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CONTENTS

A Stated Preference Analysis of Real-Time Public Transit Stop Information

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Abstract

This paper presents the results of a study conducted to examine the benefits derived from real-time public transit stop information. This research examines the preferences between several options of receiving real-time public transit stop information. The literature states that one of the main reasons individuals access real-time information is to remove the uncertainty when using public transit. This relationship was examined to ascertain if the provision of real-time public transit information can remove the uncertainty and frustration associated with using public transit.

A nested logit model structure was applied in this study to examine the benefits derived from accessing real-time public transit information. These models are estimated on segments of the dataset to ascertain how the mode of transport used by the respondents impacts the benefits derived from using real-time public transit information. The results of this study demonstrate that passengers derive the greatest benefit from accessing transit stop information from real-time information displays. Respondents were shown to obtain the second highest utility when accessing transit stop information via a mobile phone short message service (SMS). Bus users were found to gain the highest benefit from the provision of real-time transit stop information.

Introduction and Background

Real-time public transit information is an individual-specific travel demand management tool that is used to facilitate individuals while planning their public transit trips. The provision of such information has been shown to encourage individuals to examine their public transit options and choose the service that meets their requirements.

The public transport system in Dublin consists of a large bus network, two light rail lines, and a heavy rail network. At the time of this study, there was no single source of public transit information on all modes of transit available in Dublin. This lack of information can act as a barrier to individuals making integrated public transit trips. Each of the public transit operators provides a website that contains timetables of all of the scheduled services and the routes provided. Dublin Bus in 2004 introduced a short message service (SMS) called "BUSTXT." This service provides users with the departure time from the terminus of the next three services in either direction when the user sends a message requesting information on a specific bus route. This service is available at a charge of 30c per message (Dublin Bus 2007). The information provided by this service is not real-time. In the same year, Irish Rail introduced a similar service for urban rail users called "DARTXT." The service works in a way similar to the Dublin Bus service; however, the information provided is real-time information. The cost of the service is 30c per message (Irish Rail 2007).

One of the main motivations for this research was to examine what information individuals require while waiting at their transit stop or station. Given that the cost of investment in providing real-time information is so large, it is important to understand what information individuals require. This research examines individuals' preferences for accessing real-time public transit information. To measure these preferences, a stated preference study was conducted to ascertain how respondents would value the introduction of several methods of public transit stop information.

Preferences for real-time public transit information are examined in this paper using a nested multi-nominal logit model. Several characteristics of an individual's trip, such as working hours and wait-time at stop/station, are examined to determine what impact they have on the benefits derived from real-time public transit information.

Public transit users traditionally tend to overestimate their waiting time at stops/stations (Nijkamp et al. 1996). Several studies have been conducted to ascertain if the provision of real-time information at bus stops reduces passengers' perceived wait time. A study conducted on bus users in Stockholm demonstrated that passengers with real-time information displays at their stop overestimated their wait-time by 9-13 percent, compared to 24-30 percent without real-time information (Kronborg et al. 2002). In London, the provision of real-time information at stops was found to reduce perceived wait time by 26 percent (Schweiger 2003). A 2007 study conducted in the Netherlands examined the introduction of passenger information display (PID) on a tram line in The Hague and found that the introduction of this service reduced perceived wait time by 20 percent (Dziekan and Kottenhoff 2007).

Wolinetz et al. (2001) conducted a survey of residents in San Francisco to identify their preferences for real-time transport information via a call center. Initially, respondents were asked to identify their preference for paying for the service; 17 percent indicated they would pay on a monthly basis, 56 percent on a call-by-call basis, and 22 percent said they would not use the service if they had to pay. A total of 53 percent were found to be willing to pay up to $1 (USD) per call, and 38 percent indicated they would pay up to $7 (USD) per month for this service.

The empirical evidence demonstrates that individuals are very price-sensitive when it comes to paying for real-time information. Polydoropoulou et al. (1997), in an examination of the traffic information system SmarTraveler system in Boston, found that respondents in the stated preference survey were very sensitive to an increase in price. Englisher et al. (1997) conducted a study of the same system in Boston and also found respondents to be very price-sensitive to an increase in the price of accessing traffic information. The authors found that when respondents were asked if they would pay a fee to access real-time traffic information, the projected use of the system fell by 36 percent. In 2003, a similar study of the multimodal transport information system TavInfo in San Francisco found that respondents to a stated preference study were found to be quite sensitive to an increase in price (Khattak et al. 2003). Dedicated real-time public transit information systems also have been shown to be price sensitive. Molin et al. (2007), in a study of providing real-time information at public transit interchange points, found that the price of receiving this information was one of the most important attributes, demonstrating that respondents were highly price-sensitive.

Wardman (2003) examined the perceived reduction in transit stop wait-time for bus passengers after the introduction of real-time information for three bus routes in London. The findings show that respondents, in a face-to-face survey, indicated that 65 percent, 24 percent, and 21 percent (at each of the routes) demonstrated that they had a shorter wait time due to the provision of real-time information. The same study examined anxiety of waiting at a bus stop at night and found that 46 percent of respondents felt safer at their bus stop if they knew when the bus was due to arrive.

In a public transit network with a large number of passengers transferring between different modes, the requirements for accurate real-time information increases. In Hong Kong, it was estimated that up to one-fifth of passengers make a transfer during their daily commute (Abdel-Aty 2001). In a study conducted in Hong Kong to examine passenger preferences for real-time information, it was found that respondents derived the greatest benefit from information delivered via a mobile device, either a mobile phone or a personal digital assistant (PDA). The authors found that as travel time and trip complexity increased, so, too, did the likelihood that an individual would choose to access real-time information using SMS (short message service) or a PDA. The results also demonstrated that females, those with higher incomes, and those on a monthly mobile phone contract were more likely to choose to obtain real-time information.

Data

Data Collection

To establish individual preferences between real-time public transit information options, a stated preference survey was conducted. The survey took place over a two-week period from the April 18 - May 9, 2005, using web-based methods. A controlled sample was taken of office workers in Dublin city center. The selected companies were contacted via their human resources departments, and the survey was then sent out centrally to all employees. A total of 1,500 surveys were distributed to the employees of the companies targeted, and 495 fully-completed surveys were returned, resulting in a response rate of 33 percent. It should be noted that this sample contains only individuals who have access to the internet and work in Dublin City center. As such, this may result in some bias in the results.

Stated Preference Design

In the stated preference scenarios examined in this study, respondents were asked to choose between three options of accessing real-time public transit stop information: SMS, a passenger information display, or a call center. A preliminary study was conducted to ascertain individual preferences for receiving real-time public transit stop information. The results of this study are presented in Caulfield and O'Mahony (2007). The purpose of this preliminary study was to gain feed back on individual opinions of public transit information in Dublin and to inform the design of the main stated preference study (the results of which are presented in this paper). As SMS or call centers could be accessed prior to the respondent reaching the transit stop, respondents were instructed that they could choose only one of these options when they arrived at their transit stop. Each of the options considered had three cost levels, three reduction in wait-time percentages, and two options for the type of information provided. The attributes and attribute levels for each of the options considered by the respondents are as follows:

- Passenger information display: 0, 10, and 20 percent reductions in wait time at transit stop; 0, 15, and 30c increase in public transit fare per-trip; real-time information provided or static information provided.
- SMS: 0, 10, and 20 percent reductions in wait time; 0, 15, and 30c increase in public transit fare per trip; real-time information provided or static information provided.
- Call center: 0, 10, and 20 percent reductions in wait time; 0, 15, and 30c increase in public transit fare per trip; real-time information provided or static information provided.

An example of one of the stated choice scenarios presented to the respondents can be seen in Figure 1.

The data collected from the stated preference survey are modelled using a nested multinomial logit model. For more detail on this approach, see Hensher et al. (2005), Train (2003), or Louviere et al. (2000). In the survey, respondents were asked to choose between different stated preference scenarios. Respondents were presented with information on each of the options provided. The call center option was described as having an automated response providing real-time information. To aid respondent comprehension of the scenarios presented, a number of pictures of real-life examples of real-time information services were shown to the respondents in the survey. The survey also was piloted to test that individuals understood the choice scenarios presented in the survey.

Situation One: Please consider the following options A-C below, and based upon the information provided, choose your preferred method of receiving public transport information.

	Option A	Option B	Option C
	Information display at stop/station	Text message	Call centre
Information given	Real-time information provided	No real-time information provided	Real-time information provided
Time Saved	5% decrease in wait time at stop/station	10% decrease in wait time at stop/station	10% decrease in wait time at stop/station
Cost	15c per trip added to the price of your bus or train ticket	15c per message	30c per call
Please tick one	☐	☐	☐

Figure 1. Stated Preference Scenario

Results

Characteristics of the Sample

Table 1 presents characteristics of the sample and compares the age and gender profiles of the sample with those of the population using 2006 Census of Ireland data (CSO 2007). The results show that the sample collected provides a fairly reasonable approximation of the population. The income levels of respondents are not compared, as this information is not released from the Central Statistics Office. The results show that 43 percent of the respondents were male and 57 percent were females. In the questionnaire, respondents were asked to indicate their age using one of the five age bands; under 24, 25-34, 35-44, 45-54 and over 55. A total of 42 percent of respondents were found to be age 25-34, 24 percent were 35-44 and 21 percent were 45-54. Table 1 presents the reported incomes of the respondents to the questionnaire. The results show a wide distribution of income. A total of 37 percent of respondents were found to earn between €20,000 and €50,000 per annum, and 41 percent earn between €50,000 and €100,000 per annum (see Table 1).

Table 2 details the characteristics of the respondents' trips to work. The findings demonstrate that approximately one-quarter of the respondents use a private car to get to work, with 22 percent driving alone and 3 percent travelling as passengers (see Table 2). The proportion of individuals that either walk or cycle to work was 14 percent and 8 percent, respectively. The remaining respondents in the sample (53%) use public transport, with the majority of these individuals using the bus

Table 1. Characteristics of the Sample

Characteristic		Survey Sample		2006 Census Data	
		N	%	N	%
Gender	Male	215	43	119,390	53
	Female	280	57	105410	47
	Total	495	100	224,800	100
Age	Under 24	35	7	33,800	15
	25 – 34	208	42	81,480	36
	35 – 44	119	24	48,746	22
	45 – 54	104	21	36,535	16
	Over 55	29	6	24,239	11
	Total	495	100	224,800	100
Income	Less than €10 000	9	2	-	-
	€10 001 - €20 000	26	5	-	-
	€20 001 - €30 000	69	14	-	-
	€30 001 - €40 000	58	12	-	-
	€40 001 - €50 000	53	11	-	-
	€50 001 - €60 000	61	12	-	-
	€60 001 - €80 000	77	16	-	-
	€80 001 - €100 000	64	13	-	-
	€100 001 - €120 000	37	8	-	-
	€120 001 - €140 000	18	4	-	-
	More than €140 000	12	3	-	-
	I do not wish to reveal my income	11	2	-	-
	Total	495	100	-	-

(29%) and the remainder using one of the light/heavy rail options. Seventeen percent of respondents said that they took more than one mode of public transit when travelling to work (see Table 2).

The reported walk times of the respondents from their home to the nearest public transit stop/station are contained in Table 2. A total of 42 percent of respondents are less than a five-minute walk and 28 percent between a 5- and 10-minute walk from their stop/station. The reported wait times at stop/station are presented in Table 2. As with the walk time to stop/station, the majority of respondents indicated that the wait time was less than 10 minutes. A total of 32 percent indicated that they had a less than a 5-minute wait, and 44 percent were found to have a wait time of between 5 and 10 minutes.

Table 2. Trip Characteristics of the Sample

Characteristic		N	%
Mode of transport	Walk	70	14
	Cycle	39	8
	Car (Drive)	111	22
	Car (Passenger)	16	3
	Bus	142	29
	Light rail	33	7
	Rail	83	17
	Taxi	1	0
Transfer modes of transport	Yes	85	17
	No	410	83
Wait time at stop/station	0-5 min	83	32
	6-10 min	114	44
	11-15 min	39	15
	16-20 min	13	5
	21-25 min	6	2
	26-30 min	-	-
	31-35 min	2	1
	Over 35 min	1	1
Walk time from home to stop/station	0-5 min	108	42
	5-10 min	72	28
	10-15 min	33	13
	15-20 min	22	9
	20-25 min	10	4
	25-30 min	5	2
	30-35 min	1	0
	Over 35min	7	3

Opinions of Public Transit

Table 3 presents the results of a series of questions asked to ascertain what causes respondents frustration when using public transit. The results in Table 2 are segmented by the mode of transport the respondent said they used on a daily basis, bus, rail and all respondents. Respondents were initially asked if uncertainty regarding the arrival time of their service caused frustration. A total of 80 percent of all users, 79 percent of bus users, and 78 percent of rail users indicated that uncertainty as to the arrival time of their service caused frustration. In the second question, respondents were asked if not knowing if the service had already departed caused them frustration. A total of 69 percent of all users, 70 percent of bus users, and 55 percent of rail users said this caused frustration. This result shows that not knowing if the public transit service had already passed caused a higher level of frustration with bus users compared to rail users. Finally, respondents were asked if uncertainty as to the departure time of their public transit service caused frustration. The results in Table 3 show that 70 percent of all users, 73 percent of bus users, and 63 percent of rail users found this uncertainty to cause frustration. This result again shows that rail users are less frustrated with uncertainty.

Table 3. Frustration with Public Transit

	All Respondents		Bus Users		Rail Users	
	N	%	*N*	%	*N*	%
Uncertainty as to time of arrival						
Very frustrating	396	80	112	79	90	78
No opinion	54	11	11	8	12	10
Not frustrating	45	9	18	13	14	12
Not knowing if the service has passed						
Very frustrating	342	69	99	70	64	55
No opinion	104	21	27	19	31	27
Not frustrating	50	10	16	11	21	18
Uncertainty as to departure time						
Very frustrating	347	70	104	73	73	63
No opinion	104	21	24	17	29	25
Not frustrating	45	9	14	10	14	12

Respondents to the survey were asked when they would be most likely to access real-time public transit information. As shown in Table 4, 79 percent of bus users and 78 percent of rail users said they would use real-time information if the weather was bad; 41 percent of all respondents said they would use real-time public transit information if the weather was bad; 45 percent of all respondents and 55 percent of rail respondents said they would consult real-time public transit information if using more than one mode of public transit. Of bus users, 70 percent indicated that they would access real-time public transit information if using a more than one mode of public transit. This result shows that bus users have a higher information requirement when taking more than one mode of public transit.

In the survey, respondents were asked if they would they consult real-time public transit information if they were running late. Table 4 indicates that 43 percent of all respondents, 46 percent of bus users, and 48 percent of rail users would access real-time information when running late. Respondents were asked if they would consult real-time public transit information if they were using a service for the first time. The results indicated that 73 percent of bus users and 63 percent of rail users would access real-time information when using a service for the first time.

Table 4. Accessing Real-Time Information

	All Respondents		Bus Users		Rail Users	
	N	%	*N*	%	*N*	%
Bad weather						
Would use	203	41	112	79	90	78
No opinion	144	29	11	8	12	10
Would not use	149	30	18	13	14	12
When using more than one mode						
Would use	223	45	99	70	64	55
No opinion	149	30	27	19	31	27
Would not use	124	25	16	11	21	18
When running late						
Would use	213	43	65	46	56	48
No opinion	109	22	50	35	42	36
Would not use	173	35	27	19	19	16
If using a service for the first time						
Would use	342	69	104	73	73	63
No opinion	109	22	24	17	29	25
Would not use	45	9	14	10	14	12

Opinion of Real-Time Public Transit Information Provision

In the survey, respondents were asked to rate a number of aspects of public transit information provision in Dublin using a five-point scale from "very good" (5) to "very poor" (1). For each of the public transit information options analysed, an average rating was taken for bus users, rail users, and "other" users (drivers, walkers, and cyclists). Respondents were asked to rate the quality of maps provided at bus stops/train stations. Bus users were found to have the lowest rating of 1.88, followed by the "other" user group and rail users with ratings of 2.02 and 3.92, respectively (see Table 5). These results suggest that bus users have the lowest opinion of maps provided at bus stops, followed by the "other" user group and rail users. When asked to evaluate the provision of timetables, bus users were found to have the lowest rating of 2.05, followed by the "other" group with a rating of 2.10. Rail users were shown to have a considerably higher rating of 4.05, indicating that the majority of rail users in the sample were satisfied with the quality of timetables provided at rail stations.

Rail users were found to have the highest average rating of 3.99 when evaluating the quality of public transit websites. The “other” user group were found to have the lowest rating of 2.14, followed by bus users with a rating of 2.17 (see Table 5). The average rating for the bus and the “other” user groups were very similar, indicating these user groups found the quality of public transit websites to be equally poor. One explanation for this may be that the main internet site for urban rail services in Dublin provides passengers with real-time arrival information. The results show that each of the different user groups was found to equally rate the availability of information on the cost public transit, regardless of mode, with a low ranking.

Table 5. Opinion of Public Transit Information Services

Option	Bus Users	Rail Users	Others
Maps provided at bus stops/ train stations	1.88	3.92	2.02
Timetables provided at bus stops/train stations	2.05	4.05	2.10
Public transit websites	2.17	3.99	2.14
Availability of information on the cost of your trip	1.99	2.09	1.98

Modelling Results

The nested multinomial logit model results estimated in this study are presented in Table 6. For mode detail on this modelling approach, see Hensher et al. (2005). The nested structure that provided the most consistent results in terms of $\rho^2(0)$ and $\rho^2(c)$ values is presented in Figure 2. As shown in Figure 2, the nested structure had two limbs, SMS information on one limb, and passenger information display and call center on the other. The model specifications for all three models produce good $\rho^2(0)$ and $\rho^2(c)$ values. The model 1 $\rho^2(0)$ and $\rho^2(c)$ values were estimated to be 0.265 and 0.222; the values for model 2 (bus user) were 0.281 and 0.231, and 0.271 and 0.211 for model 2 (rail user).

Table 6. Nested Multinomial Logit Models

Variables		Model 1	Model 2 (Bus Users)	*Model 3 (Rail Users)*
SMS	Wait time saved	-0.032 (-4.3)**	-0.034 (-5.6)**	*-0.027 (-3.6)***
	Cost	-0.054 (-6.1)**	-0.042 (-4.8)**	*-0.073 (-2.7)***
	Information	-0.879 (-7.3)**	-1.062 (-2.0)*	*-0.718 (-6.7)***
Call Center	Wait time saved	-0.017 (-2.6)**	-0.031 (-2.1)*	*-0.023 (-4.4)***
	Cost	-0.068 (-7.6)**	-0.031 (-7.3)**	*-0.065 (-2.7)***
	Information	-1.110 (-7.2)**	-1.172 (-7.6)**	*-0.848 (-3.7)***
Passenger information display	Wait time saved	-0.043 (-7.1)**	-0.088 (-2.3)*	*-0.042 (-4.1)***
	Cost	-0.054 (-9.6)**	-0.038 (-9.4)**	*-0.039 (-4.2)***
	Information	-0.947 (-7.8)**	-1.215 (-9.5)**	*-1.037 (-2.8)***
WAIT		0.112 (4.1)**	0.696 (9.1)**	*0.309 (2.9)***
FRUST		0.048 (2.6)**	0.088 (2.0)*	*0.035 (2.4)**
DEPT		0.116 (2.8)**	0.218 (2.1)*	*0.108 (3.3)***
FIXW		-0.175 (-4.0)**	-0.502(-2.8)**	*-0.572 (-4.2)***
MULTI		0.139 (2.0)*	0.241 (2.9)**	*0.147 (3.1)***
WALKSTOP		0.417 (1.9)*	0.324 (4.5)***	*0.781 (2.9)***
N		1980	542	*440*
$\rho^2(0)$		0.265	0.281	*0.271*
$\rho^2(c)$		*0.222*	*0.231*	*0.211*

* Significant at the 95% confidence level

** Significant at the 99% confidence level

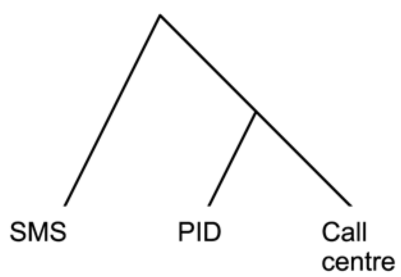

Figure 2. Nested Model Structure

The estimated coefficients for wait time saved for the SMS option were found to be negative and significant at the 99% confidence level (see Table 6). The reduction in wait time coefficient for bus users was found to be -0.034, and -0.027 and for the rail model (see Table 6). These estimates demonstrate that bus users derive a slightly higher utility from wait time saved compared to rail users.

The coefficients for cost of SMS information were found to be negative and significant at the 99% confidence level (see Table 6). Bus users were shown to have the lower cost disutility (-0.042) compared to rail users (-0.073). The estimated cost coefficients indicate that bus users are the least likely to object to paying for information via SMS. The information coefficient for SMS information was estimated to be highest for bus users (-1.062), followed by rail users (-0.718) (see Table 6). These findings suggest that, as with the other real-time information options, bus users derive the highest benefit from real-time information provided via SMS.

The coefficients for wait-time saved using a call center were found to be negative and significant at either the 95% or 99% confidence intervals (see Table 6). Bus users were estimated to derive the highest utility from wait-time saved with an estimated coefficient of -0.031. These findings indicate that bus users derive the highest benefit from a reduction in wait-time while at their bus stop. The higher preference for a reduction in wait time by bus users compared to rail users may be attributed to the perceived lack of reliability in arrival of bus services relative to rail services.

The cost coefficients for information provision via a call center were shown to be negative and significant at the 99% confidence level in each of the segmented models. Bus users were found to have the lowest cost coefficient (-0.031), followed by rail users (-0.065) (see Table 6). These cost coefficients indicate that bus users are less likely to object to paying to use the call center option compared to rail users.

The wait time saved coefficient estimates for passenger information display were estimated to be negative and significant at the 95% or 99% confidence levels (see Table 6). The bus user model produced the highest negative coefficient (-0.088), followed by rail users (-0.042). This result demonstrates that bus users derive the highest utility from the provision of information via a passenger information display while at a stop/station. These findings show that time saving is more important to bus users compared to rail users.

The cost coefficients for information provision via passenger information display were found to be negative and significant at the 99% confidence level (see Table 6). The disutility of cost was found to be lowest for bus users, with an estimated coefficient of -0.38, followed by rail users (-0.039). The coefficients for bus and rail users were estimated to be very similar. This demonstrates that both groups have a similar willingness to pay for real-time information from a passenger information display. This finding demonstrates that public transit users are more open to paying for the provision of transit stop/station information provided via a passenger information display, compared to the other user groups.

The information coefficients for the provision of information via a passenger information display were found to be negative and significant at the 99% confidence level for all models (see Table 6). A negative value implies a preference for real-time information rather than static information. Of the estimated coefficients, bus users were found to have the highest value (-1.215), followed by rail users (-1.037). These findings demonstrate that bus users derive a higher benefit from the provision of real-time information being provided via a passenger information display compared to the other user groups.

A comparison between the methods of receiving public transit information demonstrates that all three user groups derive the highest utility for wait-time saved when the information was provided via a passenger information display.

Additional Variables

This section of the paper examines a number of additional variables that were added to ascertain how certain factors impact the utility derived from real-time public transit stop information. The first variable examined in this section measures how wait time impacts the utility derived from real-time public transit stop information. The wait-time variable is a categorical variable and is defined in Table 7. A positive value for WAIT would indicate that as wait time increases, individuals are likely to derive a benefit from the use of real-time public transit information. The WAIT coefficients were estimated to be significant at the 99% confidence level (see Table 6). Each of the coefficients estimated was found to be positive. This indicates that as the wait time at stop/station increases, so, too, does the utility derived from accessing real-time public transit information. This result is in line with other studies that have shown the provision of real-time public transit stop information reduces perceived wait times and improves user perceptions of public transit (Schweiger 2003, Dziekan and Kottenhoff 2007). A comparison between the wait-time coefficients demonstrates that wait time was most likely to impact upon bus users (0.696), as this coefficient was found be higher than the coefficient estimated for rail users (0.309) (see Table 6).

Table 7. Description of Additional Variables

Variable	Description
DEPT	*Categorical variable* – Respondent departure time where the values 1-8 represent the following: before 6:30am, 6:30-7:00am, 7:00-7:30am, 7:30-8:00am, 8:00-8:30am, 8:30-9:00, 9:00-9:30 and after 9:30
CONMOB	*Dummy variable* – If pay monthly contract equals 1, if pay-as-you-go equals 0
FRUST	*Categorical variable* – Sums the individual reported values presented in Table 2
FIXW	*Dummy variable* – If respondent has fixed set working hours equal to 1, 0 otherwise
MULTI	*Dummy variable* – Those that take more than one mode of public transit on their journey to work take a value of 1, otherwise 0
WAIT	*Categorical variable* – Where values 1-7 represent the following: 0-5 minutes, 5-10 minutes, 10-15 minutes, 15-20 minutes, 20-25 minutes, 25-30 minutes and more than 30 minutes
WALKSTOP	*Categorical variable* – Where values 1-7 represent the following: 0-5 minutes, 5-10 minutes, 10-15 minutes, 15-20 minutes, 20-25 minutes, 25-30 minutes and more than 30 minutes

The first "work pattern" variable to be examined was daily departure time. The purpose of examining this variable is to ascertain if departure time impacts an individual's choice between transit information options. A categorical variable for departure time DEPT was created and is defined in Table 7. A negative or low coefficient value would indicate those who depart early derive a higher utility from transport information than those who depart later. The results for departure time were found to be significant at the 99% confidence level (see Table 6). The departure time coefficients were found to be positive, indicating that as departure time increases, so, too, does the likelihood that the individual will derive a benefit from real-time information. The bus user departure time coefficient was found to be greater than that of the rail user coefficient. This result suggests that bus users, who depart later to work, are more likely to derive a benefit from real-time information, compared to the same group of rail users.

The dummy variable FIXW was created to represent those individuals who have to arrive at work at a specific time each day. This variable examines if those on fixed start or flexible start times are more likely to use real-time information. The dummy variable FIXW is defined in Table 6. A positive value for the FIXW variable would indicate that those individuals who have to arrive at work at a specific time are more likely to use real-time information and vice versa. The FIXW variables also were found to be negative and significant at the 99% confidence level (see Table 6).

This model demonstrates that individuals who do not have a fixed working schedule are more likely to derive a benefit from real-time public transit information.

The results from Table 4 are used to create a variable to measure frustration while waiting at a public transit stop/station. The FRUST variable adds the individual responses to the questions posed in Table 3 to produce a combined frustration score (see Table 7). If the respondent indicates, for example, that not knowing the arrival time was frustrating; it is indicated by a +1, which is then added to their responses to the other two questions. This method was used to calculate the total frustration score. Therefore, the final frustration score of the individual is the sum of the responses to each of the individual questions. A positive FRUST score would indicate that the respondent was frustrated while waiting for his/her public transit service to arrive. The FRUST coefficient in each of the models examined was found to be positive and significant at either the 95% or 99% confidence levels (see Table 6). This finding indicates that as the frustration score increases, so, too, does the likelihood that the individual will derive a benefit from real-time public transit information. This result was as one would expect. The FRUST variable was estimated to be 0.088 for bus users and 0.035 for rail users (see Table 6). This result indicates that bus users who experience high frustration levels are more likely to derive a benefit from real-time public transit information compared to rail users experiencing the same levels of frustration.

Individuals who transfer between modes of transport to complete a single journey require information on two or more modes of transport. The MULTI variable was a dummy variable that takes a value of 1 if the respondent indicated that he/she uses more than one mode of transport to travel to work, and 0 otherwise (the MULTI variable is defined in Table 7). In model 1, the MULTI variable was found to be positive and significant at the 95% confidence level with a *t*-ratio of 2.0 (see model 1, Table 6). This positive value suggests that, all things being equal, those who undertake a trip using more than one public transit service are more likely derive a benefit from real-time public transit information. The MULTI variable was also found to be significant in the bus and rail models. The bus model coefficient was estimated to be 0.241, and the rail model coefficient was found to be 0.147 (see models 2 and 3 in Table 6). A comparison between the three results for the MULTI variable shows that bus users that transfer between modes of public transit derive the greatest benefit from the provision of real-time public transit information.

The WALKSTOP variable examines the impact the distance a respondent has to walk to his/her nearest bus stop or train station has upon the benefits derived from real-time public transit information. The WALKSTOP variable is a categorical variable (defined in Table 7). The WALKSTOP variable in model 1 was found to have a positive coefficient value of 0.417 and significant at the 99% level (*t*-ratio of 3.2) (see model 1 in Table 6). This result indicates that as the time taken to walk to the stop increases, so, too, does the likelihood that the respondent will derive a benefit from real-time public transit information. The bus user and rail user WALKSTOP coefficients were estimated to be 0.324 and 0.781, respectively (see models 2 and 3 in Table 6). This finding shows rail users with longer walk times derive a greater benefit from real-time public transit information compared to bus users. This result differs from the other results presented in this paper in that rail users were found in this instance to derive a greater benefit from real-time public transit information. One possible explanation for this result is that on average rail users had longer walk times to reach their station compared to bus users.

Conclusions

The research presented in this paper examines an individual's choice between real-time information options and investigates how this choice varies between bus and rail users. This paper also addresses how a number of factors such as work schedule and frustration experienced while waiting at a bus stop/train station can impact the utility derived from real-time public transit information. While the results presented in this paper provide an indication of the individual preferences for real-time public transit stop information, it should be noted that the sample used in this study was that of office-based workers in Dublin's central business district, and as such may not be representative of the whole population.

The need for real-time public transit stop information is clearly outlined in the results. The vast majority of respondents (80%) indicated that not knowing the arrival time of their service caused frustration. A similar result was found when respondents were asked if not knowing had their bus/rail service passed caused frustration; 69 percent found this frustrating. The findings presented in this paper show that for each of the different methods of obtaining real-time information considered, bus users were found to derive the greatest benefit from these services. This finding was echoed in the additional variables examined in this paper, such as in the frustration and wait-time variables. These results show that bus users who experience longer wait times and greater frustration levels were more likely to derive a benefit from using real-time information.

When examining the preferences for the different methods of accessing real-time public transit information, the results show respondents derive the greatest benefit from real-time public transit stop information displays. This result was as one would expect, as this is one of the most effective methods of relaying real-time public transit stop information. Accessing information via SMS was found to be the second most attractive option to respondents, as respondents derived a greater utility from this option compared to using a call center.

The results from this paper demonstrate which public transit users are most likely to benefit from the provision of real-time information. The findings presented in this paper can be used to demonstrate how to prioritize investment in real-time information by highlighting the users who are most likely to benefit from real-time information services. To this extent, the results of this research demonstrate that bus users derive the greatest benefit from the provision of real-time public transit information, and as such, investment should be concentrated on providing bus users with real-time public transit information. The results also demonstrate that individuals derive a benefit from the provision of real-time information and are willing to pay for this information. The research presented in this paper could be further extended by examining different types of trips such as off-peak trips, leisure trips, and retail trips. As previously mentioned, this study is limited in that it concentrates on office-based workers in Dublin City center. A further extension to this study would be to look at other groups of respondents such as individuals who work in the suburbs and in industrial areas.

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A New Customer Satisfaction Index for Evaluating Transit Service Quality

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Abstract

In this paper, an index based on customer perspective is proposed for evaluating transit service quality. The index, named Heterogeneous Customer Satisfaction Index, is inspired by the traditional Customer Satisfaction Index, but takes into account the heterogeneity among the user judgments about the different service aspects. The index allows service quality to be monitored, the causes generating customer satisfaction/dissatisfaction to be identified, and the strategies for improving the service quality to be defined. The proposed methodologies show some advantages compared to the others adopted for measuring service quality, because it can be easily applied by the transit operators.

Introduction

Transit service quality is an aspect markedly influencing travel user choices. Customers who have a good experience with transit will probably use transit services again, while customers who experience problems with transit may not use transit services the next time. For this reason, improving service quality is important for customizing habitual travellers and for attracting new users. Moreover, the need for supplying services characterized by high levels of quality guarantees competition among transit agencies, and, consequently, the user takes advantage of better services. To achieve these goals, transit agencies must measure their performance.

Customer satisfaction represents a measure of company performance according to customer needs (Hill et al. 2003); therefore, the measure of customer satisfaction provides a service quality measure. Customers express their points of view about the services by providing judgments on some service aspects by means of ad hoc experimental sample surveys, known in the literature as "customer satisfaction surveys."

The aspects generally describing transit services can be distinguished into the characteristics that more properly describe the service (e.g., service frequency), and less easily measurable characteristics that depend more on customer tastes (e.g., comfort). In the literature, there are many studies about transit service quality. Examples of the most recent research are reported in TRB (2003a, 2003b), Eboli and Mazzulla (2007), Tyrinopoulos and Antoniou (2008), Iseki and Taylor (2008), and Joewono and Kubota (2007). In these studies, different attributes determining transit service quality are discussed; the main service aspects characterizing a transit service include service scheduling and reliability, service coverage, information, comfort, cleanliness, and safety and security. Service scheduling can be defined by service frequency (number of runs per hour or per day) and service time (time during which the service is available). Service reliability concerns the regularity of runs that are on schedule and on time; an unreliable service does not permit user travel times to be optimized. Service coverage concerns service availability in the space and is expressed through line path characteristics, number of stops, distance between stops, and accessibility of stops. Information consists of indications about departure and arrival scheduled times of the runs, boarding/alighting stop location, ticket costs, and so on. Comfort refers to passenger personal comfort while transit is used, including climate control, seat comfort, ride comfort including the severity of acceleration and braking, odors, and vehicle noise. Cleanliness refers to the internal and external cleanliness of vehicles and cleanliness of terminals and stops. Safety concerns the possibility that users can be involved in an accident, and security concerns personal security against crimes. Other service aspects characterizing transit services concern fares, personnel appearance and helpfulness, environmental protection, and customer services such ease of purchasing tickets and administration of complaints.

The objective of this research is to provide a tool for measuring the overall transit service quality, taking into account user judgments about different service aspects.

A synthetic index of overall satisfaction is proposed, which easily can be used by transit agencies for monitoring service performance. In the next section, a critical review of indexes for measuring service quality from a user perspective is made; observations and remarks emerge from the comparison among the indexes analysed. Because of the disadvantages of the indexes reported in the literature, a new index is proposed. The proposed methodology is applied by using experimental data collected by a customer satisfaction survey of passengers of a suburban transit service. The obtained results are discussed at the end of the paper.

Customer Satisfaction Indexes

The concept of customer satisfaction as a measure of perceived service quality was introduced in market research. In this field, many customer satisfaction techniques have been developed. The best known and most widely applied technique is the ServQual method, proposed by Parasuraman et al. (1985). The ServQual method introduced the concept of customer satisfaction as a function of customer expectations (what customers expect from the service) and perceptions (what customers receive). The method was developed to assess customer perceptions of service quality in retail and service organizations. In the method, 5 service quality dimensions and 22 items for measuring service quality are defined. Service quality dimensions are tangibles, reliability, responsiveness, assurance, and empathy. The method is in the form of a questionnaire that uses a Likert scale on seven levels of agreement/disagreement (from "strongly disagree" to "strongly agree").

ServQual provides an index calculated through the difference between perception and expectation rates expressed for the items, weighted as a function of the five service quality dimensions embedding the items. Some variations of this method were introduced in subsequent years. For example, Cronin and Taylor (1994) introduced the ServPerf method, and Teas (1993) proposed a model named Normed Quality (NQ). Although ServQual represents the most widely adopted method for measuring service quality, the adopted scale of measurement for capturing customer judgments has some disadvantages in obtaining an overall numerical measure of service quality; in fact, to calculate an index, the analyst is forced to assign a numerical code to each level of judgment. In this way, equidistant numbers are assigned to each qualitative point of the scale; this operation presumes that the distances between two consecutive levels of judgment expressed by the customers have the same size.

A number of both national and international indexes also based on customer perceptions and expectations have been introduced in the last decade. For the most part, these satisfaction indexes are embedded within a system of cause-and-effect relationships or satisfaction models. The models also contain latent or unobservable variables and provide a reliable satisfaction index (Johnson et al. 2001). The Swedish Customer Satisfaction Barometer (SCSB) was established in 1989 and is the first national customer satisfaction index for domestically purchased and consumed products and services (Fornell 1992). The American Customer Satisfaction Index (ACSI) was introduced in the fall of 1994 (Fornell et al. 1996). The Norwegian Customer Satisfaction Barometer (NCSB) was introduced in 1996 (Andreassen and Lervik 1999; Andreassen and Lindestad 1998). The most recent development among these indexes is the European Customer Satisfaction Index (ECSI) (Eklof 2000). The original SCSB model is based on customer perceptions and expectations regarding products or services. All the other models are based on the same concepts, but they differ from the original regarding the variables considered and the cause-and-effect relationships introduced. The models from which these indexes are derived have a very complex structure. In addition, model coefficient estimation needs of large quantities of experimental data and the calibration procedure are not easily workable. For this reason, this method is not very usable by transit agencies, particularly for monitoring service quality.

More recently, an index based on discrete choice models and random utility theory has been introduced. The index, named Service Quality Index (SQI), is calculated by the utility function of a choice alternative representing a service (Hensher and Prioni 2002). The user makes a choice between the service habitually used and hypothetical services. Hypothetical services are defined through Stated Preferences (SP) techniques by varying the level of quality of aspects characterizing the service. Habitual service is described by the user by assigning a value to each service aspect. The design of this type of SP experiments is generally very complex; an example of an SP experimental design was introduced by Eboli and Mazzulla (2008a). SQI was firstly calculated by a Multinomial Logit model to evaluate the level of quality of transit services. Hierarchical Logit models were introduced for calculating SQI by Hensher et al. (2003) and Marcucci and Gatta (2007). Mixed Logit models were introduced by Hensher (2001) and Eboli and Mazzulla (2008b). SQI includes, indirectly, the concept of satisfaction as a function of customer expectations and perceptions. The calculation of the indexes following approaches different from SQI presumes the use of customer judgments in terms of rating. To the contrary, SQI is based on choice data; nevertheless, by choosing a service, the user indirectly expresses a judgment of importance on the service aspects defining the services. In addition, the user expresses a judgment of satisfaction about the service aspects when he/she describes the service habitually used. Also, SQI is calculated by a very complex procedure. Choice data can give more reliable results because the user must make a choice and makes a simultaneous comparison of all the service attributes; to the contrary, the evaluation of the attributes by rating generally influence the user to assign a high level of importance to each service attribute, and the user evaluates each attribute one by one. Nevertheless, SQI has some disadvantages because choice data are not usual for customer satisfaction surveys; in addition, this type of data must be collected by well-designed SP experiments.

A more direct measure for service quality evaluation is provided by an overall index, often called "Customer Satisfaction Index" (CSI) (Hill et al. 2003). CSI represents a measure of service quality on the basis of the user/consumer perceptions on service aspects expressed in terms of importance rates, compared with user/consumer expectations expressed in terms of satisfaction rates. CSI plugs the gap of ServQual because is based on judgments expressed according to a numerical scale. Compared to all the described indexes, CSI is based on a simple procedure, fully described in the next section, which allows the index to be easily calculated0 by transit operators.

CSI does not take into account the heterogeneities among user judgments. To the contrary, the index proposed by the authors provides an overall service quality measure introducing the dispersion of the importance and satisfaction rates among users.

Methodology

The methodology adopted in this research aims to obtain a concise indicator that provides an overall measure of service quality by considering different service aspects. The indicator can be calculated on the basis of user judgments expressed by a numerical scale; this kind of scale has some advantages compared to the scales with points described by means of words (e.g., Likert and verbal scale) because it allows quantitative techniques of analysis to be applied. To measure customer satisfaction, different numerical values can be used, generally from 1 to 3, from 1 to 5, from 1 to 7, from 1 to 9, etc. The adopted scale can also have an even number of levels, for example, the traditional numeric scholastic scale composed of points from 1 to 10.

As mentioned above, this research focuses on CSI, which is calculated by means of the satisfaction rates expressed by users, weighted on the basis of the importance rates, according to the following formula:

$$CSI = \sum_{k=1}^{N} \left[\overline{S}_k \cdot W_k \right] \tag{1}$$

in which

$\overline{S}_k$ is the mean of the satisfaction rates expressed by users on the service quality k attribute

W_k (importance weight) is a weight of the k attribute, calculated on the basis of the importance rates expressed by users. Specifically, is the ratio between the mean of the importance rates expressed by users on the k attribute and the sum of the average importance rates of all the service quality attributes:

$$W_k = \frac{\overline{I}_k}{\sum_{k=1}^{N} \overline{I}_k} \tag{2}$$

CSI represents a good measure of overall satisfaction because it summarizes the judgments expressed by users about various service attributes in a single score. The more accurate the selection of the attributes, the more accurate the measure of the overall satisfaction. For this reason, the selected attributes should describe the service aspects exhaustively.

However, not all the attributes are important for the user in the same way; an index based only on satisfaction rates cannot take into account these differences. As an example, we consider five attributes with average satisfaction and importance rates reported in Table 1, according to a scale from 1 to 10. By considering only the satisfaction rates, the overall satisfaction is 7.16, and the attribute with the highest satisfaction score is attribute 2, which contributes to the overall satisfaction with an aliquot of 1.66; on the other hand, if importance rates also are considered, the attribute with the highest aliquot to the overall satisfaction is the attribute 4 (weighted score equal to 1.94). The less important attribute is attribute 5, with an aliquot of 1.05. The value of CSI is 7.28 out of 10. By converting this score into a percentage, the satisfaction index shows that the service is about 73 percent successful in satisfying its customers. By comparing CSI with the average of all the satisfaction scores, it can be observed that there is a difference between the value of these two indicators, because each attribute adds up to overall satisfaction according to a different weighted score.

Table 1. Example of Calculating CSI (Scale of 1 to 10)

Attribute	Importance Score	Importance Weight	Satisfaction Score	Weighted Score
1	7.1	0.18	6.5	1.17
2	9.2	0.23	8.3	1.91
3	7.3	0.18	6.7	1.21
4	9.5	0.24	8.1	1.94
5	6.9	0.17	6.2	1.05
Total	**40.0**			**7.28**

However, when all the importance scores are close to a certain value, the importance weights are similar, and then the CSI value is close to the average of all the satisfaction scores. In this eventuality, CSI does not give any additional information compared to the indicator calculated by considering only the satisfaction scores. In addition, the average importance scores result from the rates expressed by a sample of customers, which can be very heterogeneous; the dispersion of the rates can be represented by the variance or the standard deviation from the mean. In the same way, the satisfaction rates can be very heterogeneous among users. These heterogeneities cannot be taken into account in the CSI calculation.

To overcome this lack, importance weights can be corrected according to the dispersion of the importance rates from the average value. Analogously, satisfaction scores can be corrected according to the dispersion of the satisfaction rates from the average value. These adjustments have been introduced for calculating a new indicator, called Heterogeneous Customer Satisfaction Index (HCSI). The differences between CSI and HCSI are shown in Figure 1.

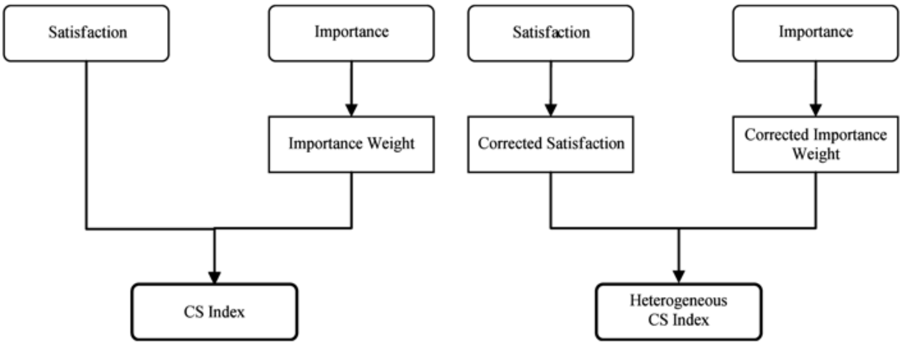

Figure 1. CS Index versus Heterogeneous CS Index

From a mathematical point of view, HCSI is calculated by the following formula:

$$HCSI = \sum_{k=1}^{N} \left[S_k^c \cdot W_k^c \right] \tag{3}$$

in which

S_k^c is the mean of the satisfaction rates expressed by users on the k attribute corrected according to the deviation of the rates from the average value

W_k^c is the weight of the k attribute, calculated on the basis of the importance rates expressed by users, corrected according to the dispersion of the rates from the average value.

S_k^c is calculated by the following formula:

$$S_k^c = \overline{S}_k \cdot \frac{\dfrac{\overline{S}_k}{\mathrm{var}(S_k)}}{\displaystyle\sum_{k=1}^{N} \frac{\overline{S}_k}{\mathrm{var}(S_k)}} \cdot N \tag{4}$$

The adjustment factor is calculated as the mean of the satisfaction rates expressed by users on the k attribute divided by the mean of the average satisfaction rates of all the service quality attributes, weighted on the variance of the satisfaction rates.

W_k^c is calculated as the mean of the importance rates expressed by users on the k attribute divided by the sum of the average importance rates of all the service quality attributes, weighted on the variance of the importance rates, according to the following formula:

$$W_k^c = \frac{\dfrac{\bar{I}_k}{\mathrm{var}(I_k)}}{\sum_{k=1}^{N} \dfrac{\bar{I}_k}{\mathrm{var}(I_k)}} \tag{5}$$

The introduction of the variance for adjusting the importance and satisfaction rates allows the attributes characterized by more homogeneous user judgments to be considered more significant; to the contrary, the attributes with heterogeneous judgments are considered less significant.

The mathematical basis of the HCSI formula is demonstrated by assuming that all the customers surveyed gave satisfaction scores of 10 out of 10 for every service characteristic, and the average satisfaction scores would all be 10. When the variance of the satisfaction judgments expressed by the customers tends to zero for all service characteristics, the mean of the satisfaction rates divided by the deviation from the mean of each k attribute would tend to the maximum value of 10, and S_k^c would tend to $\bar{S}_k$. Therefore, total customer satisfaction on all their attributes would produce a satisfaction index of 100 percent.

Application of Methodology

The proposed methodology was applied by considering an experimental case study regarding transit services in a medium-sized urban area. The urban area includes the town of Cosenza, which is a provincial capital of the Calabria region in southern Italy. Cosenza forms a single built-up area with the town of Rende, in a northerly direction. The urban area has grown over the years also because of the presence of the University of Calabria, which expanded north of Rende at the beginning of the 1970s. Cosenza and Rende represent a center of attraction for the province because of the administrative functions, job opportunities, and supply of services. The urban area has about 110,000 inhabitants. In addition, many university students live in Rende or Cosenza; approximately 35,000 students attend the University of Calabria.

The analysed transit service is a suburban bus service offering the connection between the urban area and several small villages north and south of Cosenza. A survey was addressed to the habitual passengers of two bus lines, Line 17 and Line 1, to measure transit service quality from a user point of view. Line 17 runs in a southward direction and serves a catchment area of about 5,000 inhabitants; Line 1 runs in a northward direction and serves a catchment area of about 7,000 inhabitants. Bus line characteristics are reported in Table 2.

Table 2. Transit Service Characteristics

Service Characteristics	Line 1	Line 17
Path length	19 km	18 km
# of bus stops	23	13
Travel demand	800 pass/day	700 pass/day
Service time	14 hours (from 6:00 a.m. to 8:00 p.m.)	
Service frequency	1 run/hr from 6:00 a.m to 2:00 p.m.; only 2 runs in the afternoon	
Ticket cost	from 0.50 to 1.50 Euros (depending on the covered distance)	

The survey was conducted in the spring of 2008. An operator effected face-to-face interviews on board during the service time; 218 passengers were interviewed.

Although the population is evenly spread between male and female, the majority of the habitual transit users is female (66% of the sample). Most of the interviewed users are students (49%) and younger than 20 years (44%); only 9% of the population are students, and 22% are young people. The majority of the employed respondents are clerks or workers (92%) and work in the private or public sector (71%); these percentages are the same for the population. About 65% of the sample belongs to a middle class of family income and about 28% to a lower class; the classes of income refer to the net monthly income of the family unit, expressed in Euros (Table 3).

On average, the number of family members in a family unit is 3.8 and each family has 1.64 cars. Of the 218 respondents, 77 get one-way tickets, 64 get one-day travel cards, and 69 use monthly travel cards.

Table 3. Socio-Economic Characteristics

		#	%
Gender	male	74	34
	female	144	66
		218	100
Age	up to 20 years	95	44
	from 21 to 40 years	65	30
	from 41 to 65 years	46	21
	over 65 years	12	5
		218	100
Employment	employed	66	30
	unemployed	15	7
	housewife	16	7
	student	106	49
	pensioner	15	7
		218	100
Sector of Employment	energy	1	2
	business	18	27
	private sector	26	39
	public sector	21	32
		66	100
Professional Position	businessman	1	2
	freelancer	3	5
	clerk	35	53
	worker	26	39
	artisan	1	2
		66	100
Family Income Level	up to 1,000 Euros	62	28
	from 1,000 to 2,000 Euros	96	44
	from 2,000 to 3,000 Euros	34	16
	from 3,000 to 4,000 Euros	10	5
	from 4,000 to 5,000 Euros	4	2
	over 5,000 Euros	12	6
		218	100

To evaluate bus service quality, users provided information about 26 service attributes. They expressed a rating of importance and a rating of satisfaction on each attribute on a scale from 1 to 10 (decimal included); in addition, a rating of overall service in terms of perceived quality was requested. The service attributes describe the main aspects characterizing bus services, including route and service characteristics, service reliability, comfort, cleanliness, fare, information, safety and security, personnel, customer services, and environmental protection (Table 4). A first evaluation of transit service quality is effected by analyzing the rate of satisfaction and importance by means of the calculation of the average satisfaction and importance scores (Table 4).

Generally, the attributes with an average satisfaction score lower than 6.0 can be considered critical service aspects. For the analyzed services, only two attributes had an unsatisfactory average score, availability of shelter and benches at bus stop and availability of schedule/maps at bus stops, and announcements. The attributes with the highest average satisfaction scores were ease of purchasing a ticket, security against crimes on bus, and "personnel appearance."

By analyzing the importance rates, the most important attributes for the passengers can be identified. By observing the average importance scores, it appears that all the service attributes are considered very important by the passengers; in fact, each attribute is characterized by an average importance score close to or higher than 9.0, and for only two attributes the average score is lower than 9.0: number of bus stops/distance between bus stops and cleanliness of bus exterior.

Satisfaction and importance rates were analyzed also by means of the variance (Table 4). This type of measures allows the heterogeneity of passengers in the evaluation of service quality to be verified. In this case, the passenger judgments on expected quality (rate of importance) are much more homogeneous than the judgments on the perceived quality (rate of satisfaction). In fact, the value of variance, calculated by considering the rates expressed on all the attributes, is 1.42 for the importance and 6.16 for the satisfaction; the coefficients of variation are 12.6 and 32.5 percent, respectively.

Satisfaction and importance rates expressed by the bus passengers were used for the calculation of the CSI and HCSI (Table 5). In the third and sixth column, the weighted scores are reported, which represent the contribution of each attribute to the final value of CSI and HCSI, respectively.

Table 4. Importance and Satisfaction Statistics

			Importance				Satisfaction			
Service Aspect	**Service Attribute**	#	*Mean*	*Var*	*Conf. Int.*		*Mean*	*Var*	*Conf. Int.*	
Route Characteristics	path	1	9.17	1.82	9.00	9.33	8.15	3.86	7.92	8.39
	#of bus stops, distance between bus stops	2	8.61	2.74	8.42	8.81	8.23	2.99	8.02	8.44
	bus stop location	3	9.43	1.05	9.30	9.55	8.44	3.84	8.21	8.68
Service Characteristics	service frequency	4	9.65	0.63	9.56	9.75	6.78	4.91	6.51	7.04
	daily service time	5	9.53	0.81	9.42	9.64	6.57	5.16	6.30	6.85
Service Reliability	reliability of runs that come on schedule	6	9.73	0.75	9.63	9.84	8.69	3.49	8.46	8.91
	punctuality (runs that come on time)	7	9.62	0.99	9.50	9.74	8.26	3.65	8.03	8.49
Comfort	bus crowding	8	9.36	1.65	9.20	9.51	8.55	3.57	8.32	8.77
	comfort of seats on bus	9	9.29	1.16	9.16	9.42	7.70	5.08	7.43	7.97
	air conditioning on bus	10	9.46	0.88	9.35	9.58	7.32	7.38	7.00	7.65
	levels of noise and vibration on bus	11	9.06	2.07	8.89	9.24	7.01	6.82	6.70	7.32
	availability of shelter & benches at bus stop	12	9.57	0.78	9.47	9.68	5.53	8.31	5.18	5.87
Cleanliness	cleanliness of bus interior, seats & windows	13	9.51	0.87	9.40	9.62	7.63	4.52	7.38	7.89
	cleanliness of bus exterior	14	7.85	4.58	7.59	8.10	7.44	4.13	7.19	7.68
Fare	ticket cost	15	9.12	2.03	8.95	9.29	8.41	3.81	8.18	8.65
Information	availability of schedule/ maps on bus	16	9.52	0.80	9.42	9.63	7.00	7.94	6.66	7.34
	availability of schedule/ maps at bus stops	17	9.61	0.65	9.51	9.70	3.75	5.93	3.46	4.04
	availability of information by phone, internet	18	8.94	3.00	8.73	9.15	7.44	5.30	7.16	7.71
Safety and Security	vehicle reliability, competence of drivers	19	9.91	0.19	9.86	9.96	8.45	3.93	8.22	8.69
	security against crimes on bus	20	9.80	0.59	9.71	9.89	9.10	2.69	8.90	9.29
	security against crimes at bus stops	21	9.78	0.42	9.70	9.85	7.58	5.16	7.31	7.85
Personnel	personnel appearance	22	9.35	1.35	9.21	9.49	9.04	2.04	8.87	9.21
	personnel helpfulness	23	9.75	0.41	9.68	9.83	8.25	4.78	7.99	8.51
Customer Services	ease of purchasing a ticket	24	9.65	0.75	9.54	9.75	9.34	1.69	9.19	9.50
	administration of complaints	25	9.77	0.50	9.68	9.85	7.45	6.23	7.16	7.75
Environment	use of ecological vehicles	26	9.70	0.79	9.59	9.80	6.26	7.00	5.94	6.57

Table 5. Calculating CSI and HCSI

Attribute	Importance Weight	Weighted score	Corrected Importance Weight	Corrected Satisfaction	Weighted Score
1	0.037	0.31	0.016	8.86	0.14
2	0.035	0.29	0.010	11.67	0.11
3	0.039	0.33	0.028	9.55	0.27
4	0.039	0.27	0.047	4.81	0.23
5	0.039	0.26	0.036	4.32	0.16
6	0.040	0.35	0.040	11.15	0.45
7	0.039	0.32	0.030	9.63	0.29
8	0.038	0.33	0.018	10.55	0.18
9	0.038	0.29	0.025	6.01	0.15
10	0.039	0.28	0.033	3.74	0.12
11	0.037	0.26	0.014	3.71	0.05
12	0.039	0.22	0.038	1.89	0.07
13	0.039	0.30	0.034	6.64	0.22
14	0.032	0.24	0.005	6.90	0.04
15	0.037	0.31	0.014	9.57	0.13
16	0.039	0.27	0.037	3.18	0.12
17	0.039	0.15	0.046	1.22	0.06
18	0.037	0.27	0.009	5.38	0.05
19	0.040	0.34	0.166	9.38	1.55
20	0.040	0.36	0.051	15.87	0.81
21	0.040	0.30	0.071	5.74	0.41
22	0.038	0.35	0.021	20.67	0.44
23	0.040	0.33	0.074	7.34	0.54
24	0.039	0.37	0.040	26.58	1.06
25	0.040	0.30	0.060	4.59	0.28
26	0.040	0.25	0.038	2.88	0.11
	CS Index	7.63	*Heterogeneous CS Index*		8.04

Discussion

From the experimental results, the value of CSI is 7.63. By weighting satisfaction and importance scores on the variance, we obtain a value of HCSI equal to 8.04. The difference between the CSI and HCSI values are due to the different contributions of each service attribute to each index. Obviously, if the variance of importance rates is the same for all the attributes and, contemporaneously, the variance of satisfaction rates has the same value for all the attributes, HCSI and CSI values are equal.

By analyzing the weighted scores regarding CSI, it emerges that the attributes giving the highest contribution to overall satisfaction are ease of purchasing the ticket, security against crimes on bus, reliability of runs that come on schedule, and personnel appearance. However, the values of the weighed scores range from 0.15 to 0.37 (Table 5); therefore, other attributes also make a considerable contribution. Although the gap between the two indexes is 0.41, the weighted scores of CSI are very different compared to those of HCSI, which range from 0.04 to 1.55. The attribute with the highest weighted score for the HCSI regards vehicle reliability and competence of drivers. The four most relevant service attributes for CSI are also relevant for HCSI. In addition, also the attribute regarding personnel helpfulness shows a considerable weight.

From the experimental results, HCSI can be considered a useful tool for measuring transit service quality to monitor transit agency performances and fulfil customer requirements. The index allows the causes generating customer satisfaction/dissatisfaction to be identified and the strategies for improving the service quality to be defined. HCSI introduces heterogeneity into user judgments because importance and satisfaction rates are corrected according to dispersion from the average value. By effecting this adjustment, more significance is given to the attributes characterized by homogeneous user judgments, while less significance is given to the more heterogeneous attribute.

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Bus Transit Service Planning and Operations in a Competitive Environment

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Abstract

Transit services are currently facing several challenges in the United States and around the world. For many reasons, among which the fluctuations in gas prices and the state of the economy are the major ones, transit demand has noticed a considerable increase. The challenge that transit agencies are facing is to make these increases permanent by maintaining transit's competitive edge over the private vehicle with more dense and reliable service. Current methodologies for scheduling new as well as improving existing transit routes should be able to respond to the dynamic nature of urban traffic as it is evolving through ITS and more comprehensive traffic management strategies. In this research paper, we correlate travel time obtained from buses to travel time obtained from floating vehicles in the Twin Cities metropolitan region. This research helps to introduce more reliable estimates of travel time for planning new and competitive transit services. Specifically, this work studied two bus routes over a variety of different roadway types and traffic conditions and produced statistical models that can estimate travel time based on measurements collected from buses and regular vehicle probes. The generated models revealed the characteristics causing bus service to be generally slower. Altering bus route characteristics can reduce overall travel time and minimize the travel time disparity between buses and private vehicles. In particular, the models presented in this paper lend support to *bus-only shoulder policies, stop consolidation, serving major streets with fewer stop signs, and implementation of smart transit signal priority.*

Introduction

Transit services are facing several challenges around the world, even more in the United States. In recent days transit demand has noticed an increase, which some researcher relate to the increase in gas prices. For such surge in demand to become permanent, transit agencies need to manage their systems strategically and offer a service that can be competitive to private vehicles. A service competitive to private vehicles is possible when a reliable service to passengers is present. A reliable service to a passenger is the service that can be easily accessed at origin and destination, arrives on time, has a short travel time/run time (similar or better than private vehicle travel time), and has low variance in travel time and a short waiting time (Furth and Muller 2006, 2007; Koenig 1980; Murray and Wu 2003; Turnquist 1978; Welding 1957). Achieving such service requires expanding the existing transit operations with routes that follow realistic schedules to which a bus can adhere, in addition to improving the existing service in several aspects. Schedulers rely primarily on using software that is designed based on operations research methods to introduce schedules for new bus services. Such software takes into account the expected operating environment. Unfortunately, a generic solution in transit planning based on optimization is not the best way to go and always requires some kind of fine-tuning. Some transit agencies use floating vehicles driving along corridors where new routes are planned. The vehicles are used to estimate travel time and compare it to schedules generated from optimization software prior to implementation of new service. Doing so without having an accurate understanding of the differences between floating cars and real bus service makes the outputs questionable. Currently, several agencies are looking toward increased implementation of faster services such as limited, express, and Bus Rapid Transit (BRT) services. By implementing these services, transit agencies try to compete with private vehicles to attract more choice riders (Krizek and El-Geneidy 2007). Implementing any of these services requires a full understanding of the operating environment. In this research paper, we correlate travel time obtained from buses to travel time obtained from floating vehicles in the Twin Cities metropolitan region. This research helps to introduce more reliable estimates of travel time for planning new and competitive transit services. Previous research concentrating on relating travel time between buses and floating vehicles along corridors used visualization and simple statistics (Bertini and Tantiyanugulchai 2004). They concentrated mainly on the use of transit vehicles as probes to estimate corridor travel time for systemwide implementation. Although this is not the focus of this study, findings from this study can be used in a similar manner as well. The main goal of this research is to better understand the factors affecting bus travel time towards offering a competitive service to the private vehicle in a highly complex environment. In this research, we analyze information from different roadway types (freeways, arterials, and local streets) to uncover potential traffic-flow-related dependencies.

Literature Review

Travel/Run Time

Travel time, or run time, is the amount of time it takes for a bus to travel along its route or along a specified segment. Abkowitz and Engelstein (1984) found that mean run time is affected by route length, passenger activity, and number of signalized intersections. Most researchers agree on the basic factors affecting bus run times (Abkowitz and Engelstein 1983; Abkowitz and Tozzi 1987; Guenthner and Sinha 1983; Levinson 1983; Strathman, et al. 2000). Table 1 contains a summary of known factors affecting run times.

Table 1. Factors Affecting Transit Travel Times

Variables	Description
Distance	Segment length
Intersections	Number of signalized intersections
Bus stops	Number of bus stops
Boarding	Number of passenger boardings
Alighting	Number of passenger alightings
Time	Time period
Driver	Driver experience
Period of service	How long the driver has been on service in the study period
Departure delay	Observed departure time minus scheduled
Stop delay time	Time lost in stops based on bus configuration (low floor, etc.)
Nonrecurring events	Lift usage, bridge opening, etc.
Direction	Inbound or outbound service
Weather	Weather-related conditions
Road	Road characteristics

Since buses travel with regular traffic, they are affected by the overall dynamics of the transportation system, where changes occur on both regular (i.e., peak hour traffic congestion) and random (i.e., road construction, accidents, special events) bases. These changes influence the amount of time it takes for a bus to travel from one stop to another and the level of service it provides to passengers. Street characteristic is another major element affecting bus travel time. For example, in the Twin Cities region, buses are allowed to use highway shoulders when the speed along the main lanes drops below 35 miles/hour. Buses can drive as fast as 15 miles/hour faster than the regular traffic sitting in the congested lanes, but they cannot exceed the 35 miles/hour threshold. These special privileges that buses have along the Twin Cities highway system makes estimating their travel time through regular practices difficult. It also gives buses an advantage over regular vehicles in terms of speed. Accordingly, relating travel time from buses in the Twin Cities to floating vehicles can reveal new opportunities for other agencies around the world.

Data

The goal of this research is to relate bus travel time to floating cars along a transit corridor in the Twin Cities metropolitan area. This relation helps to introduce more reliable estimates of travel time for planning new and competitive transit service along the specified corridor. In addition, it can work as a base for adjusting new bus schedules when compared to floating vehicles. The Minnesota Valley Transit Authority (MVTA), which is a relatively small suburban transit provider in the Twin Cities region, is currently planning to expand its service and upgrade levels of service along Cedar Avenue. The Cedar Avenue corridor is planned to incorporate a BRT system in addition to the current regular service. MVTA data collection is currently limited to semi-annual manual passenger counts and several TrackStick Global Positioning System (GPS) units.

To determine current travel times along the study corridor, the research team collected travel time data from two MVTA bus routes serving the Cedar Avenue corridor, Routes 442 and 444, shown in Figure 1. Route 442 is a commuter route that runs south along Cedar Avenue and Highway 77. Of all of the existing MVTA bus routes, Route 442 most closely resembles the service that will be provided by the Cedar Avenue BRT. Route 444 is also primarily a commuter route running south along Cedar Avenue and Highway 77. However, after crossing the Minnesota River, Route 444 turns westward and travels along Highway 13 and several residential streets. Route 444 was chosen for data collection to construct comparisons between car and bus travel times on freeways, arterials, and local streets.

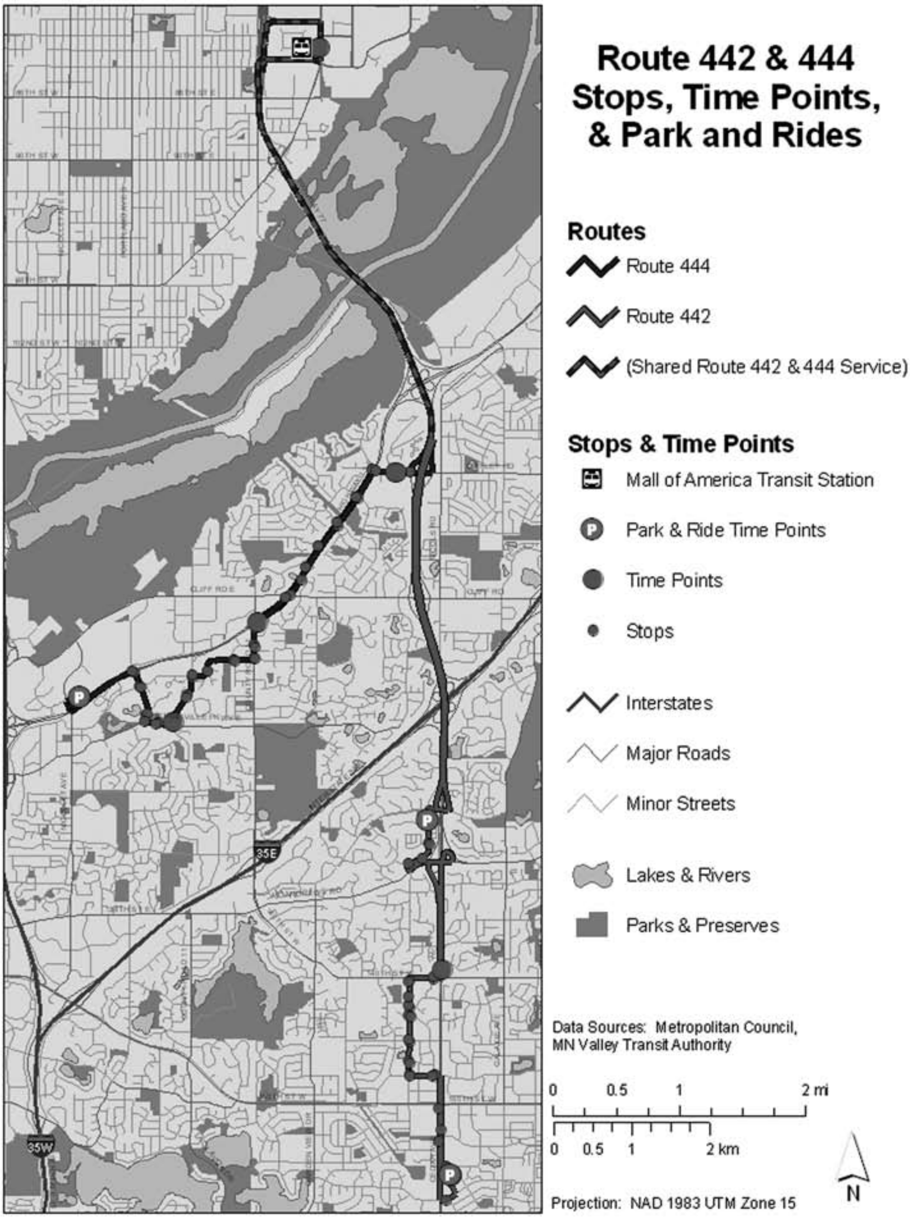

Figure 1. Studied Routes

Travel time data for buses on these routes were collected using QStarz GPS data loggers provided by the research team and several TrackStick GPS units owned by MVTA. MVTA's existing GPS units were programmed to take a data point at regular time intervals (approximately every 7 seconds), so the research team programmed the QStarz units to record points at the same interval. The research team collected data from buses running on Route 444 during the month of October 2007. Due to contractor issues, data collection on Route 442 was delayed until the following spring. The research team collected data from buses running on this route during the months of March and April 2008. During the fall data collection period, no major weather issues were present that might have an effect on travel time. Data from spring days with inclement weather (i.e., snow storms) were removed from the analysis.

Travel time data for private vehicles on Routes 442 and 444 were collected during the same time periods using probe vehicles equipped with QStarz GPS units. The research team recruited student volunteers to drive their personal vehicles along each studied transit route. Students were instructed to leave the first station on the route at the same time as a bus and to drive at the speed of traffic until they reached the end of the route.

To establish the relationship between travel times for buses and private vehicles in the study area, each bus trip was matched with a probe vehicle trip that departed at approximately the same time. After cleaning and matching the car and bus data, this data collection effort resulted in a sample of 286 matched trips (143 probe vehicle trips matched to 143 bus trips). This sample represents 130 matched trips on Route 442 and 156 matched trips on Route 444. These trips were distributed throughout the day during AM, PM, and off-peak periods.

Using these data, it is possible to determine travel times along transit routes. Unfortunately, it is not possible to accurately determine when buses make stops to serve passengers. Many of the stops along Routes 442 and 444 are located on the nearside of signalized or high-traffic intersections. Due to this combination of stop placement and the small amount of passenger activity at most stops (one passenger boarding or alighting at non-park-and-ride stops), it is not possible to distinguish actual passenger stops from regular traffic stops.

Methodology

To determine current travel times along the studied corridor and examine the relationship between travel times for personal vehicles and buses, the research team used two levels of analysis. This paper first presents a comparison of travel times for different vehicle types along Routes 442 and 444 as a whole. It then presents a comparison of travel times for different vehicle types along smaller route segments. Routes 442 and 444 provide service to a variety of areas and travel along different types of roads. To evaluate the impact of these different route characteristics on bus and private vehicle travel time, the research team divided the two routes into smaller segments with similar attributes (i.e., speed, travel direction, road classification, etc.) for analysis. Figure 2 illustrates these segments.

Using travel time data for the routes and the analysis segments, the research team conducted basic statistical analyses to determine travel time patterns. Paired t-tests also were used to examine the relationship between car and bus run times. Using only the data for the analysis segments, the research team estimated two different multivariate regression models to determine the influence of various route characteristics on travel time for both buses and private vehicles. The specifications of the models are:

(1) Run Time = f (northbound, AM, PM, length, freeway, vehicle, signals, stop signs, bus stops, ramp meters)

(2) Natural Log of Difference between Car and Bus Run Time = f (north bound, AM, PM, length, freeway, county road, signals, bus stops, meters, route)

Table 2 describes each of the dependent and independent variables used in the models. The first model examines the factors contributing to travel time for probe vehicles and buses along analysis segments. The covariants in the regressions represent the most theoretically relevant variables included in empirical studies of this type. A dummy variable for whether each vehicle is a bus or probe is included in this model. Several variables such as number of traffic signals and bus stops are also included to control for operating environment. Run time is expected to be less for private vehicles relative to buses. Run time is also expected to be less for vehicles traveling on freeway segments relative to vehicles traveling on arterials or residential streets. It is expected to increase with the number of possible stops in a segment, number of traffic signals, number of stop signs, and length of the seg-

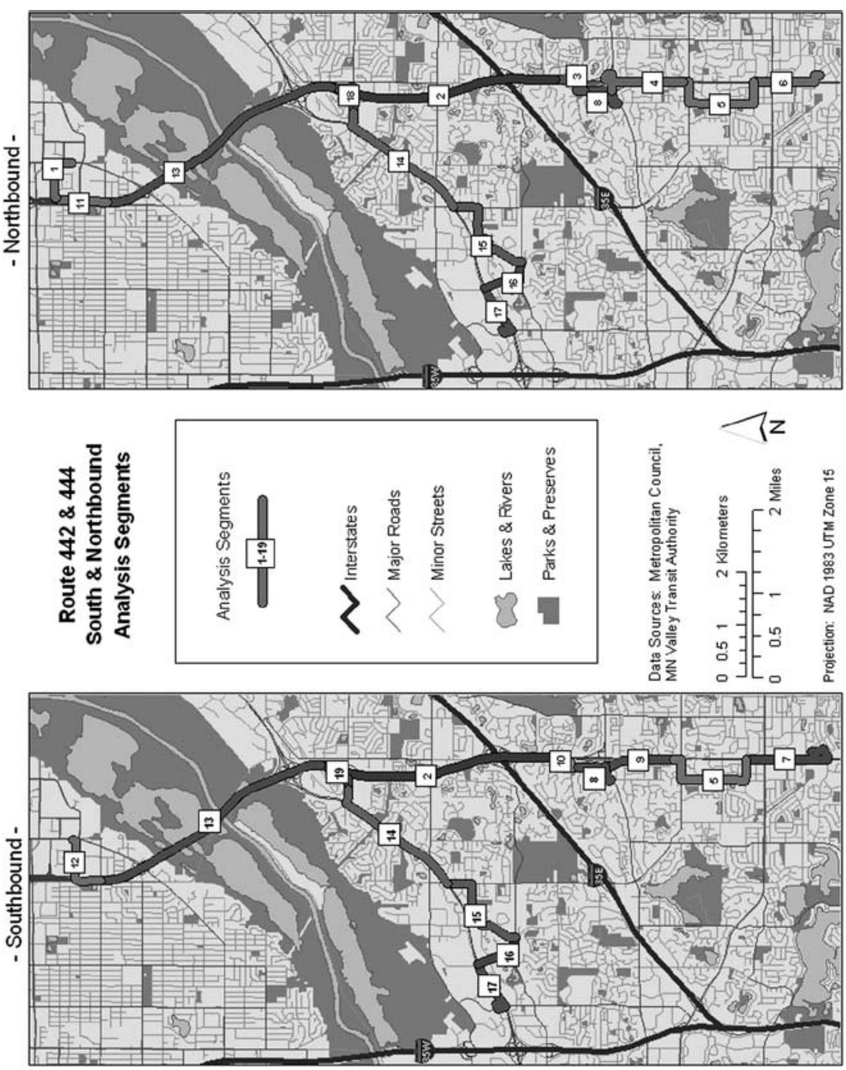

Figure 2. Routes 442 and 444 Analysis Segments

ment. Vehicles traveling during AM or PM peak hours are expected to have longer run times than vehicles traveling during off-peak hours.

The second model evaluates the impact of different route characteristics on the difference between run time for buses and private vehicles. The difference in run time equals the run time for a private vehicle along a segment minus the run time for a bus traveling along the same segment at the same time of day. The dependent variable for this model is the natural log of the difference in run times. This functional form not only helps linearize a nonlinear relationship but also provides a useful interpretation for the coefficients of the independent variables. As a result,

Table 2. Variable Descriptions

Variable	Description
Run time	The run time along an analysis segment (see Figure 2).
LN Difference Run Time	The natural log of the difference between run times for a private vehicle and bus traveling on the same analysis segment during the same time of day.
Northbound (traveling towards downtown)	A dummy variable that equals 1 if the car or bus is traveling northbound (towards downtown Minneapolis).
AM Peak	A dummy variable that equals 1 if the observed car or bus trip started during the AM peak.
PM Peak	A dummy variable that equals 1 if the observed car or bus trip started during the PM peak.
Length of Segment	The length of the analysis segment in kilometers.
Freeway	A dummy variable that equals 1 if the car or bus is traveling on a freeway segment (no stops and a speed limit of 60 mph).
County Road	A dummy variable that equals 1 if the car or bus is traveling on an arterial or county road segment (signalized stops and a speed limit of 40 mph).
Vehicle	A dummy variable that equals 1 if the observed vehicle is a car.
# of Traffic Signals	The number of traffic signals located on the analysis segment.
# of Stop Signs	The number of stop signs located on the analysis segment.
# of Bus Stops	The number of bus stops located on the analysis segment. This vari able includes all *possible* bus stops, not the number of stops actually made.
# of Ramp Meters	The number of *active* ramp meters located on the analysis segment. This variable is equal to 0 for all off-peak observations.
Route	A dummy variable that equals 1 if the observed trip is along the Route 442.

the coefficients in this model can be interpreted as the percent change in the difference in run times that results from a one-unit increase in the independent variable. For this model, the research team hypothesized that the same relationships exist with the independent variables, with the exception that the AM and PM peak variables may have negative coefficients because buses may use shoulder lanes in some areas to bypass congested traffic. If the numbers of bus stops and traffic signals have significant positive coefficients in both of these models, it is an indication that providing BRT service with consolidated stops and ITS improvements such as signal priority will lead to significant run time savings.

Travel Time Analysis

Route Travel Time Analysis

Using travel time data for the routes, the research team conducted basic statistical analyses to determine run time patterns. Figures 3 through 6 show the run time distributions for buses and private vehicles on Routes 442 and 444. For the 130 matched trips on Route 442, the run times for buses ranged from 21 to 42 minutes. The run times for private vehicles on this route ranged from 17 to 26 minutes, with a median value of 21 minutes. The standard deviation of personal vehicle run times is, not surprisingly, smaller than the standard deviation for buses. This clearly indicates that bus run time is subject to higher variation. The median observed run time for buses is 3.6 minutes longer than that for personal vehicles.

For the 156 matched trips on Route 444, the run times for buses ranged from 17 to 27 minutes, with a median value of 20.3 minutes. The run times for private vehicles on this route ranged from 13 to 24 minutes. The standard deviation of personal vehicle run times on this route is slightly larger than the standard deviation for buses. This indicates a lower variation in running time along the bus route, which can be related mainly to the length of the route. However, it is again the case that the median observed run time for personal vehicles is equal to the minimum observed run time for buses. The difference between median observed run times for buses and personal vehicles on this route is almost the same as that found for Route 442. This fact suggests that the route type, residential or arterial, does not affect the relationship between bus and private vehicle travel times. The median run time for buses on this route is 3.5 minutes longer than that for personal vehicles. Since this finding needs to be validated statistically, a detailed statistical analysis is presented in the following section.

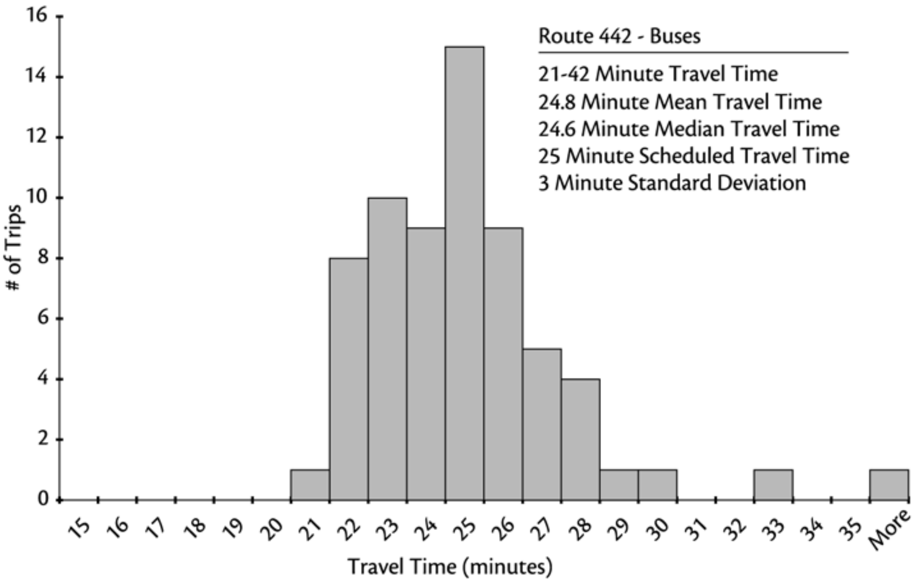

Figure 3. Route 442 Bus Run Time Distribution

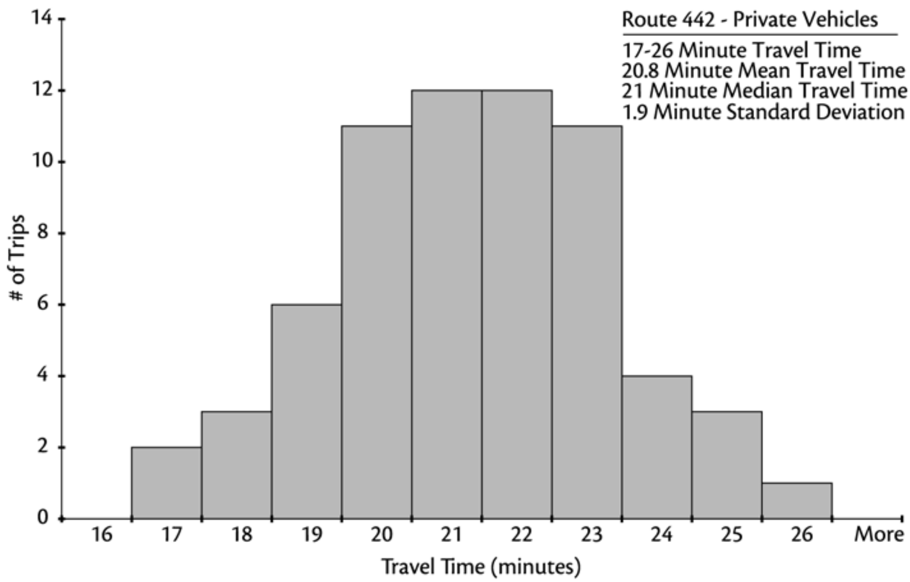

Figure 4. Route 442 Private Vehicle Run Time Distribution

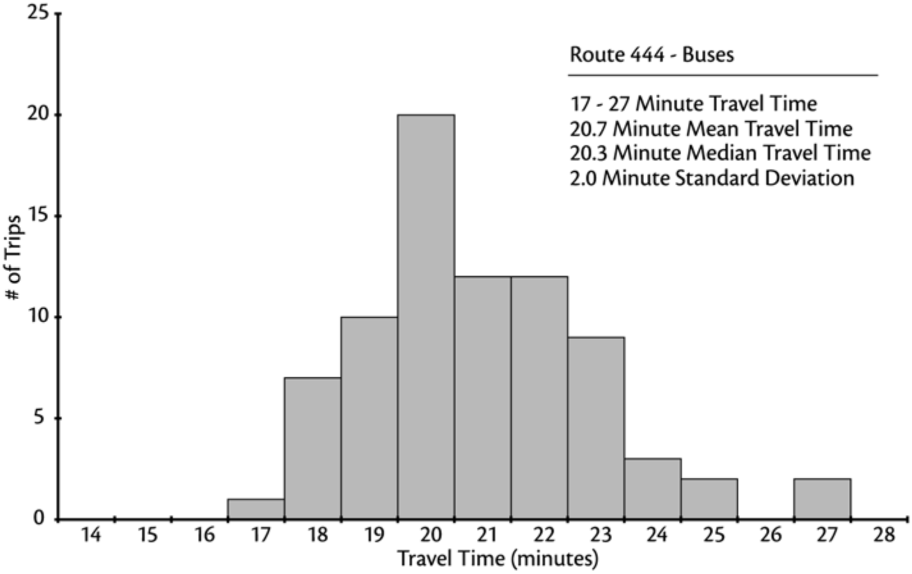

Figure 5. Route 444 Bus Run Time Distribution

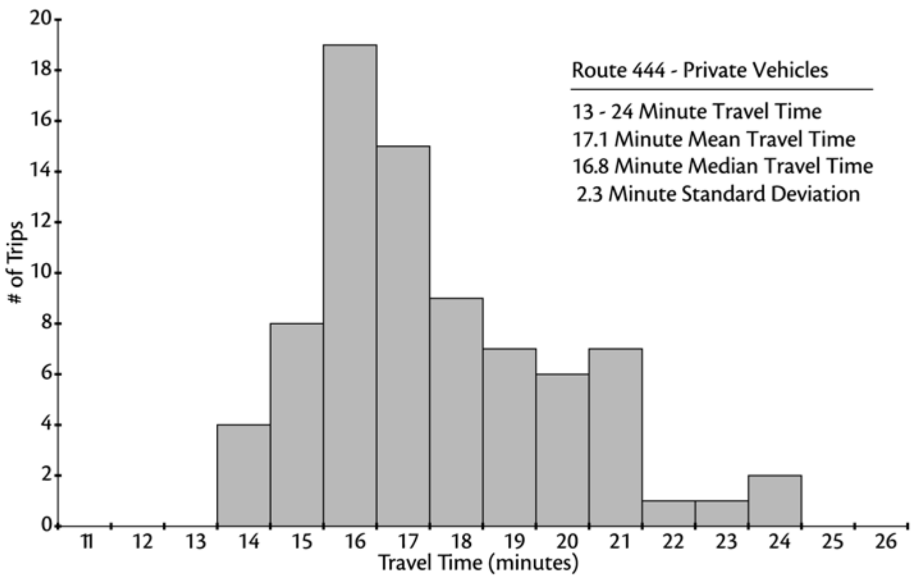

Figure 6. Route 444 Private Vehicle Run Time Distribution

Statistical Analysis

Paired T-Tests

After examining the distributions of run times, the research team used paired t-tests to examine the relationship between car and bus run times along routes and route segments. Table 3 presents the results of each of the t-test comparisons. Both of the route-level comparisons are significant at the 99% level of confidence. At the route level, the mean difference between run times for buses and private vehicles is 3.98 minutes for Route 442 and 3.59 minutes for Route 444. The difference in bus and car run times at the route level ranges from 3.08 to 4.87 minutes for Route 442 and from 2.91 to 4.26 minutes for Route 444. This statistical analysis indicates that for the bus service to be competitive along either one of the studied routes, it needs a certain amount of travel time savings ranging from 2.91 to 4.87 minutes.

Table 3. Paired T-Test Comparisons

	Road Type	Mean Difference (minutes)	95% Confidence interval of the difference			
			Lower	*Upper*	*t*	*Sig.*
Route 442	Route	-3.98	-4.87	-3.08	-8.87	.000
Route 444	Route	-3.59	-4.26	-2.91	-10.56	.000
All Segments	-	-0.52	-0.59	-0.45	-13.95	.000
Segment 1	Local Street	-0.74	-1.13	-0.35	-3.81	.000
Segment 2	Freeway	-0.91	-1.45	-0.36	-3.32	.002
Segment 3	Local Street	-0.40	-0.82	0.02	-1.95	.059
Segment 4	Arterial	-0.48	-0.60	-0.36	-8.33	.000
Segment 5	Local Street	-0.46	-0.75	-0.16	-3.06	.003
Segment 6	Arterial	-0.38	-0.93	0.17	-1.40	.171
Segment 7	Arterial	-0.60	-0.92	-0.28	-3.85	.001
Segment 8	Local Street	-0.89	-1.13	-0.65	-7.43	.000
Segment 9	Arterial	-0.22	-0.37	-0.07	-2.93	.007
Segment 10	Local Street	-0.59	-0.88	-0.31	-4.30	.000
Segment 11	Arterial	-0.08	-0.14	-0.03	-3.11	.003
Segment 12	Local Street	-0.35	-0.68	-0.02	-2.10	.040
Segment 13	Freeway	-0.05	-0.22	0.13	-0.55	.586
Segment 14	Arterial	-1.53	-1.83	-1.12	-10.19	.000
Segment 15	Local Street	-0.85	-1.05	-0.66	-8.57	.000
Segment 16	Local Street	-0.35	-0.56	-0.13	-3.19	.002
Segment 17	Arterial	-0.11	-0.32	0.10	-1.029	.307
Segment 18	Local Street	0.23	-0.03	0.48	1.79	.080
Segment 19	Local Street	-0.83	-1.18	-0.48	-4.83	.000

All but three of the t-tests conducted at the route segment level are significant at the 90% level of confidence. Segments 6 and 13 are mainly the first two segments in each route, while segment 13 is part of a 2.5-mile segment along highway 77. Observing the statistical output can help in identifying the sections where improvements in run time are needed and can lead to substantial saving and in making the transit service competitive. The second step is to understand the built environment along the selected corridors and the effects of each variable on run time to help in maximizing the savings in run time.

Regression Models

Using only the data for the analysis segments, the research team estimated two multivariate regression models to determine the influence of various route characteristics on travel time for both buses and private vehicles. The first model examines the factors contributing to travel time for probe vehicles and buses along analysis segments. In this model, observed run time (in seconds) along a route segment is used as the dependent variable. Table 4 shows the output for this model. Note that statistically significant variables are in bold.

Table 4. Run Time Model

Independent Variables	B	t	
(Constant)	20.06	4.77	***
Traveling towards Downtown	-10.75	-4.22	***
AM Peak	11.26	3.51	***
PM Peak	17.02	5.22	***
Length of Segment	37.51	26.24	***
Traveling on Freeway	-11.04	-1.15	
Vehicle is a Car	-30.27	-12.28	***
# of Traffic Signals	25.85	25.25	***
# of Stop Signs	15.80	7.42	***
# of Possible Bus Stops	8.70	13.05	***
# of Ramp Meters	-6.42	-1.66	*
Adjusted R-square	0.69		
N	2,138		
Dependent Variable	Segment Run time (seconds)		

** Significant at the 90% level*

**** Significant at the 99% level*

This model has an R-square of 0.69, with all variables having a statistically-significant effect on run time except for the freeway variable. In addition, all variables in the model have the expected sign and follow transit operation theory. For example, run time increases by 37.51 seconds for each kilometer a vehicle must travel. Relative to run times during off-peak hours, run time along each segment increased by 11.26 seconds during the AM peak and 17.02 seconds during the PM peak, holding all else constant.

For each traffic signal on a route segment, run time increases by 25.85 seconds. There are currently eight traffic signals located on the Cedar Avenue corridor through which the planned service will pass. If transit signal priority (TSP) is provided at these lights for buses, this would lead to a 3.4-minute run time savings. Each stop sign on a route segment increases run time by 15.8 seconds. By running straight down the Cedar Avenue corridor and avoiding residential areas with stop signs currently served by Route 442, the bus service will gain additional travel time savings. Route 442 currently travels through four stop signs, which add just over one minute to the route's run time. Similarly, each possible bus stop along a route segment increases run time by 8.7 seconds, whether the bus actually stops to serve passengers or not.[1] By consolidating bus stops and cutting the number of possible stops along Cedar Avenue in half, the bus will achieve more run time reductions. The 20 possible stops along Route 442 currently account for 2.7 minutes of each bus's run time. The Cedar Avenue limited or BRT, alternatively, will serve a longer segment of the corridor with only 10 possible stops, adding only 1.35 minutes to each bus's travel time.

Variables in this model with a negative effect on run time are direction of travel, number of ramp meters, traveling on the freeway, and traveling in a car. All else held constant, northbound trips have a 10.75 second shorter run time on each route segment. Each ramp meter reduces run time by 6.42 seconds. As expected, type of vehicle has the largest negative impact on travel time. On each route segment, private vehicles have a 30.27-second shorter travel time than buses. Route 442 is divided into eight segments southbound and nine segments northbound, which translates into a 4-minute shorter travel time for cars traveling south and 4.5-minute shorter travel time for cars traveling north relative to buses, all else being equal. This difference can be easily minimized if the City and the transit agency implemented some of the above-mentioned strategies for travel time savings.

The second model evaluates the impact of different route characteristics on the difference between run time for buses and private vehicles. The dependent variable for this model is the natural log of the difference in run times. As a result, the coefficients in this model can be interpreted as the percent change in the difference in run times that results from a one-unit increase in the independent variable. Table 5 shows the outputs of this model.

Table 5. Run Time Difference Model

Independent Variables	B	t	
(Constant)	-0.99	-9.20	***
Traveling towards Downtown	-0.21	-3.01	***
AM Peak	0.18	1.98	**
PM Peak	-0.08	-0.86	
Length of Segment	0.16	3.78	***
Traveling on Freeway	-1.07	-3.46	***
Traveling on County Road	-0.08	-0.84	
# of Traffic Signals	0.19	7.04	***
# of Possible Bus Stops	0.03	1.93	**
# of Ramp Meters	0.04	0.28	
Route 442	-0.08	-1.03	
Adjusted R-square	0.18		
N	762		
Dependent Variable	Natural Log of Difference between Car and Bus Run time		

** Significant at the 90% level*
*** Significant at the 95% level*
**** Significant at the 99% level*

This model has an R-square of 0.18, with the majority of variables having a statistically-significant impact on the log of the difference between bus and car run times. Again, the variables in this model have the expected signs and follow transit operation theory. The difference between car and bus run times is 18 percent greater during the AM peak hours relative to off-peak hours, all else held constant. For each additional kilometer traveled, the difference between car and bus run times increases by 16 percent. Each traffic signal increases the run time difference by 19 percent due to buses' slower acceleration time and other factors. For each possible stop, the difference in run time increases by 3 percent, whether the bus stops or not. The small magnitude of this variable could be because of the large number of possible stops and small number of actual stops being made on the studied routes. Alternatively, some of the impact of stops may be attributed to traffic signals in this model due to the prevalence of stops located on the nearside of signalized intersections along the Cedar corridor. Regardless, these results show that consolidating bus stops and implementing TSP as part of the Cedar Avenue corridor will help to reduce the travel time disparity between buses and private vehicles in the region and increase the attractiveness of transit service.

Several factors have a statistically-significant negative impact on the difference between run times for private vehicles and buses. The difference between car and bus run times is 21 percent less for northbound trips heading towards downtown Minneapolis. On freeway route segments, buses actually had a shorter travel time than personal vehicles on average, all else being equal. This is likely due to the fact that buses can bypass congested traffic and ramp queues on freeway segments of the Cedar Avenue corridor by using bus-only shoulder lanes.

Conclusions/Recommendations

The analysis presented in this paper highlights several issues related to the Cedar Avenue transit corridor in particular and to transit planning in general. This research has evaluated conditions along the Cedar Avenue corridor that will influence bus and private vehicle travel time. It has also outlined an innovative approach for estimating travel time for new transit lines based on GPS data collected by probe vehicles. The statistical analyses used in this research were conducted at two levels: the route level and the route segment level. The research team's analysis of route level travel time patterns shows that Cedar Avenue corridor buses have greater variation in their run times than vehicles. However, for both of the studied routes, the median travel time for private vehicles was equal to the minimum travel time for buses. The difference between median car and bus travel times for both routes was approximately 3.5 minutes.

The analysis of route-segment-level data provides a more detailed understanding of the relationship between vehicle type, route characteristics, and run time. While personal vehicles have an inherent travel time advantage over buses under existing conditions on the Cedar Avenue corridor (and most major arterials), our analysis shows that altering route characteristics can reduce overall travel time and minimize the travel time disparity between buses and cars. In particular, the models presented in this paper lend support to bus stop consolidation and implementation of transit signal priority along the Cedar Avenue corridor. Providing transit signal priority at the eight traffic signals currently located on the corridor would reduce bus travel time by 4 minutes for southbound trips and 4.5 minutes for northbound trips. This strategy would also eliminate the travel time advantage of private vehicles over buses on the corridor, according to our second model. Reducing the number of possible bus stops from 20 to 7 will remove an additional 1.7 minutes from the current bus travel time along this section of the corridor. Bus-only shoulder policies seem to have a great effect on the competiveness of transit vehicles over regular cars; accordingly, it is recommended to use this policy in other regions and when running bus service along congested freeway corridors. Finally, by running straight down the Cedar Avenue corridor and avoiding smaller local streets, the bus will save an additional one minute in travel time that is currently spent at stop signs. In addition to these travel time savings, remaining on the main corridor where there are freeway-like conditions will help to reduce the difference between travel time for buses and personal vehicles even more. Under these conditions, travel time via BRT running along this corridor would be approximately 2.5 minutes shorter than median run time via personal vehicle. This travel time would increase the amenity value of the BRT, attract ridership, and help to ensure the competitiveness of this transit line.

In conclusion, it should be noted that the analyses presented in this paper are based on a very limited run time dataset collected using handheld GPS units. This project was adapted to focus on the Cedar Avenue corridor, and a new methodology was developed to predict travel time for a transit provider with no existing ITS data collection systems. Due to the placement of many MVTA bus stops on the nearside of signalized intersections, the research team was not able to determine when actual passenger stops were being made. Also, budgetary restrictions prevented MVTA or the research team from being able to collect passenger counts for the entire study period. It is recommended that MVTA implement an AVL and APC system.

Future research should include budget for passenger counts for the entire study period. The number of possible stops and actual stops should be included in the future to better model the effects of bus stop consolidations. Other data that should be included in these models and may be available from transit agencies with more advanced ITS systems include smart card use, lift use, bus-only shoulder use, etc.

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Endnotes

[1] Unfortunately, using the data collected by handheld GPS units taking points at regular time (as opposed to distance) intervals, it was not possible for the research team to determine when buses actually stopped to serve passengers. In future research, the number of actual stops made as well as the number of possible stops should be included as variables in this model.

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Transit Response to Congestion Pricing Opportunities: Policy and Practice in the U.S.

Matthew H. Hardy
Noblis

Abstract

This research assesses how U.S. transit agencies have taken advantage of congestion pricing projects and answers two questions: (1) what role has transit played in U.S. congestion pricing projects, and (2) how have transit agencies responded to congestion pricing projects through service planning, operating practices, capital investment, and institutional arrangements. First, transit is seen as a direct beneficiary of congestion pricing projects since transit systems operate free of charge, thereby achieving a more reliable and/or faster travel time, thereby as well as facilitating a shift to a higher occupancy mode (buses). Second, a micro-level analysis comparing two congestion pricing projects in Northern Virginia is made.

Introduction

Congestion pricing is designed to reduce traffic congestion by charging users a higher fee when roads are busier and a lower fee when they are not and is based upon fundamental economic principles of allowing market forces and pricing to allocate the use of finite transportation system capacity (Rouwendal and Verhoef 2006). The primary intent of congestion pricing is to mitigate the effect of too much demand on the roadway infrastructure and ensure efficient system utilization. Historically, two concerns of deploying congestion pricing projects in the

United States have been technical feasibility and political acceptability (Giuliano 1992). While technical feasibility has been addressed through the development of open-road tolling and other ITS technologies, political acceptability has not been fully addressed.

Concerning political acceptability, in the commissioned paper *Curbing Gridlock: Peak-Period Fees to Relive Congestion*, Kain (1994) suggests that little political attention had been given to transit in the past because the effects are complex and require a number of assumptions that are difficult to defend. However, recent experience suggests two components concerning the political acceptability of congestion pricing projects related to transit. First, transit is seen as a direct beneficiary of congestion pricing projects since transit systems operate free of charge, thereby achieving a more reliable and/or faster travel time, thereby facilitating a shift to a higher occupancy mode (buses). For example, according to Small's (2005) assessment of London's congestion pricing system, "…better [transit] service was made possible, desirable, and financially viable by congestion pricing itself." Second, transit addresses the concern of fairness (or social equity) regarding the use of publically-funded transportation infrastructure (Giuliano 1994). Concerns about social equity center around the effect that congestion pricing may have on lower-income groups[1] (Viegas 2001). Recently, an NCHRP study regarding the public opinion of congestion pricing projects articulates social equity as a key concern of the public as well as how revenue generated by the project is used (Zmud and Arce 2008). Weinstein and Sciara conclude that social equity has a tendency to shape the overall design of the project, which often includes spending the revenue generated on alternate transportation options for users (Weinstein and Sciara 2006).

Thus, it would appear that including transit in the planning and design of congestion pricing projects appears to be essential to make it politically tenable. If congestion pricing projects require some type of transit involvement, the question becomes, with more than 15 years having passed since the U.S. implemented its first congestion pricing system in California, what role has transit really played? New initiatives by the U.S. Department of Transportation (U.S.DOT), including more than $1 billion to further demonstrate congestion pricing in the U.S., provide the opportunity to address this question more in-depth. Additionally, two congestion pricing projects using private equity being constructed in the Commonwealth of Virginia that will bring on-line nearly 150 lane-miles of congestion pricing by 2013 further add to the available data from which to draw. This paper addresses the following two research questions:

1. What role has transit played in U.S. congestion pricing projects currently in the operation, construction, or design stage of the project life-cycle?
2. How have transit agencies responded to congestion pricing projects through service planning, operating practices, capital investment, and institutional arrangements?

Methodology and Data

These research questions are investigated through a macro- and micro-level analysis of congestion pricing projects in the U.S. First, a macro-level analysis of 21 congestion pricing projects that were either operating or in the design/construction stage of the project life-cycle were identified based upon interviews with people at the federal, state, and local levels. This research purposefully excluded those projects in the planning stage since the overall role of transit was either too early to assess or too vague in nature to be of any value. Second, for each of the 21 projects, data were gathered regarding overall project characteristics from a number of sources, including planning documents, federal project applications, interviews with key project personnel, and project evaluations. Third, a ranking was given to each regarding both the involvement and impact of transit within the project. Finally, a micro-level analysis of two Virginia congestion pricing projects was undertaken. This analysis includes a more detailed review of the available planning documents associated with the projects and in-depth interviews with key personnel, including the Virginia Department of Transportation (VDOT) multimodal liaison, transit agency planning staff, and the metropolitan planning organization transportation director.

The congestion pricing projects included in this assessment are listed in Table 1, sorted according to operational year and including the following relevant data:

1. *Location*
2. *Length*
3. *Type*—Type of congestion pricing project based upon the U.S. DOT Federal Highway System classification system: variably priced lanes (VPL), variable priced toll road (VP-TR), cordon pricing (CP), or area-wide pricing (AWP).
4. *Status*
5. *Operational Year*

6. *System Type*—New construction (New) or conversion of existing roadway (Conversion).

7. *Operations*—Privately- or publicly-operated system.

8. *Transit Involvement*—A ranking of transit involvement in the overall congestion pricing project planning and design that was conducted independently by the author using available documents, reports, presentations, conference proceedings and discussions.

   - Low—No existing transit service in the congestion pricing corridor. No mention of transit as an important element in the planning documents.
   - Medium—Existing transit service in the congestion pricing corridor. Transit mentioned as an important element within the documents reviewed. Revenue from congestion pricing could be used to offer alternatives but no additional funding has been identified for transit improvements.
   - High—Existing transit service in congestion pricing corridor. Funding is codified in state law for transit improvements or funding for transit improvements have been identified and made available.

9. *Transit Impact*—An assessment of the overall impact of transit because of the congestion pricing project. The assessment is based upon Kain's (1994) analysis of transit's likely response to congestion pricing which includes improvements in speed, reliability, ridership and load factors as well as an overall expansion of service.

   - Not Significant (Not Sig.)—Transit service has been unaffected by the congestion pricing project (e.g., no improvement or service expansion).
   - Significant (Sig.)—Transit service has been improved as a result of the congestion pricing either through improved service and expanded operations.

10. *Transit Revenue Source*—Source of transit funding.

Table 1. U.S. Congestion Pricing Project Summary

Project	Location	Length (miles)	Type	Status	Operational Year	System Type	Operations	Transit Effects		
								Involvement	*Impacts*	*Revenue Source*
SR-91	Orange County	10	VPL	Operating	1995	New	Private	Medium	Not Sig.	none
I-15 FasTrak	San Diego	8	VPL	Operating	1996	New	Public	High	Sig.	VPL Revenue
Katy Freeway (I-10)	Houston	13	VPL	Operating	1998	Conversion	Public	Low	Not Sig.	none
LeeWay	Lee County	2a	VP-TR	Operating	1998	Conversion	Public	Low	Not Sig.	none
Northwest Freeway (US 290)	Houston	14	VPL	Operating	2000	Conversion	Public	Low	Not Sig.	none
New Jersey Turnpike Auth.	Various	148	VP-TR	Operating	2000	Conversion	Public	Low	Not Sig.	none
Port Authority NY/NJ	NY/NJ Interstate Crossings	6 a	VP-TR	Operating	2001	Conversion	Public	High	Sig.	VP-TR Revenue
San Joaquin Hills (73) Toll Rd	Orange County	15	VP-TR	Operating	2002	New	Public	Low	Not Sig.	none
I-394 MnPASS	Minneapolis	9	VPL	Operating	2005	Conversion	Public	High	Not Sig.	VPL Revenue
I-25 Express Lanes	Denver	7	VPL	Operating	2006	Conversion	Public	High	Not Sig.	VPL Revenue
I-15	Salt Lake City	38	VPL	Operating	2006	Conversion	Public	Low	Not Sig.	none
SR 167	Seattle	9	VPL	Operating	2008	Conversion	Public	Medium	Not Sig.	none
I-95 HOT Lanes	Miami	21	VPL	Construction	2009	Conversion	Public	High	Sig.	UPA Federal Grant
SR-520	Seattle	6.5	VP-TR	Construction	2009	Conversion	Public	High	Sig.	UPA Federal Grant
Golden Gate Bridge	San Francisco	1*	VP-TR	Design	2009	Conversion	Public	High	Sig.	UPA Federal Grant
I-95/395 HOT Lanes	Northern Virginia	56	VPL	Design	2010	Conversion	Private	High	Sig.	Public-Private Partnership Negotiation
Swoop	San Diego	27	VPL	Design	2010	New	Public	High	Sig.	UPA Federal Grant
I-35W	Minneapolis	15	VPL	Construction	2010	Conversion	Public	High	Sig.	UPA Federal Grant
I-10	Los Angeles	28 **	VPL	Design	2010	Conversion	Public	High	Sig.	CRD Federal Grant
I-110	Los Angeles	33	VPL	Design	2010	Conversion	Public	High	Sig.	CRD Federal Grant
I-495 HOT Lanes	Northern Virginia	12	VPL	Construction	2013	New	Private	Low	Not Sig.	none

* These values represent the number of bridges and tunnels included as part of the congestion pricing project.
** Lane-miles of congestion pricing roadway.

Macro Assessment of Transit Role in Congestion Pricing Projects

As seen in Table 1, the *involvement* of transit shows 13 of the 21 projects receiving a rank of High, while two were ranked Medium, and seven ranked as Low. This indicates that as part of the project design stage, transit has played an important role in shaping the congestion pricing project. For example, the I-15 project in San Diego was implemented as a tool to use available capacity on the HOV lanes on I-15 between Poway and San Diego as well as provide a revenue source to fund new transit service along the same corridor (Hultgren and Kawada 1999). Thus, transit had a vested interest in the success of the project. Other examples of high involvement include projects in Colorado and Minnesota, both of which have legislation indicating that excess revenue generated by the projects can be used to fund transit service within the corridor. Finally, there are the eight congestion pricing projects funded as part of the U.S. DOT's Fight Gridlock Now program, which includes large federal grants to demonstrate congestion pricing as well as fund transit service as an integral part of those projects.

While transit *involvement* in congestion pricing projects appears to be substantial, the reality of how transit has been affected by these projects is quite different. An initial review of the data in Table 1 indicates that the impact on transit has been substantial with 50 percent of the projects receiving a ranking of Significant and 50 percent receiving a ranking of Not Significant. Taken in isolation, this would indicate that most transit systems significantly benefit from congestion pricing projects. However, a more careful assessment shows something remarkably different. First, of the 12 operational projects, only 2 have had a significant impact on transit (compared to 4 of the 12 having a ranking of High in terms of transit involvement). This indicates that while the potential for transit is high (measured by transit involvement), the reality is that the impact on transit has not been significant for the operational projects (measured by transit impact).

Second, examining those projects in the design or construction stage reveals that each one receiving an involvement ranking of High also received a transit impact ranking of Significant. The reason is the revenue source for the transit improvements. All of the projects receiving a Significant ranking for transit impact that are in the design and construction stage have a dedicated lump-sum source of revenue that will be used to make the transit improvements. These projects do not rely on the variability of revenue generated by the congestion pricing project through tolls and user fees. All but one of the non-operational projects will use a federal grant as the means to make the transit improvements. The funding arrangement of the non-operational projects is in contrast to the operating congestion pricing projects where those projects receiving a transit involvement ranking of High rely on revenue generated by the congestion pricing projects to make transit improvements, with only two of the four receiving a transit impact rating of Significant.

In the four cases where transit involvement was ranked High, all relied on revenue generated by the congestion pricing project to fund transit improvements. Only two of the four projects resulted in significant impact to transit operations. The first is the Port Authority of NY/NJ, which implemented congestion pricing on the six interstate crossings and has produced a significant increase in funding for transit. The second is the I-15 congestion pricing project in San Diego, where revenue was used to establish a new transit service in the corridor. The other two operational congestion pricing projects (I-394 MnPASS and I-25 Express Lanes) have not generated enough revenue to cover operational costs, let alone provide additional funding for transit improvements in the corridor.

The results of this macro-level analysis revealed three common themes among the 21 projects:

1. *Transit involvement is high, but long-term opportunities are lacking*—Half of the operational congestion pricing projects that include high opportunities for improved transit service as part of state enabling legislation have not provided any revenue to the transit agency. Of the 9 non-operational systems, none include specific language as to sources of revenue for improved transit service beyond those made available as part of an initial federal grant or project negotiation. The lack of on an ongoing revenue source indicates that while transit is perceived to have an important role in the overall project, the long-term impact is by no means guaranteed.
2. *Congestion pricing projects with significant transit impact include a dedicated funding source, not just a portion of revenue*—Transit has been included as a key player in many congestion pricing projects that are either operating or in the design/construction stage. However, there is a clear distinction between the potential for transit (indicated by its involvement) and the overall impact it has. Generally, those congestion pricing projects with a significant impact on transit included a dedicated source of funding independent of the expected revenue generated.

3. *Transit must be a major partner*—In the two operational systems where transit had a significant impact, transit was an important project partner even though the role was different for each. One of the stated goals of the Port Authority of NY/NJ congestion pricing project was to encourage use of mass transit in corridors with transit alternatives *along with* reducing traffic congestion. A similar set of goals was established for the I-15 FasTrack system. However, the same is not true for the other operational congestion pricing projects. For example, the Katy Freeway in Houston has the goal of utilizing excess capacity on the HOV lanes and the LeeWay project has the goal of reducing peak-period demand.

Micro Assessment of Transit Role in Congestion Pricing Projects

The second dimension of this assessment is to assess how transit agencies have responded to congestion pricing projects through service planning, operating practices, capital investment and institutional arrangements. Based on the data gathered from the 22 congestion pricing projects in the U.S., this was difficult to accomplish since only the I-15 FasTrak system in San Diego included the operation of new transit service as a direct response to the congestion pricing system being implemented. The other congestion pricing project with significant transit impacts, Port Authority of NY/NJ, did not include any major modification to service planning, operating practices, or institutional arrangements as a result of the project.[2]

However, what was gleaned from the data gathering and assessment was an interesting difference between the two congestion pricing projects currently being designed and constructed in northern Virginia. These two projects will add more than 150 lane-miles of priced lanes to the region along some of the most highly-congested corridors. Both are being constructed using private equity under the Virginia Public Private Transportation Act (PPTA). While the I-95/395 HOT Lanes include more than $195 million in funding for improved transit service, the I-495 HOT Lanes project includes no monies. The following case study assessment provides an overview of each project and concludes with an analysis comparing and contrasting the two.

Northern Virginia Congestion Pricing Project Summaries[3]

I-495 Capital Beltway HOT Lanes[4]

Construction of the I-495 HOT Lanes began in summer 2008 with an expected completion date of 2013. The congestion pricing project will include the construction of four new variably-priced lanes along the Virginia section of the Capital Beltway between the Springfield Interchange and just south of Georgetown Pike. A consortium led by Flour-Transurban is financing and constructing the entire 14-mile project. When completed, the HOT lanes will allow transit and HOV-3 vehicles to travel free, while SOV and HOV-2 vehicles will pay a variable toll based on current travel demand to provide free-flow travel conditions. The Flour-Transurban consortium will hold a 75-year operating lease with any financial success (above and beyond benchmarks set forth in the PPTA agreement) shared with the Commonwealth of Virginia.

Initial acceptance of the HOT lanes project ran into local government and community opposition based on the perceived exclusiveness of the lanes ("Lexus Lanes"), limited community involvement, and the lack of support for alternative modes of transportation (Hardy 2008). To address these concerns, the Flour-Transurban consortium began to include more community involvement and highlight the benefits to other transportation modes. For example, the literature describing the project labeled the HOT lanes as "HOV/Bus/HOT Lanes" to promote the multi-model nature of the project. Also, the consortium emphasized the infrastructure improvements being made will create more bicycle and pedestrian access points that currently do not exist on many of the bridges crossing the Capital Beltway.

However, the role of transit within the HOT lanes project is still small, which may be a reflection of current transit service along this section of the Capital Beltway. Currently, no transit service operates on this section of the beltway due primarily to the unreliability of travel times even though two of the largest employment centers and housing areas within Fairfax County are located at either ends of the project: Springfield and Tysons Corner. The only transit service serving these two areas is Fairfax Connector Bus 401 operating on thirty-minute headways but using local streets adjacent to the beltway. Fairfax County (operator of the Fairfax Connector bus service) is currently creating a ten year long range bus plan and intends to incorporate the availability of the HOT lanes into this plan (Fairfax County Department of Transportation 2008). The Potomac Rappahannock Transportation Commission (PRTC) has listed the unreliability of travel time on the Capital Beltway as one reason they do not provide service to Tyson's Corner from southern Prince William County

(Marx 2008). Ironically, however, PRTC will be operating an express bus service during construction of the I-495 HOT Lanes between Springfield and Tyson's Corner as part of the work zone transportation management plan to mitigate mobility impacts as a result of the construction (Pardo 2008). Whether these express bus routes remain after construction is complete is not known.

I-95/395 HOT Lanes[5]

The I-95/395 HOT Lanes congestion pricing project will expand existing HOV lanes located on both I-95 and I-395 from two to three lanes and extend the lanes into Spotsylvania County near Fredericksburg. The HOT lanes will be variably priced and switch direction based upon peak period demand (northbound in the morning and southbound in the evening). Once complete, users will be able to use the HOT lanes for 56 miles from Fredericksburg to Washington, D.C. The project is being pursued under the Virginia PPTA by the Flour-Transurban consortium where private equity will be used to build-operate-maintain the HOT lanes for a 75-year lease period with any financial success (above and beyond benchmarks set forth in the PPTA agreement) shared with the Commonwealth of Virginia.

The I-95/395 corridor is currently used by many different transit agencies and operators including private bus service, express buses, local buses, heavy rail and commuter rail. In addition, there are numerous park-and-ride lots and subsequent slug lines (*ad hoc* carpools formed on-the-fly at commuter park-and-ride lots along I-95). In a reflection of transit's heavy use within the corridor, the I-95/395 HOT lanes project includes a number of direct benefits to transit users, including infrastructure improvements such as more on/off ramps that will enable faster travel times, new transit stations, additional roadway capacity and a contribution by Flour-Transurban towards capital investment for transit (purchase of buses, construction of park-ride-lots, etc.). Because of this contribution, negotiated as part of the PPTA agreement, the Commonwealth Transportation Board instructed the Virginia Department of Rail and Public Transportation (VDRPT) to develop a comprehensive transit/TDM study for the corridor to better determine how the available funding could be used (VDRPT 2008).

Project Comparison and Analysis

While the two Virginia congestion pricing projects appear to be similar in terms of location, institutional arrangements, and the use of private equity to design-build-operate, the overall impact to transit is very different. Table 2 provides a summary of the differences and commonalities between the two projects as they relate to transit impacts.

Table 2. Comparison of Transit Impacts for Virginia Congestion Pricing Projects

	I-495 HOT Lanes	I-95/395 HOT Lanes
Existing Transit Service	• Route 401 bus service (approximately 2 buses per hour during the service period)	• 127 buses per hour (peak) • 10 Metrorail trains per hour • 2 Virginia Railway Express (VRE) trains every hour • 2 Amtrak trains (peak)
Operating Agencies and Services within Corridor	• Fairfax Connector	• Potomac and Rappohannock Transportation Commission • Washington Metropolitan Area Transit Authority • Virginia Railway Express • Fairfax County • AMTRAK • City of Alexandria • Arlington County • Fredericksburg Regional Transit • Private Commuter Bus • Slug Lines • Park-and-ride Lots
Construction Type	• New	• Conversion • New
Long-Range Planning	• Included in Constrained Long-Range Plan	• Included in Constrained Long-Range Plan
Service Planning	• Fairfax County including new transit service options on I-495 HOT lanes as part of a 10-year long-range bus plan	• Extensive Transit/TDM Study conducted to determine most effective use of transit service on HOT lanes • Local agencies incorporating into service planning
Operating Practices	• New express bus being implemented as part of work zone transportation management plan	• New BRT service being considered
Institutional Arrangements	• PPTA	• PPTA • VDRPT took lead role in developing Transit/TDM Study
Capital Investment into Transit	• None	• $195 million lump sum payment
OnGoing Revenue Source*	• Potential for revenue	• Potential for revenue
Direct Benefits to Transit Improvements	• Transit operates free on HOT lanes	• Transit operates free on HOT lanes • 28-mile southern extension of existing HOV lanes • 3,000 new park-and-ride spaces in the corridor • 33 new entry/exit ramp facilities • In-line BRT station in Lorton • Enhancements to 12 existing bus stations

*Both projects include revenue sharing clauses that will provide Virginia with a portion of the revenue generated above certain benchmarks.

As seen in Table 2, there are a number of commonalities between the two projects. First, both are constructed under the Virginia PPTA and include a clause that enables Virginia to benefit from any success of the HOT lanes in terms of revenue generation above and beyond what is stipulated in the agreements. Thus, if demand is higher than projected there is the potential for an additional revenue source for Virginia; but, whether it would be spent on transit is not known. Second, both projects have been included in the regional constrained long-range plan, meaning they will be taken into account as part of the regional travel demand modeling efforts and service planning. Third, in both projects, transit will be able to use the HOT lanes free of charge. In the case of the I-495 project, this means new infrastructure on which to operate. For the I-95/395 project, this means additional capacity and access points. Finally, construction of both will include new roadway infrastructure, and the I-95/395 project also includes conversion of existing HOV lanes to HOT lanes. Previous congestion pricing projects that have converted existing HOV lanes to HOT lanes have included concerns about the impact on transit. For example, the SR 167 HOT lanes included construction of barrier separation which forced transit buses to alter their travel patterns on the lanes. However, conversion on I-95/395 will not have similar concerns since additional entry and exit points are being constructed.

What is most striking in Table 2 are the differences between the two projects in terms of existing transit service and the number of operating agencies within the corridor. The I-95/395 HOT lanes includes significantly more transit service and agencies compared with the I-495 HOT lanes project, which may have been a major factor in VDOT negotiating with the Flour-Transurban consortium a $195 million contribution towards transit improvements within the corridor as part of the PPTA. In addition, the existence of a strong transit user base more than likely contributed to the need to better articulate exactly how transit users would benefit as part of the I-95/395 HOT lanes project. With the I-495 project, no transit user base existed except for a local bus service that operated on streets adjacent to the Capital Beltway. Thus, when an assessment was made as to current demand for transit among the three major activity centers (Springfield, Merrifield, and Tyson's Corner), there were little data to use except the single bus route and speculation as to what type of demand may be created by the HOT lanes. However, with the I-95/395 HOT lanes, the amount of existing demand was easily calculated along with future demand for new transit service.

The micro-level analysis of the two Virginia congestion pricing projects revealed the following observations:

1. *Establishing a transit user base is important*—On one hand, for transit to be an integral player, an existing user base needs to be established. The I-95/395 project had a tremendous number of existing transit users whose concerns had to be addressed for the project to move forward. A similar transit user base was not identified for the I-495 project. On the other hand, congestion pricing projects could stimulate a new transit user base to be formed if the system were designed to take advantage of the transportation infrastructure. For example, the I-495 HOT lanes would create a corridor with more reliable and faster travel times for buses, enabling Fairfax County to establish new transit service, thereby establishing a new user base.
2. *Transit agencies need to adapt quickly to congestion pricing projects*—Both the I-95/395 and I-495 HOT lanes projects have moved forward very quickly considering the length of time each has been in the planning stage. This presents a barrier to many transit agencies that are not able to adapt to such an aggressive schedule. In the case of the I-495 HOT lanes, the local operating agency has just begun to incorporate the new facility into its operations. A similar observation can be made of the I-95/395 project, where VDRPT has produced an overall study about new transit service in the corridor but no changes have actually been made. The speed with which VDRPT has moved is in contrast to VDOT, which very quickly adapted to the congestion pricing proposals when they were submitted.
3. *Transit agencies need to consider innovative operations*—There is little evidence to suggest that any types of new or innovative operating practices are being considered for the Virginia HOT lanes, which may be one of the more critical elements to ensuring transit benefits from congestion pricing. Taken together, the two Virginia congestion pricing projects provide an example of a network-based HOT lane application where new transit service could operate (Poole and Orski 2003). However, it requires extensive planning and changes to existing operations and infrastructure. For example, a bus rapid transit (BRT) network could be established between Springfield and Tyson's Corner with in-line stations along the HOT lanes right-of-way and pedestrian access via the bridges going over the roadway. Establishing a BRT network that incorporates innovative operations, however, requires forethought prior to final design and construction.

Conclusions

The purpose of this research was to assess how U.S. transit agencies have taken advantage of opportunities provided by congestion pricing projects. The macro-level assessment of the 21 U.S. congestion pricing projects shows that while transit agencies have been included as important players, they have not had an active role to date. Of the 12 operating congestion pricing projects, only two have seen any type of significant impact on transit. Thus, while the involvement of transit has been significant in congestion pricing projects, the overall impact on transit has been small. This is an important finding since much of the literature states that congestion pricing could be a means to better fund transit operations. What this analysis found is that very few congestion pricing projects resulted in long-term, ongoing sources of revenue for a transit agency to provide new service or improve existing service.

However, the establishment of the U.S. DOT Urban Partnership Agreements and Congestion Reduction Demonstration programs may prove otherwise since a significant amount of the federal grants associated with these projects will directly benefit transit agencies. But, in terms of long-term opportunities for transit (e.g., new revenue sources for capital and operating expenses) none of these projects has demonstrated that to be a reality. For example, while creating a new source of revenue may be more attractive to transit agencies since many are heavily subsidized, a congestion pricing project will not guarantee this revenue stream. As seen with the I-394 MnPASS project, even though the law requires 50 percent of revenue to be spent on transit within the corridor, current revenue generated by the tolls has not covered the cost to build, operate, and maintain the system (Howard 2005). Thus, guaranteed lump sum payments, such as those being provided as part of the U.S. DOT Urban Partnership Agreements, may be a more attractive option to address immediate needs.

The results of the Virginia case study analysis yield interesting results about transit's response to congestion pricing projects. In comparing these two projects, there is evidence to suggest that transit agencies operating along the I-95/395 corridors have taken into account the potential opportunities made available to them to improve transit service as a result of the HOT lanes. In fact, VDRPT conducted a comprehensive analysis of transit opportunities as a result of the I-95/395 HOT lanes, but a similar study for the I-495 HOT lanes was not conducted. Recently, however, Fairfax County did begin developing a 10-year long-range bus operation plan that will take into account the two Virginia HOT lanes projects.

Overall, as more congestion pricing projects are implemented in the U.S., it will be important to collect data and continually monitor and evaluate the role of transit within congestion pricing projects to ensure that social equity is being addressed. The two limitations of this research center upon the availability of data. First, there was little formal evaluation data concerning existing congestion pricing systems and the impact on transit. Many of the systems had limited data, but no detailed assessment (e.g., before/after analysis) of transit operations. Second, the micro-level analysis of the two Virginia projects does not provide a complete picture of all types and flavors of congestion pricing in the U.S. However, this was an opportunity to make a true apples-to-apples comparison to examine transit agency response to congestion pricing projects. Future research should include more case studies at this level of analysis.

Endnotes

[1] For a more detailed discussion, see Litman (2005), Small (2002), Weinstein and Sciara (2006), and Viegas (2001).

[2] This should not be construed as a negative aspect of the project. The New York City metropolitan region already has the highest transit usage rate in the U.S., and any additional funding for operations and maintenance is important.

[3] The description and discussion of the I-495 and I-95/395 HOT Lanes projects was developed based upon an interview with Ms. Valerie Pardo, VDOT Multimodel Liason, on July 3, 2008.

[4] A more detailed description of the I-495 Capital Beltway HOT Lanes project is available at http://www.virginiahotlanes.com/beltway-project-info.asp.

[5] A more detailed description of the I-95/395 HOT Lanes project is available at http://www.virginiahotlanes.com/i95-project-info.asp.

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Integrating Bicycling and Public Transport in North America

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Ralph Buehler, Virginia Tech

Abstract

This paper provides an overview of bike-transit integration in large American and Canadian cities. It begins with an analysis of national trends in bike-and-ride programs such as the provision of bike racks on buses, accommodation of bikes on rail vehicles, and bike parking at rail stations and bus stops. Most of the paper, however, is devoted to case studies of bike-transit integration in six large American cities (San Francisco, Portland, Minneapolis, Chicago, Washington, and New York) and two Canadian cities (Vancouver and Toronto). Much progress has been made over the past decade in coordinating cycling with public transport, but the demand for bike-and-ride far exceeds the supply of facilities in some cities. More funding, in particular, is needed to provide more secure, sheltered bike parking at rail stations and to increase bike-carrying capacity on rail vehicles.

Introduction

Coordinating bicycling with public transport is mutually beneficial, enhancing the benefits of both modes and encouraging more bicycling as well as more public transport use (Brons et al. 2009, Givoni and Rietveld 2007, Hegger 2007, Martens 2004 and 2007, TRB 2005, U.S. DOT, 1998). Bicycling supports public transport by extending the catchment area of transit stops far beyond walking range and at much lower cost than neighborhood feeder buses and park-and-ride facilities for cars. Access to public transport helps cyclists make longer trips than possible by bike. Transit services also can provide convenient alternatives when cyclists encounter bad weather, difficult topography, gaps in the bikeway network, and mechanical failures.

In the past, bike-and-ride in North America was limited by low overall levels of cycling and public transport use in most cities, just the reverse of the situation in northern Europe (Bassett et al. 2008, Hegger 2007, Martens 2007, Pucher and Buehler 2008). In recent years, however, both cycling levels and public transport use have risen sharply in the U.S. and Canada, and bike-and-ride trips have been increasing as well. Indeed, in some cities it has been so successful that the demand for bike-and-ride facilities exceeds the available supply (TRB 2005, U.S. DOT 1998).

This paper describes the programs and policies currently being implemented in North America to integrate bicycling with public transport. It starts off with a brief overview of the various kinds of integration and the extent of their implementation. Most of the paper, however, is devoted to case studies of bike-transit integration in two large cities in Canada (Toronto and Vancouver) and six large cities in the U.S. (San Francisco, Portland, Minneapolis, Chicago, Washington, DC, and New York City). The case study analysis compares the type and extent of integration measures undertaken in the various cities, noting the strengths and weaknesses of each city's integration policies. The paper concludes by identifying the most innovative and successful policies in the eight cities and offers policy recommendations for future improvements.

North American Trends in Bike-Transit Integration

In recent years, levels of cycling and public transport use have reached record highs in both the U.S. and Canada. Between 1995 and 2008, public transport trips rose by 38 percent in the U.S. and by 46 percent in Canada (APTA 2009a and 2009b). Similarly, levels of cycling have increased considerably since 1990. In the U.S., the total number of bike trips to work increased by 32 percent from 1990 to 2005-2007 (averaged) (U.S. Census Bureau 2009a and 2009b). Over the shorter period 1996 to 2006, the number of bike trips to work in Canada rose by an even larger 42 percent (Statistics Canada 2009).

While rising public transport use and increased cycling have provided the rationale for more bike-transit integration, federal funding in the U.S. has provided the necessary financing for a wide range of projects implemented in recent years at the state and local government levels (Clarke 2003, Thunderhead Alliance 2007, TRB 2005, U.S. DOT 1998). Indeed, the federal government finances some categories of bike-transit integration projects with an especially high 95 percent federal share. There is no federal funding for urban transport in Canada, but provincial and local governments have provided large increases in funding for public transport and bicycling in recent years, including projects aimed at better integration (CUTA 2008, Pucher and Buehler 2006, Transport Canada 2006).

As documented in this article, virtually every large city in the U.S. and Canada has undertaken a range of measures to promote bike-and-ride. There are five main categories of measures to promote bike-transit integration:

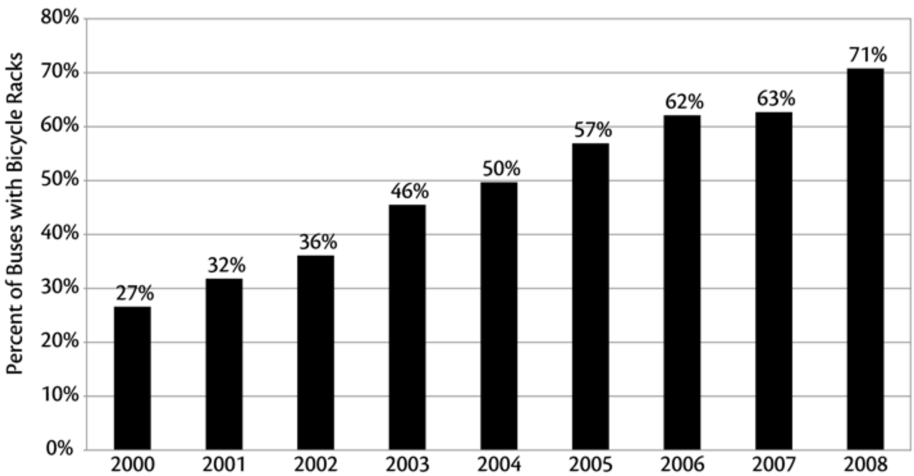
1. provision of bike parking at rail stations and bus stops, with different degrees of shelter and security
2. multi-functional bike stations providing not only parking but also a range of services such as bike rentals, repairs, parts and accessories, bike washing, showers and lockers, and touring advice
3. bike racks on buses, usually exterior, but occasionally interior storage
4. bikes on board vehicles, usually rail vehicles, sometimes with special bike racks, hooks, or even bike cars on trains
5. bike paths, lanes, and on-street routes that lead to public transport stations and stops, thus facilitating the bike's role as feeders and collectors for public transport

Extent of Bike-and-Ride Facilities in North America

The only available national statistics on bike parking at public transport stops are from recent surveys of 272 American and Canadian transit systems by the American Public Transportation Association (APTA 2006 and 2008a). In the U.S., the supply of bike parking spaces in 2008 was 24,178 at rail stations, 9,005 at bus stops, and 176 at ferry terminals. For the same year, Canadian systems reported 2,892 bike parking spaces at rail stations and 481 at bus stops. Between 2006 and 2008, the supply of bike parking increased by 67 percent in Canada and 26 percent in the U.S. (APTA 2006 and 2008a).

Unattended bike lockers are the main form of secure bike parking at North American public transport stops. Of the 56 large American and Canadian transit systems surveyed by the Transportation Research Board (2005), 14 systems provided bike lockers at some of their rail and bus stops, but the actual number of lockers was not reported. The same TRB survey reported eight staffed bike parking stations in 2005, mainly on the West Coast. A few more bike stations have opened since then (Litman 2009).

By far the most important form of bike-transit integration in North America is bike racks on buses. That is not surprising since 60 percent of all public transport trips in the U.S. are by bus (APTA 2009b). Bike racks are inexpensive to install, easy to operate, and do not take up space on the vehicles themselves (TRB 2005). The 2005 TRB survey found that systems throughout the U.S. and Canada provide bike racks on buses and that most systems have eliminated fees they had previously charged for rack use. As shown in Figure 1, the percentage of buses with bike racks almost tripled in the U.S. in only eight years, from 27 percent in 2000 to 71 percent in 2008 (APTA 2008b and 2009a).



Source: APTA, Public Transportation Factbook 2008, Table 23

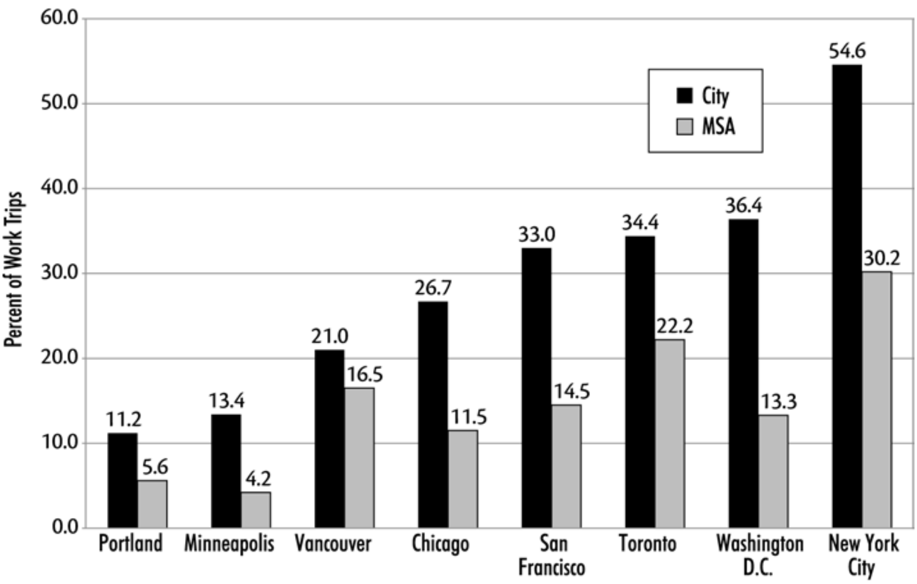
Figure 1. Trend in Percentage of Buses with Exterior Bicycle Racks in the U.S., 2000-2008

Another important form of bike-transit integration is the permission to take bikes on board public transport vehicles, since that enables cyclists to ride their bikes to and from public transport stops at both ends of their trips. Few public transport systems permit bikes to be taken on board buses unless they are compact, folding bikes, but most systems permit bikes on light rail, metro, and suburban rail trains, except during peak hour periods when crowding makes this infeasible (TRB 2005). Moreover, an increasing number of public transport systems are providing special accommodations for bikes on trains, such as bike racks, bike hooks, special bike holding areas near the doors, and even special bike cars—although rarely (APTA 2008b; TRB 2005).

The last aspect of bike-transit integration is the coordination of bike routes with public transport stops. No national statistics are available on the extent of implementation, and it would be hard to quantify at any rate. Nevertheless, the eight case studies qualitatively assess this aspect of bike-transit integration in each of the cities.

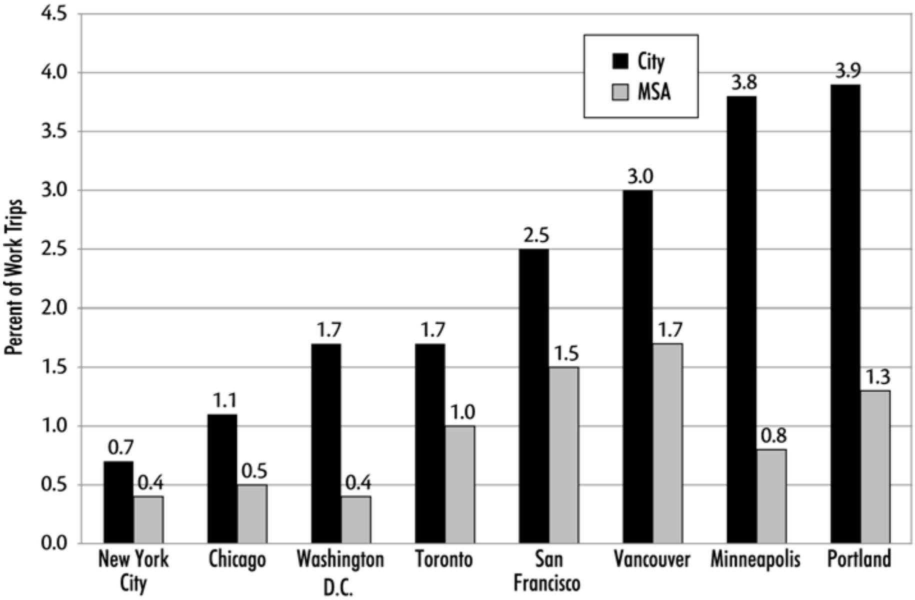
Case Studies of Bike-Transit Integration

All eight of the case study cities are large, but they vary considerably in metropolitan area population, ranging from 2.2 million in Portland, Oregon to 18.2 million in New York City. The cities also vary widely in their geographic locations, climate, and topography. Most important for this study, they vary greatly in the share of trips covered by bicycling and public transport, as shown in Figures 2 and 3.



Sources: U.S. Census Bureau (2009b) and Statistics Canada (2009)

Figure 2. Public Transport Share of Work Trips in U.S. and Canadian Cities and Metropolitan Areas, 2006/2007



Sources: U.S. Census Bureau (2009b) and Statistics Canada (2009)

Figure 3. Bicycling Share of Work Trips in U.S. and Canadian Cities and Metropolitan Areas, 2006/2007

In 2006, public transport shares of work trips for central city residents ranged from only 11 percent in Portland to 55 percent in New York (Figure 2). Public transport trip shares for metropolitan areas ranged from 4 percent in Minneapolis to 30 percent in New York. Without exception, public transport use is higher in all eight central cities than in their suburbs.

Levels of cycling also vary greatly among the eight cities (Figure 3). Portland (3.9%) and Minneapolis (3.8%) had the highest bike mode shares of work trips in 2006, but Vancouver (3.0%) and San Francisco (2.8%) were not far behind. By comparison, cycling to work in New York (0.7%) and Chicago (1.1%) is rare. Similar to levels of public transport use, bicycling is much higher in central cities than in the suburbs.

There are no comparable statistics on levels of bike-and-ride in each of these cities, since the most recent American and Canadian national travel surveys report only the main mode of transport for the work trip. Figures 2 and 3 provide useful background, however, by portraying the overall levels of cycling and public transport in the eight cities and their corresponding metropolitan areas. In general, the higher the levels of both cycling and public transport use, the greater the potential for bike-transit coordination (Hegger 2007, Rietveld 2000, Martens 2004 and 2007).

Variations in Bike-Transit Integration

Efforts to integrate cycling with public transport vary greatly among the eight case studies. New York City, for example, has done little to promote bike-and-ride, while San Francisco, Vancouver, and Portland have implemented the entire gamut of integration measures. The following section highlights the most important aspects of bike-and-ride policies in each city, noting in particular the strengths and weaknesses of current policies.

Unless otherwise indicated, the information for these case studies was obtained by the authors directly from bicycling planners, public transport systems, metropolitan planning organizations, city transport departments, and non-governmental cycling and sustainable transport organizations in each metropolitan area. The same panel of transit and cycling experts also reviewed the case studies of their cities at several stages to check for accuracy, consistency, and completeness.

San Francisco

The San Francisco Bay Area has been a leader in bike-transit integration efforts in North America. Bay Area Rapid Transit (BART) provides bike parking at almost all 43 stations, with a total of 4,313 bike parking spaces in 2009, including 1,010 in secure bike lockers. To increase convenience and flexibility, BART has been introducing electronic bike lockers (294 as of 2009), which are available on a first-come, first-served basis and do not require advance subscriptions. Caltrain, the suburban rail line from San Francisco south to Palo Alto and San Jose, provides bike parking at all 32 stations, with a total of 1,100 bike lockers and 400 bike racks.

The San Francisco Bay Area had five of the ten bike stations in the U.S. in 2009: 226 bike parking spaces at two Caltrain stations and 433 spaces at three BART stations. Utilization rates of the bike stations vary widely, from over 100 percent at the Berkeley BART station to only 11 percent at the Palo Alto Caltrain station. BART will soon triple the size of the Berkeley bike station and move it above ground to increase accessibility.

Source: Bay Area Rapid Transit

Figure 4. Electronic Bike Lockers at North Berkeley BART Station

(Insert shows smart card used to access lockers)

Source: Bay Area Rapid Transit

Figure 5. Bike Station at Berkeley

BART station is filled to overflowing but will soon be tripled in size to accommodate high demand for bike and ride.

Cyclists prefer to take bikes on board, however. A 2008 survey found that 72 percent of bike-and-ride passengers carried their bikes with them, compared to only 28 percent who parked them at BART stations. Bikes are allowed on BART trains except during peak hours in the peak direction. Although Caltrain has no time restrictions, cyclists are often denied boarding on rush hour trains because all bike spaces are already occupied. Neither BART nor Caltrain charge a fee for bringing bikes on board. Moreover, Caltrain's lead cars provide special accommodations for 16-32 bikes, depending on time of day and direction of travel. Most of the numerous ferry lines in the Bay Area also permit bikes on board with no extra fee. Folding bikes are allowed on BART and Caltrain at all times, but are not permitted on board San Francisco's MUNI buses, streetcars, cable cars, and light rail vehicles. Complementing bike access to BART and Caltrain services, virtually all buses of all public transport systems in the San Francisco Bay Area are equipped with bike racks, free of charge to cyclists.

Due to the extensive and fine-grained network of bus and rail routes in San Francisco, bike routes often lead to public transport stops, even without any explicit coordination. Outside of San Francisco, where public transport routes and stations are farther apart, many communities make an explicit effort to coordinate bike routes with key stops.

Overall, bike-transit integration efforts in the San Francisco Bay Area have been successful. The percentage of public transport trips combined with cycling has more than tripled since 1990. Nevertheless, several problems remain. For example, it is difficult for cyclists to get across the San Francisco Bay during rush hours, since bikes are prohibited from BART trains in peak directions and not permitted on the Bay Bridge. Similarly, Caltrain has problems accommodating bikes on board in the peak hour and often denies boarding to cyclists.

Portland

Bike-and-ride in Portland mainly involves bikes on transit vehicles. TriMet, Portland's public transport system, estimates that 10 times more bikes are taken on their LRT vehicles than parked at LRT stations (2,100 vs. 200 per weekday). There are no fees, no permit requirements, and no time of day or directional restrictions for taking bikes on LRT vehicles. Every train has a low-floor car especially designed to facilitate bike access, with waiting areas and four bike hooks located near the doors. But passengers without bikes have priority to board crowded trains. All buses in the Portland area have bike racks, another inducement for cyclists to ride with their bikes instead of parking them.

By comparison, Portland does not provide much bike parking at train and bus stops. In 2009, there were a total of 670 bike parking spaces at TriMet LRT stops and transit centers (major transfer hubs for several bus or LRT lines). Of those, almost half were bike lockers. In addition, there were city-owned bike lockers at 15 locations in downtown Portland, most of which were near bus or rail services. Portland does not have any bike stations, which is surprising given its high bike mode share and wide range of other pro-bike policies and programs. Bicycling planners and public transport officials plan to improve bike parking at transit stops by installing 196 bike lockers and 168 bike racks at LRT extensions.

Portland cyclists prefer taking their bikes on board transit vehicles. A survey by TriMet indicated that 76 percent of cyclists would not be willing to park their bikes at a transit stop even if there were sheltered and secure bike parking available. The advantage of taking bikes on buses or rail vehicles is that bikes can then be used at both ends of the transit trip. It also reduces the risk of bike theft and vandalism.

Portland carefully and explicitly coordinates its bikeway network with its public transport network. Bike routes are designed to facilitate access to public transport stops. Most transit centers are served by multiple bikeways. Moreover, city planners give special consideration to enhancing bike access to transit stops in outlying areas too far away from the city center for most people to cover by bike alone.

Vancouver

Metro Vancouver's unique advantage for bike transit integration is TransLink, the fully integrated, multi-modal regional transportation authority. Unlike the other case studies, public transport, major roadways, and bicycling in Vancouver are all handled within the same agency. The coordination of cycling and public transport is obvious and natural in such a multi-modal agency, as reflected in TransLink's plans, funding, construction projects, vehicle procurement, and operating procedures. Over the past 10 years, TransLink has spent more than $12 million specifically on bike-transit integration.

As in the San Francisco and Portland areas, all buses in Metro Vancouver are equipped with bike racks. Similar to San Francisco's BART, bikes are allowed on Vancouver's SkyTrain except during peak hours in the peak direction due to problems of overcrowding. Until recently, there were no special accommodations for bikes on SkyTrains, but all future vehicles will provide a special area for bikes in the rear of each car with a leaning rail and fold-up seats. Bikes are allowed at all times on West Coast Express trains for a $0.50 charge. SeaBus ferries permit bikes on board at all times without charge. Almost all of TransLink's rail and ferry services are fully accessible through elevators, ramps or level boarding, thus facilitating bike-and-ride.

Source: TransLink

Figure 6. Easy Access for Bikes on SkyTrain in Vancouver

There are bike racks at all SkyTrain and West Coast Express rail stations as well as park-and-ride lots and transit nodes with interchanges of several bus or rail lines. In 2008, Vancouver had a total of 1,060 parking spaces at transit stops: 660 spaces in racks and 400 secure bike lockers. TransLink plans to increase the overall supply of bike parking at transit stops in the coming years, with a special focus on improving the quality of bike parking, especially secure short-term bike parking.

TransLink explicitly coordinates bike routes with public transport. For example, the construction of three new SkyTrain lines included traffic-protected, parallel bike routes to foster bicyclist access to public transport. Another aspect of TransLink's multi-modalism is the focused promotion of cycling in central corridors where bus and rail vehicles are the most crowded, and where cycling has the potential to divert some of the overload and reduce crowding. That coordination of demand and supply between the two modes is rare and emphasizes the advantages of multi-modal agencies such as TransLink.

Minneapolis

Although Minneapolis is, by far, the coldest of the eight cities, it has the second highest bike share of work trips, almost as high as Portland's (3.8% vs. 3.9%). Public transport's share of work trips is slightly higher in Minneapolis than in Portland (13.4% vs. 11.2%), but much lower than in any of the other cities (Figure 2).

Metro Transit had 497 bike parking spaces at its light rail and bus stops in 2007: 271 spaces in bike racks and 226 bike lockers. Minneapolis has a staffed bike station, the Midtown Bike Center, with 100 bike parking spaces, repairs, rentals, and a café. It is only a block from the Chicago and Lake Streets transit hub, which serves two of the city's busiest bus lines.

Source: Metro Transit

Figure 7. All Buses in Minneapolis have Bike Racks

All Metro Transit and suburban transit buses are equipped with exterior bike racks, and the city has five stationary bike racks for first-time users to practice loading their bikes. Every light rail vehicle has interior vertical racks that accommodate four bikes. Bike-and-ride has become increasingly popular in Minneapolis. Metro Transit surveys in spring 2007 and fall 2008 found a doubling in the number of bicycles transported on bus racks and a 41 percent increase in bikes on light rail.

There is no explicit policy of coordinating bike routes and transit stops in Minneapolis, and City officials emphasize the need to improve cycling facilities feeding into public transport stops.

Source: Metro Transit

Figure 8. Vertical Bike Racks on Every Light Rail Vehicle in Minneapolis

Chicago

With the second largest transit system in the U.S., Chicago has made impressive efforts to integrate cycling with public transport. Its special distinction lies in the innovative provision of bike parking at rail stations, tailoring the design of parking facilities to each station's particular situation. With 6,420 parking spaces at its rail stations, Chicago has about the same amount of bike-and-ride parking as the San Francisco Bay Area and far more than other cities in North America.

There are 2,153 bike parking spaces at 131 of the 143 CTA subway and elevated rail stations and 4,267 spaces at 50 of the 76 Metra suburban rail stations. Moreover, indoor or sheltered parking is available at 83 CTA stations, more than any other transit system in North America. The specific location of bike racks inside the stations provides both weather protection and greater security, since they are usually placed within easy sight of station attendants and other passengers. Chicago is currently installing additional sheltered bike parking for 382 bikes at four CTA stations, and the city has funding to install bike shelters for 250 more bikes in 2010.

Source: Chicago Transit Authority

Figure 9. Indoor Bike Parking on Concourse of CTA Rail Station in Chicago

The largest bike station in the U.S. is located in Chicago's Millennium Park, immediately above the terminal station for two of Chicago's suburban rail lines. The bike station is easily accessible from downtown Chicago and the 18-mile Lakefront Trail. It provides secure, indoor parking for 300 bikes as well as convenient lockers, showers and towel service, bike rentals, bike repairs, and guided bicycling tours.

All of Chicago's buses have bike racks, including CTA buses and PACE suburban buses. Bikes are permitted on CTA and Metra trains except during weekday rush hours. As in most of the other cities, no fees or permits are required for the use of bike racks on buses or for bringing bikes on trains.

The biggest challenge to bike-transit integration in Chicago is the difficult access to train platforms. Because most of the rail lines are so old, only 54 percent of CTA stations and 68 percent of Metra stations are ADA accessible. Thus, cyclists are often forced to carry their bikes up long flights of stairs. Few stations have elevators, and cyclists are not permitted to use escalators.

Chicago DOT, transit agencies, and the cycling community are aware of these problems and have made improvements in bike-transit integration a top priority. Chicago's Bike Plan 2015 sets goals of further expanding and improving bike parking inside and outside of rail stations, remodeling stations to make them more accessible to bikes, providing more park-and-ride facilities, and establishing a second bike station with better transit connections.

Toronto

With more than 15,000 post-and-ring bike racks throughout the city, Toronto has more bike parking than any other city in North America. That includes bike parking at almost all rail stations. In 2008, there were 1,192 short-term spaces in bike racks at Toronto Transit Commission (TTC) subway stations and 579 short-term spaces in racks at GO Transit suburban rail stations.

Yet there is a severe shortage of secure parking, with only 114 bike lockers in the entire transit network. Consequently, Toronto plans on greatly expanding the supply of secure parking in 2009 and 2010 through installation of more bike lockers and completion of a new bike station at Union Station, the main transit hub in downtown Toronto, providing bus, streetcar, subway, and suburban rail connections. The bike station will provide secure, sheltered parking for 200 bikes. Construction of an even larger bike station at City Hall is planned to begin in 2010. That facility will be close to several bus and streetcar lines. The GO Transit suburban rail system is improving its bike parking by expanding sheltered parking to all stations by the winter of 2009-2010.

As in most cities with high levels of rail transit use, bikes cannot be taken on TTC subways and streetcars during weekday peak hours. Even when permitted, there are no special provisions for bikes on TTC subway cars. Similarly, bikes are not allowed on any GO Transit trains headed toward or leaving Union Station in the peak periods. Folding bikes are permitted on all public transport vehicles at all times. Bike access to rail transit is limited by the lack of elevators in most subway stations. Only 41 percent of TTC subway stations are wheelchair accessible, while 75 percent of GO Transit stations are accessible, either through elevators or ramps.

Toronto is making rapid progress equipping its buses with bike racks, which can be used at any time, even during peak periods. In 2008, only 55 percent of TTC buses had bike racks, but all new buses have racks, and every month about 40 older buses are retrofitted with racks. By the end of 2010, all TTC and GO Transit buses will have bike racks, thus facilitating bike-and-ride throughout the region.

There is almost no explicit coordination of bike routes with transit routes and station stops. The many transit stations and fine-grained street network in much of the central city facilitate bike access to TTC stations. In suburban areas, however, many streets are circuitous and do not connect across arterials, making it difficult for cyclists to avoid major arterials while en route to a transit station.

Washington

Bike parking is available at almost all of Washington's 86 Metrorail subway stations, with a total of 1,800 bike racks and 1,300 bike lockers. The parking facilities are popular, with usage rates at most stations ranging from 50-100 percent. In October 2009, a new bike station with spaces for 150 bikes will open next to Union Station, providing convenient connections to Metrorail as well as suburban trains leaving from Union Station. The bike station will also offer bike rentals, repairs, and accessories as well as storage lockers and changing rooms.

In 2008, a new bike-sharing program began in Washington, similar in technology to the Velib system in Paris, but on a much smaller scale: only 120 bikes compared to over 20,000 bikes in Paris. It facilitates bike-and-ride because 8 of the 10 bike-sharing docking stations are at Metrorail stops. The short-term rental bikes can be used to get to and from Metrorail stations, thus serving as feeders and distributors for transit.

Bikes are allowed on Metrorail trains except during morning and afternoon rush hours on weekdays. All 86 Metrorail stations have elevators (271 in total) and are ADA accessible, which facilitates access to platforms for cyclists as well, who are, in fact, required to use the elevators and are not permitted on escalators. In contrast to Metrorail, MARC suburban trains never allow full-size bikes on board, and VRE allows bikes only on certain trains. Both rail systems allow folding bikes at any time. All 1,450 WMATA buses have bike racks, but some buses run by suburban agencies do not.

In theory, bike plans for the Washington area establish the goal of coordinating bike routes with transit routes, but, in fact, nothing has really been accomplished in this area except by accident.

New York City

New York's transit systems have done little to promote bike-transit integration, far less than any other city in this study. The Metropolitan Transportation Authority (MTA) does not provide bike parking of any kind at the city's 467 subway stations, so the only option for cyclists is to park on nearby sidewalks. The MTA's suburban railroads, the Long Island Railroad (LIRR) and Metro-North Railroad (MNR), offer bike parking at some of their stations, but MTA has no information on the total number of spaces (MTA 2009).

Compounding the problem of insufficient bike parking along the many subway and suburban rail lines of the MTA, there is no secure bike parking at any public transport terminals in Manhattan. Train, bus, and ferry terminals do not even offer short-term parking in bike racks. Thus, cyclists must seek out the occasional bike rack on sidewalks within a few blocks of the terminals or lock their bikes to traffic signposts, lampposts, or other stationary objects.

NYC subways are unique in permitting bikes on board trains at all times, but it is difficult to get bikes to the platforms. Only 16 percent of New York's subway stations are ADA accessible via elevators or ramps. At the remaining 84 percent of stations, cyclists must carry their bikes up and down long flights of stairs, as they are prohibited from using escalators in stations where they are available. Bikes are allowed on the MTA's two suburban railroads (MNR and LIRR) except during peak hours in the peak direction, but cyclists must register in advance and purchase $5 lifetime permits. Folding bikes are allowed at all times.

Bike-bus integration is almost non-existent in New York City. Not a single bus in the MTA's fleet of 5,929 buses has a bike rack. That contrasts sharply with 100 percent of buses equipped with bike racks in most of the other case study cities. Only since spring 2008 have folding bikes been allowed on most MTA buses.

There is no explicit effort to coordinate bike routes with transit routes in New York City. That is not a severe problem in most of the city because the transit network is so dense that most neighborhoods are served by a nearby subway or bus line. In the suburbs and the outermost portions of the city, however, the complete lack of bike-transit route integration is a serious shortcoming. Precisely in those lower density areas where cycling would provide an ideal feeder mode to more distant transit stops, bikeways are almost exclusively recreational paths that do not connect to practical destinations such as transit stations.

Summary of Case Studies

Most of the case study cities have greatly improved the coordination of bicycling and public transport in recent years. They have increased bike parking at transit stops and better accommodated passengers wanting to take their bikes with them on buses and rail vehicles. Only a few transit systems have measured the actual extent of bike-and-ride, but the available evidence is encouraging. In Washington, DC, for example, the number of bicyclists riding on Metrorail increased by 60 percent between 2002 and 2007. At some stations, cyclists accounted for up to four percent of all passenger boardings. In Minneapolis, Metro Transit carries over 250,000 bicycles annually and reports a doubling of bikes on buses between spring 2007 and fall 2008. Roughly four percent of Portland MAX light rail passengers carry their bikes onto the vehicles with them. In the San Francisco Bay Area, the share of passengers accessing BART stations by bike rose from 2.5 percent in 1998 to 3.5 percent in 2008, with an average of 10,920 bike-and-ride trips per day.

As shown in Table 1, there is considerable variation among the eight case studies. The San Francisco Bay Area, for example, provides the full gamut of bike-integration measures and has been at the vanguard of innovations to promote bike-and-ride. By comparison, New York's transit systems have made few provisions to accommodate cyclists, lagging behind the other case study cities in both the quantity and quality of bike integration measures. All eight of the cities have plans to further improve bike-transit integration. Thus, it seems certain that the promising trends of recent years will continue.

Table 1. Overview of Bike-Transit Integration Measures in 8 Large American and Canadian Cities

Bike Parking at Transit Stops and Stations	Bikes on Transit: Bike Racks on Buses	Bikes on Transit: Bikes on Trains	Bike Routes and Transit Stops	Highlights: Strengths and Challenges
SAN FRANCISCO (population city: 0.8m, metro: 4.2m)				
BART provides 4,313 bike parking spaces, including 716 conventional and 294 electronic bike lockers	All buses have bike racks (usage rates vary from 17 to 43%)	BART allows bikes on all non-peak trains and during peak times in non-peak directions. BART expanded on-board space for bikes on select cars	Bike routes often parallel MUNI bus routes and intersect with transit stops. No explicit planning process coordinating transit and cycling routes in SF	STRENGTHS: Racks on all buses; extra space for bikes on Caltrain cars; bike access to BART off-peak; extensive bike parking at BART and Caltrain stations; 5 bike stations
Caltrain's 32 suburban rail stations offer 400 bike racks and 1,100 bike lockers Five bike stations with 659 bike parking spaces at BART and Caltrain Stations		Caltrain: special lead cars designated for bike use all day, space for 16-32 bikes	The Regional Bicycle Plan as well as the Bike Plans of BART and Caltrain encourage coordination of bike routes and facilities with public transport	CHALLENGES: No bike access on MUNI light rail; need more dedicated space for bikes on Caltrain; no coordination of bike routes with MUNI routes; no rush hour access for bikes on BART
PORTLAND (population city: 0.5m, metro: 2.1m)				
Bike racks and/or lockers at almost all TriMet LRT stops and transit hubs providing 670 bike parking spaces; including 320 secured spaces	All buses have bike racks	MAX light rail: bikes permitted if space is available on cars, but passengers without bikes have priority	Explicit coordination of bike routes with transit stops with the goal of establishing a seamless link between the two modes	STRENGTHS: Racks on all buses; dedicated space on LRT for hanging bikes near doors; free access for bikes 24/7; easy access to low floor trains
15 downtown locations with bike lockers; usually close to light rail or bus stops				CHALLENGES: Lack of good quality and quantity of parking at most train stations; poor design of access to stations by bike; cyclists are often denied boarding on LRT during peak

Table 1. Overview of Bike-Transit Integration Measures in 8 Large American and Canadian Cities (cont'd.)

Bike Parking at Transit Stops and Stations	Bikes on Transit: Bike Racks on Buses	Bikes on Transit: Bikes on Trains	Bike Routes and Transit Stops	Highlights: Strengths and Challenges
VANCOUVER (population city: 0.6m, metro: 2.1m)				
660 bike parking spaces in bike racks at SkyTrain stations and at transit transfer nodes	All buses have bike racks	SkyTrain: bikes allowed anytime except in peak periods in peak direction	Central Valley Greenway and BC Parkway facilitate access to and from transit stations	STRENGTHS: Bike racks on all buses; bikes allowed on SkyTrain except during peak hours in peak direction; integration of bike network and transit stops; bike parking at all major transit stops; 24/7 no cost bike access on SeaBus
400 secure bike lockers at most Sky Train and all West Coast Express stations		SeaBus: bikes allowed at all times	Translink's $2.55 million annual cost sharing of cycling infrastructure favors projects that facilitate access to transit	CHALLENGES: Need more and better bike parking; need more capacity on SkyTrain to accommodate cyclists
MINNEAPOLIS (population city: 0.4m, metro: 3.2m)				
271 bike parking spaces and 226 bike lockers next to Metro Transit stops and at park and ride lots. Usage rate of 28% of bike parking spaces at Hiawatha LRT line	All buses have bike racks. Bike on bus demonstration racks in various locations	27 light rail vehicles with on-board interior vertical racks that accommodate 4 bikes per vehicle	No explicit coordination of bike routes and transit. But connection to transit lines is a prioritizing criterion for bike projects funded by the MPO	STRENGTHS: Bike racks on buses and trains; bike racks and lockers at most train stations; marketing information on bike transit integration provided by Metro Transit
City bicycle ordinance encourages parking bikes at sign posts, which are within a block of most bus stops. Bike station 1/10 of a mile from the Chicago and Lake Street transit hub			The Hiawatha LRT line parallels an off-street bike path for most of its length in Minneapolis	CHALLENGES: Bike racks needed at four more LRT stations; lack of bike paths and lanes leading to train stations and bus stops

Table 1. Overview of Bike-Transit Integration Measures in 8 Large American and Canadian Cities (cont'd.)

Bike Parking at Transit Stops and Stations	Bikes on Transit: Bike Racks on Buses	Bikes on Transit: Bikes on Trains	Bike Routes and Transit Stops	Highlights: Strengths and Challenges
CHICAGO (population city: 2.7m, metro: 9.5m)				
2,153 bike parking spaces at 131 of the 143 CTA stations and 4,267 bike parking spaces at 50 of the 76 METRA suburban rail stations. Most (83) CTA stations provide indoor or sheltered bike parking. Usage rates of 90% and 50% for indoor and outdoor racks	All CTA and PACE buses have bike racks	Bikes permitted on CTA and METRA trains during off-peak. Bikes not permitted on escalators in stations	The routing of on-street bikeways in Chicago takes the location of transit stations into account. CTA system maps show bike parking possibilities at stations	STRENGTHS: Ample bike parking at 131 CTA stations, of which 83 provide indoor parking. State-of-the-art Millennium bike station at downtown terminus of suburban rail line; CTA regularly collects bike rack usage data to add parking where needed
Largest bike station in the USA with indoor parking for 300 bikes, right above the terminal station for two of Chicago's suburban rail lines				CHALLENGES: The CTA subway is old with limited ADA facilities; flights of stairs make it difficult to bring bikes on board
TORONTO (population city: 2.5m, metro: 5.5m)				
1,771 short-term bike parking spaces and 114 bike lockers at TCC subway and GO Transit stations	55% of TTC buses and all GO Transit buses have bike racks	Bikes permitted on TTC subways, RT trains, streetcars, and buses without bike racks except during peak hours	The guiding principle of bike facility planning is to put every resident with a 5 minute bike ride of the bike network	STRENGTHS: Extensive transit system with high mode share; bike racks on most buses; bikes allowed off-peak on streetcars, subways, and suburban rail; bike parking at most transit stops
New bike station at Union Station (opening spring 2009) with secure, sheltered parking for 200 bikes. Second bike station planned	All TTC buses will be equipped with bike racks by end of 2010	Bikes permitted on GO Transit trains except on trains arriving at and departing from Union Station in peak direction	The Waterfront Trail which spans the Greater Toronto Area parallels the busy GO Rail Lakeshore corridor and is in close proximity to many stations	CHALLENGES: No bikes allowed on rail transit during peak hours; lack of elevators in many stations; more bike parking and secure lockers needed at stations; no coordination of bike routes with transit stops

Table 1. Overview of Bike-Transit Integration Measures in 8 Large American and Canadian Cities (cont'd.)

Bike Parking at Transit Stops and Stations	Bikes on Transit: Bike Racks on Buses	Bikes on Transit: Bikes on Trains	Bike Routes and Transit Stops	Highlights: Strengths and Challenges
WASHINGTON, DC (population city: 0.6m, metro: 5.3m)				
1,800 bike racks and 1,300 bike lockers at Metro stations. No bike parking at bus stops, except major transit hubs with rail stations	All WMATA buses have bike racks	Bikes allowed on Metro trains during off-peak. Cyclists must use elevators between the street and the station platforms	Drafting of DC bike plan took the location of metro stops into account, particularly for the bike route network and facility recommendations	STRENGTHS: Bike racks on all buses; bikes on Metro except during peak; lockers and racks at all stations; SmartBike short-term rentals at 8 Metro stations
Bike station for 150 bikes opened in October 2009 at Union Station		Bikes not allowed on MARC trains. VRE allows bicycles on some trains		CHALLENGES: Restricted bike access hours on Metro; bikes restricted on VRE and MARC suburban rail
NEW YORK CITY (population city: 8.2m, metro: 18.8m)				
No dedicated bike parking at rail stations or transit terminals. Some bike parking provided by NYCDOT on sidewalks, often near transit stops. No secure bike parking of any kind in NYC	No buses with bike racks in NYC	Bikes permitted on the NYC subway at all times, but only 16% of stations ADA accessible, with elevators or ramps	No explicit coordination; but the transit network in the city is so dense that most of the bike network is close to transit	STRENGTHS: 24/7 bike access and no fees or permits on NYC subway system, most extensive in North America
Bike parking provided at only a third of MTA suburban train stations in New York; bike lockers at 18 L IRR and 6 MNR stations		All suburban trains allow bikes on board during off-peak hours, but limit of 2-4 bikes per car on weekdays	No coordination of bike network with transit stations and routes in suburbs; most suburban cycling facilities are recreational and do not lead to transit stops	CHALLENGES: No bike racks on MTA buses in NYC; limited parking at MTA suburban rail stations and no bike parking at two main train stations in Manhattan; no secure bike parking; difficult to access platforms: only 16% of subway stations with elevator access

Conclusions and Policy Implications

North American cities have been making impressive progress integrating cycling with public transport. Since 2000, the percentage of buses with bike racks has almost tripled. Bike-rail integration has also advanced. Most light rail, metro, and suburban rail systems permit bikes on their rail vehicles except during peak hours, and they increasingly provide special accommodations for cyclists such as bike hooks, racks, and rails in special areas of rail cars. Complementing provisions for bikes on transit vehicles, bike parking at transit stops has been vastly expanded over the past 10 years, with large increases in the number of racks as well as improvements in the convenience, security, and shelter of bike parking.

While cycling and public transport have considerable synergies, there are some inevitable conflicts. Surveys in some cities indicate that cyclists prefer to take their bikes with them on rail vehicles so they can use them at both ends of the trip. That can cause problems during peak hours, however, when all available capacity is needed to accommodate passengers and there is no extra room for bikes. Taking bikes on buses is much less of a problem since bike racks are external and do not reduce passenger-carrying capacity. But even bike racks can be filled to capacity during the peak, forcing cyclists to wait for later buses.

Paradoxically, bike-and-ride can become problematic where it is most successful. Capacity problems are most likely to arise in cities with well-used public transport and high levels of cycling. That is why the European approach to bike-and-ride has favored the provision of ample, sheltered, secure bike parking at transit stops instead of accommodating bikes on transit vehicles. Similarly, in North American cities with overcrowding of rail vehicles during rush hours, the focus should probably be on providing improved bike parking at rail stations. Not only is more parking needed, but it should be of higher quality, with more sheltered and secure spaces. Major transit terminals should include multi-service bike stations, such as those in northern Europe. Similar to the concept of "complete streets," an appropriate goal of transit systems in North America should be to provide "complete stations," which fully accommodate the needs of cyclists. That includes making rail platforms more accessible to cyclists, which would also improve accessibility for persons with disabilities.

Such bike-and-ride provisions cost money, but they are much cheaper than park-and-ride facilities for motorists (TRB 2005). Transit systems should shift their focus from park-and-ride to bike-and-ride, which is more cost-effective as well as more environmentally friendly. To encourage that shift, federal, state, and local government agencies should vastly expand funding for further improvements in bike-and-ride measures.

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The Concept of a Regional Maintenance Center

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Abstract

Key contributors to address maintenance concerns for rural transit systems are an aging fleet, poor maintenance practices, and a lack of technical expertise. This lack of local maintenance expertise is especially severe in rural areas. This paper examines the general requirements and maintenance service approach for a Regional Maintenance Center model in rural transportation systems. Among other findings of this study, it was determined that Regional Maintenance Centers, with a training center for mechanics and drivers, could improve vehicle reliability, increase vehicle longevity, and improve service to transit clientele. Also determined was that a generalized "one-size-fits-all" regional maintenance program could actually be counter-productive. Regional Maintenance Centers must be designed and located so potential use by rural transit service providers is maximized in order to provide superior serviceability and quality customer service.

Introduction

This article starts with a brief literature review of public transportation in rural areas and continues with current approaches to rural transit vehicle maintenance.

The State of Illinois Regional Maintenance Center (RMC) model describes and illustrates a practical application of the RMC concept. Finally, the Regional Maintenance Center model is detailed with recommendations on minimum specifications, requirements, and service features, along with conclusions. The major benefit of this work is to provide an actual framework for creating an RMC and increase the base knowledge of rural transportation maintenance issues.

Public Transportation in Rural America

Transportation services for rural areas are composed of varying programs such as rural transit, elderly and disabled special services, human services, and intercity bus and rail that service rural passengers. In rural counties across the nation, there is an approximate 50 percent availability of public transit, which totals about 1,200 systems (Stommes and Brown 2002). These federally-funded transit systems commonly fall under Section 5310 (Elderly and Disabled Programs), Section 5311 (Rural Areas Program), and Rural Transportation Assistance Program (RTAP) (Federal Transit Administration 2007).

The State of Texas has a population of approximately 23 million people and is expecting a 64 percent increase over the next 25 years (Heiligenstein et al. 2006). Two goals of the Strategic Plan for 2007-2011 for Texas Department of Transportation (TxDOT) are to reduce congestion and increase transportation asset values (Heiligenstein et al. 2006). Accomplishment of these goals is connected to TxDOT strategies to empower local and regional leaders to resolve their respective transportation problems. The majority of Texas population is concentrated in metropolitan areas such as Austin, Houston, Dallas-Fort Worth, and San Antonio. This leaves a vast number of rural areas in the state where the remaining 17 percent of the population lives. Many of these rural transit systems operate in remote areas with difficult road conditions. Long travel times between destinations and poor transit conditions create an additional burden on these vehicles and organizations. Vehicles in these areas are more difficult to maintain and often need replacing more frequently than those in urban settings (Turnbull, Dresser, and Higgins 1999).

Various Approaches to Vehicle Transit Maintenance

Currently, rural transit service providers obtain maintenance for their vehicles through two major methods: in-house or third-party maintenance contracting.

In-house maintenance performed by rural transit providers requires the service provider to maintain a technical staff that can service various vehicles types and keep an extensive and potentially expensive parts inventory. The crucial issues in maintaining a successful in-house maintenance program are a good inventory control system, determining the optimal location and design, shaping operating procedures for the maintenance facility, and the realization that maintenance is more than reorganizing or good housekeeping.

Rural transit providers can seek third-party maintenance contracting through approved and selected DOT contractors. The key to success in contracting maintenance to service providers depends mainly on the selection of contractors approved by a particular state DOT. When a state DOT has numerous maintenance contractors, difficulties arise in tracking cost and determining overall effectiveness of the maintenance provided. A rural transit provider may have to rely on local garages or local dealerships for its maintenance needs. This practice may expose it to untimely repairs, faulty workmanship, and inflated repair costs, all of which can lead to disrupted service if an alternate (loaner) vehicle is not available. Due to this lack of maintenance expertise, and regardless of maintenance method (i.e., third-party, local garage, etc.), other issues affect rural transit maintenance services, such as specialized equipment (e.g., wheelchair lifts), alternative fuel vehicle servicing, and warranty recovery being serviced in a timely manner.

A central or regionalized approach to maintenance would greatly improve overall maintenance for rural transit providers and their vehicle fleets. However, regional maintenance programs have to be developed so they are location specific and have the capacity to support servicing multiple vehicle types. A generalized "one-size-fits-all" regional maintenance program could actually be counter-productive to servicing rural transit providers because of varying factors. It is important to locate a regional maintenance center so the most natural pairing of its closest clients enables the maximum number of rural transit providers to become its potential beneficiaries. The vehicle type, model, age, and environment (climatic and economic) in which that vehicle is used are all factors needed in determining the type and frequency of prescribed maintenance. An RMC would act as a central location with full-time technical expertise to handle varied maintenance repairs efficiently and possibly at fixed costs, thus reducing overall costs for individual rural transit providers.

In an effort to examine the significance of maintenance cost in developing an effective maintenance program, Purdy and Weigmann (1987) studied 68 California transit agencies on the cost elements that contributed to the total cost of vehicle maintenance. They found that transit agencies with fewer than 100 vehicles had maintenance costs amounting to 15-20 percent of the agency's total budget, while the maintenance cost for agencies with more than 100 vehicles was approximately 20-30 percent of the total budget. The five main elements in maintenance cost are direct labor, maintenance administration, material and supplies, fringe benefits, and maintenance overhead. It would first appear that an agency with less than 100 vehicles has a lower maintenance cost than those with over 100 vehicles. This is somewhat misleading when considering that the increments in scaling were too wide to make an accurate determination. It would have been interesting to see the same data in 50-vehicle increments so the economies of scale could be examined. This would be important information in determining the number of vehicles required for the lowest overall associated cost. The Purdy and Wiegmann study highlights the importance of such economies of scale factors.

Illinois Regional Maintenance Centers

Our research revealed that the State of Illinois has, for several years, successfully operated an RMC model that services its rural transit providers. This example highlights the major points of Illinois' RMC model: commitment to the client, partnership with urban system, RMC locations, background reasons, vehicle loan program, and educational features.

The State of Illinois currently has three RMCs that service rural transit vehicles purchased through Illinois Department of Transportation (IDOT) funds. In addition, IDOT focuses on the welfare of the client and allows its RMCs to service non-profit Illinois agencies (nursing homes, hospitals, etc.) with transit vehicles. The IDOT Division of Public Transportation and its urban system, Illinois Mass Transit Systems, have a formal partnership that incorporated the RMCs into the mass transit systems. A formal Memorandum of Understanding (MOU) between these two parties ensures that financial concerns are separate and customer service agreements are met (Rural Transit Assistance Center 2006).

Presently, IDOT's RMCs are located in Springfield, Rockford, and Danville. These RMC facilities became official transit vehicle regional maintenance centers in 2001 for Springfield and Rockford and 2004 for Danville. According to the Rural Transit Assistance Center (2006) annual report prepared for IDOT, the Springfield RMC was the largest facility, servicing 41 agencies; the Rockford RMC serviced

19 agencies; and the Danville RMC serviced 4 agencies. The number of agencies served by IDOT's RMCs has increased from 35 in fiscal year 2003 to 64 in fiscal year 2006. Data for fiscal years 2001 and 2002 were unavailable. All agencies must be registered with the State before any repair and maintenance scheduling occurs with any RMC. The RMCs are located such that most transit agencies are within a 60-mile radius (one-hour drive) for travel to their closest naturally-paired RMC.

According to David Spacek, IDOT's Division of Public and Intermodal Transportation Bureau Chief, the following were primary reasons IDOT moved toward a regional concept to service its transit vehicles:

- Funds were being poorly spent on maintenance repairs because vendors were not repairing vehicles correctly.
- Warranty repairs were not being honored.
- Vehicle maintenance issues/concerns needed to be identified sooner.
- There was a lack of standardization and accountability.

IDOT undertook the RMC initiative after conducting field visits throughout the state and recognizing recurring trends.

For Illinois, the main purpose for RMCs is to perform non-routine maintenance and repairs and not to compete with local garages or vendors. According to Mr. Spacek, an added benefit to IDOT RMCs is that work is completed by mechanics already knowledgeable through experience in Illinois' urban mass transit system. Because each RMC completed the process to become a warranty center, IDOT's RMCs are recognized as such and receive authorized parts and labor rates.

Additionally, IDOT RMCs have a loaner vehicle program that is available to State-registered agencies that participate. In the past, transit agencies with an out-of-service vehicle often did not have an extra vehicle to use; thus, clients waited until the transit vehicle was repaired. The loaner vehicle is a 14-passenger van equipped with a wheelchair lift and does not require a commercial driver's license (CDL) for operation (Rural Transit Assistance Center 2006). If required, the loaner vehicle is allocated when the agency schedules a repair or maintenance through an RMC scheduler. The loaner vehicle is available to all IDOT agencies within the designated 60-mile radius and is serviced on a first-come-first-served basis. If any damage is incurred to the loaner vehicle, the borrowing agency is responsible for repairing those damages. The borrowing agency is also responsible for fuel consumed during the loan period.

All transit vehicles using State funds are centrally procured through IDOT Division of Public Transportation. Registered agencies apply for vehicles, and IDOT develops the technical specifications, negotiates with suppliers, purchases desired equipment, and informs agencies of equipment delivery. The IDOT Division of Public Transportation hosts bi-annual training seminars named "Round Tables" for mechanics, IDOT transit representatives, and transit providers. IDOT decision making representatives (executives, maintenance managers, etc.) are important participants in these "Round Tables" because they gain a deeper understanding of critical technical issues and concerns the mechanics and transit operators are addressing and trying to resolve. By actively attending and participating, IDOT decision makers can greatly assist in the resolution of mechanical issues and concerns due to their authoritative role.

Regional Maintenance Center Model

Specifications for a public transportation regional maintenance facility are crucial in ensuring that regional transportation maintenance facilities operate in a similar manner and enable rural transit agencies to reap the maximum benefit of using an RMC. Researchers for this project reviewed the websites of all 50 state Departments of Transportation, related transportation agencies, and associated organizations, reviewed more than 100 publications, visited several private entities, and conducted observational interviews to gain a thorough baseline understanding of the state of rural transportation in general and address several critical topics. However, this paper is limited to information specifically relevant to the development and operation of an RMC.

The following specifications are a conglomeration of reviewed materials and researcher expertise and are the proposed minimum essential requirements for a regional transportation maintenance facility. These specifications are thorough but not exhaustive and cover a general definition, location specifications, building and service requirements, and other general requirements.

General Definition of a Regional Maintenance Center

An RMC is defined as a centralized public transportation maintenance facility that provides general maintenance and services to rural transit providers, as indicated in Table 1.

Table 1. General Description of a RMC

• Provides preventive maintenance (PM), preventive inspection, major components repair, and replacement services to rural transit agencies within a given service area, county, and/or maintenance district.
• Provides maintenance and repair services beyond the scope that a local garage would provide.
• Provides services to specialized transit vehicles and equipment, including but not limited to wheelchair lifts and electric, propane and hybrid vehicles.
• Serves as a technical information center and provides technical expertise to rural transit agencies, other transit providers, and private maintenance contractors.
• Acts as warranty recovery center for all parts and labor and possibly as a designated warranty center to work on authorized original equipment manufacturing (OEM) parts.
• Provides loaner vehicles to rural transit agencies if necessary.

Regional Maintenance Center Location

A critical factor to the success of a regional maintenance center is the strategic location of the RMC as it relates to its potential rural transit providers, as indicated in Table 2.

Table 2. Considerations for RMC Location

• Most rural transit would travel routine routes in close proximity to the RMC on a regular basis to facilitate vehicle repair and maintenance.
• Maximize number of rural transit agencies that could utilize and benefit from the facility.
• Minimize overlap in coverage area by each RMC.
• Maximize market and population service.

Building Requirements

The building for a RMC may be a newly-constructed facility or a retrofitted facility, but the building requirements for such a facility should adhere to all lawful codes, address security concerns, and have enough operational capacity for vehicle maintenance and parking (Maintenance Design Group 2007). Each of these requirements is discussed briefly in Table 3.

Table 3. Considerations for RMC Building Requirements

BUILDING CODE
All RMC facilities must comply with local, state, and federal building codes including but not limited to fire safety, structural safety, and health requirements.
SITE SECURITY
Maintenance facilities should uphold, at minimum, basic site security including but not limited to visitor sign in, camera surveillance, and secured parking for vehicles that require overnight service.
PHYSICAL SPECIFICATION
Square footage, number of bays, washing bays, and types of building should be determined by each regional RMC location and the number of rural transit vehicles serviced by the RMC. An RMC should provide a lobby or waiting area for rural transit vehicle operators waiting for vehicle maintenance.

Service Requirements

The various types of services an RMC can conduct on rural transit vehicles may range from inspections to towing services. Information on preventive maintenance, inspections, repairs, warranty services, road calls, wrecker, and loaner services is presented in Table 4. Further details on these services can be found in "TxDOT Maintenance Management and Safety Guide" (Texas Department of Transportation 2003), Schiavone (2007), and "Handbook for Rural Transit Providers" (Kansas University Transportation Center 1997).

Table 4. Typical Service Types of a RMC

PREVENTIVE MAINTENANCE (PM)
RMC should provide PM to rural transit vehicle when requested. PM procedure should comply with federal, state, local guidelines, and vehicle manufacture specifications.
PREVENTIVE MAINTENANCE (PM) INSPECTION
PM inspection on all components of a vehicle should be performed on each rural transit vehicle once it has been brought in for maintenance and repair and again before returning it to its corresponding transit agency. PM inspection should comply with federal, state, and local guidelines. An RMC should inform the corresponding agency of any wear and tear, defective or broken parts that require attention noted during the inspection and potentially set an appointment to resolve the noted problem.
SAFETY INSPECTION
In addition to safety Inspections specified by federal, state, and local guidelines, an RMC should inspect auxiliary equipment to ensure that all equipment is in working condition. Auxiliary equipment on all vehicles serviced should be inspected, including fire extinguishers, seat belts, wheelchair restraint belts, overhead compartments, etc.
REPAIR SERVICES
All services performed by RMCs should comply with the original equipment manufacturer (OEM) and any other manufacturer specifications. Repair and maintenance services an RMC should provide include but are not limited to:
• Drive Train

– Engine services, including but not limited to major services such as repair and replace engine, replace water pumps, and minor services such as filters and fluid change.
– Transmission services, including but not limited to routine checks on existing components, service on transmission, replacing worn and broken parts, and replacing transmission with refurbished or new system.
– Differential services, usually performed in conjunction with brake service, including service, repair, and replacement of component parts as required.
• Diagnostic services, including but not limited to emission testing, transmission electronic code checks, and engine diagnostic.
• Brake services, including but not limited to pad replacement, turning or replacing brake drum, inspection and testing of pneumatic or hydraulic systems.
• Tire-related repair, including but not limited to repairing punctures, tire balancing, and tire replacement.
• Alignment and suspension services, including but not limited to replacement of worn or broken suspension part, inspection of all steering assemblies, front-end alignment, replacement and repair of worn or broken parts.
• Vehicle air conditioning system, including servicing and replacing damaged and worn components.
• Special equipment services, including but not limited to servicing and testing various types of wheelchair lifts and servicing propane, electric and hybrid vehicles.
WARRANTY RECOVERY SERVICE
An RMC should recover the warranty on all defective parts on behalf of rural transit agencies. The RMC should strive to be the designated warranty center, i.e., authorized by vehicle manufacturers to repair and replace faulty parts using original parts and authorized labor rates.
ROAD CALL SERVICES
An RMC should have a minimum of one road-call vehicle in the facility to dispatch when a vehicle breaks down.
An RMC should establish an operating procedure for using a road-call vehicle, addressing the responsibilities of the RMC and rural transit agencies when using a road-call vehicle, risk and cost sharing.
The mechanic dispatched should be able to diagnose the cause of breakdown and assess the situation. Depending on the severity of the breakdown, the mechanic should:
• Perform the repair if the repair job requires less than 30 minutes.
• Dispatch for a replacement vehicle and a wrecker vehicle if the repair requires more than 30 minutes.
WRECKER SERVICES
An RMC should establish an operating procedure that includes but is not limited to conditions to use a wrecker, a procedure to use a wrecker, and detailed responsibilities of each party involved when using a wrecker vehicle. If an RMC does not own a wrecker, the RMC should sub-contract towing services to local towing/wrecker service provider at the lowest rate possible.
LOANER VEHICLE SERVICE
Depending on the geographical location and services provided, an RMC should provide loaner vehicles to rural transit agencies on a limited basis when the rural transit vehicle requires a prolonged time period for repair. The RMC and funding entity should decide if a loaner vehicle program is needed and establish a program. This program should include but is not limited to operating procedures, conditions when a loaner vehicle is required, any charge(s) imposed on rural transit agencies for the loaner vehicle, certification required to operate a loaner vehicle, responsibilities of the RMC and the rural transit agencies on the loaner vehicle, and risk and cost sharing pertinent to the loaner vehicle.

General Requirements

The general requirements for a RMC should cover safety concerns for the facility, employees, equipment, and maintenance training for technological advances. These factors are presented in Table 5.

Table 5. General Requirements of an RMC

WORKPLACE SAFETY
An RMC should comply with all OSHA rules and regulations pertinent to a vehicle maintenance facility. A comprehensive safety and health program should be recognized, implemented, and enforced in the maintenance workplace to prevent accidents where possible.
EQUIPMENT
An RMC should have equipment that can support the services listed in "Service Requirements."
COMPUTER SOFTWARE
An RMC should have computer software that enables it to:
• Record the details of rural transit agencies of that particular RMC, including but not limited to the number of rural transit vehicles owned by each agency, the age of each vehicle, the history of maintenance and repair on each vehicle, and the next date for preventive maintenance.
• Classify detailed documentation on each maintenance and repair activity per vehicle.
• Track the warranty recovery process.
• Track inventory, including but not limited to parts, vehicles, equipment, and machinery.
• Schedule and track the work orders within the RMC.
PERSONNEL
An RMC should maintain adequate technical and administrative personnel to cover technical assistance questions and answers for rural transit agencies or other transit providers, perform routine and non-routine maintenance and repair, ensure efficiencies in handling a vehicle loaner program, provide road call assistance, conduct warranty tracking and processing, and provide wrecker services.
MECHANICS
Classification: Mechanics should be classified based on skill level, years of experience, and demonstrated competence.
Certification: Mechanics that operate special machinery or perform maintenance and repair of special equipment should obtain proper certifications pertinent to the work performed.
TRAINING
Proper training should be provided to all mechanics prior to operating any machinery and repairing and performing maintenance on vehicles. Mechanic training on maintenance should comply with federal, state, and local guidelines/regulations.
Training should be provided to transit operators and their drivers on safety, equipment preservation, and RMC general operations.
An RMC should conduct quarterly or bi-annual maintenance roundtable sessions to keep mechanics and decision-makers abreast of issues related to transit vehicle maintenance.
• Discussion topics should include frequently-encountered problems in maintenance and repairs, latest technologies and techniques in maintenance and repairs, and benefits of PM.

• Special issues, events, and governmental policy changes could be addressed during roundtable sessions. This includes inviting a guest speaker from the state DOT, etc.
• The typical duration of roundtable session is half day to full day.
• Attendance of all mechanics and directors of rural transit agencies (decision makers) should be mandatory.

Conclusions

The utilization of the Regional Maintenance Center concept offers many advantages over traditional in-house and third-party contracted maintenance. The opportunity to improve maintenance and increase equipment longevity while controlling cost is a very attractive undertaking. It is also important to note that each RMC should be location-specific (natural pairing with local area rural transit service providers). A "one-size-fits-all" approach is not a successful approach. Influential factors such as vehicle type, fleet age, RMC maintenance capacity, and human resource availability are very important. To service rural transit vehicles, there is an expected added cost due to possibly adding mechanics, staff, inventory parts, and specialized equipment. This added cost can be offset by a better utilization of physical and human assets. In addition, it is expected that a synergistic effect will be generated by an RMC that is related to training and dissemination of information. A centralized location such as an RMC can be used to offer specific training and certifications for transit operators and their personnel. The problems identified relate mainly to determining where to locate an RMC and what services to offer. The major benefit of this work has been increasing the base knowledge of rural transportation and providing a schema for a Regional Maintenance Center model.

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