federal funding can be a critical component for rail expansion, but receiving it is contingent on institutional and financial capacity, as shown in Figure 4. The award of discretionary federal funds is through a demanding application process that requires institutional planning capacity. Part of the federal process is an assessment of the long-term fiscal health of the sponsoring agency. It is precisely because of a lack of long-term fiscal capacity that FTA opted not to award expansion funds in Miami. Federal capital funds supported construction of Denver's existing lines, and FTA has issued grant agreements for \$1.3 billion to build three more. FTA awarded \$900 million for two Houstonian lines in late 2011. Thus, while FTA is powerful, it responds to existing local capacity, demonstrating the "bottom-up federalism," which Altshuler and Luberoff (2004) claim characterized the mid-century era of mega-projects.

In sum, factors that emerge before a ballot measure vote appear to dramatically shape the progress toward implementation in Denver, Houston, and Miami. We suggest an interactive role between campaign support and strategies, ballot measures, and the rail plan. The latter two factors become an intervening variable for implementation, as shown in Figure 4. Likewise, Figure 4 depicts that agency capacity affects federal support which acts as an intervening variable for implementation.

Research and Policy Implications

Rail ballot measures are critical moments for infrastructure investment and urban politics, but they represent only one moment in a complex process of planning and implementation. While these rail plans—like many—may not be fully implemented, there is significant variability in how much agencies have implemented rail plans. Reflecting both coalition make-up and political strategies to win votes, the transit capital plans and each ballot measure are highly ambitious and only partially feasible in all of our case studies. In other words, winning at the ballot box does not equate to building the proposed a rail system, but campaign-related variables and transit agency capacity contribute to varied progress toward implementation.

Coalition building—or vote attraction—strategies can build advocacy support for implementation or create political frustration. Denver’s transit supporters formed and maintain a regional coalition. The continuing support, at least from some key supporters, may lead to further increases in sales tax, although not in 2012. The additional revenue would enable further implementation. The support behind Houston’s rail measure was more centralized, but the continued political will of Houston mayors, along with the capacity of the transit agency, will result in three new lines. Like Denver, progress toward implementation is visible across multiple lines. Miami’s plan contained benefits for all, but was not backed by a strong coalition or transit agency. While some support persists in Denver and Houston, no leaders or coalitions are pushing rail investments based on the 2002 Miami plan. The extremely limited implementation has also created such voter animosity that elected officials discuss repeal of, rather than an increase in, sales tax.

Thus, for regional coalitions and transit supporters, coalition building and transit agency capacity merit at least as much attention as passing ballot measures. The public can become more frustrated and transit funds more difficult to secure following implementation failure, as in Miami. There the transit agency’s failure to implement a promised rail system led to frustration and a proposal to repeal the associated tax. The major newspaper called the commission’s vote to redirect the associated sales tax the “final betrayal” related to the People’s Transportation Plan. Despite continued support by major actors, suburban municipalities northwest of downtown Denver hired their own consultant and one local mayor explained her frustration and a potential desire to leave the transit district:

This area has been ignored, this entire area from about I-70 north, we rarely get transportation dollars. We will fight, and have stood together, we are standing together. This was sold as a system [FasTracks], and if

they don't [do] it [build the Northwest line], then undo it so it releases our citizens from paying for stuff in their areas. We can make an RTA and build our own.

Given the challenges of implementation, some political fall-out may be inevitable. But, policy makers and rail advocates should consider capacity for implementation, more permanent coalition building, and the consequences of partial implementation.

Because rail investment depends on transit agencies with institutional capacity and adequate operating funds, local and federal actors could adopt tools to strengthen transit agencies. FTA logically wants to fund projects that an agency can operate fully and without starving existing services of resources. This strategy, however, has the effect of strengthening the systems that already have capacity or do not shoulder the cost of older infrastructure. With aging infrastructure and an operating deficit, MDT was ill-equipped to expand as the campaign promised.

Additional research is also needed on the governance processes that occur after plan adoption or votes. In addition to potential political fall-out, infeasible ballot measure plans blur the site of actual decision making. Because implementation is typically partial, decisions about the sequence of projects may have important distributional or environmental consequences. Ballot measures—or other citizen inputs—may provide a veneer of planning democracy, but the actual critical decision sites are scattered across time and space during implementation.

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Assessment of Passenger Satisfaction with Intra-City Public Bus Transport Services in Abuja, Nigeria

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Abstract

The aim of this study was to investigate passenger satisfaction with the service quality attributes of public bus transport services in Abuja, Nigeria. To achieve this, a survey was conducted between February and July 2011. In 10 sample bus stop areas selected for this study, 300 public bus transport users were randomly selected to elicit their overall satisfaction and factors that influenced their satisfaction in the use of public bus transport services in Abuja using a self-rated questionnaire. Data obtained were analyzed using descriptive statistics, correlation, and principal component and regression analyses. The results of these analyses showed that passengers were not satisfied with the public bus transport services in Abuja. Using Principal Component Analysis (PCA), four underlying factors were extracted that influenced passenger satisfaction with public bus transport services in the city. The four components together explained 83.87 percent of the cumulative variance of PCA, leaving 16.32 percent of the total variance unexplained. The standardized regression coefficients further showed that comfort has the greatest impact on overall satisfaction, followed by accessibility. Adequacy and bus stop facilities were the third and fourth factors in the order of relative importance in influencing passenger satisfaction of

public bus transport services in the city. On the basis of the findings, recommendations were made to improve public bus transport services in the city of Abuja.

Introduction

Transport needs of major cities in Nigeria now present significant challenges for policy makers as unpredictable shifts in population dynamics in response to the need for employment, housing, and sustenance continues. The expansion of the cities in Nigeria, coupled with increasing urban population, results in greater demand for transport provision. This demand has, however, not always been met, and efforts to provide adequate transport infrastructural facilities are *ad hoc*, uncoordinated, and poor (Aderamo 2008).

Commonly identified urban transport problems in Nigerian cities are long waiting times for buses, traffic congestion, parking difficulties, air pollution, and traffic accidents (Asiyanbola 2007; Aderamo 2010; Ashiedu 2011). This is because of the increasing travel demand and preferences in using private vehicles in Nigerian cities (Afolabi 2008; Banjo 2008). To prevent more problems caused by the rise in demand for urban transport and increase in private motorization, it is highly recommended by many researchers as well as public decision makers to provide an attractive public transport service as an alternative transport mode in many cities (Banjo 2008, Federal Government of Nigeria 2010).

Public transport, by definition, connotes the act or the means of conveying a large number of people *en masse*, as opposed to conveyance in individual vehicles carrying very few people at a time. Public transport comprises mainly rail systems, light rail systems, tramways and monorails, bus systems, and, where possible, water transport. The choice of any or a combination of these public transport systems could be influenced by the population and area of a city. Given the low level of technological development in Nigeria, the bus system was chosen in this study. The bus system is the transport system that uses buses that may have a range of passenger capacities and performance characteristics and may operate on fixed routes with fixed schedules or may be flexibly routed (Smerk 1974). Bus systems have the potential of extending transport services to greater proportions of urban residents who do not have private cars and cannot afford frequent taxi fares (Andeleeb et al. 2007). They have the potential of being used as policy tools to reduce the number of cars on urban roads and thus reduce traffic chaos in cities. Despite the vital role that buses are able to play in any urban area, their services in Nigerian cities are frequently insufficient to meet demand, and the services provided suffer from

low output (Ali and Onokala 2009). As a result, often, they have a negative public image.

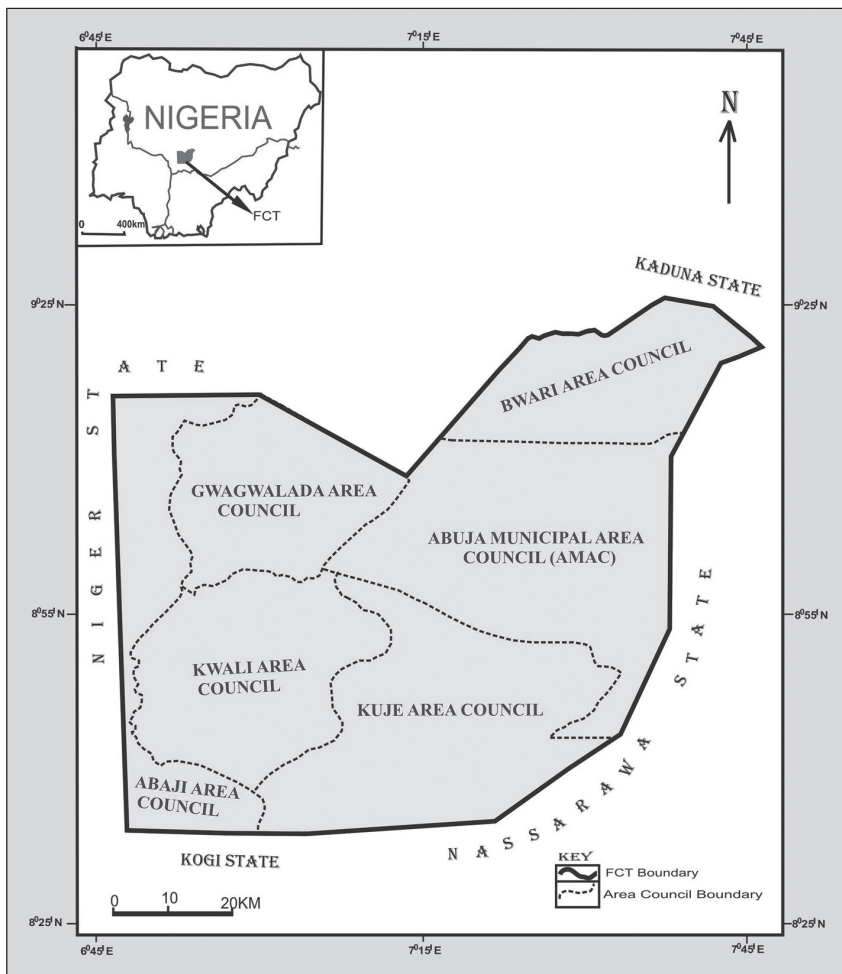
The transport system in Abuja, the Federal Capital Territory (FCT), caters to more than 1.5 million people and faces numerous and significant challenges, efforts of the federal government to improve the system notwithstanding. The complex and heterogeneous traffic pool, largely dominated by private vehicles, most of which are poorly maintained, and inadequate enforcement of traffic rules in Abuja creates serious and unbearable congestion and heavy pollution of the city environment (Chung 2010). This situation is further compounded by the dwindling efficiency of service delivery of the Abuja Mass Transit bus services (Oiboh 2010). To improve the public bus transport system in Abuja, it is important to elicit insights from actual passengers of the system about changes they would like to see to better meet their needs. This is because the provision of public bus transport services is passenger-centered. By identifying the key dimensions that offer value and influence passenger satisfaction, alternative bus strategies can be devised so that more people (especially private car owners) opt in favor of this service. In turn, this would alleviate the present traffic congestion and related problems faced by the city of Abuja and its population.

Previous studies on public bus transport services at national and local levels focused on constraints (Aworemi 2009; Aderamo 2010), impacts (Gbadamosi 2009; Ashiedu 2011), and the effect of congestion on vehicle movement (Ibitoye et al.2012), but there is scant literature on passenger satisfaction with levels of public bus service provision in Nigerian cities. To keep and attract more bus passengers, public bus transport must have high service quality to satisfy and fulfill a wider range of different passenger needs. Increases in passenger satisfaction are translated into retained markets, increased use of the system, new customers, and more positive public image. To accomplish these ends, transit needs reliable and efficient methods for identifying the determinants of service quality from customer perceptions. Thus, the focus of this paper is to investigate the service quality attributes that influence passenger satisfaction with the public bus transport system in Abuja.

Two basic objectives of this study are to identify important factors determining service quality of public bus transport system in Abuja that explain passenger satisfaction and to evaluate the relative importance of these factors to determine the priority of quality improvements to enhance passenger satisfaction.

Study Area

The Abuja Federal Capital Territory is located in the center of Nigeria. It covers an area of about 8,000km² and is bordered on all sides by four states: Kaduna State to the north, Niger State to the west, Nassarawa State to the east and Kogi State to southwest (Dawan 2000). According to the National Population Commission (NPC) (2007), the population of Abuja in 2006 was 1,406,239 persons with a growth rate of 9 percent. Abuja Federal Capital Territory comprises six Area Councils: Abuja Municipal, Bwari, Gwagwalada, Kuje, Abaji. and Kwali (Figure 1.)



Source: Abuja Geographical Information System (AGIS), 2004

Figure 1. Map of Federal Capital Territory, Abuja

Concepts of Passenger Satisfaction and Service Quality Attributes

An improvement to a supplied service quality can attract more users. This fact could resolve many problems (e.g., helping to reduce traffic congestion, air and noise pollution, and energy consumption) because individual transport would be used less (Eboli and Mazzulla 2007).

On one hand, satisfaction is defined as customer fulfillment (Oliver 1997). It is a judgment that a product or service feature or the product or service itself provides a pleasurable level of consumption-related fulfillment, including levels of under- or over-fulfillment (Budiono 2009). Satisfaction is defined as “fulfillment of a need, demand, claim, desire, etc.” Need fulfillment is a comparative process giving rise to satisfaction responses. The dominant theoretical model employed in research into customer satisfaction is the expectancy/disconfirmation model in which customers are satisfied (dissatisfied) if their experience and perceptions of the service they perceive exceed (fall short of) their expectations (Payne and Holt 2001). Within this framework, satisfaction is analyzed by examining the expectation of service quality and the attributes of the service quality that influence the experience and perceptions. On the other hand, service quality is defined as a comparison between customer expectation and perception of service (Gronroos 1984).

Service quality, in general, consists of five distinct dimensions: tangibles (physical facilities, equipment, appearance of personnel); reliability (ability to perform the promised service dependably and accurately), responsiveness (willingness to help customers and provide prompt service), assurance (knowledge and courtesy of employees and their ability to inspire trust and confidence), and empathy (caring or the individualized attention a firm provides its customers) (Budiono 2009). Quality is one of the key dimensions that is factored into consumer satisfaction judgments. Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated and implied needs. In the short term, product or service features determine quality, which then satisfies customer needs.

Several studies regarding satisfaction and dissatisfaction in public transport have been conducted to develop and create attractive public transport. The Department for Transport (2003) identified high frequency of service, services that are reliable, and fares that offer value for money as important needs of UK public transport users. In India, transport systems have also been criticized for their low quality of services, reflected in the growing number of standing passengers, lack of punctuality, irregularity, and substandard amenities (Mishra and Nandagopal 1993). Negative critical incident and customer/passenger dissatisfaction could be a

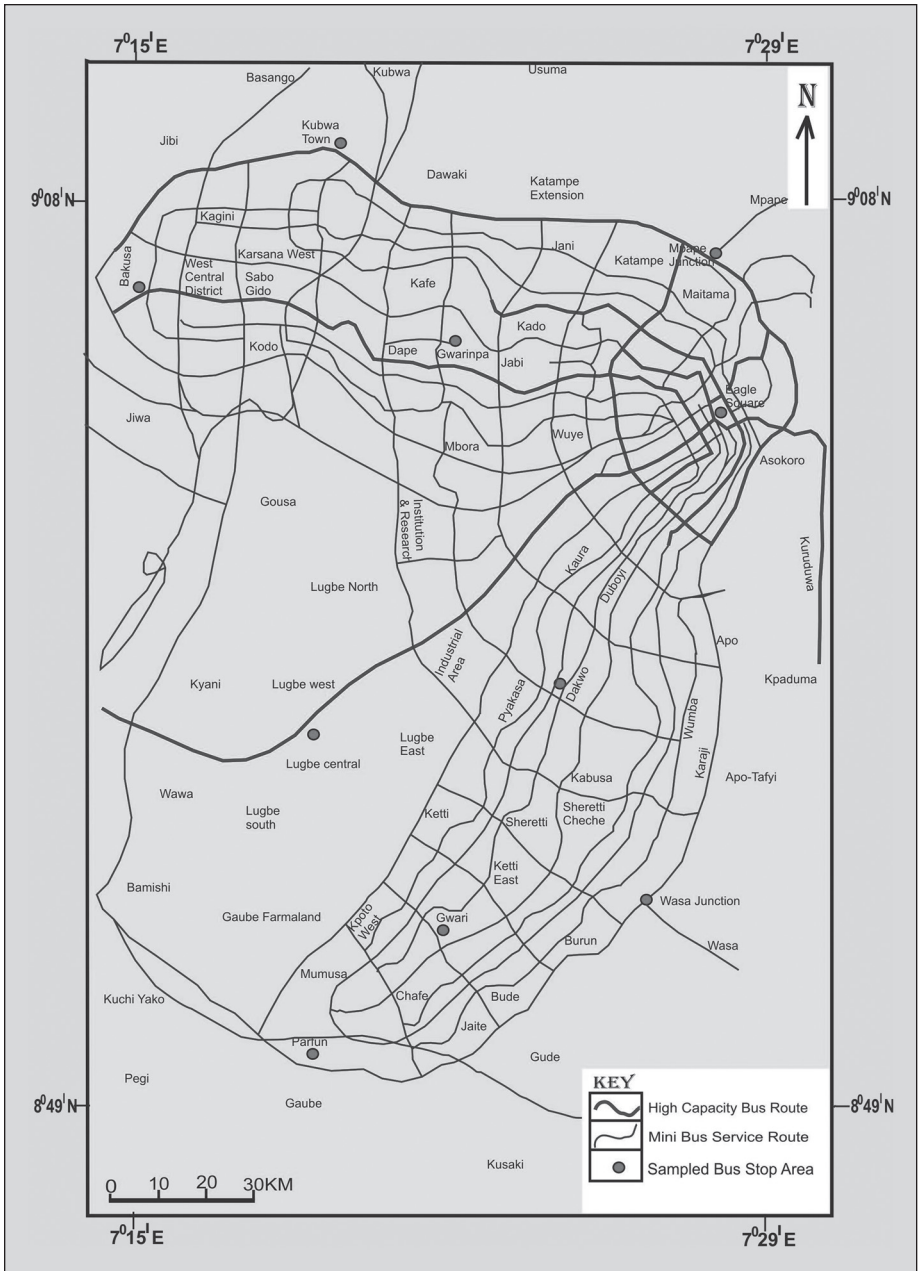
constraint for people to continue using public transport (Friman et al. 2001; Friman and Garling 2001). Based on the factors/attributes identified in the above reviewed studies, the author's personal experiences with bus services, in-depth interviews with the bus passengers, and brainstorming, attributes of public bus transport services that influence bus passengers satisfaction were constructed and used in this study in Abuja.

Methodology

Sampling and Data Collection

Data were collected by the use of a questionnaire, field observations, and oral interviews between February and July 2011. The questionnaire used in study was based on the published studies reviewed in this work, as well as in-depth interviews and extensive brainstorming. Abuja bus commuters (both transit-dependent and choice transit riders) were the target population in this study because they are homogeneous in their use of buses but heterogeneous in their other characteristics (profession, age, income, mobility, and the like). Their judgments or opinions mainly sought were because they would be best able to evaluate the existing levels of public bus services and levels of satisfaction with such services in Abuja. Ten major bus stop areas (clusters) in Abuja were selected as sample sites for this survey (Figure 2). From each bus stop area, systematic sampling was used to select households on the left or right of randomly-selected streets. Respondents from each household were selected to participate if they use bus services in the city and were between ages of 15 and 60. They were chosen because people in these ages have a routine commuting travel behavior.

A self-rated questionnaire was used to collect data for this study. Respondents were asked to rate their overall satisfaction with public bus transport services and factors/attributes of public bus transport services that influence their satisfaction (Table 1). The attributes of public bus transport service that influence bus passenger satisfaction used in this work were based on published studies reviewed for this work, extensive brainstorming, in-depth interviews with bus passengers, and the author's personal experiences with public bus transport services. A five-point Likert scale with "strongly agree" equal 5, "agree" equal 4, "undecided" equal 3, "disagree" equal 2, and "strongly disagree" equal 1 was used in the rating.



Source: Office of the Secretary, Transportation FCT, Abuja, 2011

Figure 2. Bus route network in Federal Capital Territory, Abuja

Table 1. Public Bus Service Quality Attributes Measures

Variable Code	Variable Description
OS	Overall satisfaction with public bus transport services
S1	Seats generally available in buses
S2	Enough leg-space in buses
S3	Frequency of bus service
S4	Short waiting time at bus stop
S5	Facilities inside buses are in good condition
S6	Bus stops have enough shelters
S7	Ceiling heights of buses are comfortable
S8	Buses are well maintained
S9	Short passenger walking distance to bus stops
S10	Sufficient benches available at bus stops
S11	Sufficient number of buses in city
S12	Transport price affordable
S13	Safety of passengers on board
S14	Not afraid of being pickpocketed on bus
S15	Buses provide short travel time
S16	Drivers and conductor behave well
S17	Buses are clean inside

Thirty respondents were systematically sampled and administered the questionnaire in each of the 10 spatially-segregated and randomly-selected major bus stop areas (Figure 2), giving a total of 300 respondents sampled for this study. Of the 300 respondents, 191 respondents were transit-dependent riders, representing 64 percent of the public bus passengers interviewed; 109 respondents were choice-transit riders, representing 36 percent of the passengers interviewed (Table 2). This was done to capture the responses of all categories of public bus users in the city for an in-depth understanding of their problems. Internal consistency for the scale was examined using Cronbach’s alpha (α .)

Table 2. Distribution of Passengers Interviewed among Bus Stop Areas

	Sampled Bus Areas	Transit -Dependent Riders		Choice Transit Riders		Total Passengers Interviewed per Sample Bus Stop Area	
		#	%	#	%	#	%
1	Kubwa Town	17	57	13	43	30	100
2	Mpape Junction	18	60	12	40	30	100
3	Bakusa	20	67	10	33	30	100
4	Gwarinpa	19	76	11	24	30	100
5	Eagle Square	24	80	6	20	30	100
6	Dakwo	21	70	9	30	30	100
7	Lugbe Central	18	60	12	40	30	100
8	Gwari	16	53	14	47	30	100
9	Wasa Junction	22	73	8	27	30	100
10	Panun	16	53	14	47	30	100
	Study Area	191	64	109	36	300	100

Analysis of overall satisfaction (dependent variable) and specific service quality attributes (independent variables) was based on the frequency values obtained from the self-rated questionnaire. The frequency values are the number of times respondents mentioned a variable as their answers or options. This enabled us to obtain the mean scores, standard deviations, and variances of the frequency counts of the response values. Adding all the ratings (strongly=5 + agree=4 + undecided=3 + disagree=2 + strongly disagree=1] gave us 15 points for overall satisfaction and for each of the specific service quality attributes that affect passenger satisfaction.

Thus,

$$Q = \frac{\sum fx}{N} \tag{1}$$

Where,

Q = mean

\sum = summation

Fx = frequency of x

N = number of occurrences

By summing the nominal values and dividing by the total number of scaling variables, the cut-off point is determined. Thus,

$$Q = \frac{\sum fx}{N} = \frac{15}{5} = 3.0$$

Dividing the total ratings of each variable gives us a mean of 3. Thus, any mean above 3 indicates passenger satisfaction and below 3 indicates passenger dissatisfaction with service quality attributes and overall satisfaction of the public bus transport system. A mean of exactly 3 shows undecided on satisfaction level. Correlation analysis was performed to measure the linear relationship between the variables. Then, Principal Component Analysis was used to extract the major underlying dimensions of service quality attributes influencing passenger satisfaction. Thereafter, a regression analysis was performed to evaluate the effect of each underlying factor on overall satisfaction.

Results and Discussion

Analysis of Frequency Distribution

The statistical frequency distribution of respondents' perception of the overall satisfaction and specific service quality attributes that affect their satisfaction of public bus transport services in the city of Abuja is shown in Table 3. From Table 3, the perceived overall satisfaction of public bus transport services by passengers scored 33.7 percent for "disagree." "Strongly disagree" scored 20.3 percent, "agree" scored 29.3, and "undecided" scored 16.7 percent. "Strongly agree" scored zero percent. With a mean of 2.6 (mean < 3.0), a standard deviation of 0.5, and a variance of 0.4, the overall satisfaction of public bus transport services has been unsatisfactorily perceived by passengers in the city.

The specific service quality attributes of public bus transport services that affect passenger satisfaction were also poorly perceived (Table 3). For instance, variable S1 (seats are generally available in buses), with a mean score of 2.2 (mean < 3.0), a standard deviation of 0.3, and a variance 0.1, recorded 53.7 percent under "disagree" and 18.3 percent under "strongly disagree," for a total of 72 percent for both. "Undecided" and "agree" scored 21.7 percent and 6.3 percent, respectively, and "strongly agree" scored zero percent. Variable S15 (buses provide short travel time) recorded 55.7 percent for "disagree" and 12.7 percent for "strongly disagree." The scores for "agree" and "undecided" were 26 percent and 5.3 percent, respectively; "strongly agree" was 0.3 percent with the mean score of 2.5 (mean < 3.0), a standard deviation of 0.3, and a variance of 0.2.

Table 3. Absolute and Relative Frequency Distribution of Satisfaction and Quality of Service Attributes Responses (N = 300)

Variable Code	Variable Description	Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree		Mean	Std. Dev.	Variance
		#	%	#	%	#	%	#	%	#	%			
OS	Overall satisfaction with public bus transport services	0	0	88	29.3	50	16.7	101	33.7	61	20.3	2.6	0.5	0.4
S1	Seats are generally available in buses	0	0	19	6.3	65	21.7	161	53.7	55	18.3	2.2	0.3	0.1
S2	Enough leg-space in buses	4	1.3	17	5.7	67	22.3	149	49.7	63	21	2.4	0.4	0.2
S3	High frequency of bus service	6	2	35	11.7	75	25	154	51.3	30	10	2.5	0.5	0.3
S4	Short waiting time for buses	0	0	6	2	40	13.3	160	53.3	94	31.4	2.5	0.4	0.2
S5	Facilities inside buses are in good condition	0	0	17	5.6	44	14.7	158	52.7	81	27	2.6	0.5	0.3
S6	Bus stops have enough shelters	10	3.3	40	13.3	30	10	151	50.3	69	23	2.9	0.4	0.3
S7	Ceiling heights of buses are comfortable	25	8.3	70	23.3	57	19	141	47	7	2.2	2.8	0.4	0.2
S8	Buses are well maintained	0	0	44	14.7	4	1.3	164	54.7	88	29.3	2.4	0.3	0.2
S9	Short passenger walking distance to nearest bus stops	56	18.7	69	23	22	7.3	138	46	15	5	3.0	0.5	0.2
S10	Sufficient benches available at bus stops	4	1.3	38	12.7	39	13	162	54	57	19	2.1	0.5	0.3
S11	Sufficient number of buses in city	3	1	16	5.3	87	29	128	42.7	66	22	2.4	0.4	0.1
S12	Transport price is affordable	20	6.7	87	29	92	30.7	84	29.9	17	5.7	3.0	0.4	0.2
S13	Safety of passenger on board	45	15	163	54.3	2	0.7	80	26.7	10	3.3	3.5	0.6	0.4
S14	Not afraid of being pickpocketed on board	25	8.4	99	33	73	24.3	64	21.3	39	13	3.0	0.3	0.2
S15	Buses provide short travel time	1	0.3	78	26	16	5.3	167	55.7	38	12.7	2.5	0.3	0.2
S16	Drivers and conductors behave well	36	12	117	39	68	22.7	52	17.3	27	9	3.20	0.6	0.4
S17	Buses are clean inside	3	1	24	8	36	12	151	50.3	86	28.7	2.8	0.7	0.5

Only two variables met the expectation of passenger satisfaction of public bus transport services in the city of Abuja. The first, variable S13 (safety of passengers on board), with a mean of 3.5 (mean > 3.0), a standard deviation of 0.6 and a variance of 0.4, scored 54.3 percent under “agree” and 26.7 percent for “disagree.” “Strongly agree” and “strongly disagree” scored 15 percent and 10 percent, respectively; “undecided” scored 0.7 percent. The second variable, S16 (drivers and conductors behave well), also scored a mean of 3.20 (mean > 3.0), a standard deviation of 0.6, and a variance of 0.4. “Agree” scored 39 percent, “undecided” scored 22.7 percent, “strongly agree” scored 12 percent, “disagree” scored 17.3 percent, and “strongly disagree” scored 9 percent. Passengers/respondents were found to be undecided on three variables: S9 (short passenger walking distance to nearest bus stop), with the mean of 3.0 (mean = 3.0), a standard deviation of 0.5, and a variance of 0.2; S12 (transport price is affordable), with a mean of 3.0 (mean = 3.0), a standard deviation of 0.4, and a variance of 0.2; and S14 (personal security on board), with a mean of 3.0 (mean = 3.0), a standard deviation 0.3, and a variance of 0.2.

The frequency distribution is presented in Figure 3, showing that out of 17 variables analysed, 13 service quality attributes of public bus transport service in the city of Abuja were unsatisfactorily perceived by passengers. Only two variables (S13 and S16) met the expectation of the passengers, and passengers were undecided on variables S9 and S14. The conclusion from the analysis is that, generally, passengers of public bus transport are not satisfied with the services provided in Abuja.

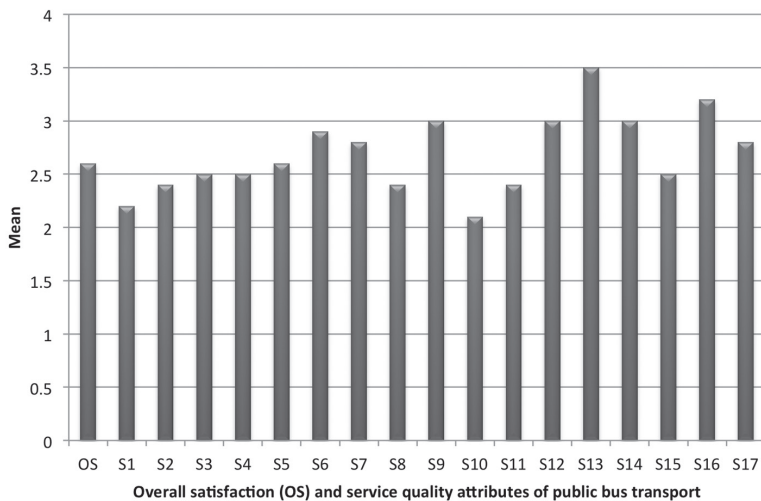


Figure 3. Frequency distribution of overall satisfaction (OS) and service quality attributes

Principal Component Analysis

The 17 service quality attributes plus the overall satisfaction were transformed into a matrix of inter-correlation between the variables to know the strength of their correlations. Observation from the correlation matrix (not shown in this paper) shows that there are strong inter-correlations between the variables, which accounted for the existence of many redundancies among some variables. To remove the effect of these strong inter-correlations, as well as include the contributions of the apparently redundant (weakly correlating) variables, PCA was employed to collapse the 17 specific service quality attributes of public bus transport services into a few orthogonal factors that could define broader areas for planning and action by the shareholders in the provision of public bus transport services in the city.

The results of the analysis of the varimax rotated components are presented in Table 4, which succeeded in reducing the 17 variables to 4 components. The 4 components together explain 83.87 percent of the total explained variance, leaving 16.13 percent unexplained due to other factors not included in this analysis.

Component 1 has an eigenvalue of 4.30 and accounts for 30.47 percent of the total explained variance. The component has high positive loadings on S2 (enough leg-space-in buses), S5 (facilities inside buses are in good condition), S7 (ceiling heights of buses are comfortable), S8 (buses are well maintained), and S17 (buses are clean inside). These variables describe conditions in buses that affect passenger satisfaction. Thus, component 1 is identified as “comfort in buses.”

Component 2 has high and significant positive loadings for S3 (0.760), S4 (0.813), S9 (0.644), and S15 (0.802). It generally describes service quality attributes affecting passenger satisfaction in getting access to use public bus transport to get to their destinations in the city. Component 2 is then identified as “accessibility to public bus transport services.” It has an eigenvalue of 3.38 and accounts for 22.13 percent of the total explained variance.

Component 3 has positive loadings on S6 (bus stops have enough shelters) and S10 (sufficient benches are at bus stops), with an eigenvalue of 2.72, and it accounts for 16.32 percent of the total explained variance. Component 3 describes the facilities at bus stops in the city. It is, therefore, identified as “bus stop facilities.”

Component 4 has an eigenvalue of 2.24 and accounts for 14.95 percent of the explained variance; it has positive loadings on S1 (seats are generally available in buses) and S11 (sufficient number of buses in the city). Component 4 generally

describes the capacity of public bus transport in Abuja. Component 4 is identified as “adequacy of the capacity of public bus transport services.”

Table 4. Result of Varimax Rotated Principal Components Matrix for Service Quality Attributes of Public Bus Transport Services in Abuja

Variable Code	Variable Description	Components			
		1	2	3	4
S1	Seats are generally available in buses	0.463	0.216	0.028	0.703*
S2	Enough leg-space in buses	0.812*	0.431	0.098	0.040
S3	High frequency of bus services	0.314	0.760*	0.309	306
S4	Short waiting time for buses at bus stops	0.406	0.813*	0.470	0.008
S5	Facilities inside buses are in good condition	0.842*	0.473	0.101	0.441
S6	Bus stops have enough shelters	0.277	0.108	0.782*	0.201
S7	Ceiling heights buses are comfortable	0.722*	0.213	0.240	0.111
S8	Buses are well maintained	0.874*	0.114	0.524	0.089
S9	Short passenger walking distance to bus stops	0.517	0.644*	0.123	0.180
S10	Sufficient benches are available at bus stops	0.308	0.266	0.810*	0.283
S11	Sufficient number of buses in city	0.215	0.541	0.117	0.646*
S12	Transport price is affordable	0.307	0.484	0.414	0.428
S13	There is safety of passenger on board	0.331	0.401	0.567	0.529
S14	Not afraid of being pickpocketed on board	0.487	0.291	0.488	0.510
S15	Buses provide short travel time	0.520	0.704*	0.318	0.272
S16	Drivers and conductors behave well	0.389	0.491	0.504	0.008
S17	Buses are clean inside	0.802*	0.185	0.104	0.0308
Eigenvalue		4.30	3.38	2.72	2.24
% explained		30.47	22.13	16.32	14.95
Cumulative %		30.47	52.60	68.92	83.87

*Significant loadings are 0.60

1 = Comfort in buses

2 = Accessibility to public bus transport services

3 = Bus stop facilities

4 = Adequacy of capacity

The internal consistency for each of the factors along with the measures of satisfaction were examined using Cronbach’s alpha (α). The alphas showed a high reliability (0.80), which exceeded the value of 0.70 recommended by Nunnally (1978). Table 5 depicts the correlation among underlying factors identified. As can be seen

from Table 5, there is a low correlation between different underlying factors, the highest being 0.383 (between “bus stop facilities” and “adequacy of capacity of public bus transport services”). This means that all the four underlying factors are independent, which indicates that they are measuring unrelated dimensions. The results provide statistical evidence to support the identified underlying dimensions/determinants of passenger satisfaction as comfort in buses, accessibility to public bus transport services, bus stop facilities, and adequacy of the capacity of public bus services.

Table 5. Factor Correlation Matrix

Factor	Comfort in Buses	Accessibility to Public Bus Transport Services	Bus Stop Facilities	Adequacy of Capacity of Public Bus Transport Services
Comfort in buses	1.000	0.182	0.316	0.284
Accessibility to public bus transport services	0.182	1.000	0.289	0.342
Bus stop facilities	0.316	0.289	1.000	0.383
Adequacy of capacity of public bus transport services	0.284	0.342	0.383	1.000

Extraction method: Principal axis factoring. Rotation method: Oblimin with Kaiser normalization

The overall satisfaction scores were further regressed on the four underlying factors that affect passenger satisfaction in Abuja. This was done to evaluate their effects on the overall satisfaction. The results are presented in Table 6.

Table 6. Regression Model

Independent Variables	Unstandardized Coefficient		Standardized Coefficient	T	Sig (p)
	B	Std Error	Beta		
(Constant)	0.521	0.312		1.214	.067
Comfort in buses	0.276	0.131	0.285	2.293	0.032
Accessibility to public bus transport services	0.165	0.112	0.251	2.021	0.035
Bus stop facilities	0.068	0.053	0.069	0.864	0.102
Adequacy of capacity of public bus transport services	0.113	0.067	0.109	0.904	0.068

Adjusted R² = .681, F_{4,52} = 52.417, P < .001
 Dependent variable: Overall satisfaction

So, the satisfaction model of public bus transport services is described thus:

$$\begin{aligned} \text{Overall satisfaction} &= 0.52 + 0.29 (\text{comfort}) + 0.25 (\text{accessibility}) \\ &+ 0.07 (\text{bus stop facilities}) + 0.11 (\text{adequacy}) \end{aligned}$$

The interpretation to the above equation is that the slope of the regression line is significantly greater than zero, indicating that overall satisfaction tends to increase as the four underlying factors increase. The equation also shows that the overall satisfaction of public bus transport services by passengers in Abuja will be 0.52 percent when all 17 service quality attributes are at the zero level. Again, the standardized regression coefficient beta (β) values indicate that the underlying factor “comfort” has the greatest impact on passenger overall satisfaction of public bus transport services in Abuja. It is followed by “accessibility” ($\beta=0.251, \rho = 0.035$), “adequacy” ($\beta = 0.109, \rho = 0.068$), with “bus stop facilities” having the least impact ($\beta= 0.069, \rho = 0.102$). The explanation of the underlying components/factors is presented as follows.

Comfort

Apparently, the comfort level provided by Abuja city buses is a major element that leaves much to be desired, thereby reducing passenger perceived value and satisfaction with public bus transport services. This finding is in accordance with the findings of Straddling et al. (2007) and Andaleeb et al. (2007) that comfort has the greatest impact on passenger satisfaction. With the exception of some high-capacity buses serving only seven routes (for example, the Abuja First BRT, the green Nationwide Unity buses, and Abuja Urban Mass Transit buses), the operators/owners of other buses do not pay adequate attention to passenger comfort. The basic public bus passenger requirements, such as comfortable seats and open windows for airflow, do not measure up to the standards. A majority of public buses are minibuses, which do not provide adequate legroom or even adequate ceiling heights for standing. Passenger discomfort worsens during rush-hour traffic when many passengers have to travel standing all the way in extremely crowded conditions. The results suggest that if comfort can be increased, rider satisfaction may lead to increased patronage in the use of public bus transport services in the city of Abuja. Comfort is an important consideration for riders of public bus transport and, as such, basic standards for comfort must be established and monitored to ensure that the Abuja bus operators adhere to them.

Accessibility

Our model also identified poor accessibility to public bus transport services for a majority of riders in the city. Passengers perceived that bus routes, especially high-capacity bus routes, are not well spread in the city, which, according to riders, has reduced access to most destinations by bus for disadvantaged groups in the Nyanya, Gwagwalada, Karimo, Kuba, and Kuje areas of the city. This requires them to walk relatively long distances before getting to the nearest bus stops to catch a bus. Added to this physical accessibility constraint is the time accessibility constraint, which manifests itself in the long waiting times for buses experienced by many riders due to the low frequency of bus services, mainly caused by vehicle traffic jams. This situation will not encourage people (especially private car owners) to use public bus transport for their daily travels. This is because bus riders do not wish to walk very far to their bus stops, and having arrived at the bus stop, they do not wish to wait for very long (Faulks 1990).

Bus Stop Facilities

Abuja commuters are not provided with adequate bus stop facilities. Inadequate facilities at bus stops was identified by our model as another source of dissatisfaction of public bus passengers in the city. Very few bus stops (especially those in the city center area) offer appropriate physical structures and facilities for riders. Many bus stops (especially those outside the seven high-capacity bus routes) do not provide protection (shelters) for passengers from sun, rain, dust, pollution, and other basic elements that have significant implications for health and safety. Moreover, passengers have no place to sit for a long wait at bus stops, so there is no alternative but to remain standing. Unless these situations are corrected, expecting private car owners to use public bus transport will not materialize. The effects are that Abuja will continue to clog up, and this situation will be exacerbated in future as the city's population continues to grow. The opportunity costs of the traffic jams are incalculable.

Bus Capacity Adequacy

Passengers also perceived inadequacy of the capacity of public bus services to serve their needs as a factor that reduced their satisfaction. There is a problem of capacity in public bus transport services in the city of Abuja. The lack of availability of sufficient numbers of buses (especially high-capacity buses) is reflected in the long waiting lines and times, the frantic struggle to board a bus upon its arrival at most stops, and the lack of seating capacity in the buses. If a sufficient number of buses are provided for the Abuja commuters, enabling them to reach their destinations

comfortably and on time, it will interest more people to use buses for their daily traveling needs.

Conclusions and Recommendations

This study has shown that passengers are not satisfied with the public bus transport services provided by operators in Abuja. The contribution of this study is the identification of factors that determine passenger satisfaction with the quality of services provided by public bus transport operators in Abuja. The determinants (underlying factors) identified are comfort in buses, accessibility to public bus transport services, bus stop facilities, and adequacy of bus capacity. The study thus provides a direction for public bus transport administration in the city whereby areas for improving services may be identified and passenger satisfaction of public bus transport services may be enhanced.

Based on the findings, we make the following recommendations. Comfort is a huge passenger priority and, as a result, basic standards for bus passenger comfort must be established and monitored by FCT to ensure that the operators abide by them. The six Area Council Governments that make up the FCT should partner with the FCT administration in the provision of buses for intra-city transport services so as to increase bus service frequency and reduce passenger waiting time and walking distance in the area, especially at the peripheries of the city. Like Lagos, “dedicated bus lanes,” also known as Bus Rapid Transit (BRT), should be established in Abuja to reduce bus travel time and increase service frequency. This will encourage more people (including private vehicle owners) to use the bus transport system, thereby reducing the number of vehicles on city roads. The government should construct more city link roads, especially in the peripheries of Abuja, and should maintain the existing ones to increase accessibility to encourage bus operators to provide more services to more areas in the city. FCT administration should be faithful to the terms of the public-private partnership agreement it entered into with the private sector in the provision of public bus transport services in the area to enhance private operator operation and serviceability standards required of them to increase passenger satisfaction. Shelters and benches should be provided at bus stops to provide protection from sun and rain for boarding and alighting commuters.

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Application of Simulation Method and Regression Analysis to Optimize Car Operations in Carsharing Services: A Case Study in South Korea

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Abstract

A carsharing service is a form of public transportation that enables a group of people to share vehicles based at certain stations by making reservations in advance. One of the common problems of carsharing is that companies can have difficulty optimizing the number of vehicles in operation. This paper reports on investigations of the relationship between the number of cars and the number of reservations per day with either the acceptance ratio or utilization ratio based on the commercially-operational dataset of a carsharing company in Korea. A discrete event simulation is run to analyze a round-trip service for every possible number of cars and number of reservations with the output acceptance ratio and utilization ratio. The simulation data revealed that increasing the number of reservations with respect to a certain number of cars will decrease the acceptance ratio, thus increasing the percentage of the utilization ratio. Based on the simulation data results, a rational regression model can achieve high precision when predicting the acceptance ratio or the utilization ratio compared to other prediction algorithms such as the Multi-Layer Perceptron (MLP) and the Radial Basis Function (RBF) models. K-means clustering was

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used to understand the pattern and provide additional policies for carsharing companies. Consequently, opening a carsharing business is very promising in terms of profit, escalating the level of customer satisfaction. In addition, a small reduction in the utilization ratio by operators will create a large increase in the acceptance ratio.

Introduction

As the world population grows, private vehicles are becoming more attractive, leading to high energy consumption and high vehicle emission levels. Carsharing is one of the transportation strategies that can reduce personal transportation usage and its negative impacts. Because of the worldwide environmental benefits involved, carsharing evolved out of the economic motivations of individuals who could not afford to purchase a vehicle into a mainstream, worldwide transportation system. In recent carsharing systems, customers can access the portal of a carsharing company and easily make a reservation via an Internet connection or by phone. The information, including traveled distances and rent duration, is recorded and charged as to the customer's bill. An intelligent transportation system can play an important role in making a carsharing system user-friendly, easy to manage, and efficient.

Because of these benefits, carsharing as an alternative transportation paradigm has become increasingly popular in many countries (Barth and Todd 1999). Previous research has demonstrated that the benefits of carsharing include reducing costs and the negative impacts of private vehicle ownership and the environmental impacts of auto usage (e.g., congestion, energy consumption, vehicle emissions, and inefficient land use). In North America, the impact of carsharing includes the reduction of emissions as a result of less driving and a 27 percent reduction in the average number of observed vehicle kilometers traveled per year (Martin and Shaheen 2011). According to another review, an additional benefit is cost savings, which was reported to be the main motivation for new memberships from 2006 to 2010. In addition, there has been a change in carsharing activity, as can be seen from the number of worldwide carsharing memberships. In 2006, Europe was the epicenter, but it shifted to North America in late 2010. Stabilized growth in neighborhood residential carsharing and rapid growth in the business and university markets in North America from 2006–2011 was the key trigger. Importantly, there was a worldwide increase in the number of carsharing memberships and in total vehicles and member-vehicle ratios from 2006–2010. As carsharing increasingly becomes a mainstream transportation mode, it is expected that it will be further

integrated into metropolitan transportation, land use strategies, and multimodal nodes (Shaheen and Cohen 2013).

Up-to-date carsharing systems enable a car to be driven among multiple stations (one-way service), whereas traditional service (round-trip/two-way) allows users to use a car and return it to the same station only. Although one-way service can provide convenience for customers, the cars from each station become disproportionately distributed. Thus, a strategy of vehicle relocation is necessary to elevate the satisfactory level of users. A carsharing system must be efficient, user-friendly, easy to manage, and advantageous to both companies and customers (Barth et al. 2001).

Studies concerning data mining have been intensively conducted in carsharing-related research areas. In particular, the forecasting technique is used to predict the net flow of vehicles in a three-hour period by using neural networks and support vector machines (SVM) (Cheu et al. 2006), and the results show that multilayer perceptron has slightly better accuracy compared to SVM. In another case, such as the one-way type, it is difficult to maintain the distribution balance of parked vehicles among stations. A method for the optimization of vehicle assignment is used according to the distribution balance of parked vehicles; thus, it is possible to maintain distribution balance of parked vehicles and keep the convenience of the carsharing system (Uesugi et al. 2007).

In regard to car optimization, one study shows an international comparison regarding carsharing services (Shaheen and Cohen 2007). The paper shows that the member-vehicle ratio is an important key factor that characterizes worldwide carsharing operations. The comparison demonstrates that the member-vehicle ratio based on the survey of each country is different; Asia, Australia, Europe, and North America are 26:1, 17:1, 28:1 and 40:1, respectively. The estimation for the average national ratios are approximately 20:1 and are lower in new markets where carsharing companies must first position their vehicles to gain membership. However, in other research (Morency et al. 2007; Habib et al. 2012; Costain et al. 2012), studies about user behavior in carsharing transaction data sets show interesting results. The data are from Communauto, Inc., a carsharing company in Montreal from January –December 2004. The result reveals that there is variability in the number of transactions and distance traveled by each customer. Another study (Costain et al. 2012) found that increasing the home-to-parking-lot distance reduces trip duration. Thus, it is important to evaluate the member-vehicle ratio with respect

to other parameters such as variability of the number of transactions, traveled distance, and traveled time by the customer.

Advanced simulations in carsharing have focused on developing a relocation model to evaluate one-way car availability (Kek et al. 2009). In addition, a forecasting model for relocation has been suggested to optimize the results of relocation and predict efficient routes (Cheu et al. 2006; Wang et al. 2010; Karbassi and Barth 2003; Correia and Antunes 2012). However, to implement those models, it is important for carsharing companies to decide first on the initial vehicles before focusing on relocation models. Because it is difficult to predict the initial number of cars needed without losing customer interest and company profits, this paper aims to demonstrate that a simulation model must be developed first to evaluate the acceptance ratio and utilization ratio for traditional, round-trip services based on traveling frequency, number of vehicles, and Vehicle Hours Traveled (VHT) and Vehicle Kilometers Traveled (VKT) patterns.

Two output parameters were used in this paper. The first was the acceptance ratio, which can be simply explained as successful reservations over total reservations made by customers; this parameter can be expected to reveal general customer satisfaction. The second parameter is the utilization ratio, which is the percentage of total actual driving hours of rented cars over the total possible driving hours of cars, which elucidates company profits. Later, the simulation data results are analyzed using regression and other forecasting techniques to generate a prediction model. This paper aims to focus on how to develop a model that can be used to optimize the number of cars needed with respect to a certain number reservations per day, time patterns, and thresholds of either the acceptance ratio or the utilization ratio.

Section 2 of this paper provides an overview of the results of the literature review. Section 3 describes the methodology of the simulation and algorithm analyses. Results and a discussion of the proposed model in are presented in section 4, and limitations and future research of this paper are discussed in section 5.

Background

Carsharing Service

Carsharing services can be placed under shared-use vehicle system models based on the similarities in types and models of service. A shared-use vehicle system consists of a vehicle that is used by several groups of people throughout the day. To create a formal structure, previous research developed a classification system

for evaluating various models. Generally, the classification of shared-use vehicle systems consists of neighborhood carsharing, station cars, multi-nodal shared-use, and hybrid models. Carsharing—or what is traditionally referred to as neighborhood carsharing—began in Europe and placed a network of vehicles in strategic parking areas (mostly in residential neighborhoods) located throughout denser cities. The second type is the station cars model, in which typical car stations are placed at major rail stations along a commuting corridor, thus enhancing transit connectivity and providing a convenient way to access a user's home or work from the public transit station. Another model is the multi-nodal shared-use model, which allows customers travel from one center to another, as in, at resorts, recreational areas, and corporate university campuses. The trips are more likely to be one-way service. The hybrid model or the future of the shared-use vehicle system has the characteristics of many of these systems. In the hybrid system, the vehicles used may be linked to transit (referred to as station cars) and left at transit stations and could also be used for several other purposes such as daily-use trips of both a business and a residential nature (Barth et al. 2002).

The history of successful experiences of carsharing began in Europe in the mid-1980s, and carsharing organizations in Europe are now firmly established and on steep growth trajectories. Meanwhile, the North American experience with carsharing is far more limited. One of the formal carsharing demonstrations in the United States was Mobility Enterprise, operated as a Purdue University research program from 1983 to 1986. As carsharing emerges, researchers have concluded that operators are more likely to be economically successful when they provide a dense network and a variety of vehicles; serve a diverse mix of users; create joint-marketing partnerships; design a simple, flexible rate system; and provide easy emergency access to taxis and long-term car rentals (Shaheen et al. 1998).

Carsharing services represent an intermediate service that bridges public transportation and private vehicle ownership to reduce the number of cars, provide cost savings, and reduce parking demand, among other benefits. To clarify, carsharing was first implemented in Europe but has gained popularity in North American cities (Cervero and Tsai 2004; Zhou and Kockelman 2011) and Asia, including Singapore and Japan. Basically, members subscribe to a carsharing company and are able to use cars by making reservations in advance. The vehicle is picked up at the start of the trip and returned to the original station at the end of the trip (two-way or round-trip). Members pay a fee each time they use a vehicle, which covers the cost of vehicle use, insurance, maintenance, and fuel. An example, a carsharing

study in the U.S. was a pilot program called CarLink, which categorized users as home-based users, work-based commuters, and work-based day users. During the field test, each group paid a different fee according to the duration of usage. All user fees included fuel, insurance, and maintenance costs (Shaheen and Wright 2001). A carsharing company generally offers different service options based on these categories. The service options generate different benefits and satisfy each member's requirements.

South Korea is a densely populated country in East Asia with about 48 million inhabitants. The process of rapid industrialization over the last few decades has transformed South Korea into an economic hub of Asia. One of the factors that has always played an important role in influencing the formation of urban societies is transportation. Advances in transportation have made possible changes in our way of living and the way in which societies are organized, and they, therefore, have a great influence in the development of civilizations. The big challenge for the implementation of carsharing services in South Korea, especially in Seoul, is public transportation, because most Koreans use public transportation. Information released by Seoul Metro about the transport mode share in Seoul reveals that the subway, city buses, and passenger cars have market shares of 34.7, 27.6, and 26.3 percent, respectively, and the rest comprises taxis, with a total number of daily passengers of about 4.04 million people (Seoul Metro 2011). To address real situations, one research project and paper has been published about carsharing as one of the product service systems that defined a service blueprint for carsharing in Korea (Yoon et al. 2012). The research revealed that a new carsharing service model is applicable to South Korea because it would foster sustainable development while reducing traffic problems and air pollution. The Korean carsharing service model interfaces with a public transport system for increasing mobility. It serves people who are not sufficiently mobile. Therefore, car-sharing stations need to be installed at transport interchanges and in areas with low access to public transportation.

The first pilot program of carsharing in South Korea began by offering round-trip service from November 2011 to June 2012 to and from the campus of Dongguk University. The pilot program was implemented to minimize the negative impact of the first carsharing market in South Korea. In addition, similar to the CarLink pilot program in the U.S., it was important to run a pilot program first before progressing to a larger market area. Previous research has revealed that the success of pilot programs will lead to the success of continuous programs, and this is main reason that pilot programs must be developed first in South Korea. In the campus

pilot program, the operator offered off-road parking in the general campus area and parking lots in residential areas nearby. The program attracted approximately 500 total customers, which consisted of staff members, students, and residents near campus.

Upon first implementing the pilot program, the proportion of residential users was small because of the limited number of parking lots near the campus and the limitation of service promotions, while the biggest users were staff members and students, respectively. The type of car that was offered was a small, domestic type, with a total of 50 cars. The member-vehicle ratio upon start-up was about 10:1 in order to gain membership. During the field test, each member paid a fee based on the duration of car use (a combination of distance and time), and all user fees included fuel and maintenance costs. The Dongguk campus program combined short-term rental vehicles with communication and reservation technologies (i.e., an automated reservation system by website and phone, GPS for vehicle tracking, and smartcards for vehicle access) to facilitate easy access. In addition to vehicle support services, staff supported the program with cleaning and maintenance and by maintaining the customer service via phone.

Korea Carsharing is the first carsharing company in South Korea that successfully transferred a pilot program to a larger area once the initial pilot program was completed. The program was successful in upgrading the quality of service by identifying the need for increasing public area parking lots and identifying hardware and software problems during the pilot program. Currently, the number of stations is increasing as an improvement in carsharing services in South Korea, and the primary focus of services is on residential, business, and public venues, as seen in the increase in residential customers, with a total number of 1,000 members. As the number of customer has increased, the user type has changed from mostly on-campus staff and students to business users and residential users. The emergence of carsharing services in South Korea involves the government and automobile manufacturers who are quite active in helping to sponsor programs. The increase in memberships required the development of integrated carsharing technologies, such as upgrading the system for coordinate vehicle tracking, and a reservation system (WeShareCar 2013). Reservations by smartphone now enable members to make reservations, and, thus, technology is able to enhance service capabilities.

Methodology

Simulation Model

A simulation approach is a process to design and conduct experiments for the purpose of understanding system behavior or evaluating various strategies for the operation of the system. A good solution from the results of the simulation is recommended for implementing a new system. In a discrete-event simulation, the operation of a system is represented as a chronological sequence of events. Each event occurs at an instance in time and marks a change of state in the system. The structural components of a discrete event simulation include entities, activities and events, global variable, random number generators, and calendar. The idea of a discrete event simulation is that the clock jumps to the next event as the simulation proceeds (Ingalls 2001).

A simulation approach is used for testing the relocation techniques, namely shortest time and inventory balancing (Kek et al. 2006). Shortest time relocation involves a process to move a car from a neighboring station in the shortest possible time. Inventory balancing relocation is an approach to moving a car to a station that has a shortage of cars from another station that has an oversupply of cars. Another simulation study proposed a static relocation to move a car immediately after a customer requests one (Barth and Todd 1999). In particular, a forecasting model has been implemented to predict the net flow of vehicles in a three-hour period by using neural networks and support vector machines (Cheu et al. 2006). The results of the simulation experiment demonstrate that all of the aforementioned techniques have the potential to improve carsharing services in a realistic situation. In general, the simulation implementation will greatly assist a carsharing company in evaluating its policies before implementing a service in a realistic situation.

In this paper, a simulation model that reflects a reservation algorithm is presented to evaluate round-trip service only, which allows customers to use a car and return it to the same station. A comparison could not be presented in this paper of the acceptance and utilization ratios for other services such as one-way and open-ended services, which offer flexibility to users without identifying the ending time for a reservation (Schwieger and Wagner 2003). The simulation tool for a carsharing reservation system has been designed to be as realistic as possible. The reservation acceptance and car utilization ratios are presented to evaluate round trips for every possible number of cars and number of reservations. The car utilization ratio is very important for a carsharing company to optimize operation time, which can improve profits and reduce operational car costs. The reservation acceptance ratio

is important to customers, and it can provide a benchmark for revealing customer satisfaction. Thus, the number of initial cars must be chosen carefully with respect to the thresholds of the acceptance and utilization ratios.

First, artificial data are generated, using a trip generator based on customer travel demand distribution (VKT, VHT, time of day, day of week). Second, the artificial data are simulated with a simulation tool to evaluate round-trip service for every combination of the number of cars and the number of reservations. Finally, the simulation results are presented and are analyzed with prediction techniques to define the proposed model.

Regression Analysis

Multiple Linear Regression

Multiple linear regression attempts to model the relationship between the dependent variable and one or more independent variables, by fitting a linear equation to the observed data. The goal of regression analysis is to model the expected value of a dependent variable \hat{y} in terms of the value of an independent variable (or vector of independent variables) x . In simple linear regression, the model the dependent variable (\hat{y}) is given by:

$$\hat{y} = \beta_0 + \sum_{i=1}^l \beta_i x_i + \epsilon \quad (1)$$

where x_i ($i = 1, \dots, l$) are the explanatory independent variables, β_i ($i = 1, \dots, l$) are the regression coefficients, and ϵ is the error associated with the regression and assumed to be normally distributed with both the expectation value of zero and constant variance (Agirre-Basurko et al. 2006). Multiple regression has been implemented in many areas, such as building areas (Catalina et al. 2008) and brain research areas (Klein et al. 2005), and has shown good prediction models.

Polynomial Regression Analysis

Polynomial regression is nonlinear, which describes the relationship between any set of independent and dependent variables. The polynomial regression model, which contains more than two predictor variables, is called MPR (Multiple Polynomial Regression) (Zaw and Thinn 2009). Polynomial regression models are usually fit using the method of least squares. The least-squares method minimizes the variance of the unbiased estimators regarding the coefficients, under the conditions of the Gauss–Markov theorem. In general, we can model the expected value of y as an n -th order polynomial, yielding the general polynomial regression model.

$$\hat{y} = a_n x^n + a_{n-1} x^{n-1} + \dots + a_2 x^2 + a_1 x + a_0 \tag{2}$$

Rational Function

A rational function is a function f that is a quotient of two polynomials, that is, $f(x) = p(x)/q(x)$ where $p(x)$ and $q(x)$ are polynomials and where $q(x)$ is not the zero polynomial. The domain of f consists of all inputs x for which $q(x) \neq 0$. Typically, the rational model is a class of model description, which is nonlinear in the parameters. The following is a brief review of the work in the identification of nonlinear rational models.

$$\hat{y} = \frac{a_n x^n + a_{n-1} x^{n-1} + \dots + a_2 x^2 + a_1 x + a_0}{b_m x^m + b_{m-1} x^{m-1} + \dots + b_2 x^2 + b_1 x + b_0} \tag{3}$$

with n denoting a non-negative integer that defines the degree of the numerator and m is a non-negative integer that defines the degree of the denominator. For fitting rational function models, the constant term in the denominator is usually set to 1. Rational functions are typically identified by the degrees of the numerator and denominator. For example, a quadratic for the numerator and a cubic for the denominator is identified as a quadratic/cubic rational function (Dette et al. 1999; Zhu 2005).

Multilayer Perceptron Neural Network

Multilayer perceptron (MLP) has to be configured such that the application of a set of inputs produces (either “direct” or via a relaxation process) the desired set of outputs. The ANN learning algorithm used here is back propagation. Various methods to set the strengths of the connections exist. One way is to set the weights explicitly, using a *priori* knowledge. Another way is to “train” the neural network by feeding it teaching patterns and letting it change its weights according to some learning rule. During this process, inputs are fed forward from the input layer and through the hidden layers, and, ultimately, the network provides its output, which for an untrained network is different from the known target output. The training process consists of estimating weights, which minimize deviations between network outputs and actual data. The deviations are then propagated backwards through the network and weights are adjusted to reduce error. Here, three layers were used in the ANN: input, hidden, and output layers. The detail explanations about MLP are described elsewhere and are not repeated here (Larose 2005; Krose and Van Der Smagt 1996).

Radial Basis Function Network

The Radial Basis Function (RBF) network emerged as a variant of the artificial neural network in the late 1980s. However, their roots are entrenched in much older pattern recognition techniques as, for example, potential functions, clustering, functional approximation, spline interpolation, and mixture models. The construction of an RBF network in its most basic form involves three entirely different layers. The input layer is made up of source nodes (sensory units). The second layer is a hidden layer realizing the radial basis function with high enough dimensions, which serves a different purpose from that in a multilayer perceptron. The output layer supplies the response of the network to the activation patterns applied to the input layer. The transformation from the input space to the hidden unit space is nonlinear, whereas the transformation from the hidden unit space to the output space is linear. The detail explanations about the RBF network are described elsewhere and are not repeated here (Zhao et al. 2010; Li et al. 2010).

Data Collection and Analyses

The best way to investigate the impact of carsharing in detail is through targeted sample data collection. Therefore, this paper presents the results of an investigation of carsharing user behavior through the examination of the dataset from a carsharing service in South Korea. Although the choice of information used in this study is limited by data availability, sufficient information is available to investigate key issues of interest. The aforementioned Dongguk pilot program was successfully implemented in the campus area and has now become one of the stations for Korea Carsharing. For the simulation, the data distribution must be set to obtain good results, and, thus, the input parameters were collected based on the carsharing pilot program that operated from November 2011 to June 2012. More details on the input parameters are shown in Table 1.

Based on the Korean Carsharing pilot program dataset, the traveling time of customers is between 30 minutes and 6 hours. Customers traveling for less than 30 minutes prefer to use a taxi service; for 6 hours or more hours of travel, customers prefer to rent a car. VHT and its distribution can be seen in Figure 1(a). The dataset reveals that the average VHT by customers is 2–3 hours. The dataset provides detail about the trip behavior of the carsharing member, and it is interesting to note that trips are made by carsharing members throughout the whole day. The information in the dataset indicates that time of day distribution is grouped into three clusters: morning, afternoon, and night. It reveals that the majority of trips are made at night, beginning immediately after the end of Korean work time at around 6 PM

and lasting until midnight, with the average time being 9 PM, as seen in Figure 1(c). VKT illustrates that the majority of trips made by carsharing members are short-distance trips of less than 100 km, and the average is 20–30 km. Details are shown in Figure 1(b).

Table 1. Input Parameters

Input Parameters	Values
Total operated cars	Start with 5, increase until 100
Total stations	Automatically generated, depends on number of cars (1 station has about 5 cars)
Operation time	1 week, 24 hours per day
Service	Round-trip
Reservation per day	Start with 5, increase until 2,000
VHT (Vehicle Hours Traveled)	Between 30 minutes to 6 hours, with distribution
VKT (Vehicle Kilometers Traveled)	Between 5–120 km, with distribution
Time of day	Distribution of customer reservations in 24 hours

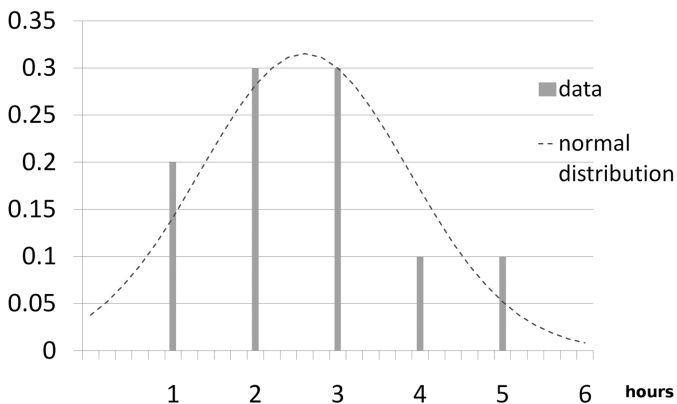


Figure 1a. Customer travel patterns

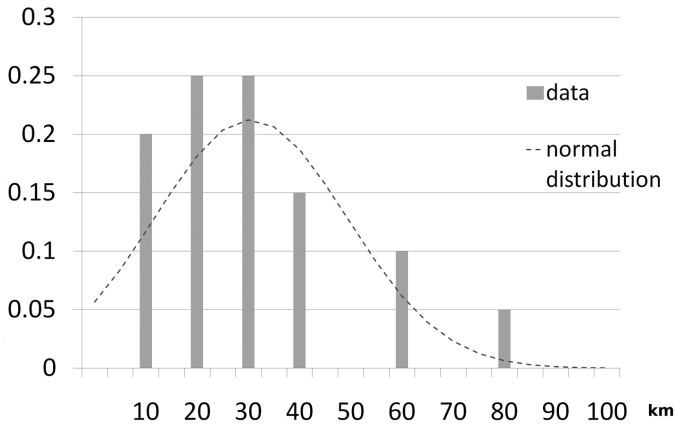


Figure 1b. Customer travel patterns

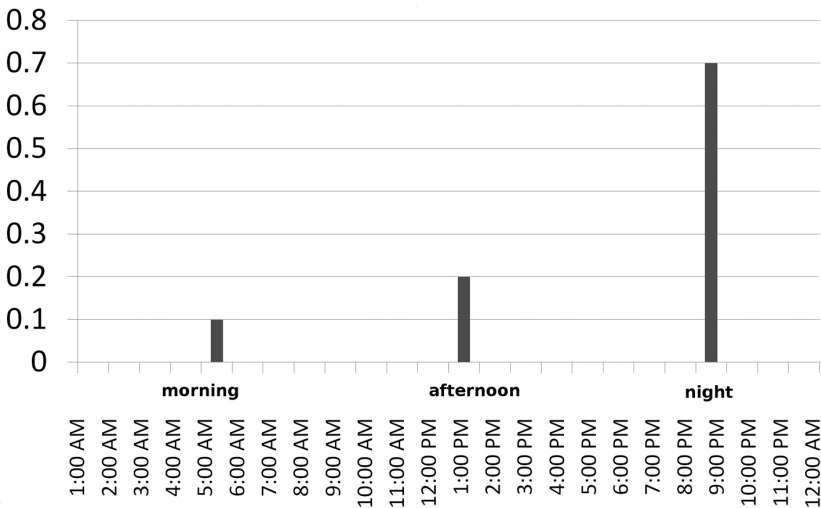


Figure 1c. Customer travel patterns

In addition, to understand the trip behavior of carsharing members, Figure 1d presents the week distribution of the trips. The result shows that the major peak occurs on the weekends, which mean customers prefer to travel during the weekend, starting from Friday night around 6 PM until Sunday midnight. In terms of the

day of the week, the percentage of trips is lowest at the beginning of the week and increases as the week progresses.

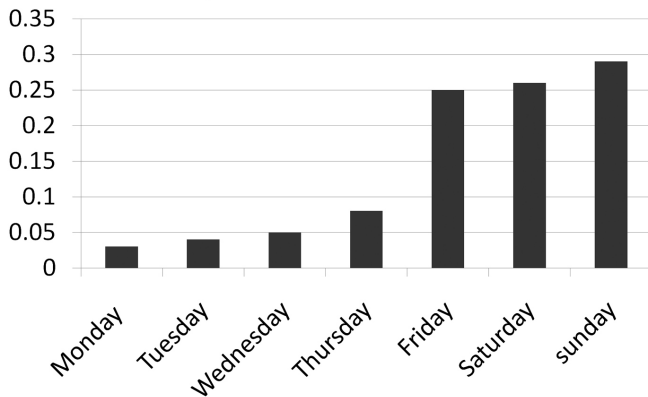


Figure 1d. Customer travel patterns

A trip generator was developed to transform the time of day, VHT, VKT and the week-long distribution into artificial reservation data based on these distributions (see Figure 1) for every number of reservations in a week. In this paper, we focused only on one dataset for investigating carsharing behavior; therefore, the use of similar datasets with different distributions from other companies would contribute to an increase in understanding but would generate different simulation data results. However, there is a similarity in the distribution of trips between a Toronto case study (Costain et al. 2012) and our dataset regarding trip length distribution and day of the week. In the Toronto case study, more than 60 percent of trips were less than 40 km, whereas in our dataset, trip length was mostly 10–40 km. This indicates that carsharing contributes to an increase in short-distance urban auto trips in Seoul and Toronto, and this is also true in other cities around the world (Morency et al. 2007; Zhou and Kockelman 2011). In addition, there is a similarity in day of the week distributions shown in the Toronto study. The percentage of trips is lowest at the beginning of the week and increases as the week continues, which is similar to our dataset in which major peaks occur on the weekends. Meanwhile, the time of the day shows a different pattern: in our dataset, peak travel occurred at night, whereas in the Toronto case study, the majority of trips were made between 9–11 AM, which is immediately after the morning peak period. These similarities illustrate that there are general patterns of customer usage among carsharing

operators in different parts of the world. Therefore, the simulation model that has been developed for this project can be used by other operators as a general benchmark of the relationship between utilization and acceptance ratios of operators.

In addition, the artificial reservation data are designed to be similar to a reservation table in a real carsharing system. Each record in a carsharing system database consists of a single reservation with a member identification number, vehicle identification number, transaction number, and the time and date (beginning and end of the reservation). This transaction table can be linked to other tables such as a member table, a car table (year, model, parking ID), and a parking lot table (capacity, location) (Morency et al. 2007). The artificial reservation table in this study consists of several columns (transaction number, member identification number, service identification number, vehicle identification number, beginning reservation, end of reservation, station to station, date of reservation, and calling time), which can be seen in Figure 2.

id_reservation	id_customer	id_service	numb_car	start_time	end_time	from_location	to_location	id_day	call_time	id_service_detail
1	13192	15	15	04:39:48	06:39:48	140	140	533527	01:04:47	33
2	11619	15	15	09:59:58	11:59:58	140	140	533527	01:22:56	33
3	13239	15	15	18:26:45	20:26:45	140	140	533527	18:06:19	33
4	12517	15	15	11:55:59	13:55:59	140	140	533527	04:49:59	33
5	12941	15	15	14:57:51	16:57:51	140	140	533527	05:40:41	33
6	11837	15	15	19:58:31	21:58:31	140	140	533527	16:37:09	33
7	12652	15	15	19:52:37	21:52:37	140	140	533527	09:47:18	33
8	12727	15	15	07:59:51	09:59:51	140	140	533527	05:34:34	33
9	12256	15	15	15:59:37	17:59:37	140	140	533527	11:59:05	33
10	13306	15	15	13:56:57	15:56:57	140	140	533527	03:55:55	33
11	11551	15	15	19:25:45	21:25:45	140	140	533527	03:18:25	33
12	13249	15	15	19:58:32	21:58:32	140	140	533527	15:27:20	33
13	12638	15	15	18:38:40	20:38:40	140	140	533527	05:16:13	33
14	12350	15	15	02:41:31	04:41:31	140	140	533527	01:28:30	33
15	12959	15	15	08:59:54	10:59:54	140	140	533527	06:54:53	33
16	11592	15	15	18:55:34	20:55:34	140	140	533527	02:44:32	33
17	12140	15	15	11:51:50	13:51:50	140	140	533527	09:45:20	33
18	12406	15	15	17:45:24	19:45:24	140	140	533527	15:33:07	33
19	12882	15	15	17:50:59	19:50:59	140	140	533527	04:50:58	33
20	12121	15	15	14:52:32	16:52:32	140	140	533527	09:40:25	33

Figure 2. Artificial reservation table

Selection of Output Variables for Simulation Model

Two outputs (car utilization ratio and reservation acceptance ratio) are defined in the simulation to evaluate the performance of round-trip service.

Company Car Utilization Ratio

The car utilization ratio is the percentage of total actual driving hours of rented cars over the total possible driving hours of cars per day. In addition, in this discrete-event simulation, the data are generated and simulated for one week. Since a car-sharing company normally wants to optimize the number of operation cars, the company needs to ensure that all cars can be rented (fully operated) to increase the profit and reduce operational car cost. Thus, the formula for calculating the utilization ratio in this simulation tool is:

$$\text{Car Utilization Ratio} = \frac{(\text{vehicle-hours of cars used})}{(\text{available vehicle-hours of entire fleet})}$$

Reservation Acceptance Ratio

The Car Acceptance Ratio is information on how many reservations are accepted over the total number of reservations. Accepted reservations mean that when a customer makes a reservation, the carsharing reservation system will check whether the customer can acquire an available car or not. If they receive an available car, and there is an empty space at a destination station, the reservation is accepted or, otherwise, rejected. Since the system does not suggest a customer to delay his/her reservation to get the other car, the customer is expected to find another reservation that has no conflict with others. In this paper, all reservations are assumed to be done by customers in a problem-free scenario, such as there is no conflict of destination stations when the cars are parked. This reservation acceptance ratio can provide the ideal situation to reveal customer satisfaction. The formula for calculating the car acceptance ratio in this simulation tool is:

$$\text{Acceptance ratio} = \frac{(\text{complete reservations})}{(\text{total reservations})}$$

Experimental Scenarios

A reservation algorithm that can handle reservations was implemented in the simulation tool and its data stored in the database. In this paper, the discrete-event simulation is implemented on the basis of structural components as shown in Table 2.

Table 2. Structural Component of Discrete Event Simulation

Component	Implementation
Entities	List of customers who intend to use car by making reservation in advance.
Events	Customer makes phone call for reservation, customer picks up car, drives car, then returns car to destination station.
Random number generator	Generates number of reservations to reservation table based on input distribution. Random number generator generates arbitrary names of customers who will make reservation and decide starting time, VKT, VHT by its distribution.
Queue (wait for an unspecified period)	Time for customer to pick up car and return it must be explicitly decided for queue activity.
Logic activity	Decision whether customer gets free car or not, depending on availability of car.
Global variable	Available to entire model for all times, e.g., station characteristics, operation time.
Calendar (list of events)	Assigned from calling time, starting time, and ending time from artificial reservation table.

This simulation tool will check the event from the calendar sequentially from the earliest event until the last event, and the simulation tool will implement the task based on the calendar. For instance, if the CurrentTime is 07.00 and that time is the actual calling time, the simulation tool will check if there is a car available at that time and, if at least one car is available, will assign a car to the reservation and change the status of that car from “Parked” to “Booked.”

In addition, if the CurrentEvent is at the starting time of a reservation, the simulation tool will change the status of the car from “Booked” to “On Road.” Moreover, if the CurrentEvent is at the ending time, the status of the car on the road is changed to “Parked” again. The reservation system in this simulation tool is basically the same idea as the common reservation system in carsharing services. The system checks customer reservations sequentially, and if there is a car available at a departure station, then it will assign the car to that reservation or it will be rejected (see Figure 3). The simulation tool is used for all 24 hours in a week for round-trip service regarding every step number of cars and reservations. At the end of the week, the simulation will show the average car utilization ratio and reservation acceptance ratio for a certain number of cars and reservations. All simulation results are collected and ready to be analyzed by the proposed prediction techniques.

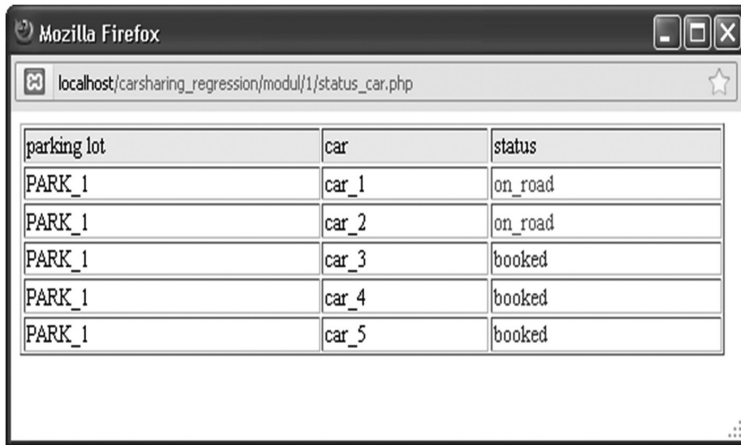
Mozilla Firefox
localhost/carsharing_regression/module1/process.php?mid_day=533527&start=yes&action=no

[Start][Pause][Reload]
total simulation time: 2700
iteration of simulation time: 10
Simulation time : 01:18:16
id reservation = 338813

ID	Reservation	Call time	End time	From	To	Service	Return	Time Service	Round Trip	Car	Customer
338813	01:18:16	12:27:24	16:27:24	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_438
338983	01:04:11	15:28:43	15:28:43	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_2	cust_905
339306	01:05:49	13:06:54	13:06:54	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_2	cust_747
339386	01:06:08	13:21:35	13:21:35	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_3	cust_548
339405	01:08:00	13:38:40	16:38:40	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_2	cust_1910
339221	01:10:51	01:49:59	04:49:59	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1615
338819	01:11:56	05:56:57	05:56:57	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_2	cust_841
338676	01:13:21	19:32:45	21:32:45	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1711
339028	01:15:33	13:36:58	17:36:58	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_3	cust_1259
338920	01:15:52	09:39:55	13:39:55	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_4	cust_910
338861	01:17:58	12:58:58	16:58:58	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_5	cust_409
338813	01:18:16	12:27:24	16:27:24	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_5	cust_438
339290	01:18:29	01:52:49	04:52:49	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1729
339074	01:19:08	10:57:41	14:57:41	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_79
339374	01:19:49	15:54:50	18:54:50	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_3	cust_718
338834	01:20:01	06:50:57	10:50:57	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_70
338961	01:20:48	04:34:48	08:34:48	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1680
338787	01:20:54	17:32:59	21:32:59	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_312
338869	01:22:12	09:34:16	13:34:16	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1406
339298	01:28:06	09:38:14	12:38:14	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_77
338844	01:28:33	13:32:34	17:32:34	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1074
338653	01:33:01	15:57:55	17:57:55	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1773
339230	01:35:26	12:44:31	15:44:31	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1709
338871	01:36:58	14:37:58	18:37:58	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_680
339231	01:37:37	06:40:39	09:40:39	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_584
339282	01:37:57	04:49:59	07:49:59	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1299
338663	01:39:28	12:46:41	14:46:41	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_16
339131	01:41:00	03:50:14	07:50:14	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_065
339342	01:41:19	05:57:22	04:57:22	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_140
339271	01:41:40	08:49:54	11:49:54	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1132
339007	01:42:12	12:49:13	16:49:13	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_566
338805	01:44:57	04:54:58	08:54:58	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1187
338805	01:44:57	04:54:58	08:54:58	PARK_1	PARK_1	Specified	Return	Time Service	Round Trip	car_1	cust_1187

Waiting for localhost...

Figure 3a. Reservation simulation



parking lot	car	status
PARK_1	car_1	on_road
PARK_1	car_2	on_road
PARK_1	car_3	booked
PARK_1	car_4	booked
PARK_1	car_5	booked

Figure 3b. Reservation simulation

Training and Testing Procedure

In this paper, the accuracy of the proposed prediction techniques was tested and compared with each other. There were two possibilities when developing the model. First, the model is too simple and not able to learn the specificities of the data (underfitting) and second, it is too complex and will learn irrelevant details of the data and eventually its noise (overfitting). Thus, a solution to solve this problem was to rate the different complexity models with their cross-validation error estimator and to choose the superior one. This is a good solution to find which model is adapted to a certain data set. In this paper, to prevent overfitting and underfitting when predicting the data, a tenfold cross-validation was used to select the optimal model.

The difference comparison between the predicted and actual value was assessed by the correlation coefficient R , root mean square error (RMSE), average absolute error (AAE), maximum absolute error (MAE), and residual, as defined in Table 3. The RMSE gives an indication of the overall accuracy of the approximation, whereas MAE indicates the presence of a range that exhibits poor approximation capabilities (Al-Anazi and Gates 2010). The correlation coefficient is widely used as a measure of the strength of linear dependence between two variables (actual value and predicted value); the residual is the difference between the actual value and the estimated function value. The error measurement above becomes the benchmark to reveal the accuracy of the models. The experiment is run with a 95% confident interval with subjects $N=100$ for the simulation data.

Table 3. Error Measures for Accuracy Assessment

Accuracy Measure	Mathematical Expression
Correlation coefficient (R)	$\frac{\sum_{i=1}^l (y_i - \bar{y}_i)(\hat{y}_i - \bar{\hat{y}}_i)}{\sqrt{\sum_{i=1}^l (y_i - \bar{y}_i)^2 \sum_{i=1}^l (\hat{y}_i - \bar{\hat{y}}_i)^2}}$
Root mean square error (RMSE)	$\sqrt{\frac{1}{l} \sum_{i=1}^l (y_i - \hat{y}_i)^2}$
Average absolute error (AAE)	$\frac{1}{l} \sum_{i=1}^l y_i - \hat{y}_i $
Maximum absolute error (MAE)	$\max y_i - \hat{y}_i , i = 1, \dots, l$
Residual	$y_i - \hat{y}_i, i = 1, \dots, l$
Max residual	$\max (y_i - \hat{y}_i), i = 1, \dots, l$
Min residual	$\min (y_i - \hat{y}_i), i = 1, \dots, l$

Results and Discussion

Relationship between Number of Reservations and Number of Cars over Acceptance Ratio

The simulation data results (number of cars, number of reservations, and acceptance ratio) were plotted in three-dimensional data with its models, as can be seen in Figure 4. The objective of a multiple regression analysis is to predict the single dependent variable (acceptance ratio) using a set of independent variables (number of cars, number of reservations). The purpose of this model for operators is to use it to predict their acceptance ratio based on their recent information on total operational cars and number of reservations. The simulation data revealed that if the number of reservations increases with respect to a certain number of cars, then the acceptance ratio will decrease (most customers will not receive a free car), but if the number of cars increases with respect to a certain number of reservations, then the acceptance ratio will increase (customers have a greater chance of receiving a free car). The maximum point for increasing the acceptance ratio up to 100 percent means that all customer reservations are absolutely accepted, and the lowest percentage is close to 1 percent (which means that only 1% of the total reservations will receive a free car).

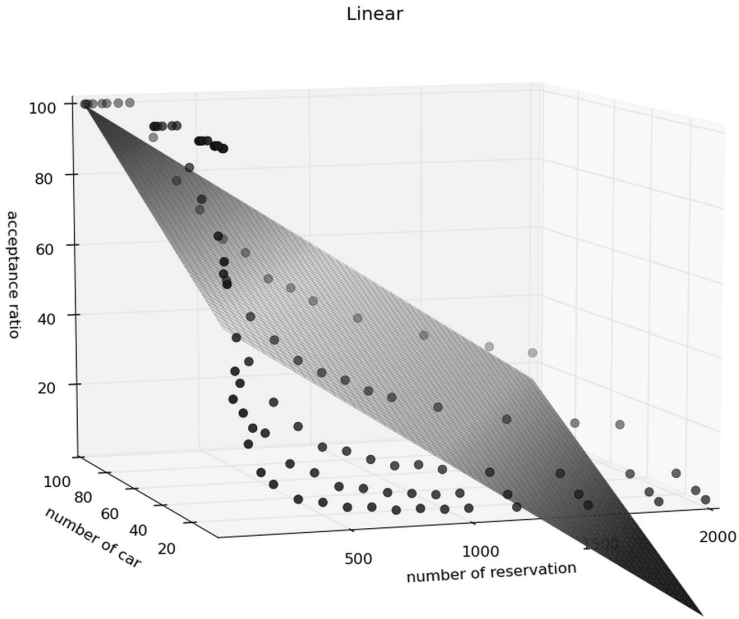


Figure 4a. Prediction models for evaluating acceptance ratio

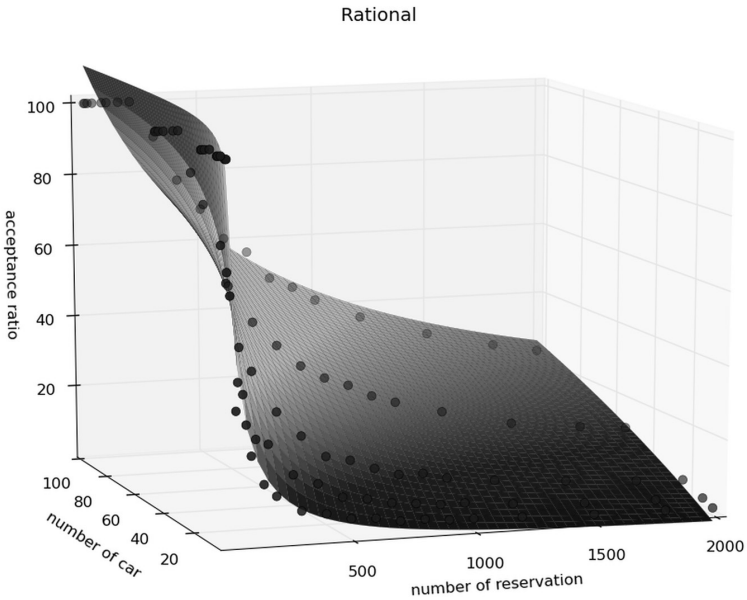


Figure 4b. Prediction models for evaluating acceptance ratio

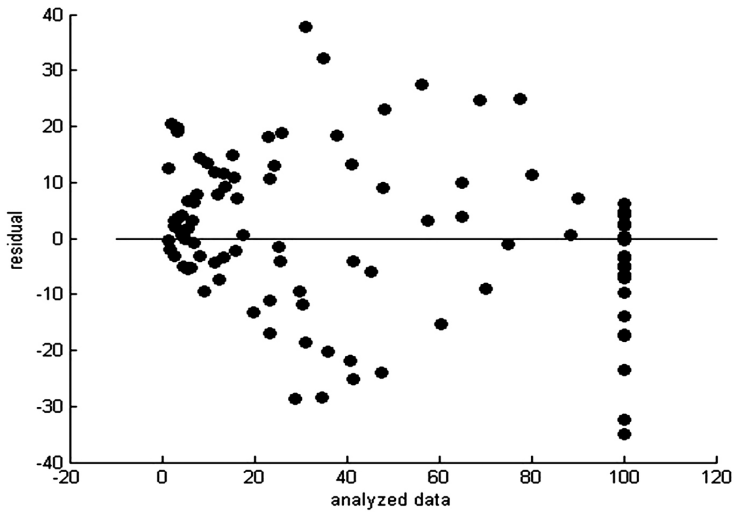


Figure 4c. Prediction models for evaluating acceptance ratio

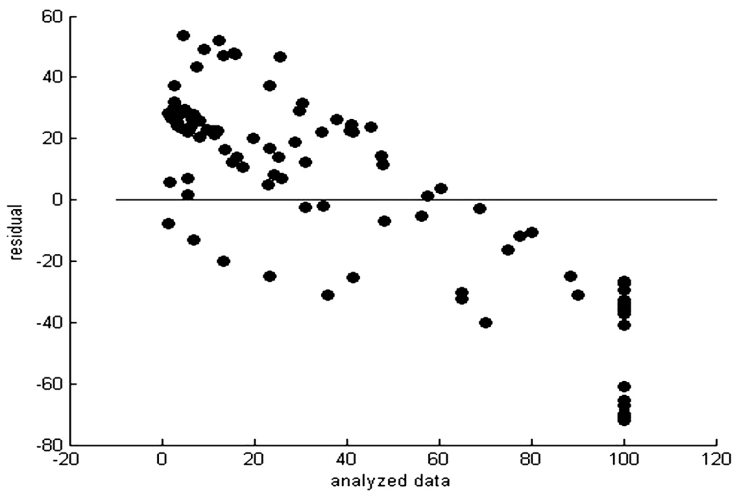


Figure 4d. Prediction models for evaluating acceptance ratio

As can be seen in Figure 4, this paper attempts to find the appropriate model to fit the data, so that the model can be used for prediction. Table 4 shows the percentages by the average error measures (RMSE, AAE, MAE, R, Residual) and correlation coefficient (R) of the models when predicting the acceptance ratio.

Table 4. Comparison of Models to Predict Acceptance Ratio

Model	Detail	RMSE	AAE	MAE	R	Residual	
						Min	Max
Linear regression	$\hat{y} = a + bx_1 + cx_2$	21.376	17.984	46.829	0.820	-46.829	33.261
Quadratic regression	$\hat{y} = a + bx_1 + cx_2 + dx_1^2 + ex_2^2 + fx_1x_2$	14.675	11.391	39.462	0.920	-39.462	30.317
Cubic regression	$\hat{y} = a + bx_1 + cx_2 + dx_1^2 + ex_2^2 + fx_1^3 + gx_2^3 + hx_1x_2 + ix_1^2x_2 + jx_1x_2^2$	11.696	8.750	34.796	0.950	-34.796	25.096
Rational regression	$\hat{y} = (a + bx_1 + cx_2) / (1 + dx_1 + ex_2)$	5.512	4.057	15.774	0.989	-13.874	15.774
Multi-layer perceptron	2 input node, 1 hidden layer, learning rate 0.3, momentum 0.2	13.835	10.551	37.772	0.930	-35.078	37.772
Radial basis function		32.738	28.044	72.086	0.484	-72.086	53.514

Multiple linear regression (Figure 4a) is applied first and results in an inaccurate prediction with RMSE 21.38; thus, the quadratic regression (non-linear regression) is applied to get the better model from the data. The quadratic regression model improves the prediction with an RMSE of about 14.67, and cubic regression is expected to smooth the prediction by showing a slight improvement of accuracy with an RMSE of about 11.7.

Rational regression (Figure 4b) was also used to predict the data, and among the proposed models, it generated the best results, with an RMSE of 5.51. The strength of dependence between the two variables (actual value and predicted value) for the rational regression is 0.989, the highest of all the results. The equation for the rational regression for predicting the acceptance ratio with the independent variables number of reservations and number of cars is described as follows:

$$\hat{y} = (a + bx_1 + cx_2) / (1 + dx_1 + ex_2) \tag{4}$$

where \hat{y} is the dependent variable acceptance ratio percentage while x_1 is the number of reservations and x_2 is the number of cars. Moreover, for other prediction algorithms, MLP achieves an RMSE of only 13.84, and RBF achieves an RMSE of 32.74. Both residuals can be seen in Figures 4c and 4d, respectively.

Relationship between Number of Reservations and Number of Cars over Utilization Ratio

Prediction techniques were also used to analyze the utilization ratio based on a certain number of cars and reservations. Since the real information on the utilization ratio can be extracted from a real transactional dataset, the difference when compared to the prediction result can be used to measure the maximum error of our prediction model. In addition, this model can be used to predict future utilization ratios as the operator predicts the increase of customers in the future or predicts the effect of new policies on increasing the capacity of car operations. For each operator, the model does not predict exactly or perfectly because of the variation in datasets, but it can be used to understand the pattern of the acceptance ratio or the utilization ratio given total reservations and the total number of cars operated. The similarities in the trip patterns of operators in many parts of the world (Costain et al. 2012; Morency et al. 2007; Zhou and Kockelman 2011) to our dataset can serve as one of the measurements that this simulation model is able to use to interpret general information regarding acceptance ratios or utilization ratios. More details on the results of the simulation data and its models can be seen in Figure 5.

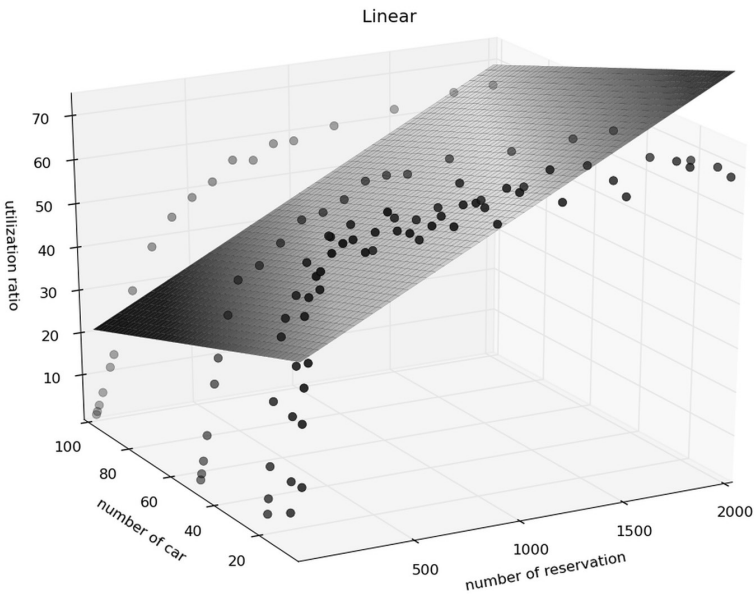


Figure 5a. Prediction models for evaluating utilization ratio

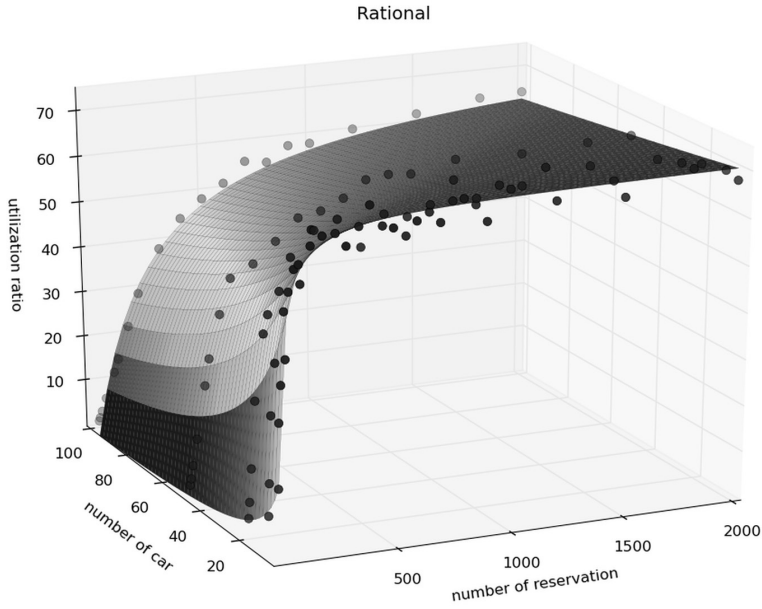


Figure 5b. Prediction models for evaluating utilization ratio

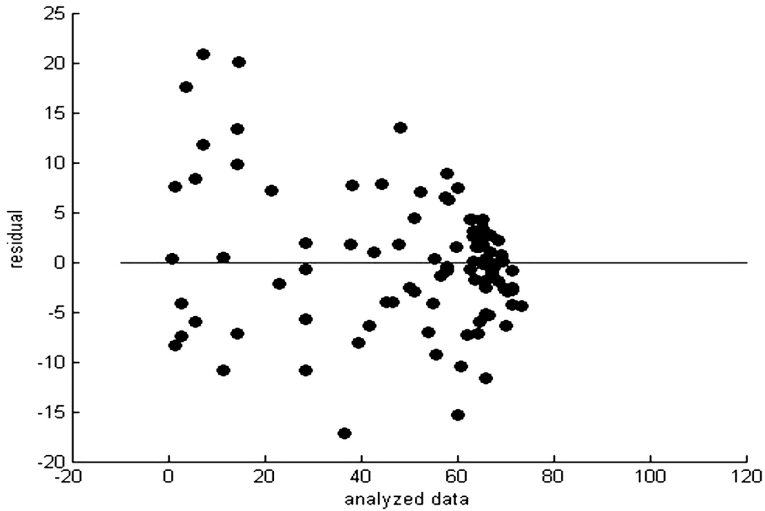


Figure 5c. Prediction models for evaluating utilization ratio

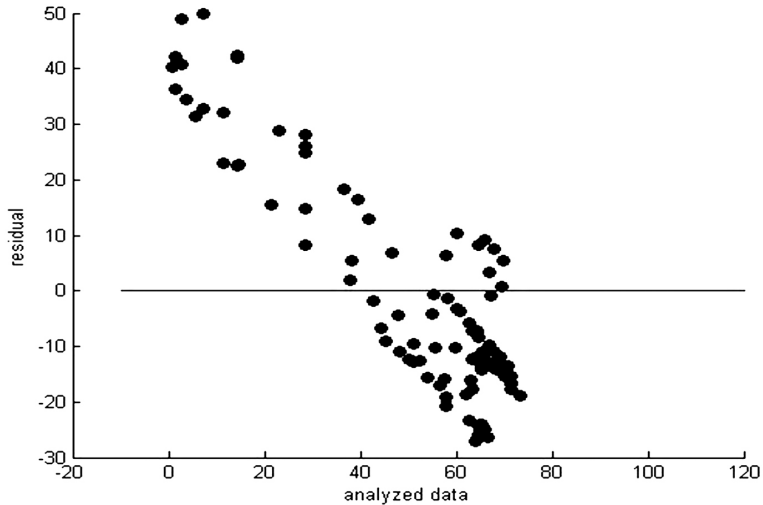


Figure 5d. Prediction models for evaluating utilization ratio

Investigating the simulation data reveals that by increasing the number of reservations with respect to a certain number of cars, the percentage of the utilization ratio will be increased, which means that the company will gain more profit (more cars will be in operation) and operational car costs will go down. But, if the number of cars increases with respect to a certain number of reservations, then the utilization ratio will decrease. This would mean that a lot of cars are not being operated, which creates costs for the company. The lowest percentage of the utilization ratio is close to 0.7 percent (which means that the minimum average car can be optimized only 0.7% of the time during any given day), whereas the utilization ratio can increase to no more than 70 percent, which means the maximum average car can be optimized nearly 70 percent of the time during any given day. In this paper, the maintenance and cleaning time variables (and other variables that may reduce the utilization ratio) are not used as input, but rather it is assumed that every free car is ready to be used for a reservation (all cars are working perfectly without any problems). But in a real situation, the maintenance variable (the time required for operators to perform maintenance for each car) and the cleaning time variable (the time required for the operator to clean the car) will definitely affect the utilization ratio, and thus the maximum utilization could be predicted to be less than 70 percent. As the maintenance time for each vehicle increases, the error of prediction in this model could increase as well. If the operator uses electric vehicles, the error

prediction is not as high compared to the use of conventional vehicles, such as a gasoline or diesel cars that require more maintenance time. Because of the unused maintenance and cleaning parameters in the simulation, this result is quite surprising, because the expectation of the company could reach 100 percent (cars could operate for 24 hours nonstop), which can provide a big advantage to the company. In other words, even though the company increases the number of reservations to the maximum level or decreases the number of cars into the minimum threshold level, the operation of cars cannot be fully optimized because there will be time conflict during reservations made by the customers. The idea behind this simulation is to generate artificial reservation data based on the distribution of VHT, VKT, day of the week, and time of day (see Figure 1), and thus the conflict time during the reservations are absolutely possible.

Figure 5a reveals that the prediction by linear regression achieves low accuracy with RMSE 14.52, and it shows improvement by quadratic regression of about RMSE 9.72, whereas the cubic regression can increase into RMSE 7.44. Rational regression was also applied in this simulation data, which achieved the best accuracy, up to RMSE 2.22, while the strength of dependence between two variables (actual value and predicted value) for rational regression 0.995 showed the highest result compared to others (see Figure 5b for the model). The equation for rational regression to predict utilization ratio with the independent variable number of reservations and number of cars described as follow:

$$\hat{y} = (a + bx_1 + cx_2)/(1 + dx_1 + ex_2) \tag{5}$$

where \hat{y} is the dependent variable utilization ratio percentage, while x_1 is the number of reservations, and x_2 is number of cars. In addition, the prediction algorithm, MLP, shows RMSE of 6.62, whereas RBF did not show good model prediction, with only RMSE 20.11 (both residual Figure 5c and 5d). The detailed results show the comparison between those models to predict the utilization ratio, as can be seen in Table 5.

Table 5. Comparison of Models to Predict Utilization Ratio

Model	Detail	RMSE	AAE	MAE	R	Residual	
						Min	Max
Linear regression	$\hat{y} = a + bx_1 + cx_2$	14.516	12.327	35.226	0.752	-20.201	35.226
Quadratic regression	$\hat{y} = a + bx_1 + cx_2 + dx_1^2 + ex_2^2 + fx_1x_2$	9.716	7.691	27.463	0.897	-18.578	27.463
Cubic regression	$\hat{y} = a + bx_1 + cx_2 + dx_1^2 + ex_2^2 + fx_1^3 + gx_2^3 + hx_1x_2 + ix_1^2x_2 + jx_1x_2^2$	7.437	5.594	23.022	0.941	-16.223	23.022
Rational regression	$\hat{y} = \frac{(a + bx_1 + cx_2)}{(1 + dx_1 + ex_2)}$	2.218	1.792	6.2	0.995	-4.744	6.2
Multi-layer perceptron	2 input node, 1 hidden layer, learning rate 0.3, momentum 0.2	6.623	4.848	20.802	0.954	-17.125	20.802
Radial basis function		20.107	16.785	49.802	0.411	-27.111	49.802

Relationship between Acceptance Ratio and Utilization Ratio

The acceptance ratio is an important parameter, as it can be one parameter to reveal customer satisfaction, but it is difficult to acquire this information in the real carsharing system, because this simulation idea and real carsharing implementation is totally different. Information communication technology is widely used in many areas, especially in carsharing. Internet access can be easily used by the customer to make the reservation, and it can also be seen in the carsharing system always having a portal website, which allows the customer to easily make a reservation. Customers can avoid conflicting times by choosing different reservation times if they have a flexible time schedule. Otherwise, they will find another car from a different company or alternative transportation, which means the previous company is losing money. Thus, it is difficult to trace acceptance ratio information (searching history of customer is not stored in carsharing database). In this simulation, the reservation data are generated from the distribution of VHT, VKT, and *time of the day*, which is similar to phone reservations (not by website). Thus, this simulation focuses only on the assumption that every customer makes an appointment/reservation by phone (or website, with a condition that every customer’s searching history can be traced). Afterwards, the system will store all request reservations and evaluate whether the reservation is accepted or not.

In another case, the utilization ratio is one parameter to measure the profit of a company that can be obtained easily from the real carsharing system database. The information about cars operated is standard information in a carsharing database; thus, this parameter can be easily implemented in the real carsharing system. Based on this problem, the relationship between the utilization ratio and the acceptance ratio is an important issue. The value of the acceptance ratio can be predicted (dependent variable) if the value of the utilization ratio (independent variable) is obtained first. This result, shown in Figure 6, shows the relationship between the acceptance ratio and the utilization ratio by simulation. The investigations reveal that the acceptance ratio is an inverse negative logistic in regard to the utilization ratio with respect to a certain number of cars and reservations.

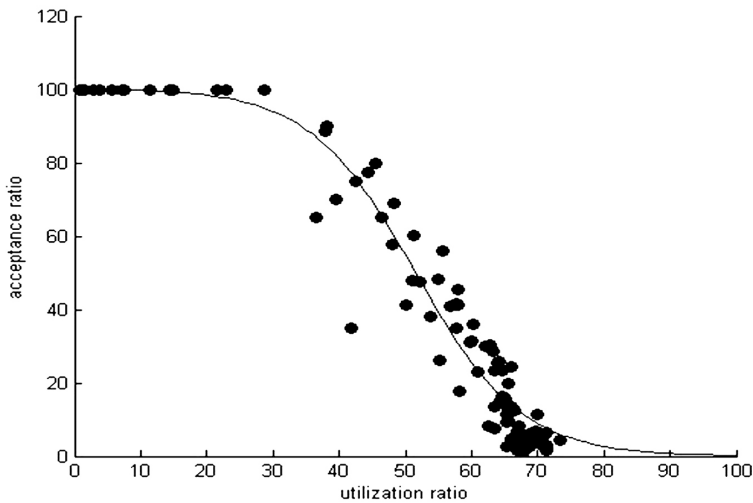


Figure 6a. Prediction models for evaluating acceptance ratio (utilization ratio as input)

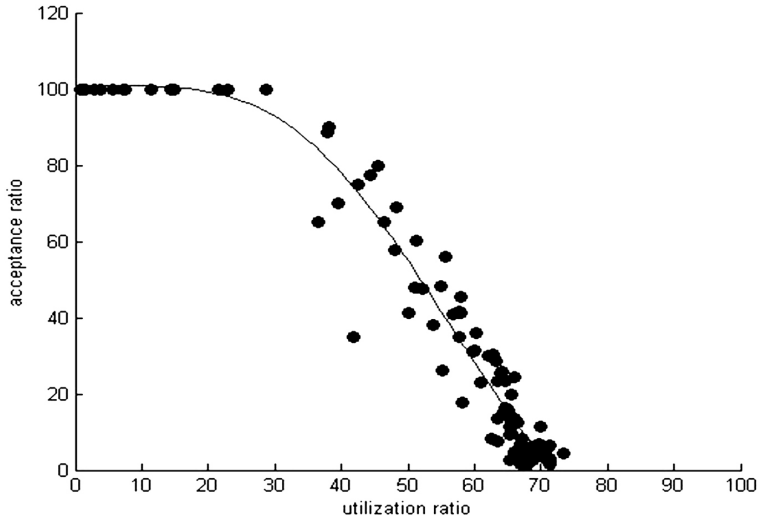


Figure 6b. Prediction models for evaluating acceptance ratio (utilization ratio as input)

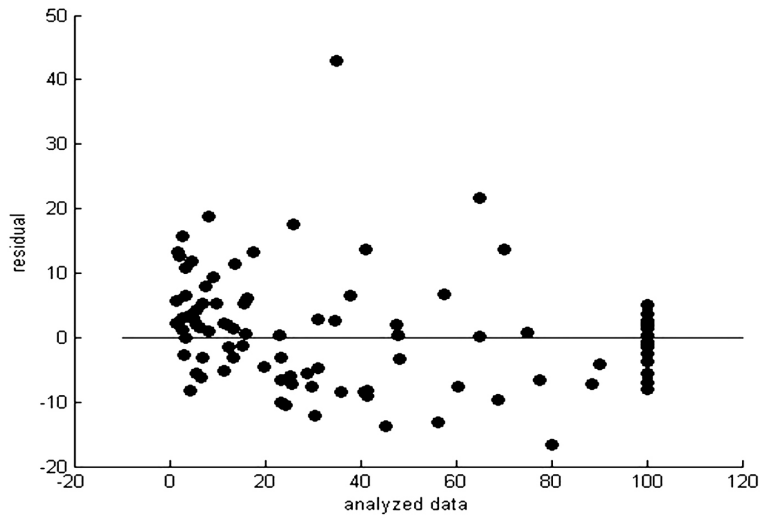


Figure 6c. Prediction models for evaluating acceptance ratio (utilization ratio as input)

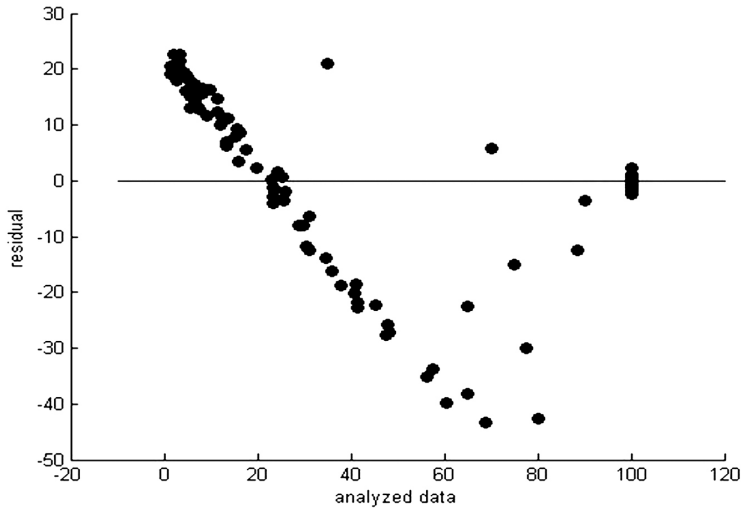


Figure 6d. Prediction models for evaluating acceptance ratio (utilization ratio as input)

As can be seen in Figure 6, the relationship of both parameters can be mapped into the proposed prediction models. Again, regression analysis is the best way to obtain the model from the information above. The investigations reveal that the logistic curve (Figure 6b), which obtained RMSE 7.71, is the best model compared to other regression models, whereas the prediction algorithms MLP and RBF achieve only RMSE 8.55 and 16.41, respectively (both residuals of the model can be seen in Figure 6c and 6d). As explained before, the acceptance ratio can approach 100 percent, whereas the utilization ratio is only 70 percent. Thus, the linear, quadratic, and cubic regression models are not good for predicting the highest point acceptance ratio and the sigmoidal regression model (Figure 6a) is not good for predicting the highest utilization ratio (the predicted value increases to 100%). The logistic curve model (Figure 6b) is the best model, with a maximum point nearest 100 percent for the acceptance ratio and reaches to about 70 percent for the maximum utilization ratio. The equation for logistic curve to predict acceptance ratio with independent variable utilization ratio described as follows:

$$\hat{y} = a + ((b - a)/(1 + (x1/c)(-d))) \tag{6}$$

where \hat{y} is the dependent variable acceptance ratio percentage and x_1 is the utilization ratio. However, if there is a finding in the real data where the utilization ratio can be optimized until 100 percent, not 70 percent as the predicted by simulation, others propose that models such as sigmoidal regression (Figure 6a) can be predicted as the better model. The detailed model can be seen in Table 6.

Table 6. Comparison of Models to Predict Acceptance Ratio (utilization ratio as input)

Model	Equation	RMSE	AAE	MAE	R	Residual	
						Min	Max
Linear regression	$\hat{y} = a + bx_1$	12.683	10.373	29.747	0.941	-29.747	21.606
Quadratic regression	$\hat{y} = a + bx_1 + cx_2$	8.039	5.921	37.298	0.977	-15.173	37.298
Cubic regression	$\hat{y} = a + bx_1 + cx_2 + dx_3$	7.803	5.842	37.228	0.9779	-15.647	37.228
Sigmoidal regression	$\hat{y} = a \cdot \exp(-\exp(-(x_1 - b)/c))$	7.791	5.482	40.620	0.9780	-15.359	40.62
Logistic curve	$\hat{y} = a + (b - a)/(1 + (x_1/c)^{-d})$	7.710	5.386	39.553	0.9785	-16.027	39.553
Multi layer perceptron	1 input node, 1 hidden layer, learning rate 0.3, momentum 0.2	8.559	6.129	42.92	0.974	-16.553	42.92
Radial basis function		16.410	12.561	43.45	0.898	-43.45	22.737

In addition, as can be seen from Figure 6b, the slope of the logistic function is highly negative; in other words, increasing a little input will create a high decrease of output. Thus, it is appropriate for the operator to be more careful when deciding to propose utilization ratio.

Clustering Acceptance and Utilization Ratio

It is important for the company to decide the appropriate ratio before implementing its policy of carsharing service in real situations. Since the threshold of the proposed acceptance ratio and utilization ratio can be standard to determine the number of cars with respect to the information of a certain number of reservations, the company is faced with three big policy choices: increase profit (utilization ratio), which will reduce customer satisfaction (acceptance ratio); decrease profit, which will increase customer satisfaction; or choose the appropriate profit and provide satisfaction to the customer. However, to understand whether the accep-

tance ratio or utilization ratio is high, medium, or low is difficult for managers; thus, it is appropriate to cluster the simulation data into three clusters, which represent the three issues above. The K-Mean clustering was used to cluster the data by using the Euclidian distance technique. The details can be seen in Figure 7.

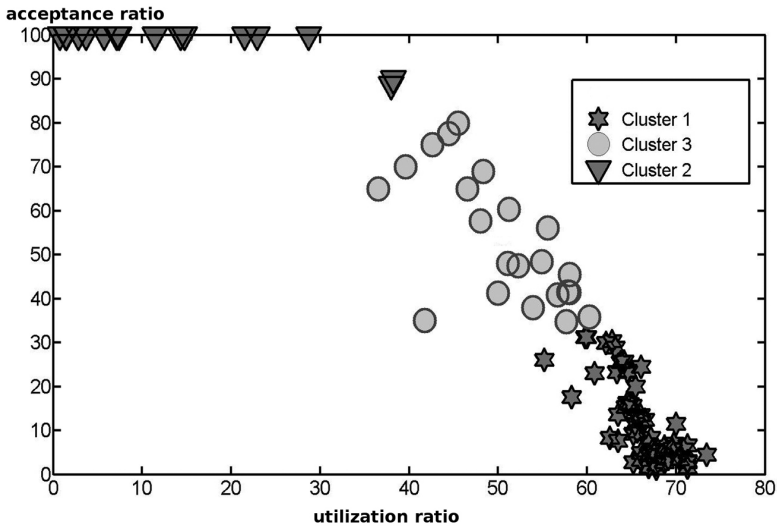


Figure 7. Results of K-means clustering

As can be seen from Table 7, the three clusters are found with its centroid, or, in other words, the policy of the company can be divided into three options (see Table 8). Every company has a different assessment to measure the level of profit and customer satisfaction. Thus, this information can not only be the one measure in regards to the level of profit and customer satisfaction but it also can be a benchmark to simply understand the grouping of simulation data. Based on Table 8, the company can consider its policy to refer to the three clusters. Companies can either increase their profit and lose customer satisfaction (Cluster 1) or vice versa (Cluster 2) or take the safe route, increasing profit without losing customer satisfaction (Cluster 3).

In addition, as can be seen from Table 7, the probability of the simulation result becoming cluster 1, 2, or 3 is about 53, 25, and 22 percent, respectively (seen from the total data in each cluster). It means that there is a 53 percent chance of the company starting its standard mode carsharing business with Cluster 1. This result demonstrates that opening a carsharing business is very promising in terms of

profit, but it is appropriate to encourage the level of customer satisfaction. Furthermore, as can be seen in Figure 6f, the slope of the logistic function is highly negative, which means that reducing only a little input value of the utilization ratio will create a big increase of the acceptance ratio. In other words, without too much profit or loss, a company can substantially increase the acceptance ratio.

Table 7. Cluster of Acceptance and Utilization Ratio

Attribute		K-Mean		
		Cluster		
		1	2	3
Utilization Ratio	Centroid	65.9515	15.3648	50.4805
Acceptance Ratio	Centroid	12.602	99.147	53.344
Total data		53	25	22

Table 8. Details of Clusters

Cluster	Company Profit	Customer Satisfaction
1	High	Low
2	Low	High
3	Medium	Medium

Conclusions and Future Work

Because it is difficult to predict the initial number of operation cars needed in car-sharing without losing customer interest and company profit, this paper demonstrates that a simulation model must be developed first to evaluate the acceptance and utilization ratios for traditional round-trip service that is based on traveling frequency, number of vehicles, and VHT and VKT patterns. The two evaluation parameters proposed in this paper are the acceptance ratio, which is the parameter that reveals customer satisfaction, and the utilization ratio, which reveals operator profit. In this paper, the Korea Carsharing (WeShareCar) dataset was collected and converted into artificial reservation data according to its distribution. The discrete event simulation was developed and run to analyze the acceptance and the utilization ratios for every combination of the number of cars and the number of reservations in a week. The simulation data revealed that increasing the number of reservations with respect to a certain number of cars will decrease the acceptance ratio (most customers will not receive a free car), but it will increase the percentage

of the utilization ratio (more cars will be rented by customers). Based on this result, regression analysis is the best model for predicting the percentage of the acceptance and the utilization ratios compared with other prediction algorithms such as MLP and RBF. Later, both can be used as a threshold for carsharing companies to optimize the number of operating cars with respect to their recent number of reservations. In addition, in this paper, a prediction model is proposed to investigate the relationship between the acceptance and the utilization ratios. Thus, through using this model and the real utilization ratios that the company collects from its operational database, it can predict the general acceptance ratio of customers. Our investigations have revealed that if the percentage of the acceptance ratio is increased, the utilization ratio will decrease and vice versa.

Put simply, the simulation data are clustered into three groups that can be considered as additional options for company policy before starting their business. Companies can either increase their profit and lose customer satisfaction, or vice versa, or take the safe route and increase profit without losing customer satisfaction. In addition, the cluster results of simulation data show that half of the companies that start carsharing businesses will make a profit, but they need to maintain and increase customer satisfaction levels. This result can be used as additional evidence to strengthen the case for the benefits of carsharing that have been demonstrated by previous research and that have concluded that operators are more likely to be economically successful. Furthermore, as an effect of the need to maintain customer satisfaction, the relationship model of the acceptance and the utilization ratios reveal that a small reduction in the input value of the utilization ratio will create a large increase in the acceptance ratio. The implication for the company is that without too much loss in profits, a company can substantially increase the acceptance ratio (customer satisfaction).

Finally, there were evident limitations to this project. First, only the operational dataset was used for basic round-trip service in carsharing because of the necessity for the preliminary step of implementing carsharing in South Korea. In the future, increasing the size of the dataset, increasing the sample of the subject experiment, and introducing and upgrading the simulation model for additional services such as one-way and open-ended service in this simulation might be considered as future projects. The evaluation of other parameters in the future might also be considered, such as the option of relocating with its costs, the pricing of services, the number of customers (its relation with the number of reservations), fuel costs,

profit, the distance between home and parking lot, cleaning costs, and maintenance costs.

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