JOURNAL OF

Public Transportation

Volume 6, No. 4, 2003
ISSN 1077-291X

The *Journal of Public Transportation* is published quarterly by

National Center for Transit Research
Center for Urban Transportation Research
University of South Florida • College of Engineering
4202 East Fowler Avenue, CUT100
Tampa, Florida 33620-5375
Phone: 813•974•3120
Fax: 813•974•5168
Email: *land@cutr.usf.edu*
Website: *www.nctr.usf.edu/journal*

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Laurel A. Land, *Managing Editor*
Center for Urban Transportation Research (CUTR) • University of South Florida
4202 East Fowler Avenue, CUT100 • Tampa, FL 33620-5375
Phone: 813•974•1446
Fax: 813•974•5168
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Our troubled planet can no longer afford the luxury of pursuits confined to an ivory tower. Scholarship has to prove its worth, not on its own terms, but by service to the nation and the world.
—Oscar Handlin

The Importance Customers Place on Specific Service Elements of Bus Rapid Transit

Michael R. Baltes
National Bus Rapid Transit Institute

Abstract

Bus Rapid Transit (BRT) is a rapidly growing national trend in the provision of public transportation. At present, with more than 150 New Start Rail Projects currently in the FTA pipeline, a wide range of alternatives is necessary to fulfill the demand for cost-effective rapid public transportation. As a lower cost, high-capacity mode of public transportation, BRT can serve as an option to help address the growing traffic congestion and mobility problems in both urban and nonurban areas. Careful documentation and analyses of BRT systems and the unique features of these projects will help determine the most effective features offered by the BRT systems such the most successful service characteristics, level of transit demand, region size, and other amenities. This article presents a statistical analysis of the data from two on-board customer surveys conducted in 2001 of the BRT systems in Miami and Orlando, Florida. Using data from the two on-board surveys, the simplest method for measuring the importance that customers place on specific BRT service characteristics is to calculate mean scores for each characteristic using some type of numeric scale (e.g., a scale of 1 through 5, with 5 being the highest). While there are no real discernable drawbacks to this simple method, an alternate technique to measure the importance of each service attribute is to derive the importance of each attribute using STEPWISE regression. This statistical method estimates the importance of each *attribute to overall customer satisfaction. The results indicate that customers place a high value on the BRT service characteristics frequency of service, comfort, travel time, and reliability of service.*

Introduction

One of the main goals of the Federal Transit Administration's (FTA) Bus Rapid Transit (BRT) Demonstration Program is to determine the effects of 10 nationwide BRT demonstration projects through a scientific evaluation process. The FTA designated the South Miami-Dade Busway, Busway for short, as one of its 10 BRT demonstration sites. While not one of FTA's 10 designated BRT demonstration projects, the Lynx LYMMO in Orlando was chosen by the FTA for evaluation due to its Intelligent Transportation Systems (ITS) and as a model for the implementation of similar BRT systems. According to the FTA, careful documentation and analyses of the BRT demonstration projects and the unique features of these projects will help determine the most effective features (i.e., type of service offered, most successful service characteristics, level of transit demand, region size, and other amenities). It is anticipated that the BRT demonstration projects will serve as learning tools and as models for other locales throughout the country, and possibly the world. For these demonstrations to have maximum effectiveness in their respective operational capacities, a consistent and carefully structured approach to project evaluation is necessary.

The following, taken verbatim from *Evaluation Guidelines for Bus Rapid Transit Demonstration Projects* (Schwenk 2001), are the four evaluation guidelines for the 10 BRT demonstration projects:

1. Determine the benefits, costs, and other impacts of individual BRT features, including ITS/APTS applications, and of the system as a whole.
2. Characterize successful and unsuccessful aspects of the demonstration.
3. Evaluate the demonstration's achievement of FTA and agency goals.
4. Assess the applicability of the demonstration results to other sites.

In addition, the FTA plans to examine specific impacts of the BRT demonstration projects. These impacts include: degree that bus speeds and schedule adherence improve; degree that ridership increases (due to improved bus speeds, schedule adherence, and convenience); effect of BRT on other traffic; effect of each of the BRT components on bus speed and other traffic; benefits of ITS/APTS applications to the demonstration project; and effect of BRT on land use and development. To meet these objectives, it is necessary to collect a variety of data on several aspects of the BRT demonstration project, including measurable impacts to BRT customers via the on-board survey process.

In keeping with the FTA's evaluation guidelines, the National Bus Rapid Transit Institute at the Center for Urban Transportation Research (CUTR), working jointly with Miami-Dade Transit (MDT) and Lynx, conducted on-board surveys of South Miami-Dade Busway customers in March 2001 and Lynx LYMMO customers in December 2001. The South Miami-Dade Busway and Lynx LYMMO are examples of different applications of BRT systems that are specifically designed to offer faster travel choices to customers compared to standard local bus service and possibly, even the private automobile. Evaluation of the various components of the Busway and LYMMO are crucial parts of the demonstration project. The two on-board surveys serve as the first phase of the independent review of the Busway and LYMMO BRT systems. The second phase will include analyses of the more detailed components of each BRT system, including engineering and construction, technical documentation, ITS, and system performance.

The on-board surveys were conducted to assess customer perceptions, behavior, and to develop customer profiles. The survey instruments asked customers to evaluate the various BRT elements of service as well as overall satisfaction, with the ultimate purpose of measuring the impacts of the systems on customer perceptions. Other questions focused on customer behavior, including trip origins and destinations and frequency of use.

Objective

This article presents a statistical analysis of the data from two on-board customer surveys of the BRT systems in Miami and Orlando, Florida. Using data from the two on-board surveys, the simplest method for measuring the importance that customers place on specific BRT service characteristics is to calculate mean scores for each characteristic using some type of numeric scale (e.g., a scale of 1 through 5, with 5 being the highest). While there are no real discernable drawbacks to this simple averaging method, an alternate technique to measure the importance of each service attribute is to derive the importance of each attribute to overall satisfaction using more advanced statistical procedures such as STEPWISE regression. This statistical method estimates the importance of each service attribute to overall customer satisfaction. While there may be a degree of intercorrelation between each of the service attributes, this method can be used to measure the relative importance of each attribute when determining what elements or combination of elements best comprise overall customer satisfaction with these two BRT systems.

South Miami-Dade and Orlando LYMMO BRT Systems

South Miami-Dade Busway

The South Miami-Dade Busway, or Busway for short, is an 8-mile, two-lane bus-only roadway constructed in a former rail right-of-way (the former Florida East Coast Railroad corridor) adjacent to US 1, a major north-south arterial in southern Miami-Dade County. Miami-Dade Transit (MDT) opened the first phase of the Busway on February 3, 1997. The Busway was designed for exclusive use by transit buses and emergency and security vehicles. The purpose of the Busway service is to address the need for faster travel choices for MDT customers. Much of the Busway BRT service uses 20-seat minibuses to keep costs to a minimum.

Currently, there are 18 intersections and 15 stations in each direction (30 total stations), as shown in Figure 1. The Busway corridor over much of its length is within 100 feet of the west side of US 1, one of the most heavily traveled corridors in Miami-Dade County. There are several types of service in the Busway corridor:

Local—Only operates on the exclusive Busway and makes every stop at all times (referred to as the Busway Local).

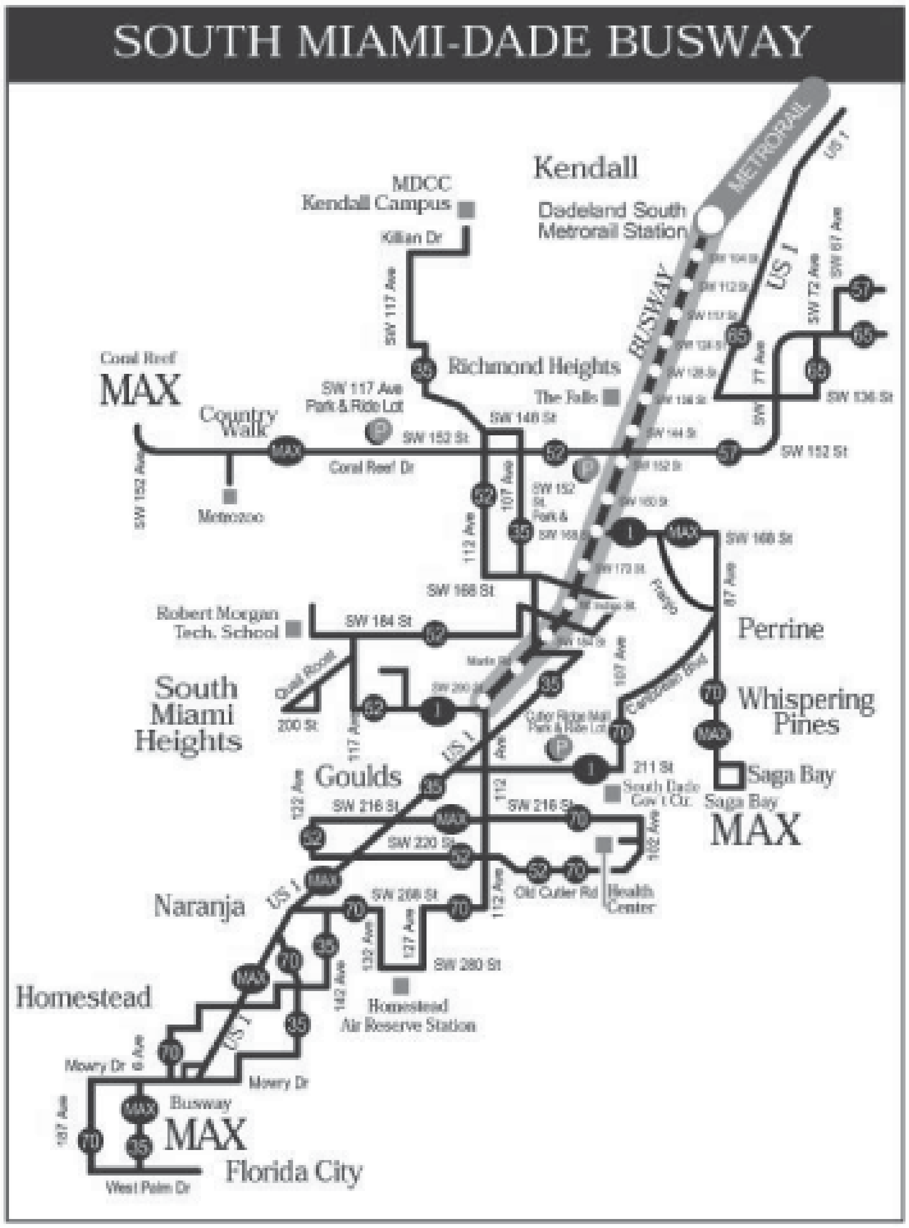
Limited Stop—Operates along the length of the Busway and beyond, skips stops nearest the Metrorail station during peak periods (Busway MAX or Metro Area Express).

Feeder—Collects passengers in neighborhoods and then enters the Busway at a middle point (service is known as either the Coral Reef MAX or Saga Bay MAX).

Crosstown—Preexisting routes in the corridor that now take advantage of the Busway when possible. These routes enter and exit the Busway at middle points. These routes are designed to provide access to many destinations in the region, not just to the center city (Routes 1, 52, and 65).

Intersecting—Routes in the corridor that intersect with Busway routes, sometimes stopping at Busway stations.

Figure 1. Map of South Miami-Dade Busway



The Busway stations are located at roughly half-mile intervals, more than twice the customary stop spacing for conventional MDT local bus service. For example, when Route 1 operated on US 1, it had 19 designated stops southbound and 23 northbound (on the portion of the route using US 1). When it was moved to the Busway, only 10 Busway stations served the same distance. Most stations are on the far side of intersections. In two locations there are mid-block stops to serve major generators. All stations have large shelters designed to protect customers from the weather. Stations platforms are in three lengths: 40 feet, 60 feet, and 80 feet. Busway vehicles operate parallel in a bidirectional manner with vehicular traffic operating separate from Busway vehicles.

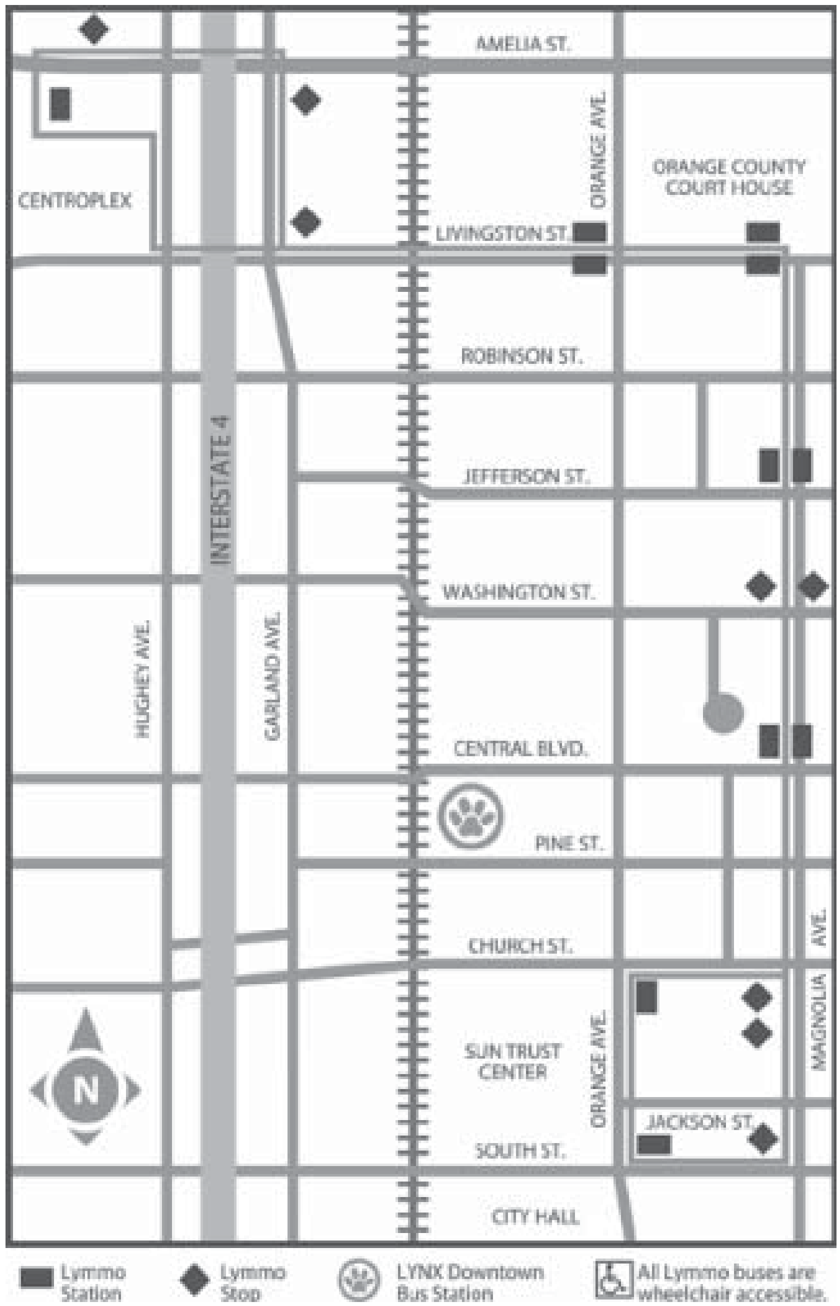
According to MDT, bus ridership on the U.S. 1 corridor in South Miami-Dade County increased greatly with the implementation of the Busway service. As a result of Busway service, ridership in the corridor increased by 49 percent on weekdays, 69 percent on Sundays, and 130 percent on Saturdays since May 1998. MDT staff indicated that the major reasons for the increases in ridership were the increase in service provided, in terms of new areas served, more frequent service, and a greater span of service. Except for Saturdays, revenue miles increased even faster than boardings and operating costs increased at only half the rate of the increase in vehicle revenue miles—due to the use of 20-seat minibuses, which cost the MDTA $31 to $35 per hour to operate, significantly less than the $51 to $53 per hour it costs to operate full-size buses. The difference in cost is due to fuel and maintenance costs and to the lower wages paid to minibus operators.

Orlando LYMMO

The LYMMO BRT system is very different in application from the Busway operated by MDT. It operates on a 3-mile continuous loop through Downtown Orlando using a combination of the various types of dedicated running ways including median and same-side travel way configurations. The exclusive running ways are paved with distinctive gray-colored pavers to delineate them from general traffic lanes. They are separated from general traffic lanes either with a raised median or a double row of raised reflective ceramic pavement markers embedded in the asphalt.

Because the LYMMO operates in places and directions contrary to other traffic, all bus movements at intersections are controlled by special bus signals. To prevent motorist confusion, these signal heads use lines instead of the standard red, yellow, and green lights. When a LYMMO bus approaches an intersection, an em-

Figure 2. Map of the LYMMO System



bedded loop detector in the dedicated running way triggers the intersection to allow the bus to proceed either in its own signal phase or at the same time as other traffic is released when no conflicting traffic movements are permitted.

The LYMMO uses 10 low-floor vehicles fueled by environmentally friendly compressed natural gas. The vehicles use high-quality, modern interiors that incorporate the Transit TV Network, an ITS system. The Transit TV Network provides real-time information such as Downtown events, weather, and fun and trivia to customers. In addition, public art exteriors are used on the vehicles to enhance the customer's experience with the LYMMO. The LYMMO system has 11 lighted and computerized stations and 9 additional stops, as shown in Figure 2.

LYMMO vehicles operate approximately every 5 minutes during office hours; after office hours, vehicles operate approximately every 10 minutes. Since the inception of service, the LYMMO has been free to ride during all hours of operation. Operation and maintenance of the LYMMO is 100 percent funded by revenue generated by the City of Orlando's Parking and Enterprise Fund. The LYMMO operates from 6 A.M. to 10 P.M., Monday through Thursday, 6 A.M. to midnight on Friday, 10 A.M. to midnight on Saturday, and 10 A.M. to 10 P.M. on Sunday. LYMMO's target market is customers who drive to Downtown Orlando and then use LYMMO to get to other Downtown locations, such as the courthouse, restaurants, shopping, and other land uses.

For comparison, Table 1 shows the key components of the both the Busway and LYMMO BRT systems.

Survey Methodology and Statistical Procedures

The Busway survey instrument was printed in English on one side and Spanish on the other due to the bilingual nature of Miami. It contained 18 questions and provided space for additional written comments by customers. The LYMMO survey instrument was printed in English only and contained a total 13 questions. NBRTI/CUTR and MDT and Lynx staff developed the survey instruments jointly.

The on-board surveys specifically targeted customers riding only those routes that operate along the Busway for either all or a portion of their trips and for all or a portion of their trips in Downtown Orlando on the LYMMO. At least half of all trips on a particular Busway route were selected for surveying. For example, if there were eight trips on a route, four were to be surveyed. If there were nine trips, five were surveyed. The trips selected for survey distribution spanned the service

Table 1. Key Bus Rapid Transit Components

Key BRT Attributes	Busway		LYMMO	
	Yes	No	Yes	No
Simple route structure	✔		✔	
Frequent service	✔		✔	
Headway-based schedules	✔		✔	
Less frequent stops	✔		✔	
Level boarding and alighting		✔	✔	
Color-coded buses		✔		✔
Color-coded stations/stops	✔		✔	
Bus signal priority		✔	✔	
Exclusive lanes	✔		✔	
Modern vehicle interiors		✔	✔	
Higher-capacity buses		✔		✔
Multiple door boarding and alighting		✔	✔	
Off-vehicle fare payment		✔		✔
Feeder network	✔			✔
ITS/APTS on vehicles	✔		✔	
ITS/APTS at stations		✔	✔	
Coordinated land-use planning	✔		✔	

hours (i.e., morning peak, midday off-peak, afternoon peak, and evening). For the LYMMO, surveying began at the start of service and concluded at about 7 P.M. Given that the typical weekday LYMMO schedule consists of about 186 21-minute round trips (circulations) and the last trip begins at 10 P.M., this translates into just over 90 percent of all weekday trips being included in the sample.

Surveyors were instructed to offer a survey form to each customer upon boarding a bus. Every time a customer boarded a Busway or LYMMO vehicle to make a subsequent trip (regardless of the whether the trip was their second, third, fourth, and so on), they were asked to complete another survey. Surveyors were instructed to do the best they could to encourage participation in the survey. If a survey could not be handed directly to a customer, surveyors were instructed to “drop” a survey in each vehicle seat. All surveys were collected on-board buses. No mail-back provision was provided for returning the completed surveys.

Once collected, survey data were entered into an Excel spreadsheet for archiving and later analyses. CUTR staff performed the review and data analyses using SPSS (Statistical Product and Service Solutions) software.

Prior to the analyses, survey responses were weighted based on the total weekday ridership and completed surveys for each route to more accurately reflect Busway and LYMMO ridership as a whole. Weighting factors were derived to ensure proper representation of Busway and LYMMO customers. Specifically, weights were calculated by dividing the total weekday ridership (obtained from MDT and Lynx staff) for the survey period by the number of surveys returned. The resulting weight factors were applied to each completed survey's data for statistical analysis. The survey methodologies involved the survey of willing customers. The methodologies correspond most closely with ridership data that are reported as unlinked trips. Table 2 indicates Busway ridership figures for March 19–23, 2001 and Table 3 shows ridership for the LYMMO for December 20, 2001. The data in Table 2 are representative of the five-day (Monday through Friday) total weekday ridership and the data in Table 3 represent monthly LYMMO patronage. Daily ridership figures were not available for either of the two BRT systems.

Table 2. Weekday Busway Ridership (March 19–23, 2001)

Entire Route	*Weekday Ridership**	*Percent of Ridership on Trips Surveyed*
1	8,182	17.4
31/231 (Busway Local)	8,820	18.8
38 (Busway MAX)	17,368	37.0
52	6,619	14.1
252 (Coral Reef MAX)	4,491	9.6
287 (Saga Bay MAX)	1,491	3.2
Total Busway routes ridership	**46,971**	**100**

* Total weekday ridership for the entire route length.

Table 3. Monthly LYMMO Ridership (December 2001)

Week (Saturday through Friday)	***Ridership***	***Proportion of Ridership on Trips Surveyed***
December 1-7	20,618	27.8
December 8-14	20,592	27.8
December 15-21	19,992	27.0
December 22-28	10,304	13.9
December 29-31	2,541	3.4
Total ridership	**74,047**	**100**

The response rates for the on-board surveys of Busway and LYMMO customers ranged from a low of 6.45 percent to 23.7 percent. Although somewhat low, these response rates are fairly usual for surveys of this type where prior experience has shown them to be in the 10 to 20 percent response range. It should be noted that the following results are based on a sample of system users and not a 100 percent census. There is the chance of some customers not choosing these two BRT systems because they felt that additional factors not discussed in the results were more important to their selection of mode choice. In addition, survey instruments were not originally designed to ask customers of these two BRT systems about their satisfaction with the Busway and LYMMO compared to other alternatives such as standard local bus. For example, the Busway survey could have included a question asking respondents to indicate their satisfaction with the travel time on Busway buses versus the travel time on standard local Miami-Dade Transit bus service. Everyone has a different approach to determining satisfaction with the various components that comprise a particular mode including travel time and frequency of service, for example. It is only when customers are asked to directly compare the various BRT components to those of other modes that comparable results can be obtained. Nevertheless, the results presented in this article show the measurement of actual customer satisfaction with the two BRT systems. Currently, there are many BRT systems in the planning and design phases as well as in operation that will benefit from the results presented in this article.

Measuring the Importance of BRT Elements

Mean Scores

Questions 17 (Busway) and 13 (LYMMO) on the survey instruments were multipart questions that asked customers to rate their perception of different aspects of Busway and LYMMO BRT services, using five-point scales (1 = "very dissatisfied" and 5 = "very satisfied"). Each survey included a question that asked about overall customer satisfaction with the BRT services offered by both systems.

These two questions offered customers an opportunity to rate their individual levels of satisfaction with various service characteristics. Using the five-point rating system's numerical scoring values, an average score was calculated for each service characteristic. The resulting mean scores give a good indication of overall customer satisfaction with each of the service aspects. Since a score of 5 indicates a "very satisfied" rating, the closer to 5 that a characteristic's mean score is, the higher the degree of customer satisfaction is with that particular characteristic.

Table 4 presents all of the weighted average customer satisfaction ratings for the service characteristics included in the surveys. The responses indicate a very high level of satisfaction with the services offered by the Busway and LYMMO; all mean scores fell between "neutral" and "very satisfied," including the aspects travel time and reliability. An analysis of the very high customer mean scores and importance of the service attributes inquired about clearly shows that users regard the Busway and LYMMO BRT systems as premium services.

STEPWISE Regression

The simplest way to measure the importance that customers of public transit place on specific service characteristics is to calculate mean scores for each characteristic on some type of numeric scale (e.g., a scale of 1 through 5). While there are no real discernable drawbacks to this simple method, an alternate and more advanced technique to measure the importance of each service attribute is to derive importance by examining the relationship of each attribute to overall customer satisfaction. This methodology uses STEPWISE regression analysis to estimate the importance of each service attribute. While there is a degree of intercorrelation between each of the service attributes, this method can be used to measure the relative importance of each attribute when determining what elements or combination of elements comprise overall customer satisfaction of these two BRT systems. By using STEWISE regression, the r-squared values can be used as surrogates for customer satisfaction.

Table 4. Means Satisfaction Scores for Busway and LYMMO

Characteristics	***Mean Score***	
	Busway	***LYMMO***
Safety on bus	3.81	4.41
Availability of seats on the bus/comfort	3.60	4.41
Dependability of buses (headway adherence)	3.18	4.47
Travel time on buses	3.63	4.48
Cost of riding buses	3.76	Not asked
Availability of information/maps	3.69	Not asked
Convenience of routes	3.69	Not asked
Satisfaction with recent changes to Busway (traffic signals)	3.68	Not asked
Safety at Busway stops	3.65	Not asked
Hours of Busway service	3.50	Not asked
Frequency of Busway service	3.25	Not asked

The STEPWISE regression analysis enters independent factors (each BRT service characteristic) one at a time, backwards and forwards, to determine which one has the highest correlation with the dependent factor (in this case, overall customer satisfaction). Additional independent factors are entered into the regression equation only when they make a significant contribution to the predictive power of the equation. During the process, if any of the independent factors falls below the specified criterion, it is removed automatically from the equation building process. In this case, the criterion for entering the regression equation was $p < 0.05$, and the criterion for removal from the regression equation was $p > 0.10$. The STEPWISE regression analysis resulted in all four of the service characteristics entering the regression equation, accounting for 69.3 percent of the customers' overall satisfaction with the LYMMO service. For the Busway, the STEPWISE regression analysis resulted in all eight of the service characteristics entering the regression equation, accounting for 67.3 percent of the customers' overall satisfaction with

Table 5. Results from LYMMO Customer Satisfaction STEPWISE Analysis

Model Depend. Variable	*Model Independent Variables*	*R*	*R-Square*	*Adjusted R-Square*	*Std. Error of the Estimate*
overall customer satisfaction	Comfort	0.750	0.563	0.563	0.473
	Comfort + Travel Time	0.810	0.656	0.656	0.419
	Comfort + Travel Time + Reliability of Service	0.830	0.689	0.689	0.399
	Comfort + Travel Time + Reliability of Service + Safety	0.832	0.692	0.693	0.396

Table 6. Results from Busway Customer Satisfaction STEPWISE Analysis

Model Depend. Variable	*Model/Service Characteristics*	*R*	*R-Square*	*Adjusted R-Square*	*Std. Error of the Estimate*
overall customer satisfaction	Frequency of Service	0.694	0.481	0.480	0.734
	Frequency of Service + Convenience	0.771	0.594	0.593	0.649
	Frequency of Service + Travel Time + Seat Availability	0.792	0.628	0.627	0.622
	Frequency of Service + Travel Time + Seat Availability + Convenience	0.805	0.649	0.647	0.605
	Frequency of Service + Travel Time + Seat Availability + Convenience + Hrs of Service	0.814	0.662	0.660	0.594
	Frequency of Service + Travel Time + Seat Availability + Convenience + Hrs of Service + Safety on Bus	0.818	0.669	0.667	0.588
	Frequency of Service + Travel Time + Seat Availability + Convenience + Hrs of Service + Safety on Bus + Dependability	0.821	0.674	0.671	0.584
	Frequency of Service + Travel Time + Seat Availability + Convenience + Hrs of Service + Safety on Bus + Dependability	0.823	0.677	0.673	0.582

Busway service. Or, put another way, these service characteristics aided in understanding between almost 64 and 70 percent of overall customer satisfaction with the Busway and LYMMO services, as shown in Tables 5 and 6.

Busway

For the Busway, the first three-service characteristic to enter the regression equation were "frequency of service," "travel time," and "seat availability" (comfort). These three independent variables accounted for 62.7 percent of the equations overall predictive power, or overall customer satisfaction with the Busway. This finding is not surprising given the results for the simple mean scores for these service aspects where Busway customers rated each highly given the more "rapid" (real or perceived) nature of Busway service compared to MDT local service. Each of these service aspects (independent variables) is an important element of BRT service. The remaining service aspects to enter into the Busway STEPWISE regression model were, in order of entry, "convenience of routes," "hours of service," "safety on Busway vehicles," dependability (on-time performance), and the availability of route information. These remaining five variables added only 4.6 percent to the models overall predictive power. All of the service characteristics are significant at the $p < 0.05$ level.

However, one important Busway service characteristic, "cost of riding the bus," did not enter into the regression equation as originally hypothesized. This result is counterintuitive to what is assumed about the factors that customers weigh in their decision to use local bus service. However, with a premium service such as that offered by a BRT system, it appears that cost is less of a concern than the overall quality of the BRT service and travel timesavings offered to customers. By its omission in the regression model, the data seem to indicate that if high quality premium service is offered, persons are willing to pay a little extra for the additional benefits of such a system.

LYMMO

The first service characteristic to enter the regression equation was "comfort of the LYMMO vehicles," accounting for 56.3 percent of the equations overall predictive power. This result is not surprising given that customers indicated that they liked the low-floor vehicles and modern vehicle interiors the most, each of these an important "comfort" element and aspect of BRT service. The second service characteristic to enter the regression equation was "travel time on LYMMO vehicles." The entry of "travel time" into the regression equation increased its overall predictive power to 65.6 percent, a significant increase in predictive power. Again, this result is not too surprising given that LYMMO customers indicated that they elected to use the LYMMO service because it is faster than walking to their destination. This finding is consistent with the "rapid" or "perceived rapid" nature of BRT services such as the LYMMO. The third variable to enter the regression equation was "reliability of LYMMO service." Interestingly, this service characteristic only marginally increased the overall predictive power of the regression model. This result is somewhat hard to explain, given that customers of public transit systems typically put a high premium on vehicle reliability that includes both on-time performance and vehicle breakdowns. The same holds true for the final service characteristic, "safety on vehicles," that entered into the regression equation. This service characteristic increased the predictive or explanatory power of the overall regression equation by only 0.004 percent. All of the service characteristics are significant at the $p < 0.05$ level.

Discussion and Conclusions

Based on the results of the STEPWISE regression analysis, it appears that an argument could be made for a narrow and comprehensive set of traits as the basis for defining and providing different applications of BRT service. Based on the idea of providing a premium service that is more comfortable, frequent, rapid, and reliable than "typical" local bus service or other modes, BRT could be treated as an attempt to inject new energy and life into stagnant local transit bus services. Building on the results from this analysis, the unique services aspects of BRT that can be added to improve other bus services is good for all concerned.

Much discussion of late in the transit industry has been made about how to make BRT distinct and different from standard local service within an individual transit system. The answer may be found not in the type of vehicles that are provided to riders, but found mainly in the quality of BRT service that is ultimately offered. One only has to look at the success (increased ridership, decreased travel times) of the different BRT applications in Los Angeles; Pittsburgh; Ottawa, Canada; Brisbane, Australia; and Curitiba, Brazil to see the virtue of this statement. All of these BRT systems provide extremely frequent, reliable, easy to use, comfortable, safe, and fast (rapid) service (even in mixed traffic) essentially using conventional-looking buses. The results from the STEPWISE regression analysis seem to suggest that these systems are providing the right mix of service aspects to foster sustained patronage and growth. Perhaps what the customer really wants is to get from home to work and back again in the shortest time with the greatest overall level of comfort and personal safety (and to a degree, the cost of riding may not be an overriding factor). The results from this article suggest that future customers will rely more on the quality of the BRT service that's offered than any other aspect. Again, the success in terms of ridership gains and public acceptance of the Busway and LYMMO provide ample evidence to support this suggestion.

Based on MDT analysis, the Busway seems to have provided little or no travel timesavings for Busway vehicles compared to existing local service—yet, ridership in the corridor increased by 49 percent on weekdays, 69 percent on Sundays, and 130 percent on Saturdays since May 1998. This increase is mostly explained by the 72 percent increase in weekly revenue miles. This suggests that the MDT management did a good job of listening to customers when deploying and implementing Busway service. The combination of Busway service characteristics including high frequency, both in the peak and off-peak, travel time (real or perceived), and seat availability (comfort) are clearly central factors leading to this success.

Lynx reports that despite exclusive running ways and signal preemption, average roundtrip speeds are not as great as expected and are one-third slower on the LYMMO than its downtown predecessor the *FreeBee*. The reasons for this are hard to discern. One possible explanation is that LYMMO buses stop at each station, whether customers are waiting or not. Another possibility is that increased ridership has resulted in additional station dwell time during the boarding and alighting process—despite the use of low-floor vehicles and no fare collection. Despite the slow average system speed, LYMMO ridership has increased dramatically since system implementation—the real measure of success. Additional possible sources for increased ridership other than increased service hours is the creation of an overall pleasant and safe riding experience, an aggressive marketing campaign, comfort of the LYMMO vehicles, travel time (whether real or perceived) of LYMMO vehicles, reliability of LYMMO service, and safety on LYMMO vehicles and at stations.

Every customer of public transit has a different approach to determining their satisfaction with the various components that comprise a particular mode including travel time and frequency of service, for example, and their decision to use that mode at any given time. There is a chance that factors not present in the two BRT systems analyzed in this article could have caused customers not to choice the BRT mode for their trip making. For example, the Transit Cooperative Research Program (TCRP) Report 47 (1999) offers many different potential measures of transit service quality including overcrowding, bilingual signage and system information, quietness of vehicles, fairness of fare structure, announcements of delays, cost of making transfers, absence of offensive odors, ease of paying fare, number of transfer points outside of the downtown core, courteous system staff, physical condition of stations, station access, posted minutes to next bus, and so on in addition to the factors presented in this article. The survey instruments used to gather information for this article were not originally designed to ask customers about every possible service characteristic related to the Busway and LYMMO. Nevertheless, the results presented here show the measurement of actual customer satisfaction with important service characteristics of the two BRT systems and those elements that are important to all BRT systems. At present, there are many BRT systems in the planning and design phases as well as in operation that will benefit from the results presented in this article even using a limited number of service quality measures to determine overall customer satisfaction.

Although the R^2 –values are fairly high even with the small number of independent factors (4 for the LYMMO and 10 for the Busway), it is important to note that about 33 percent of with the Busway and 31 percent with the LYMMO service related to overall customer satisfaction remains unexplained. As part of the BRT evaluation processes, a number of focus groups will be conducted that could aid in uncovering the remaining factors related to overall customer satisfaction. Certainly, the four service characteristics included in the regression equation make it clear that they are important factors to customers of this BRT system. However, the unexplained variance also makes it clear that a full understanding behind the dynamics of customer satisfaction may require the inclusion of additional independent variables in futures regression analyses as noted in the preceding paragraph. These service characteristics would certainly include those present in other BRT systems or perhaps psychological factors related to customer satisfaction.

While BRT is the talk of the U.S. public transit industry (and even the global transit industry), there is still a long way to go to make this a successful and publicly accepted mode of public transportation as in other places including Canada, South America, Australia, and Europe. There is a continued need for marketing, vehicle development, data collection, project evaluation, an updated Alternatives Analysis process to include BRT, revised New Starts eligibility criteria, research, and additional technology transfer. The author supports the statements made by the FTA that no single mode of public transportation is right for all situations. However, given the incontestable merits of BRT, it should receive serious consideration as an important alternative in the planning toolkit.

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About the Author

Michael R. Baltes (*baltes@cutr.usf.edu*) is a senior research associate at the National Bus Rapid Transit Institute (NBRTI) located at the Center for Urban Transportation Research in Tampa, Florida. He has worked at the Center for Urban Transportation Research for 12 years. During his tenure at the center, he has gained extensive experience in the areas of Bus Rapid Transit (BRT), transit planning, transportation economics, Intelligent Transportation Systems, and a variety of other transportation research areas. Mr. Baltes holds both graduate and undergraduate degrees from the University of South Florida. He is an active member in a number of professional organizations, and is regularly cited and published in academia and media on BRT and other transportation issues. He is also a member of the Transportation Research Board Committee on Bicycle Transportation and the American Public Transportation Association's BRT Task Force.

Bus Transit and Land Use: Illuminating the Interaction

Andy Johnson
Oregon Department of Transportation

Abstract

Attracting people to public transit in urban areas has proven to be a difficult task indeed. Recent research on the transportation–land use connection has suggested that transit use can be increased through transit-friendly land use planning. While significant evidence exists that a relationship between land use and transit is apparent, the exact nature of the relationship remains ambiguous. Despite the murky nature of the relationship, many practitioners and researchers have asserted claims regarding land use policy, namely TOD, and its effect on travel. This article examines the effect of land use, socioeconomics, and bus transit service on transit demand in the Twin Cities. The findings suggest that vertical mixed-use is important close to transit access and retail plays an important role up to a quarter mile from transit service. Population density is more important at a block-group level than block level, suggesting that density adjacent to the line may not play as critical a role as density in the larger surrounding area.

Introduction

Why do some intraurban areas attract more transit riders than others? What types of neighborhoods may induce greater transit demand? The pressure to find an answer has increased as a result of population growth, congestion, and discontent with existing transportation options.

Despite the growing disenchantment with urban transportation, people have shown little interest in changing their ways; transit's share of work trips is still only about 4.5 percent nationally (Bureau of the Census 2000). An increase in travel times and the stability of the auto modal split suggests that people remain willing to sacrifice transportation convenience for perceived housing and neighborhood amenities. The relative low cost of auto ownership, existing cultural preferences, and transit-inefficient land use patterns only reinforce the current auto-oriented transportation situation.

The relationship between transportation and land use has received increased attention in recent years, however, the exact nature of the relationship relative to other causes remains somewhat ambiguous. Despite the ambiguous nature, proponents of transit use have focused much attention on regulating development in a manner that is more supportive of transit use, which has been coined *transit-oriented development* (TOD). TOD proponents have blamed much of today's transportation woes on inefficient development patterns, and propose TOD as one of many contributors to a solution.

In response to this problem and policy response, this article seeks to illuminate the complex relationship between transit demand and its influences, including density, land use, socioeconomic characteristics, and transit service.

This analysis seeks to answer the question: What intraurban qualities make one area generate more or less demand for transit services? This article will first summarize the current state of transportation land use and transit literature; secondly, describe the methodology employed: next, present findings of this research; and finally expand on the findings to suggest directions of future research and public policy.

State of the Literature

Transportation Land Use and Travel Behavior

The interaction between land use and travel behavior has been studied heavily in recent years; one need look no further than the most recent studies eloquently compiled by Ewing and Cervero (2001), and Seskin and Cervero (1996). The surveyed research typically measured one of six different outcome variables: trip frequency, trip length, mode choice, cumulative person miles traveled (PMTs), vehicle miles traveled (VMTs), or vehicle hours traveled (VHTs) (Table 1). The latter three variables are different measures representing the same phenomenon—aggregate travel. Research to date has found the primary determinant of the various outputs to vary, although these concepts are interconnected.

Table 1. Output Variables from Travel and Land Use Studies

Output Variable	***Primary Determinants***
Trip frequency	Socioeconomic characteristics
Trip length	Regional accessibility
Mode choice	(1) Density/(2) land use
Cumulative PMTs/VMTs/VHTs	Regional accessibility

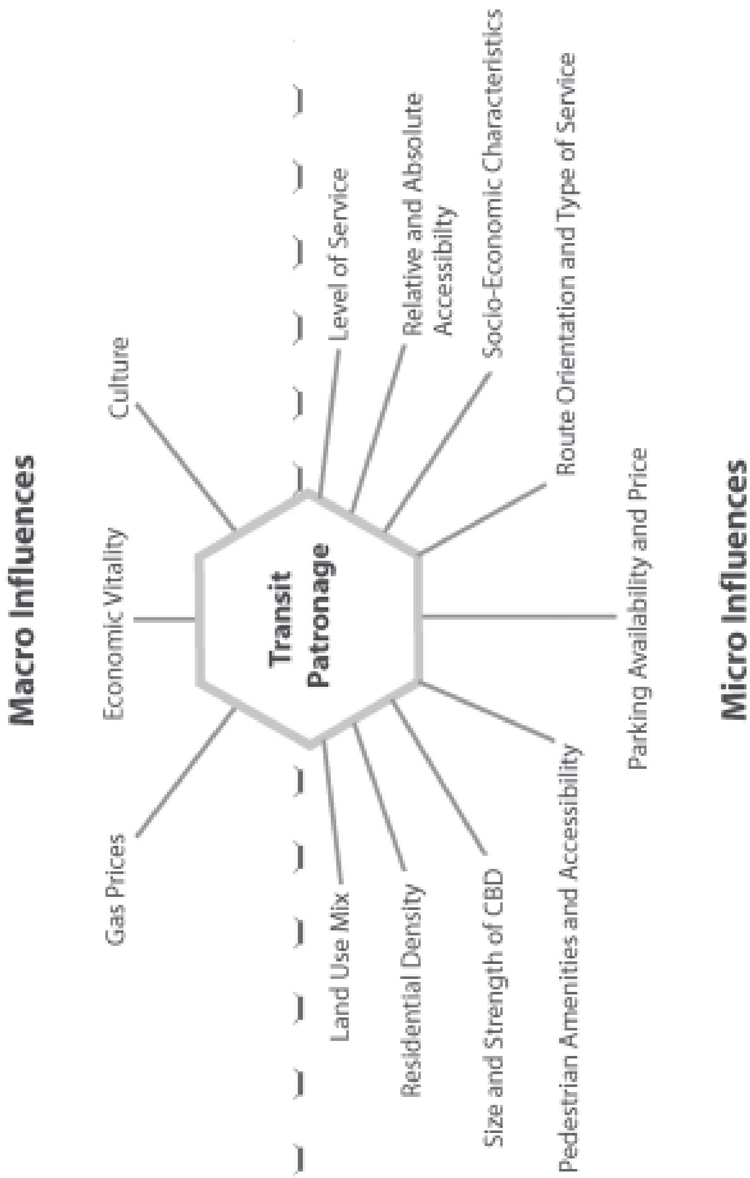
Source: Ewing and Cervero, 2001.

Generally, mode choice is affected primarily by density and land use (Table 1). This is particularly important given that local-level public policy has little direct effect on neighborhood socioeconomics or regional accessibility in the short term, while local land use regulations and neighborhood-level policy directly affect the land use and density.

In addition to density, transit ridership appears to be a function of size of the central business district (CBD) and the distance from downtown (Puskarev and Zupan 1977), as well as parking supply and price, transit service quality, pedestrian accessibility, and land use mix (Figure 1). The size of the CBD and distance from the CBD of a given stop is important because, due to the radial nature of most public transit systems, a larger CBD equates to a more accessible transit system. In addition, a larger CBD often means fewer parking spaces per person or job, which decreases the incentive to drive.

While those characteristics cited by Pushkarev and Zupan are important, parking supply, accessibility, and land use mix are also important. Recent research suggests a positive relationship between parking price and transit use (Hess 2001). This is particularly troubling to transit supporters due to the finding that free parking is enjoyed at the end of 99 percent of all trips (Cervero 1998). In addition to the economic influences of parking, parking lots, and ramps are poor land uses for inducing transit ridership. Although accessibility of transit systems has been shrinking relative to automobile accessibility for decades due to increased growth at the suburban fringe, it remains an important aspect of transit service. In addition to

Figure 1. Influences of Transit Demand



regional accessibility by means of transit, accessibility *to* transit is a critical factor in willingness to use transit. Due to safety concerns, perceived comfort and the effect of climate, the design of transit stops and station area amenities play an integral role in transit patronage. The importance of climate and comfort is particularly important in areas such as Minneapolis-St. Paul that often endure harsh winter weather conditions.

The effect of land use on transit is murky, although it is believed that a positive feedback loop between transit and land use exists. Transit availability increases aggregate accessibility to a given location and the attributes of the specific location determine whether people visit the location. However, the precise effects of different land uses on transit use are unclear, in part, due to the degree of interconnectedness with density and socioeconomic influences. What is clear is that the greater the intensity of land use, the greater demand for transit.

The general applicability of this research is unknown because most research has focused around rail transit, despite the prevalence of bus transit. Rail transit has become increasingly en vogue with policy-makers, the media, and researchers alike due to nostalgia (e.g., "*new* urbanism" or "rail *revival*"), potential environmental efficiency, the ease in the provision of high-frequency service, and the attractiveness of guaranteed service provision to potential developers and investors.

TOD has received increased attention in recent years. TOD's bark is perhaps bigger than its bite; it has been rarely practiced due to reluctance in the private land market and institutional barriers (Boarnet and Crane 1998). Also, there is little empirical evidence to support that individual TOD projects in a sea of single-family homes can actually sustain transit and lower auto reliance (Cervero 1998). A similar affinity toward TOD near rail transit has persisted, leaving the relationship between bus transit and TOD unclear at best.

Minneapolis-St. Paul: Transit, Land Use, and History

The Minneapolis-St. Paul metropolitan region has enjoyed significant economic vitality in recent years, and as a result significant population growth. The growth has manifest as primarily moderate- to low-density development on the urban fringe. The Minneapolis-St. Paul region has long befriended the automobile and auto-oriented development. The Metropolitan Council, the regional transit operator and land use planning agency, has responded with several public policy and marketing programs aimed at limiting geographical dispersion of residential growth and concentrating development along transit corridors. The Livable Communities Act was created to achieve these goals by dedicating a pool of public money that is awarded on a competitive basis for "Smart Growth" developments. The goal of the policy is to encourage developments that could be more easily served by transit in hopes of avoiding the high cost of constructing or expanding the highway system.

The regional transit system, as of 2002 exclusively bus–transit, carries about 250,000 riders per weekday. The bus system will soon be joined by an 11-mile, $750 million light-rail transit line connecting the Minneapolis CBD, the Minneapolis-St. Paul International airport, and the Mall of America, the largest enclosed shopping mall in the United States. Metro Transit, the regional transit operator, currently operates the annual 73 million bus trips offered, primarily in the two central cities and inner-ring suburbs.

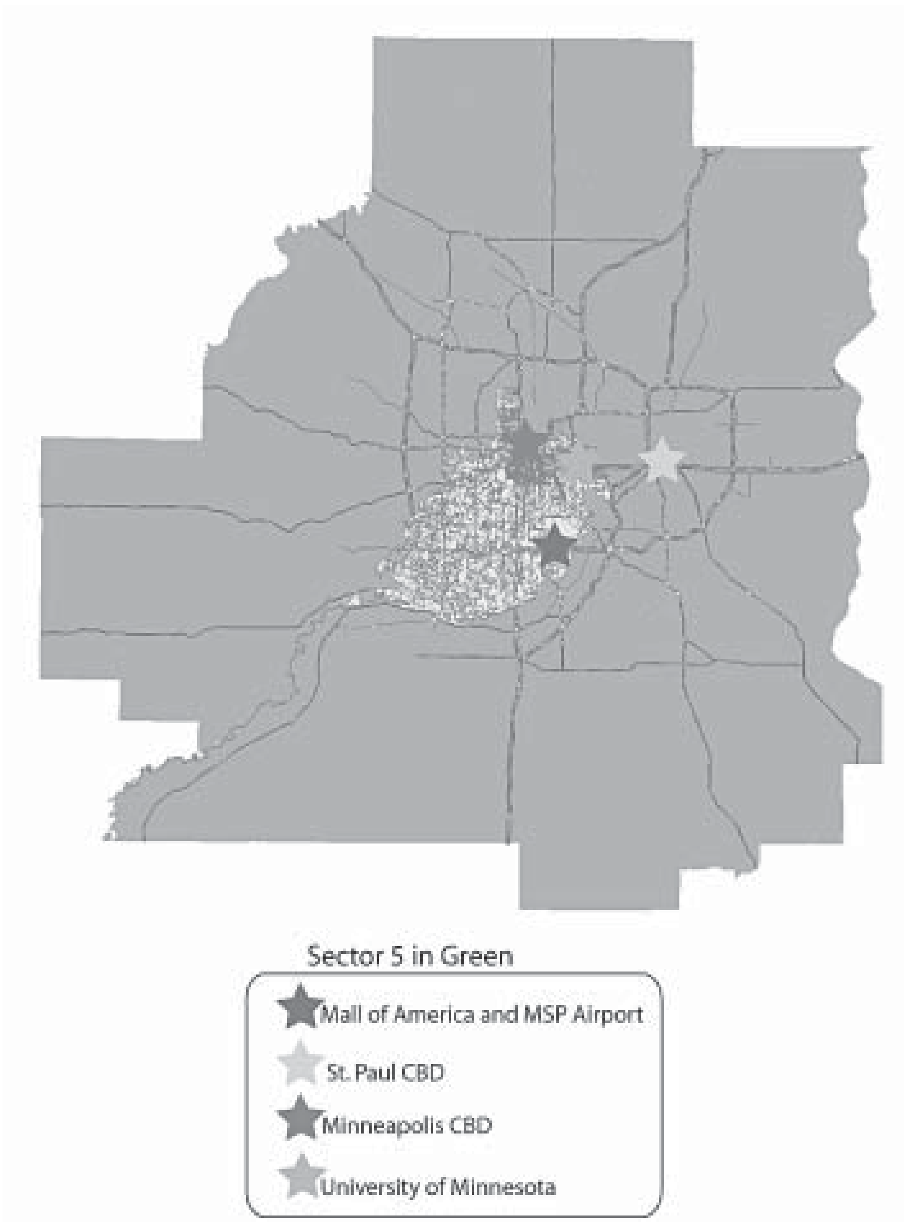
Methodology

This analysis uses the Sector 5 restructuring data obtained from the Metropolitan Council, the regional planning agency for the Minneapolis-St. Paul metropolitan area. Sector 5 is the transit planning subregion that consists of downtown Minneapolis and a radial slice running due south and southwest (Figure 2). Sector 5 contains four of the primary trip generators in the entire metro region: the Minneapolis CBD, Mall of America, International Airport, and part of the University of Minnesota Twin Cities campus. These data count only the downtown boardings onto buses that serve Sector 5.

The attractiveness of Sector 5 in this analysis primarily lies in its relative importance and potential for increased service. It currently serves 55 percent of all transit riders, offers 38 percent of all routes, and almost 20 percent of the jobs and residents in the entire region. This is particularly important given the area only comprises about 10 percent of the geographic area.

The Sector 5 data used for this analysis consist of weekday transit boardings at bus stops in Sector 5 south of the Minneapolis CBD and west of the Mississippi River, known as areas B and C of Sector 5 (approximately 95% of all stops in the sector). Bus stops of different routes at the same location have unique ID numbers, which allowed control of route orientation and service. Only boardings were used due to the correlation between boardings and alightings; in other words, people start their return trip the same place they ended the beginning trip. This assumption was affirmed via visual confirmation of boarding and alighting maps and tables.

Figure 2. Sector 5 Reference Map



The data were compiled using GIS to select and join the relevant census and land use information with the exact location of the bus stop. The data were entered into a demand model and analyzed using a linear regression model. The land use data were simplified by combining open space, roads, and other categories and omitted from the model to allow a comparison of other land uses to relatively "dead" transit uses.

The cross-town routes are controlled for, while the radial routes feature approximately the same levels of parking availability and price. Generally all parking for all destinations on routes going away from the CBD is free, and all radial routes going toward the CBD terminate there.

The use of transit stops as data collection points, as opposed to individual data via travel behavior surveys, is useful for several reasons. First, transit agencies plan routes based primarily on area statistics. Similarly, land use planning can more easily create types of environments that are more conducive to transit ridership, than it can cause people to use transit. Although ideally both would be used, the small area level analysis is often overlooked, and potentially more useful to local planning agencies.

The transit demand model was created to illuminate the intraurban differences, and so many causes of demand were eliminated. For example, macro-level predictors on transit certainly affect transit use. Recent evidence shows that much of the 12 percent decline in transit ridership in the first half of the 1990s can be attributed to a sluggish economy and low gas prices, while the increased gas prices and burgeoning economy resulted in a 21 percent increase in ridership in the later half of the 1990s (Pucher 2001). Density, land use, and transit service provide stronger explanatory power given the complex decision-making process associated with mode choice within a metropolitan region. Because this analysis only looked at one market at one point in time the macro-level predictors were eliminated from the analysis. Similarly, parking prices and size of the CBD were left out because these aspects are relatively constant in the area of analysis.

The land use data were classified into basic categories: single-family, multifamily, retail–commercial, office, industrial–-utility, mixed-use, and other. The other category includes open space, roads, and unused/vacant lands or spaces. Interaction variables were entered to tease out the influence that various mixes have on transit demand. Land uses were categorized into groups based whether they are primary job-based (office, industrial–utility), shopping-based (retail–commercial), and housing-based (single-family, multifamily).

Findings

Geography

A majority of the weekday transit demand in Sector 5 is currently located inside the City of Minneapolis, and more than 12 percent of total boardings in Sector 5 occurred in downtown Minneapolis (Table 2). Demand is clustered along Lake Street in South Minneapolis and peaks at the confluence of other transit routes (Figure 3). The ridership clustered along the Lake Street corridor, featuring cross-town service, is the area of maximum transit accessibility in Sector 5. This area is at maximum accessibility because route 21 runs the distance of Lake Street, connects to nearly every radial route in sector 5, and offers very high-frequency service.

Table 2. Weekday Boardings by Location in Sector 5

Location	*Boardings*	*% of Total*
Minneapolis City	46964	76.1%
St Paul City	6551	10.6%
Minneapolis Suburbs	7571	13.3%
Total Boardings in Analysis	**61697**	**100.0%**
Major Trip Generators		
Minneapolis CBD	8553	13.9%
Mall of America	838	1.3%
Airport	238	0.4%

Transit Service

The type of transit service plays a significant role in demand of a given stop (Table 3). Compared to the Urban Local service, the most prevalent service in the core area, Urban Local-Limited Stop was negatively associated with demand (Table 3). Surprisingly the level of weekday service was not a significant determinant of transit demand. To better understand the relationship between transit service and ridership, a longitudinal analysis is warranted.

Figure 3. Total Boardings by Bus Stop in Sector 5

Some degree of reverse causality is likely occurring and subsequently, altering the findings. Transit planning is ideally demand responsive; the direction of causality is likely in reverse. The level of service is altered to more accurately reflect existing demand and the routes have reached a point of relative equilibrium.

Table 3. Linear Regression Model of Transit Demand

Independent Variables	*Beta (standardized)*	*Sig*
(constant: t =.186)		.852
Transit Service (stop level attributes)		
Buses/hour weekday	0.026	.149
Radial (1 yes/0 no)	-0.013	.545
Distance from CBD	0.009	.788
(omitted Urban Local Service)		
Suburban Local	-0.035	.101
Urban Local–Limited Stop	-0.045	.007 **
Express Service	-0.033	.111
Socioeconomic Characteristics (block-group level attributes—percentages)		
Percent with high school diploma	-0.005	.916
Percent with college degree	0.025	.573
Household income ($)	0.030	.417
Household size	0.014	.720
Percent with access to automobile	-0.112	.002 **
Percent non-White	0.037	.276
(omitted age cohort 30–50)		
Age cohort 0–16	0.117	.003 **
Age cohort 16–30	0.055	.162
Age cohort 50–65	0.018	.476
Age cohort over 65	0.007	.817
Population density (adjacent block–per sq. mile)	0.007	.705
Population density (adjacent block group–per sq. mile)	0.115	.000 **
Land Use (percent of parcels in a given use)		
1/8 mile radius (omitted open space, roads, and other)		
Single-family	-0.002	.918
Multifamily	-0.080	.009 **
Mixed-use	0.083	.000***
Retail–commerical	0.208	.000***
Office	-0.008	.802
Industrial–utility	-0.007	.794
1/8 to 1/4 mile radius (omitted open space, roads, and other)		
Single-family	0.001	.844
Multifamily	0.072	.035 *
Mixed-use	0.006	.701
Retail–commerical	0.046	.089
Office	-0.015	.661
Industrial–utility	0.005	.844
Land use balance and interaction (total difference between land use area percentages)		
Housing–jobs	-0.076	.007 **
Housing–shopping	0.085	.004 **
Shopping–jobs	0.033	.070
Adjusted R sq = .170	*	< .05
F = 21.887; sig < .000	**	<.01
N = 3362	***	<.001

Socioeconomics

Areas of with higher percentages of the population in the 0–16 cohort enjoy higher transit demand relative to the 30–50 cohort (Table 3). Most likely, people without a driver's license must rely on transit service, as they, theoretically, are unable to operate an automobile. Also, these areas are likely to have a larger household size and have lower levels of income available for more convenient transportation (i.e., the automobile).

The percentage of residents with access to an automobile was not surprisingly negatively associated with transit demand (Table 3). The greater the percentage of the population with access to an auto, the more likely someone will drive, especially given that most people enjoy abundant free or inexpensive parking in the Twin Cities. This finding seems particularly troubling given most people have access to an automobile.

The general lack of significance of socioeconomic variables suggests that some of the myths regarding urban public transportation may be easily debunked. For example, a general perception exists that transit (especially buses) is for poor people and poor areas; however, the evidence here fails to support such a notion. Similarly, the model fails to support any notion regarding public transit use as related to race/ethnicity, household size, or education.

Density

Nearly every study that has focused on transit ridership has provided evidence that density is the primary determinant of transit ridership (see Seskin and Cervero 1996 and Table 1). A study by Nelson/Nygaard (1995) showed 93 percent of the variation of transit demand in different parts of the Portland region is explained by employment and housing density, even after controlling for 40 land use and sociodemographic variables. One problem with density is that it is highly intercorrelated with other variables, as studies that have focused on density are probably missing everything that comes with it (Handy 1996a).

While population density of the block the bus stop is on is unrelated to transit demand, population density of the larger block group is significantly related to transit demand (Table 3). Many bus routes run along commercial corridors and so the lower demand associated with density at the block level is likely a result of adjacent commercial uses and while the residential areas are off the block proper. The significant relationship at the block-group level would support this notion and give further credence that density is of primary importance relative to transit demand.

Land Use

Multifamily residential land use was associated with lower transit demand within an eighth mile of transit stops, and associated with higher demand from an eighth mile to a quarter mile of transit stops. While the negative association near transit stations is counter to the hypothesis, the positive association within a quarter mile gives further credence to the finding that larger densities within the larger area have stronger implications on transit demand than do high densities adjacent to the line.

Transit demand is related to the percentage of mixed-use and retail-commercial land within a quarter mile of the bus stop (Table 3). The significance of adjacent vertical mixed uses to transit demand is consistent with the claims of TOD proponents and existing literature. The positive association of retail–commercial use suggests that people use transit for both nonwork and work-related travel or that employees of retail–commercial activities are more likely to use transit. Retail use is positively related to transit demand both within an eighth mile and quarter mile of the transit stop (Table 3).

Land Use Interaction Effects

Some land use interaction is evident (Table 3). The greater the difference between housing-based and employment-based land uses, the lower the demand for transit (Table 3). Jobs–housing balance is believed to be the outcome of a free market, as jobs and housing colocate to maximize access to one another (Cervero 1996). However, there is generally little evidence to support that jobs–housing balance actually occurs, and secondly, that it has any noticeable impact on transit.

A negative relationship exists between housing–shopping balance and transit ridership (Table 3). While this contradicts the standard TOD model, it is consistent with the standard gravity model. In other words, if shopping opportunities exist nearby, there is no need to travel longer distances to reach the same opportunities.

Greater opportunity is considered preferable to most because it reduces the *need* to travel. However, reducing the need to travel does not necessarily equate to less travel. Some people enjoy travel in the automobile (i.e., the culture of cruising); however, there is little evidence that people ride transit in that manner (except for tourism). In other words, a greater balance between shopping, housing, and employment-based land uses would seem to lower transit demand.

Future Research Direction

Significant advances have been achieved in transit/transportation–land use research in recent years, but much is left to be desired. Future research of this kind should focus on determining the catchment areas of the various land uses and density variables. The general rule estimates that people are willing to walk a quarter mile to transit stations. However, it remains unclear exactly how this assumption was estimated and how this number might change based on the quality of service and climate differences, as it is unlikely to be a one-size-fits-all application.

Understanding the temporal variation of transit demand would greatly enhance the ability to provide efficient and effective transit service. Travel behavior literature has created a strong foundation for understanding how people change their behavior, including mode choice, based on the time of day that they are able to travel. For example, people may be more likely to visit retail locations via transit between the hours of 5 and 7 P.M. during the week, and middle of the afternoon on the weekends. Information such as this, combined with spatial transit demand data would increase the ability of transit planners to provide the service transit-dependents require, while capturing a larger share of "choice riders," or those who choose transit over other modes. This information is particularly useful given the general propensity of government funding toward the auto and auto-oriented uses and lack of funding available for transit.

Another major drawback to transit–land use analyses is the difficulty in measuring land use design and diversity measures. Diversity measures have employed entropy measures and a dissimilarity index (Cervero and Kockelman 1997; Frank and Pivo 1994), and estimated the distances between several different retail commercial uses and residential units (Handy 1996b). While these measures are innovative uses of existing data, they leave much to be desired . To truly illuminate the complex causes of transit demand, a much more robust statistical foundry is needed. Considering the difficulty in funding such comprehensive data collection and entry, and slim funding to transit agencies, large data enhancement is as unlikely as it is necessary. Similarly, researchers have made significant progress on operationalizing other aspects of land use in recent years (Evans et al. 1997; Loutzenheiser 1997; Cervero and Kockelman 1997; Krizek 2002; Hess et al. 2002). Despite these improvements, highlighting the effect of pedestrian environmental factors (street lighting, sidewalk width, timing of crosswalks, on-street parking) or land use factors (setbacks, presence of front porches, windows facing the front), and possibly even social connectivity (tightness of community, social organizations) could greatly enhance the collective understanding of the effect of design and diversity on travel behavior and transit ridership.

Also, the existing measures fail to address the interaction between different land uses and the effect of interaction on travel behavior and transit use. The use of a heterogeneity measures assumes that every mix is the same, which is inaccurate (Hess et al. 2002). Measuring land use complementarity is an important step toward crafting "transit-friendly" land use plans and regulations, as well as testing and increasing the effectiveness of TOD.

Finally, a combination of a cross-sectional and longitudinal analyses, as well as both area and individual level data, will provide a stronger foundation to predict the effect changes in service have on ridership and development patterns near transit stops. In addition, such an analysis would help control for self-selection, and would provide insight toward the effect that various levels of transit service change have on residential demand near transit stops.

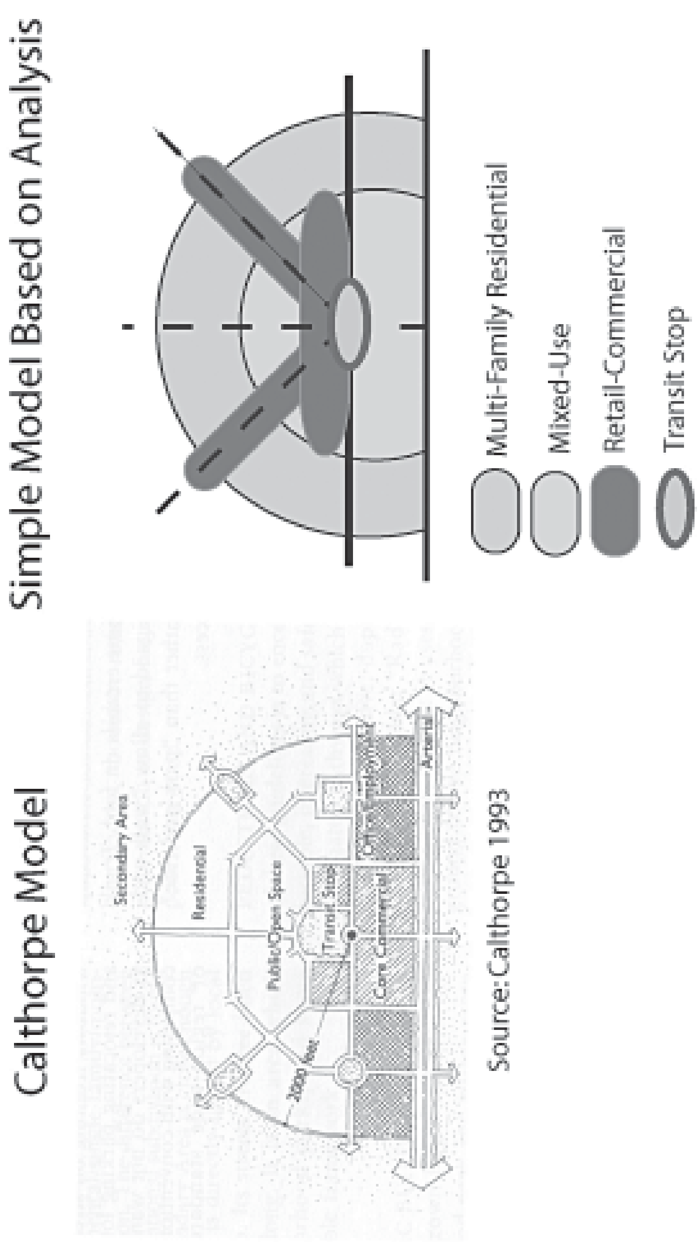
Conclusions and Policy Implications

Land Use Implications

The results of this research suggest there are three primary means available to planners to enhance transit ridership through land use planning: increase residential density in the areas near transit corridors, concentrate mixed-use development within an eighth mile of the transit corridors, and channel a greater proportion of the retail development within a quarter mile of transit lines. In fact, this analysis suggests that transit planners would increase ridership to a greater degree through catalyzing retail, mixed-use and multifamily development than increasing transit service.

While the results of the model provide support to TOD, some minor changes to the traditional TOD model are proposed. The clustering of vertical mixed-uses and retail–commercial near transit stops and higher density residential within a quarter mile of transit stops remains consistent with the traditional Calthorpe TOD model. However, existing literature in conjunction with this analysis would not promote office use in neighborhoods, but would rather cluster office uses in the CBD. Although the model in Figure 4 is crude, it provides a visual representation of the land use findings from this analysis.

Figure 4. Comparison of the Traditional TOD Model and Model Resulting from this Analysis



Despite the auspiciousness of land use planning as a transit ridership tool, it is difficult to determine the degree self-selection affects these results. Most likely those who choose to ride transit choose their residential location based on that premise. In other words, changing the land use or density around a given bus stop does not necessarily make people in the vicinity more likely to use transit

While substantial improvements are needed in the world of research, even greater improvements are needed in the world of practitioners. Those ideas that have been reinforced by numerous studies (i.e., intensity of use and limited parking result in higher transit ridership) have yet to be implemented by planning agencies to any significant degree. To increase ridership to the point that an effect on congestion and the built environment is evident, strong land use planning, investment in transit, and political will are necessary.

Finally, while these results illuminate the causes of transit demand, the effect is quite small. Predicting complex human behavior is a problem that has plagued the social sciences since their development. While some of these results are statistically significant, they fail to explain much of the variation associated with transit demand. The result of implementing these results will increase transit demand, but only marginally, which is evident given the small coefficients associated with these predictors. However, the results, and subsequent policies prescribed, should be weighed in light of the alternatives. The effect of these contributors to transit demand may be small, but they are better than the continuation of the omnipresent auto-oriented environment in the United States.

As urban America becomes increasingly disgruntled with its transportation options, public officials will have their feet held to the policy flame in order to make changes. At some point politicians and researchers will be forced to convince the American public to change or balance their preferences for accessibility and housing-related amenities. Enhanced research, and putting what is known into practice, will go a long way toward doing so.

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About the Author

Andy Johnson (*onejmd@yahoo.com*) is a long-range transportation planner for the Oregon Department of Transportation. He is a graduate of the master's in Urban and Regional Planning program at the University of Minnesota and the Center for Transportation Studies. Mr. Johnson worked as a planning consultant for the Ventura Village neighborhood on the Southside of Minneapolis and been involved with transit, land use, and travel behavior research at the University of Minnesota. He was recently awarded the Barbara Lukermann Service to Planning Award for his efforts in connecting the planning program to the larger community.

Evaluating the Urban Commute Experience: A Time Perception Approach

Yuen-wah Li

Abstract

This article examines the perception of travel time and evaluation of the urban commute experience. It reviews the literature on time perception in psychology, positing perceived travel time as a function of commute characteristics, journey episodes, travel environments, and expectancy. Insights from emerging behavioral economics are drawn to illuminate evaluation of the urban commute experience. The perception–evaluation correspondence presents the potential of a new research approach to travel behavior. A time perception model for evaluating urban commute experience is formulated to accommodate all the posited relationships, with possible moderations by goal attainment, economic values associated, and time urgency. Practical significance of the model is exemplified through its use in explaining mode choice, and as a guide for service planning and design.

Introduction

Like many other domains of consumer behavior, travel behavior has conventionally been studied with the approach that treats all (including monetary and temporal) aspects of evaluation of a travel experience as a single dimension. A traveler is assumed to view temporal and monetary expenditures alike, and trade one for another on a compensatory basis. In the transportation literature, this single measure is referred to as the "generalized cost," and represents the overall utility (or disutility) of a given commute. The conventional approach, despite its prevalence in transportation research, has devoted inadequate attention to possible distinctive features of temporal experience and expenditures. In consumer research literature, time behavior has received increasing interest over the past decade with the growth of service industries (Carmon 1991). Yet, most of the studies have been conducted primarily with waits (see Durrande-Moreau 1999 for a review) among experiences of time consumption. While waiting time is just one episode of a travel journey, the temporal experience of an urban commuter over the entire journey has rarely been examined in sufficient detail.

Given the fact that daily commutes incur a rather substantial amount of temporal rather than monetary expenditures, investigation of commuters' perceptions of the travel time and their evaluation of the travel experiences is justified. This article discusses the perceived time (i.e., psychological time) vis-à-vis objective clock time that one spends in daily commutes, and examines how it relates to the evaluation of one's travel experience. This proposed research approach is of potential to expand the extant body of knowledge in travel behavior that rests primarily on utilitarian assumptions. It illuminates the human processes, such as perception, underlying the evaluation of travel experiences, rather than the evaluative outcomes per se. The time perception approach is promising not only because it opens up new venues for transportation research, but also because of its implication for the design and planning of transportation systems and the formulation of transport policy. Advances in knowledge and practice as a result of innovative research approaches should be pursued by transport planners and policy-makers who have endeavored to promote the use of public transportation while auto dominance (ownership and use) has been on the rise during the past decades. It is, therefore, particularly worthwhile to focus the research context on public transportation.

This article begins with a brief review of the potential contribution of time perception research to the understanding of a traveler's temporal experience in daily commute. Next, findings from the time perception literature are drawn and discussed as pertinent to the specific context of urban commute, with tentative conclusions proposed in the form of research hypotheses. Then commuter evaluation of travel experience, as inspired by the emerging behavioral decision theory, is examined as a way to explore its possible connection to the perception of commuting time. Based on the tentative conclusions arrived, a framework proposing time perception to be pivotal to evaluation of daily commute experience is advanced to guide future empirical validation and further research. Lastly, summary and concluding remarks are presented. As public transportation offers the most diverse form of urban commute experiences, discussion and tentative conclusions are made and drawn with reference to this specific context.

Concepts and Models for Time Perception

Time perception has a long history in psychology research, dating back to the late 18th century (Roeckelein 2000). Research findings have rendered a valuable source of reference to the understanding of temporal experience of the daily commute. This article presents a selective review of essential concepts and models from major contributors such as Fraisse (1984), Block and Zakay 1996), Boltz (1993), and Hornik (1992).

Time Perception

The notion of time refers to succession and duration, two different concepts but both related to one's experience of change (Fraisse 1984). The concept of succession involves the perception of two or more different and sequentially organized events, whereas the concept of duration concerns the interval between two successive events. Temporal experience refers to an individual's perceptual physical changes, and the duration in perception is measured against a regular sequence of succession. Time perception, according to Fraisse's conception, is defined as "the attention to, or apprehension of, change through the integration of a series of stimuli and characterized by the ability to conceive of duration, simultaneity, and succession" (Roeckelein 2000, p. 53). It implies that time in perception bears no straightforward relationships to physical time (Fraisse 1984). Hence, the subjective duration experienced by a traveler may be different from the objective time passed.

In fact, this conception lies with the major research interest of time psychophysics that concerns the psychological magnitude of the passage of time (Grondin 2001). Evidences from the psychophysics literature have suggested perceived (subjective) time as a power function of the objective clock time, which is often referred to as "Stevens' law" (Roeckelein 2000; Grondin 2001). Growth of the psychological magnitude of a given duration may be faster than, slower than, or equal to growth of the physical magnitude, subject to the exponent value being greater than, lower than, or equal to unity respectively (Grondin 2001). Eisler (1976), for instance, concluded an exponent value of 0.9 as the best overall approximate for the psychological law applied to time perception.

Contextual-Change Model

Several models of psychological time have been advanced in the literature with an attempt to better explain and model psychological time. These models fall into two conventions of research: sensory-process convention and cognitive convention (Block and Zakay 1996). The cognitive approach has prevailed research in psychological time, namely because it offers a more useful way to understand duration experience based on such basic concepts as attention, information processing, and memory (Block and Zakay 1996; Grondin 2001).

Block's (1985) contextualistic model, among cognitive models, proposes that duration experience results from an interaction among:

1. contents of time periods (e.g., empty or filled time);
2. activities during time periods, including temporal and nontemporal attentions;
3. subjects' characteristics (e.g. personality); and
4. temporal behavior (e.g., method of measurement).

Block's model seems to corroborate Fraisse's conception of time perception as related to contextual changes on the one hand, and has elaborated the effect of the contextual changes in terms of attentional processes on the other. Subsequently, Block and Zakay (1996) advanced the contextual-change model that highlighted the importance of temporal attention in determining prospective duration judgments. According to Block and Zakay's model, contextual changes are encoded as time-tags in one's temporal information processing, and hence directly influence duration judgment. However, given the scarcity of one's cognitive resource, nontemporal events taken place in the meantime may compete with temporal cues for attention and processing, and affect duration judgment.

The literature on psychological time has also distinguished between prospective and retrospective duration judgments or estimations (Block and Zakay 1996; 2001). The prospective paradigm refers to the situation in which participants are aware of being engaged in a duration estimation task. Participants may encode temporal information as part of the experience of the time period, and so their judgment is referred to as an "experienced duration." On the other hand, in the retrospective paradigm, participants have no prior knowledge of the duration judgment task. When asked afterward about the duration, participants may retrieve whatever information available in memory. Their judgment is referred to as a "remembered duration." As most urban commutes (e.g., going to work) are made regularly, and draw one's attention and estimation of the time spent somehow, the prospective paradigm should be appropriate for the task of judging an experienced duration of commute.

Temporal and Situational Environments

Corroborating Fraisse' (1984) conception of time as the succession of events over a period, researchers such as Boltz and her colleagues (e.g., Jones and Boltz 1989) have advocated that the structure of events constitutes the temporal environment of duration judgment tasks. The temporal pattern of events (usually in the form of nontemporal information) over a period of time affects the way individuals attend to the events, and thus their determination of duration estimates. Highly coherent events present structural predictability over an arbitrary time span, and hence conducive to future-oriented attending, whereas lowly coherent events contain little predictability, and hence conducive to analytic attending. Individuals adopting future-oriented attending will seek higher order time patterns and generate expectancies about the start and end of a series of events, whereas those adopting analytic attending will turn to adjacent events in organizing ill-structured information. Therefore, in duration judgment tasks, the former group will be biased by the disconfirmation of expected (starting or ending) times, and the latter group by their attention to the amount of local details. Urban commutes of a daily or regular practice should be more conformed to events of high coherence, and so individual travelers are likely to adopt future-oriented attending in their perception of the commute time consumed.

On the other hand, the consumption and perception of time is also situation bound (Hornik 1982; 1984; 1992). Hornik's (1992) research evidence focuses on the effect of affective moods as a situational variable on temporal judgment. It is hypothesized that mood biases temporal judgment by influencing the information to be recalled from memory. Individuals in a good (bad) mood, for instance, are prone to retrieve positive (negative) information, which in turn biases their judgment in a direction congruent with the mood. Alternatively, their judgment may be conceived as a direct consequence of the affective responses, positive or negative, to the stimuli under investigation. Urban commuters moving through hassles of various kinds are liable to fluctuating affective states that influence their temporal judgment of the commute.

Time Perception in an Urban Commute Context

It is hypothesized in this article that the perceived travel time of urban commuters (presumably with public transportation) varies with commute characteristics, journey episodes (i.e., ride, wait, access and transfer, service environments), and their expectancies. These relationships are discussed below, making reference to the insights from the time perception literature. The discussion is summarized in the form of research propositions as shown in Table 1.

Table 1. Summary of Propositions for Perceived Travel Time

Commute Characteristics	
Commute Duration	
P1	Commuters will perceive a short duration as being longer, and a long duration shorter (than the objective clock-time).
Commute Stages	
P2a	Commuters making a given journey involving more commute stages will perceive the journey time as being longer.
P2b	Given a constant number of stages, commuters making a journey involving more evenly distributed commute stages will perceive the journey time as being longer.
Journey Episodes	
Ride	
P3	Commuters riding on board are likely to perceive a given duration as being the shortest among the journey episodes.
Wait	
P4	Commuters in wait are likely to perceive a given duration as being the longest among the journey episodes.
Access or Transfer	
P5	Commuters in access or transfer are likely to perceive a given duration as being shorter than are those in wait, but longer than are those riding on board.
Travel Environment	
Comfort	
P6	Commuters will perceive a given duration as being shorter in more comfortable service environments.
Entertainment	
P7	Commuters will perceive a given duration as being shorter in a travel environment with amusing entertainment provided.
Expectancy	
Commuter Expectation	
P8	Commuters will perceive a given duration as being longer (or shorter) than it should be, if the duration is longer (or shorter) than one's expected duration.
Commute Reliability	
P9	Commuters will perceive a given duration as being longer for a journey of lower commute reliability.

Commute Characteristics

Commute characteristics include commute duration and commute stage.

Commute Duration

Dating back to the 19th century, Vierordt, among the pioneers of time psychophysics, conducted experiments on time judgment. His observations are referred to as Vierordt's law (Roeckelein 2000). One conclusion is that "for all categories of time from seconds to years, the same law holds good (i.e., relatively short intervals are lengthened by judgment, and relatively long intervals are shortened" [p. 73]). In regard to a commute experience, a traveler will find a short commute duration longer, whereas a long commute duration shorter, compared to the objective clock-time measurement. This implies that commute duration per se biases the commuter's perceived duration.

Commute Stage

Urban commuters, particularly those using public transportation, are used to journey interrupts of various kinds (e.g., making transfers in the middle of a trip). These interrupts may be conceived as dividing a single journey into multiple commute stages. Fraisee's principles (Roeckelein 2000) provide insights into the understanding of the effect of staged journeys on perceived travel time. The principles state:

1. A divided interval of time appears to be longer than an empty (standard) interval of the same duration.
2. An interval of time with more divisions appears longer than one with fewer.
3. Of two divided intervals, the one that is evenly divided appears longer than that which is irregularly divided. (p. 124–125).

The first principle supports the prediction that travelers perceive a given commute experience as being longer, when the journey has more commute stages. In other words, from the commuter's perception, interrupts over a journey are time consuming. Fraisee's second principle further suggests that the more commute stages (e.g., transfers) a journey requires, the longer the travel time will be perceived. The third principle, on the other hand, reveals how the distribution of interrupts affects one's experienced duration of a journey. It suggests that, given the same number of interrupts as required by a journey, travelers subject to more evenly distributed stages perceive the travel time as being longer. To illustrate, all else being equal, travelers perceive a given two-staged journey comprising two equal-duration segments as being longer, than a short (long) duration segment followed by a long (short) duration segment.

Journey Episodes

Access, wait, ride, and transfer characterize the episodes of urban commute experience, particularly with public transportation. Perceived duration, however, is likely to vary across the episodes in the light of the relative attention to temporal and nontemporal information (Block and Zakay 1996) and the likely affective state elicited (Hornik 1992) in particular episodes. A description of the general experience in each commute episode follows.

Ride

Given a reasonably stable and comfortable environment, urban commuters in ride episode are likely to be engaged voluntarily or involuntarily in activities such as scheduling daily jobs, reading, day dreaming or napping, and chatting with friends (in person or on phone). These activities demand either a considerable amount of cognitive resource or high involvement by commuters, thus substantially undermining the chance of temporal information processing. The taking place of these activities in concurrence with one's commute characterizes the polychronic time use (i.e., "two or more activities are performed within the same time block, apparently at the same time") (Kaufman, Lane, and Lindquist 1991, p. 393). That is, riding in a setting of reasonable comfort is conducive to polychronic time use which shortens the perceived duration of travel. Urban commuters in ride episode, compared to other journey episodes, are likely to experience the fastest pace of time passage and perceive a given duration as being the soonest.

Wait

Travelers on wait (e.g., for bus service) are subject to unoccupied time, and thus very attentive to the passage of time (Block and Zakay 1996). Temporal cues embedded in the wait context (e.g., repeated passing of unintended bus services or frequent time-checking behaviors by travelers in the same queue), will easily elicit the traveler's temporal attention and temporal information processing. Moreover, the waiting experience will expose travelers to an unfulfilled goal. A discomfort or dissatisfying mood may lead to overestimation of the traveler's temporal judgment. In combination of these effects, urban commuters in wait episode are plausibly perceiving a given duration as being the longest among the journey episodes.

Access and Transfer

Travelers in access or transfer for public transportation will be required to accomplish nontemporal tasks, such as walking, looking for guides, and making their way out of a moving crowd. Subject to the scarcity of cognitive resources, travelers may be inattentive about temporal information, thus not noticing time passage. However, unlike riding on board, access or transfer requires efforts that cannot free travelers for other activities of their choice. Furthermore, travelers may find dealing with access or transfer a stressful task, particularly with an unfriendly arrangement or setting. The negative affect thus aroused may bias the perceived duration upward. As a consequence, urban commuters are likely to perceive a given duration in access or transfer episode as being longer than in ride episode, though shorter than in wait episode.

Travel Environment

Given the fact that both temporal attention and affect are context dependent, perceived travel time is subject to an array of environmental factors. The effect of comfort and entertainment provided along the journey episodes are examined below.

Comfort

Comfort has been widely reported in the literature as one of the key dimensions of customer satisfaction for public transportation (see Li 2001 for a review). It is a composite measure of attributes related to service environment, including but not limited to seat availability, smoothness of rides, spaciousness (or loading), air-conditioning (or ventilation), lighting, cleanliness, spatial layout, and furniture and facilities design. A comfortable and pleasant commute environment is, on the one hand, conducive to polychronic time use, and on the other hand, of benefit to mitigate commuting stress and the negative emotions elicited. These effects in combination lead to underestimation of one's temporal judgment.

Entertainment

Entertainment is provided in commute environments, as in many service settings, as a time filler to direct customer attention to the nontemporal stimuli presented so as to undermine temporal information processing. Moreover, amusing entertainment is able to elicit positive moods during one's commute. These effects altogether appear to be conducive to shorten perceived travel time of urban commuters. However, the use of time fillers (e.g., visual and audio entertainment, and music broadcasting as commonly used in public transportation) can lead to mixed results. Entertainment containing overly repetitive or perpetually familiar content has been shown to lengthen one's perceived duration (Kowal 1987), when presenting as temporal cues, or inducing boredom, or both. Also, customer affective responses to musical pieces vary with individual tastes and preferences (North and Hargreaves 1999).

Expectancy

Urban commute, regardless of the transportation mode used, is likely to be habituated through repeated practice as a routine activity. Conceiving the daily routine as a series of highly coherent events, urban commuters may have adopted future-oriented attending, and generated certain temporal expectations or predictions (Jones and Boltz 1989) for the duration normally required for each journey episode and the journey as a whole for instance. Research by Boltz (Jones and Boltz 1989; Boltz 1993) has indicated that departures from one's temporal expectation led to biased temporal perception. Therefore, urban commuters perceive a given duration of travel as being longer (shorter) if the duration is longer (shorter) than expected, that is when the expectation is negatively (positively) disconfirmed.

In a relatively unstable commute environment (e.g., frequent road congestion for car commuters or public transportation with frequent delays), travelers may have difficulty apprehending temporal expectancy, making the commute an uncertain task. Given the correlation between task uncertainty and overestimated duration (Boltz 1998), an urban commute taking place in a rather unpredictable setting is expected to result in longer perceived journey time.

Evaluation of the Urban Commute Experience

Traditional decision theory presumes people make choices based on "decision value" (i.e., the predicted outcome for future experiences with perfect accuracy and option evaluation) (Kahneman and Tversky 1984). Emerging behavioral economics, in contrast, recognizes the important role of "experience value" in the decision-making process. It assumes decision-makers to be hedonic and concerned about "the degree of pleasure or pain, satisfaction or anguish in the actual experience of an outcome" (p. 170), instead of being utilitarian and concerned about the anticipated outcome. In this article, evaluation refers to the "experience value" that commuters rate toward a given urban commute experience. The following sections examine evaluation of the urban commute experience by commute characteristics, journey episodes, and expectancy. The extant body of literature on behavioral economics, particularly the Prospect theory (Kahneman and Tversky 1979), is taken as the primary source of reference, with support from the findings of transportation research where appropriate. Tentative conclusions are summarized as propositions in Table 2.

Table 2. Summary of Propositions for Evaluation of the Urban Commute Experience

Commute Characteristics	
Commute Duration (asymmetric effect)	
P10	Commuter value of time will exhibit a convex function: the longer the duration, the lower the marginal value of time.
Commute Stages (segregation effect)	
P11a	Commuters making a given journey involving multiple commute stages will suffer segregated losses: the more stages involved, the greater the losses in accumulation.
P11b	The more evenly distributed the stages, the greater the losses in accumulation
Journey Episodes	
Peak-End (peak-end effect)	
P12a	Commuters will appraise specific moments of a given journey that arouse strong negative affect as incurring greater losses (e.g., wait, transfer, or ride without a seat), than other moments of the journey.
P12b	Commuters will value disproportionately the end moment of a journey, during which goal attainment will be evaluated, and intense emotionality will be elicited.
Duration (duration neglect)	
P13	Commuters will sometimes value the duration of an episode as negligible (e.g., ride in a reasonably comfortable environment), as compared to the peak and end moments.
Expectancy	
Commuter Reference (reference effect)	
P14a	Commuters will evaluate temporal gain or loss about an expected or habituated duration as the reference point.
P14b	Commuters will rate temporal losses as more important than temporal gains.
Commute Reliability (certainty effect)	
P15	Commuters will rate a reliable (e.g., punctual, adhered to schedule) service or a stable commute as disproportionately high.

Commute Characteristics

Commute Duration

The Prospect theory suggests that value is assessed with respect to gains or losses, and the value function generally exhibits a concave shape in the gain domain and a convex shape in the loss domain (Kahneman and Tversky 1979). To the extent that commuting time is considered a loss, the value function of commute duration is expected to exhibit convexity. Other things being equal, the experience value for a given urban commute is expectedly subject to diminishing sensitivity of the total travel duration: the longer (shorter) the commuting time, the lower (higher) its marginal value. Findings from the transportation research literature also lend support to the convexity of the value function of commute duration (e.g., Kjoerstad and Renolen's [1996] valuation of travel time in five Norwegian towns, and Small and colleagues' [Small, Noland, Chu, and Lewis 1999] willingness to pay study for reduced congestion delay for various trip lengths in the United States).

Commute Stages

Travelers making a multistaged journey may be conceived as subject to combined prospects, in which losses are segregated by commute stages (Kahneman and Tversky 1979). Given a convex loss function, the segregated losses in accumulation shall loom larger for a multistaged journey, compared to an equivalent journey of no or fewer commute stages. Furthermore, for a constant number of commute stages over a journey, the segregated losses in accumulation will be greater if those stages are more uniformly distributed temporally. Though these predictions are by and large consistent with the decision behavior based on monetary evaluation, urban commuters as consumers of time are expected to demonstrate an even stronger propensity to integrate losses (Leclerc, Schmitt, and Dube 1995), say by reducing the number of commute stages. Kjoerstad and Renolen (1996) reported a strong preference for direct trips without transfer, even if the journey time was longer. In two Norwegian cities, direct connection without transfer was rated 1.8 to 5.0 times as valuable for a journey requiring a transfer with a 5-minute waiting time, or 2.5 to 9.2 times as valuable for the one with a transfer with 10 minutes waiting time.

Journey Episodes

Peak Episode

Kahneman's research (1999) notes that "retrospective evaluations of affective episodes are strongly influenced by the affect experienced at singular moment" (p. 2). As far as urban commute experience is concerned, some singular moments along the journey episodes may be more affect-laden than the others (e.g. ride without seats, waiting on-street unsheltered). These instances are likely to arouse strong negative affect, and return the most regretful value (i.e., the greatest loss) to the commuters, characterizing "the most extreme affect experienced" (p. 6) moment(s) or the "peak" snapshot(s) of a journey. For instance, in six Norwegian towns, travel time standing was found to be very "expensive"—rated 2.0 to 3.0 times as undesirable for travel time seated (Kjoerstad and Renolen 1996). Walking access, waiting, and transfer were rated 2.0 to 2.5, 1.5 to 3.4, and 1.3 to 2.9 times, respectively, as undesirable for travel time seated. Recent research studies for the United States revealed the value of out-of-vehicle times to be 2 to 3 times of that of in-vehicle times (U.S. Department of Transportation 1997; Bhat 1998), remaining in order with study findings reviewed in Cherlow (1981). Riding with discomfort and out-of-vehicle episodes, such as wait or access, are likely to be the peak experiences during an urban commute.

End Episode

On the other hand, evaluation as to whether the journey's goal can be attained will usually be processed near the end of a trip. This near-end evaluation may again lead to an extreme affect as at the peak episode, characterizing the "end" snapshot of a journey (Kahneman 1999). For example, failing to get to work on time is very likely to elicit a commuter's intense negative mood. Such strong emotion can overwhelm one's evaluation of the commute, and the entire journey may be viewed as being overly negative, even though all previous episodes are satisfying. The end-episode effect may offer partial support to the notion of higher willingness to pay for more reliable arrival time to work than nonwork trips in the United States (Small et al. 1999).

Duration Neglect

The "peak" and "end" snapshots, as Kahneman (1999) suggested, determine the overall evaluation of a given experience, and undermine the significance of the experience duration. This undermining is referred to as "duration neglect" in the behavioral decision literature. Duration neglect suggests that, given the intense emotionality of certain singular moments along a journey, the duration is likely to be negligibly valued, if not totally neglected, in one's evaluation. Ariely and Carmon (forthcoming) recently set out two conditions for duration neglect to be in place:

1. when the duration as an attribute is not attended to; and
2. when the duration of the experience is inherent to the experience.

Though duration is inherent to urban commute experience, commuters will somehow care about the duration (e.g., for scheduling or comparing services). It is therefore unlikely that duration neglect will take place in full range in the urban commute context.

Expectancy

Commuter Reference

As mentioned above, through repeated practice, urban commuters have generated certain temporal expectancies. These expectancies are encoded in a commuter's mental account as costs for routine (temporal) transactions, rather than occasional losses (Thaler 1985). They serve as a reference context for one's assessment of temporal gains (time saved) or losses (time wasted). Given the S-shape of the value function about a given reference point (Kahneman and Tversky 1979), temporal losses shall loom larger than temporal gains with reference to a commuter's expectation.

Commute Reliability

Prospect theory (Kahneman and Tversky 1979) predicts that decision-makers rate the importance of sure gains as more valuable than probable (i.e., uncertain) gains, contrasting traditional decision theory that assumes evaluation based on expected value criteria. Leclerc, Schmitt, and Dube (1995) further contend with empirical evidence that individuals are more highly risk averse toward temporal resources, compared to monetary resources. One reason given is the low transferability of temporal resources. The certainty effect in regard to temporal resources will be considered more appealing than monetary resources. As for the urban commute, the certainty effect is likely to imply a disproportionately high value attached to a stable commute, be it a reliable service (in terms of punctuality and adherence to schedule for instance) or a flow traffic. The predictability associated with a stable commute allows urban commuters to plan how to use their temporal resources more effectively. Kjoerstad and Renolen's

(1996) report revealed that passengers in Oslo, Norway, had strong preferences for highly reliable services, and considered even short delays a problem.

Time Perception Model of Evaluating the Urban Commute Experience

Correspondence Between Perception and Evaluation

The propositions set out for time perception in the urban commute context and temporal evaluation of the urban commute experience are outlined and compared in Table 3. The comparison exhibits high correspondence between the two proposition sets. The correspondence reminisces the psychological origin of the emerging behavioral economics, particularly the Prospect theory. The S-shaped value function, for instance, seems to reverberate Stevens' power law as proposed in the psychophysics literature (Roeckelein 2000).

Table 3. Comparison of Propositions Sets for Perceived Travel Time and Evaluation of the Urban Commute Experience

Variables	*Perceived Travel Time*	*Commute Experience Evaluation*
	Commute Characteristics	
Duration	Longer for short duration; shorter for long duration	Convex loss function (asymmetric effect)
Stages	Longer for a multiple-staged journey	Segregated losses
	Journey Episodes	
Peak	Longest for waits, transfers, or uncomfortable rides	Peak snapshot
End	—	End snapshot (related to journey goal attainment)
Duration	Shortest for rides (with reasonable comfort)	Duration neglect
	Expectancy	
Commuter Expectations	Longer when longer than expected shorter when shorter than expected	Temporal loss looming larger than temporal gain (reference effect)
Commute Reliability	Longer for low-commute reliability	Certainty effect

Furthermore, the correspondence suggests a more coherent relationship with one's evaluation for the perceived rather than the physical stimuli, despite the departure of the perceived reality from the physical reality which Tversky referred to as "perceptual illusion" (McFadden 1998). In other words, subjective time, however illusive, may be rather informative of one's evaluation of a commute experience, as compared to the objective clock time. In fact, research studies on waiting times have offered consistent evidence for the connection of increased perceived (wait) time with more negative customer evaluation (e.g., Katz, Larson, and Larson 1991; Pruyn and Smidts 1998; Antonides, Verhoef, and van Aalst 2002).

The Model

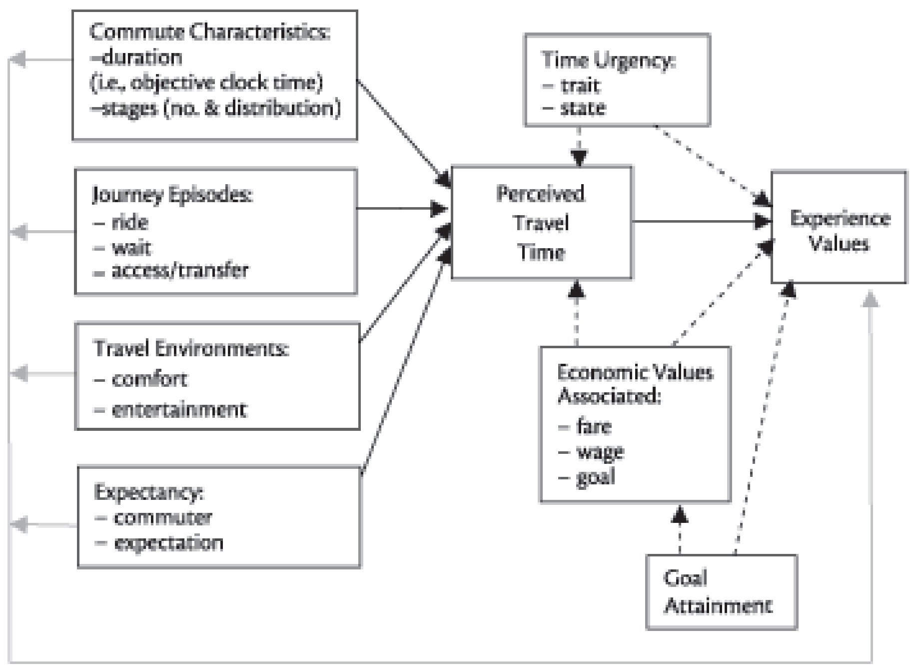
This section discusses the development potential of a research approach to commute behaviors that places perceived travel time as central to one's evaluation of a commute experience. A tentative model is proposed, linking the hypothesized factors to one's perception of travel time, and hence commute experience evaluation, as represented by the black solid lines in Figure 1. More specifically, perceived travel time is expected to vary with four factor categories:

1. commute characteristics (objective duration and number of commute stages);
2. journey episodes (e.g., commuters are riding or transferring);
3. service or commute environment (comfort and the provision of entertainment or the quality of entertainment provided); and
4. expectancy (commuter expectancy and service reliability).

Furthermore, the perceived travel time determined is expected to be predictive of one's evaluation of the commute experience.

Despite the postulated importance of perceived travel time to commute experience evaluation, the proposed model accommodates potential direct impacts of the identified factor categories on a commuter's evaluation. These direct contributions may be conceived as support for the notion of duration neglect as discussed above. The model, however, leaves open for empirical evaluation the question as to the extent of explained variances on the commute experience evaluation to be accounted for by the four factor categories with and without the mediation of perceived travel time.

Figure 1: Time Perception Model of Evaluating the Urban Commute Experience



Moderators for Perception–Evaluation Link

There may be other constructs at play (e.g., goal attainment, economic values, time urgency) that influence commuters' perceptions, or moderate the perception–evaluation link, as represented by the dotted lines in Figure 1.

Goal Attainment

As mentioned above, goal attainment is usually assessed near the end of the journey, and the assessment will possibly bring about intense emotions that moderate the perception–evaluation link. On the other hand, as the goal of most urban commutes is associated with production or economic activities (e.g., going to work), goal attainment is related to economic gains or losses, which lead to corresponding changes in experience value.

Economic Values

The economic costs or values associated with a commute also influence a commuter's evaluation. For one, fare represents the monetary payoff for the chosen public transportation modes. Wage reflects the economic cost of the time consumed, as most economists assumed (e.g., Becker 1965). Part of the economic values may also be related to goal attainment (e.g. monetary penalty for late-comers). Antonides et al.'s work (2002) presents the moderating effect of monetary cost of time on the perception–evaluation link for a telephone wait setting.

Time Urgency

While perception and evaluation involves subjective judgment of individual commuters, individual differences should have their part to play. In particular, time urgency as a personality trait or a personality state (Koslowsky, Kluger, and Reich 1995) is expected to affect time perception and experience evaluation of individual commuters. As a personality trait, time urgency refers to an individual's disposition about time in general (e.g., Type A behavior), whereas as a personality state, it reflects specific time demands of the external environments (e.g., getting to work on time).

Implications

Explaining Modal Choice

The postulated time perception model is of potential contribution to a better understanding of travel behavior, such as the notion of auto dominance and the preference for bus over rail as exemplified below.

Auto Dominance

The private car has remained the prevailing mode of transportation for the urban commute. In 1995, the automobile accounted for 43 percent of passenger kilometers worldwide (Pucher 1999). The time perception model of commute evaluation may well explain the notion of auto dominance in regard to a commuter's perception of travel time. An auto commute is attractive in most courses of perceived travel time, compared to a public transportation commute. It is most likely a door-to-door service, thus minimizing the number of commute stages. It spends time predominantly on the ride episode, usually with seats secured and even entertainment (e.g., music) of the commuter's choice. It demands the commuter's (i.e., driver's) continuous attention to road conditions and motor operation, rather than temporal cues or information, and hence exploits the cognitive resource for nontemporal information processing. Also, it avoids the temporal and monetary losses due to unreliable public transportation services. All these may result in a given journey perceived as shorter for an auto commute, and hence the commute experience to be more positively evaluated than for a commute with public transportation. Though people intending to travel by car to save time are not necessarily objectively justified, their savings in the experienced time and positive evaluation associated may be arguably real (Hjorthol 2001).

Bus Versus Rail

Of the public transportation modes, bus and coaches are the most preferred. In 1995, bus and coaches recorded a 20 percent modal split of the world's passenger transport in terms of passenger kilometers, compared to only a 6 percent split for rail-based modes (Pucher 1999). The notion of a larger modal split for bus than rail remains valid for well-developed countries such as the United States, where modal shares (in passenger-miles) of bus and rail were 1.1 percent and 0.5 percent, respectively, in 1997. Though there are many reasons (e.g., the investment required) to the relative prevalence of bus over rails, the time perception model potentially offers a good account. For instance, bus is usually more accessible than rail and is likely to entail fewer commute stages or transfers for urban commuters. On the other hand, bus is more likely to offer commuters with seats than is rail, and hence more conducive to polychronic time use (Kaufman et al. 1991). Therefore, though the objective travel time for a given journey may be longer for bus than rail, the perceived travel time can be shorter for a commuter with bus than rail, leading to a more desirable evaluation of the bus mode. The reliability of bus services, however, is more susceptible to road conditions, and in some cases renders bus to be less preferred than rail in view of possible temporal and monetary losses as a result of service delays.

Guiding Service Planning and Design

The proposed time perception model of evaluating commute experience is intended not only to provide a better understanding of urban commute behaviors, but also to be of practical value to the planning and design of a public transportation system. Of the potential contributions, it highlights perceptual vis-à-vis physical aspects in service planning and design for public transportation. The conventional approach to service planning design has been obsessed with such efficiency criteria as maximum flows and shortest paths (travel durations). The proposed approach, however, calls for the creation of commute patterns conducive to polychronic time use, and the provision of reliable services and a pleasant travel environment. It also lends support to the potential of developing walking as a desirable transportation mode.

Transfers

Most public transportation networks are designed with an overwhelming concern on efficiency, resulting in transfer points of various kinds for intramodal or intermodal connections. It is inevitable that, in their journey with public transportation, urban commuters go through more than one commute stage, and experience the transfer episode(s). The tolerance of urban commuters in regard to the number of transfers required, and their temporal distribution, over a journey, however, has yet to be determined. Obviously, travel disrupted by frequent transfers hampers commuters' polychronic time use. Travel requiring a transfer midway keeps commuters attentive for half of the journey and the related temporal information. It appears, for instance, that the number of transfers required for a journey to work should be limited to two, though more transfers may be acceptable for commutes of other purposes (e.g., leisure). On the other hand, a congenial design of transfer points reduces the extent of perceived contextual changes, and hence the perceived passage of time during the transfer episode. Transfer points so designed, among others, may require just a brief access from one line (mode) to another, and have an integrated in and out for all modes available.

Reliable Services

The time perception model suggests that unreliable or disconformed services are evaluated as extremely undesirable by urban commuters, because the travel time is perceived as unreasonably long. The negative evaluation is likely to be coupled with failure in goal attainment, for instance, due to delayed arrivals. This is in contrast with the auto commute experience in which, under normal road conditions, the driver has control over the departure time, route choice, speed used, and even the arrival time, as conformed with the commuter's expectation. The comparative disadvantage on commute reliability or predictability of public transportation may be one reason that continues to motivate urban commuters to use autos. Service reliability is, therefore, extremely important in attracting urban commuters to public transportation, though not equally important in drawing auto commuters. However, transport operators obsessed with efficiency are tempted to publicize the best achievable service level or the shortest travel time, ignoring the adverse impact of variability on commuters' perceived duration and service evaluations. Whereas, planners having regard to perceptual elements should seek to manage commuters' expectations, say by presenting realistic or rather conservative estimates of service information on the one hand, and give variability a disproportionate weight in service planning and design on the other.

Travel Environment

A comfortable and pleasant travel environment is conducive to polychronic time use, and reduces commute stress and hence a negative mood. Such an environment helps to shorten perceived travel time, and bring about positive evaluation of the commute experience. In regard to the determination of service levels for public transportation, for instance, planners overwhelmed with doing more for less are tempted to pack as many passengers in a given compartment as the safety requirement would allow at the expense of commuter's experiences. However, it is recommended to establish target load levels for different periods of operation that balance efficiency and perceptual concerns. On the other hand, congeniality, suggested as the guiding principle for the design of transfer points, should also be adhered to wherever possible in the design of other commute environments (e.g., wait and access areas). It encompasses the logistic aspects as well as perceptual factors such as temperature and color tones. It should be noted that while entertainment in public transportation settings is intended to distract commuters' attention from temporal information, reaction toward the entertainment used, be it visual or audio, depends very much on individual taste. Thus, the effect is rather unpredictable. A boring film, for example, may be a driver to attend to time passage, or to go napping while traveling. It is, therefore, difficult to generalize the use of entertainment as a tool for managing perception.

Walking as a Mode

Walking as a nonmotorized transport mode accounted for 17 percent passenger kilometers made among the world's passenger transport in 1995 (Pucher 1999). Walking has met with increasing recognition by policy-makers as an important transportation mode in both the United States and European countries. While the time perception model suggests that a short commute is likely to be perceived as longer, walking presents potential to reduce perceived travel time particularly well for relatively short-distance travels, say within 800M. Unlike commutes with public transportation, walking demands the traveler's continuous attention to the environment and motor operation. This may help divert a traveler's attention from temporal information to nontemporal goals (e.g., a certain building ahead), thus reducing the perceived duration of travel. On the other hand, walking, like an auto commute, allows travelers (commuters) to control departure time, route choice, and arrival time, possibly leading to conformed expectation in travel time. It is equivalent to, and as valuable as, a highly reliable transportation mode, particularly for short-distance travels. However, the walking environment provided, including facilities (e.g., air-conditioning), traffic priority, pedestrian safety measures, etc., is essential to promoting walking as a desirable alternative mode. Policy-makers in this pursuit should endeavor to create a pleasant and safe walking environment.

Summary and Concluding Remarks

This article has attempted to contribute an alternative approach to the research of transportation behavior which has been drawing predominately on conventional decision theory and particularly random utility models. It examined the subjective perception of travel time spent for the urban commute and evaluation of the commute experience. In view of the long history of time perception in psychology research, the time perception literature was reviewed, particularly psychophysics and cognitive models of time perception, as pertinent to the context of the urban commute. Through the literature review, perceived travel time of urban commuters was hypothesized to be contingent with (1) commute characteristics (duration and the number and distribution of commute stages); (2) journey episodes (ride, wait, and access and transfer); (3) travel environments (condition of comfort and entertainment provided); and (4) expectancy (commuter expectation and commute reliability).

The article has also made reference to the emerging behavioral decision theory, particularly Kahneman and Tversky's Prospect theory, in the examination of the evaluation of the urban commute experience. It appeared that (1) asymmetric and segregation effects was relating evaluation to commute characteristics; (2) peak-end effect and duration neglect (less likely though) were at play to affect evaluation through journey episodes; and (3) reference and certainty effects accounted for the impact of commuter expectation and commute reliability on evaluation. Furthermore, the hypothesized relationships exhibited high correspondence with those identified for perceived travel duration. A time perception model of evaluating urban commute experience was proposed, accommodating all the posited relationships, and placing perceived travel time as central to the evaluation of a given urban commute experience. Some possible moderators for the link between perceived travel time and evaluation were also postulated and discussed, namely goal attainment, economic values associated, and time urgency.

The proposed model not only suggested an innovative approach for transportation research, but also to be of descriptive and prescriptive value for practitioners. It was applied to explain mode choice behaviors, namely auto dominance and the preference of bus over rail, from the perspective of perceived duration. More importantly, it drew the attention of transport planners and policy-makers to the perceptual vis-à-vis physical aspects of transportation system. Transfers, service reliability, travel environment, and walking as a transport mode were highlighted and discussed.

Some limitations of this article are acknowledged. The literature reviewed was by no means exhaustive of the total body of the research in psychology and behavioral economics. Also, research studies adopting the behavioral economics approach to the investigation of transport behavior are parsimonious. This article may be among the few of its kind. In addition, the hypothesized relationships of the model are tentative, and yet to be confirmed by empirical evaluation. There should be much room for modification and development based on the result of empirical examination. Apparently, it is remote to apply behavioral decision theory to inquire transport choice behavior, to the same extent as conventional decision theory is applied. Despite these limitations, this article hopefully presents a pioneering attempt.

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About the Author

Yuen-wah Li (*yuenwahli@sinaman.com*) is a DBA candidate at Argosy University/ Sarasota. Mr. Li received an MA in economics from the University of Oklahoma (Norman) and a BA in quantitative analysis for business at City University of Hong Kong.

Since 1993, Mr. Li has served as assistant manager for planning and development at Hong Kong's Kowloon Motor Bus Co. Ltd., one of the world's largest public bus companies owned by private enterprises.

A Review of Approaches for Assessing Multimodal Quality of Service

Rhonda G. Phillips
Urban and Regional Planning Department, University of Florida

Martin Guttenplan
Systems Planning Office, Florida Department of Transportation

Abstract

Prompted by a need to respond to increasing traffic congestion, national, state, and local organizations have called for increased multimodal planning. This changing focus has added more complexity, data needs, and desire for supportive analytical tools to the transportation planning process overall. Multimodal performance methodologies are needed that can be readily applied. This article provides an analysis of existing methodologies to assess quality of service and related concerns for pedestrian, bicycle, and transit modes. It explores the methodologies in the context of supply-side considerations and provides considerations for their use. By placing transit-level service in line with pedestrian and bicycle, it brings all the modes together, making management easier.

Introduction

The Transportation Equity Act for the 21st Century (TEA-21) has recently called for communities to provide a multimodal transportation system in response to increasing traffic congestion. Pressure is increasing for local governments and planning organizations to respond by planning for multimodal transportation systems, yet tools to assist in these efforts are not readily apparent. The multimodal performance measures in many local congestion management plans are cursory at best—a confirmation of the lack of tools to help devise effective plans. The end result is that many communities do not utilize multimodal transportation options to ease congestion, as there are not many available methodologies to quantify the results or even measure the problem.

Quality of service (QOS) and related methodologies can function as tools to assist communities in planning multimodal transportation options. This article provides a summary of the types of QOS and related methodologies. While a few of these are not directly considered a QOS methodology, they provide a useful supply-side analysis, or in some cases, a relative demand potential perspective that is used in conjunction with supply approaches. Also, it should be noted that QOS literature for transit focuses on work by only a few researchers. The dominance of the transit level of service technique is apparent in the literature. While several attempts at pedestrian methodologies exist, they have not produced validated models as those for the bicycle mode; thus, the literature in this area is not as plentiful. The following section summarizes current approaches and relates them transit-level service.

Multimodal QOS Concepts

The words, "quality of service" are often used interchangeably with "level of service" (LOS) and "performance measures," yet caution is needed, as the three sets of terms are distinct. According to the *Transit Capacity and QOS Manual* (Kittelson et al. 1999d), the terms are simply defined as:

> *Quality of Service:* The overall measure or perceived performance of service from the passenger's or user's point of view.
>
> *Level of Service:* LOS is a range of six designated ranges of values for a particular aspect of service, graded from "A" (best) to "F" (worst) based on a user's perception.
>
> *Performance Measures:* A quantitative or qualitative factor used to evaluate a particular aspect of service.

The primary differences between performance measures and service measures are (Kittelson, et al. 1999d: 5–2):

- Service measures represent the passenger's or user's point of view, while performance measures can reflect any number of points of view.
- Service measures should be relatively easy to measure and interpret in order to be beneficial to users.
- LOS grades (A–F) are typically developed and applied to service measures. The term has been used for more than 30 years in the *Highway Capacity Manual*.

Also, performance measures are typically viewed as the operator's point of view, are more vehicle-oriented, and incorporate various utilization and economic measures. For example, operator-based performance measures usually reflect ridership and economic factors while vehicle-based performance measures include such factors as roadway capacity and traffic signal delay time (Kittelson et al. 1999c:2). In contrast, service measures are person-oriented to reflect the passenger's or user's point of view.

To further illustrate the QOS concept, the case of transit is explored, using examples from the *Transit Capacity and QOS Manual* (Kittelson et al. 1999c, 1–38/39). Generally, a person is faced with a decision whether to use transit or an alternative mode. There are two parts to this decision process: (1) the potential passenger will assess the availability of transit and whether transit is an option for the trip; and (2) the potential passenger will compare the comfort and convenience of transit to alternative modes.

The following five conditions affect transit availability. All of these conditions must be met for the potential passenger to consider transit as an option for the trip: (1) transit must be provided near one's trip origin; (2) transit must be provided near one's destination; (3) transit must be provided at or near the times required; (4) information on using the transit service must be available; and (5) sufficient capacity must be provided. If these conditions are met, then transit is an option for the potential passenger; however, comfort and convenience issues are then considered. If these factors compare favorably with competing modes, then transit will be used. Some of the comfort and convenience factors affecting transit quality are: reliability of the transit service (time required to arrive at their destinations); total door-to-door travel time, as compared with alternative modes; costs of using the transit service, compared with alternative modes; safety and security of using the transit service, including accessing transit stops; passenger amenities provided; appearance and comfort of transit facilities and stops; and passenger loads on the transit vehicles (Kittelson et al. 1999d: 1–39).

Any of these factors (and others identified by local transit systems operators and transportation planners) can be analyzed for a particular transit stop, route segment, or an entire system to generate a QOS assessment. LOS measures, typically the A through F range, can be applied at this point. However, it is important for transit system planners and operators not to focus entirely on the LOS range calculations as a variety of other factors influence QOS that may not readily lend themselves to an "A–F" categorization.

Current Approaches

Difficulties are reported by both users and researchers with many of the existing methodologies used for measuring multimodal performance (Phillips, Karachepone, and Landis 2001). The difficulties are primarily due to the limited scope of factors imposed by these methodologies. For example, the *Highway Capacity Manual* (Transportation Research Board 1985) defines performance measures for bicycle and pedestrian environments simply as the degree of discomfort to the user due to overcrowding of the facilities. However, this measure may apply to only a small percentage of collector and arterial networks throughout urban areas; thus its applicability is severely limited. Other measures from the user's point of view to assess QOS are not standardized, or routinely utilized, leaving transportation planners with little or no feasible methodologies to use.

Similarly, much of the current transit QOS methodological approach follows the *Highway Capacity Manual* guidelines of evaluating the performance of the transit trip only. Other factors, such as transit accessibility, including how the user accesses the transit vehicle, are rarely included. For example, many transit stops do not have adequate amenities, such as sidewalk access; other areas have extremely long waiting times (headways) yet these areas are considered to have transit service. The obstacles the user must overcome are rarely considered in this type of methodological approach, leaving an inadequate and unclear assessment of transit's quality of service. Solutions to these obstacles can be integrated into pedestrian and bicycle planning as well, supporting all three modes.

Until recently, traditional concepts applied to highway and roadway policy, planning, and design have been superimposed to try to fit the needs of multimodal planning. Rarely has this worked to the extent that effective QOS methodologies are utilized to support planning and design for bicycle, pedestrian, and transit modes. As part of the overall transportation planning process, considerations for multimodal facilities have often been lacking due to the quiet nature and lack of knowledge of bicycle and pedestrian modes, in particular. For example, low trip volume, low space requirements as compared with motor vehicles' needs, and the inability of some travel demand models to account for these trips often commands less attention than other modes (Burrell 1994/95). Methodologies and tools are needed that can bring the level of analysis for multimodal to the same degree of confidence and usability as that for highway and roadway planning, yet take into account the distinct needs of multimodal planning. Bringing together the pedestrian, bicycle, and transit modes makes management easier at the local and municipal planning organization (MPO) level.

QOS methodologies are considered supply-side assessments—in other words, evaluation of existing facilities (Cambridge Systematics 1998a, b, c; Landis et al. 1996). Thus, past assessments have often focused on factors such as overcrowding of facilities and transit vehicle performance, or the *quality of supply* of multimodal facilities. Supply-side assessments do not predict or estimate future demand. However, they are invaluable in providing information for decision making regarding investments in improved or new multimodal facilities. They are indicators of the quality and benefits to users—information that can be used to guide or justify provision of additional facilities. Quality norms and perceptions of quality are essential to effective transportation planning; as described by Pettina (1991), quality can be assessed by usage, experience of the trip, and future values. Usage is determined by travelling time; experience is determined by safety and comfort; and future value is mostly determined by maintenance.

Comparatively, demand-side methods are used to generate quantitative estimates of demand for multimodal facilities. A variation of demand models are relative demand potential methodologies, those methods that assess the potential demand levels rather than predict actual demand. Supply-side assessments can be used in tandem with some of the demand-side methods, especially when demand is associated with the quality of existing facilities. For example, the City of Olympia, Washington, is considering measuring transit LOS through assessing the latent demand for transit service—basically how many people want to travel through a corridor or segment, a demand estimation technique (Lazar 1998). By combining this with more traditional transit LOS indicators, the City hopes to generate information and direction for complying with the Washington Growth Management

Act stipulation that transportation systems be measured and assessed. There are numerous demand models in existence.[1] The focus of this article however is on supply-side methods.

Reviews of Methodologies

Environment Factors for Bicycle, Pedestrian, and Transit Modes

Supply-side approaches for measuring the quality of an area's bicycle and pedestrian characteristics typically are used in conjunction with regional travel models. While substantial field data collection is required to develop environment factor ratings for local application (Antonakos 1994), the factors are generally relevant to a variety of regions and area types (Cambridge Systematics, Inc. 1998b). Environment factors can also be used for predicting transit trips as well as for bicycle and pedestrian modes because the quality of the pedestrian environment can influence transit selection. A "Transit Friendliness Factor" was developed for the Triangle Transit Authority in Raleigh, North Carolina, to predict automobile versus transit choice (Evans et al. 1997). Four elements were rated (on a scale of one to five): sidewalks, street crossings, transit amenities, and proximity to destinations. It was reported that including the transit friendliness factors greatly improved the model's ability to predict automobile versus transit trip selection (Cambridge Systematics, Inc. 1998a). These transit friendliness factors are directly related to pedestrian and bicycle mode planning as they are interrelated and support each other.

Portland, Oregon, was one of the first areas to develop a pedestrian environment factor (PEF) system, incorporated with its regional travel model. Portland's PEF includes: sidewalk availability, ease of street crossing, terrain, and connectivity of the street and sidewalk system (Cambridge Systematics, Inc. 1998a and 1998b). The factors are ranked, with points ranging from 0 to 12; bicycle factors are added for an additional range of 0 to 15. Portland has reported success with improvements for predicting automobile versus pedestrian and bicycle mode split. Also, the significance of the scoring system is that the higher the PEF score, the more likely people choose walking, bicycling, or transit over automobile usage. In other words, there was a measurable relationship between the quality of the pedestrian environment and the travel mode choices being made (Parsons Brinckerhoff Quade and Douglas, Inc. et al. 1993).

This relationship is powerful support for integrating pedestrian environment analysis into transportation planning efforts. For example, in the 1970s communities began to realize that for transit systems to operate effectively, conditions such as high-speed traffic, wide streets, and narrow sidewalks that make it difficult to operate convenient service for riders must be addressed. Instead of relying on transportation agencies to make decisions from the top down, communities have encouraged a more integrated process of merging traffic and transit concerns with development and environmental concerns. This livable community approach is detailed in the Transit Cooperative Research Program Report 33 (1998:3):

> *For the transit user, better management and design of streets (and other conditions) not only can improve reliability of service—by reducing the competition for street space among cars, buses, or light rail vehicles—but can also make it safer and more accessible for transit patrons….(these approaches) can be combined with other transit strategies to realize even greater social and economic impacts, whether it be revitalizing a downtown, restoring cohesiveness to a community, or creating new development opportunities.*

Further, some travel demand methods are enhanced by incorporating pedestrian environment analysis (Turner et al. 1998). By merging "supply" with demand analysis to provide a more complete analysis of issues for bicycle, pedestrian, and transit facilities, cities are able to implement a more holistic or integrated approach to transportation planning. Other areas have followed Portland's lead, applying environment factors to regional travel models. These areas include Washington, D.C. (Chesapeake Bay Foundation 1996) and Sacramento, California. Montgomery County, Maryland, developed a different pedestrian and bicycle environment factor (PBEF) that includes five elements: amount of sidewalks, land-use mix, building setbacks, transit-stop conditions, and bicycle infrastructure (Cambridge Systematics, Inc. 1998a and 1998b). Montgomery County reports a significant improvement in the performance of its regional travel model by including the pedestrian and bicycle environment factor.

Compatibility Measures for Bicycle, Pedestrian, and Transit Modes

Another type of supply-side or quality of supply approach is compatibility analysis. There are several types of compatibility approaches: pedestrian stress level and LOS assessments, bicycle stress level and LOS assessments, and transit LOS assessments. Pedestrian compatibility approaches measure the quality of existing facilities for pedestrian travel, rather than forecasting demand for expanded facilities. Pedestrian approaches and methods are considerably less developed than for bicycle or transit modes (Dixon 1996; Khisty 1994; Landis 1998b). Yet the value of assessing pedestrian facilities ranks high as an important tool in improving the transportation planning process (FDOT 1992). Khisty (1994:49) points out several applications of pedestrian compatibility approaches: results can be used as a tool to guide decision-makers in evaluating quality of facilities beyond quantitative measures of flow, speed, and density; results identify ideal benchmarks; can be used as a planning tool to develop future routes; and results can be used in budgeting funds for improvements. Although pedestrian approaches and methodologies are still "emerging," the inclusion of the pedestrian element has long been recognized by some as vitally important, with the need to fully integrate the process of pedestrian facility planning into other planning activities such as comprehensive planning, subarea planning, and site plan review (JKL & Associates et al. 1987).

As part of a congestion management plan, the City of Gainesville, Florida, incorporated LOS measures for pedestrian facilities. This methodology represents one of the more comprehensive approaches taken to date. A point system, ranging from 1 to 21 was used to evaluate actual roadway corridors for pedestrian suitability. Scores were then converted into a LOS range from A to F. The following criteria were used: pedestrian facility type (dominant facility type, sidewalk width, off-street parallel alternative facility); conflicts (number of driveways and sidewalks, pedestrian signal delay times, reduced turn-conflict implementations, crossing widths, speed of traffic, medians present); amenities in right-of-way (buffers, benches or pedestrian-scale lighting, shade trees); maintenance; and TDM and multimodal support (Dixon 1996).

Gainesville's method focuses on pedestrian facility conflicts, amenities, maintenance, and several other factors. Another pedestrian LOS and stress level method was developed by Mozer (1998). This approach focuses on facility design with speed, outside lane width, and volume as the primary criteria. Both methods have not been designed to be incorporated with travel demand models, in contrast to the environment factors approach. Similar to Dixon's checklist of pedestrian travel conditions, the City of Fort Collins, Colorado, provided a LOS standards for five areas of concern: directness, continuity, street crossings, visual interest and amenity and security. For each of these areas, brief descriptions were given to provide a scale, with LOS A representing the best pedestrian environment through level-of service F representing the worst pedestrian environment. It attempts to apply particular LOS standards to geographical areas of the Fort Collins community, determining a minimal LOS standard for that area. For example, the downtown business district, where compactness is an asset, would score highly on all LOS thresholds.

A different method developed by Romer and Sathisan (1997) combined factors to analyze entire pedestrian systems, rather than individual factors. Using the key variables in each of the three method elements (sidewalks, corner areas, and crosswalks), a balanced approach is attempted to provide an overall LOS assessment. A method used in Europe assesses existing quality against desired quality, with less quantitative focus than LOS methodologies (Centre for Research and Contract Specialization in Civil Engineering 1993).

At the behest of the Hillsborough County (Florida) Metropolitan Planning Organization, Sprinkle Consulting, Inc. assisted in the formation of a community-wide pedestrian system plan. With the expressed purpose of designing a mathematical model to quantify the perceived safety of the pedestrian environment, the Sprinkle methodology provided Hillsborough County with a method in which roadways could be prioritized for sidewalk construction and sidewalk retrofit. In the mid - 1990s Hillsborough County searched for a "blueprint" in which to upgrade its pedestrian environment. Sprinkle's criteria for evaluating the pedestrian environment included six performance factors (of which three were considered significant) and were rigorously tested in Hillsborough County (Hillsborough County Metropolitan Planning Organization 1999). The factors, determined by group consensus, include:

1. lateral separation between pedestrians and motor vehicle traffic;
2. outside (motor vehicle) lane volume;
3. effect of (motor vehicle) speed;
4. roadway (transverse) crossing inconvenience;
5. environmental amenities; and
6. sidewalk surface condition.

Designed to assess walking conditions (with or without the presence of sidewalks), the evaluation was based on a mathematical approach called the Roadside Pedestrian Condition model (RPC). Hillsborough County streets were given LOS letter grades, ranging from A to F. Hillsborough County used this LOS ranking system to assist in evaluating and prioritizing its roadways for sidewalk retrofit and construction.

A variety of bicycle stress level and LOS assessments (Eddy 1996; Turner et al. 1997) exists, including the Bicycle Compatibility Index (BCI) developed for the Federal Highway Administration. The BCI is an attempt to promote a methodology that can be widely applied by transportation planners and engineers to determine how compatible a roadway is for allowing operation of both bicycle and motor vehicle traffic (Cambridge Systematics, Inc. 1998c). It incorporates roadway variables with those bicyclists typically use to assess the "bicycle friendliness" of a roadway (Harkey et al. 1998a and b). The BCI uses several independent variables for the model, including: presence of bicycle lane or paved shoulder and width, presence of a parking lane with more than 30 percent occupancy, type of roadside development, 85^{th} percentile speed of traffic, curb-lane width, curb-lane volume, and other lane volume. The method has good validation techniques that improve its effectiveness and is considered an improvement by some researchers (Cambridge Systematics 1998a) upon earlier stress level work of Sorton and Walsh (1994a) and the Geelong Planning Committee (1978).

Sorton and Walsh (1994a and b) provided an earlier model to determine the stress level for bicyclists and bicycle compatibility of roadways. Building on three primary variables (curb-lane speed, curb-lane width, and peak hour volume), a bicycle LOS measure was developed. However, the model has been criticized for leaving out crucial factors, such as pavement conditions, roadways with bicycle lanes, and intersection density and volume (Cambridge Systematics 1998a).

In addition to the pedestrian compatibility approach developed by Gainesville, Florida (Dixon 1996), a bicycle LOS measure was also developed and implemented. The LOS developed is more comprehensive than some of the earlier efforts, and reflects an improvement upon the works by Davis (1987), Epperson (1994), and Sorton and Walsh (1994a). A point system was developed to evaluate roadway corridors, and then converted into an LOS range of A to F. Measures for the bicycle LOS included: basic facilities (outside lane width, off-street facilities); conflicts (driveways and sidestreets, barriers, no on-street parking, medians present, unrestricted sight distance, intersection implementation); speed; motor vehicles; maintenance; and transportation demand management multimodal facilities.

The Interaction Hazard Score model was developed several years ago to provide a supply-side measure of the on-road bicycling environment (Landis 1994 and 1996). The model utilizes existing traffic and roadway data and variables to estimate the perceived hazard of bicycle and automotive compatibility. The interaction model was developed to overcome deficiencies of earlier models, such as Florida's Roadway Condition Index (Epperson 1994), the Segment Condition Index, and the Davis model's Bicycle Safety Index Rating (Davis 1987; Horowitz 1996).

Several factors influence a bicyclist's perception of interaction hazard: speed of the motor vehicle traffic, traffic characteristics, proximity of the bicyclist to motor vehicle traffic, and the volume of the motor vehicle traffic (Landis 1996). Cities throughout the United States utilize the interaction model, often translating the results into LOS categories for bicycle facility planning. This practice has prompted the acceptance of the perception of hazard as a valid LOS measure.

The Interaction Hazard Score model led to the development of the Bicycle Level of Service model (BLOS), designed to quantify the level of comfort or threat of roadway hazard that, in theory, is connected with the use of roadways. The model is statistically based, and reflects the effect on bicycle compatibility due to factors such as traffic volume, pavement surface conditions, motor vehicle speed and type, on-street parking, bike lane widths and striping, and roadway width (Landis 1998a). The BLOS model differs from others in that it provides a theoretical basis for testing. A study measuring the responses of 150 bicyclists in Tampa, Florida, was used as the baseline data for developing the model and software, which according to the developer, can be applied to the majority of roadways in the United States (Landis 1998). The BLOS is based solely on human responses to measurable roadway and traffic stimuli (Landis et al. 1996:120), rather than estimations or proxies as are some of the other stress level approaches.

Another approach at assessing bicycle facilities was formulated by Nelson and Allen (1997) to analyze existing data for 18 U.S. cities (Goldsmith 1994). The research was driven by the question: Does providing bicycle facilities mean that people will use them? In other words, this research incorporates a supply-side approach to assessing facilities. A regression equation was used to test the research question with somewhat inconclusive results. The most statistically valid finding was the strength of the relationship between the miles of bicycle paths per 100,000 residents and the percentage of commuters using them—as the miles of paths increased, so did usage (as was expected). The researchers use these results to promote the theory that a latent demand for bicycle facilities may only be tapped by providing bicycle facilities, as suggested earlier by researchers at the University of North Carolina Highway Safety Research Center (1994).

Transit Measures

Existing measures of transit availability—a key measure of transit quality—typically overstate the degree to which transit service is available at a location. To overcome this, the Florida Department of Transportation contracted with Kittelson & Associates (1999a) to develop the FDOT Transit Level of Service (TLOS) indicator to address both the spatial and temporal aspects of transit availability. The TLOS indicator, which is software-based, uses percent person-minutes served, defined as the average percent of time that people have transit service available (over time) and accessible (spatially) to them (Kittelson & Associates 1999a and b).

An even more extensive QOS measure was presented in *The Transit Capacity and QOS Manual* (Kittelson & Associates, Inc. 1999d), the transit counterpart to the *Highway Capacity Manual*. This measure is broader than the Transit Level of Service indicator because it addresses factors other than accessibility and modes other than fixed-route transit; it is more generalized because it requires less detailed information, although it produces less precise results. However, the Transit Level of Service indicator is compatible with this national QOS framework. The measures used in the Transit Capacity and QOS framework are:

- *Availability:* Transit stop (frequency, availability, passenger loads), route segment (hours of service, accessibility), system (service coverage, % person-minutes served indices);
- *Quality:* Transit stop (passenger loads, amenities, reliability), route segment (reliability, travel speed, transit/auto travel time), and system (transit/auto travel time, travel time, safety) (Kittelson & Associates 1999a and d).

Conclusion

All of the methods explored represent varying degrees of improvement over past efforts. Each approach offers contributions and often one or more approaches are used to provide a more comprehensive assessment. With improvement, all are tools to bring transit level service "to the table" so that pedestrian, bicycle, and transit can be considered together.

A shortcoming of current methodologies is the lack of consideration for parallel paths, trails, or sidewalk systems that are used or could be used, as transportation corridors. If safe and relatively direct paths can be provided away from vehicular traffic, then it is likely that bicycle, pedestrian, and transit mode choices would increase. Urban trails and other alternative routes may help create a shift in demand from vehicular usage to pedestrian and bicycle modes, yet little research has been conducted in this area. Increasing bicycle and pedestrian modes will enhance transit level service as all three modes interface.

Advances made in assessing conditions for nonautomobile transportation can help in the routine accommodation of these modes in transportation systems. Local governments can now set quantifiable standards for levels of service. Some local governments are already doing this in the areas surrounding schools, parks, and other areas with high demand for nonautomobile transportation.[2] In closing, the work summarized in this article should help bring legitimacy to providing for all modes of transportation and provide information to governments concerned with multimodal quality of service. By strengthening all modes, transit level service is improved as well.

Endnotes

[1] For examples of demand-side models see: comparison studies (Wigan et al. 1998); aggregate behavior studies (Nelson and Allen 1997; Ridgway 1995); discrete choice models (Loutzenheiser 1997; Kitamura et al. 1997; Noland and Kunreuther 1995; Taylor and Mahmassani 1996); regional travel models (Cambridge Systematics, Inc. 1998b; Hunt et al. 1998; Replogle 1996; Replogle 1995; Stein 1996); and sketch plan methods (Ercolano et al. 1995; Ercolano 1997; Matlick 1996).

[2] Florida DOT has adopted a simplified methodology using default assumptions, which integrates the SCI Bicycle LOS, Pedestrian LOS, Transit Capacity and *Quality of Service Manual* and the *Highway Capacity Manual.* By integrating these into a stand-alone interactive software product, it is now possible to conduct what-if-type analysis to see how proposed changes in the roadway environment affect each of the modes. This should become a powerful tool for alternatives analysis in preliminary engineering studies. Florida DOT has also been expanding its initial multimodal Q/LOS research to include intersection, transit stop, corridors, pedestrian mid-block crossing, and areawide analysis. The most up-to-date information on this work can be found at the Florida DOT's Level of Service webpage: *http://www11.myflorida.com/planning/systems/sm/los/default.htm*.

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About the Authors

Rhonda G. Phillips (*rhondap@ufl.edu*) is director of the Center for Building Better Communities at the University of Florida where she teaches economic and community development in the Urban and Regional Planning Department. She holds dual professional certifications in planning (AICP) and economic development (CED).

Martin Guttenplan (*martin.guttenplan@dot.state.fl.us*) is a manager in the Florida Department of Transportation's Systems Planning Office where he conducts a variety of projects for multimodal integration in communities throughout Florida.

Externalities by Automobiles and Fare-Free Transit in Germany – A Paradigm Shift?

Karl Storchmann
Yale University

Abstract

To mitigate automobile-caused externalities, several European cities have introduced fare-free transit schemes. Best known are the plans introduced in Hasselt, Belgium, and Templin, Germany. The staggering increases in ridership in both cities seem to prove the overwhelming success of this policy. In addition, a study carried out for the German Federal Ministry of Transportation scrutinized the program in Templin and found that a positive net effect is likely and fare-free transit is a viable policy to curb automobile externalities. Fare-free schemes are based on the economic theory of the second-best. Automobile users should be encouraged to shift to environmentally friendly transit. An undesired side effect, however, may be the increase in the demand by former transit users and the attraction of pedestrians and bicycle riders. In Templin, the side effect was prevailing, whereas the shift from automobile to transit was only minimal. The positive net benefit was due to the reduction in fatalities and casualties: Since pedestrians and bicycle riders belong to the most endangered road users, every decrease in these modes will lead to a reduction of automobile-caused costs. The undesired side effect thus became the main effect.

Introduction

The growth in transportation with respect to number of trips, passenger miles and vehicle miles is second to none not only in the United States but in most developed countries. From 1960 to 2000 passenger miles by automobiles and transit have risen by about 250 percent—from 1,276 billion to 4,442 billion. Due to decreasing occupation rates, vehicle miles have even grown from 587 billion to 2,536 billion—more than 330 percent. Most countries in Western Europe have experienced the same level of transportation growth in recent decades. Even if this increase is losing in dynamics, saturation is not in sight. Most, if not all, of this growth is driven by the automobile. Public transportation barely benefits from this development, resulting in little or stagnating growth rates. However, the mounting costs of externalities caused by automobile travel (e.g., accidents, traffic jams, environmental problems), suggest a modal shift from cars to public transportation as an increasingly desirable goal. Given the immense spatial and temporal concentration, this is particularly true for the commuter streams during peak hours.

Several policy options can initialize and support this modal shift. Aside from regulatory instruments, such as the reduction of parking opportunities or an increase in the supply of public transportation services, economists focus on the change of relative prices. In general, they distinguish transit-supporting policies (pull policies) from schemes aimed at constraining automobile use (push policies). The first policy is considerably more popular with the public as well as transit companies.

Against this background, the long-time muted demand for fare-free transit is awakening. For a long time, it seemed as though the intense discussion of the 1970s about free transit would be on the decline and eventually disappear. However, recent developments have shown that a renaissance is imminent if not already flourishing. Several environmental groups (e.g., Greenpeace and Robin Wood) and political parties, such as PDS[1] (the successor of the former east German socialist party) have put fare-free transit on their agendas.

At the same time the number of European cities that have adapted fare-free transit schemes is growing steadily. One of the most stunning examples of the plan's success is Hasselt, Belgium. Since the abolishment of all transit fares for the entire urban area in July 1997, ridership has increased by more than 1,000 percent (City of Hasselt 2000). The reasoning behind the idea of fare free transit is the following: A considerable modal shift from car travel to public transportation makes the construction of new roads unnecessary, and existing roads can even be built back. The resulting savings more than offset the increasing subsidies for transit services, thus leading to a positive financial net effect. Following the attractive example set by Hasselt, many cities, especially in Germany, hope to resolve their financial and transportation issues through the introduction of fare-free transit schemes. The German town of Templin is another positive example of fare-free transit. Since 1997 the purchase of a ticket has been obsolete in several small German cities, including Templin (14,000 inhabitants). A study carried out for the German Federal Ministry of Transportation investigated and evaluated the benefits of fare-free schemes using Templin as reference (Keuchel et al. 2000). Overall, the results are fairly positive and encouraging—the benefits outweigh the costs by far. This could lead to a dominance of pull policies over push policies. Is this the beginning of a paradigm shift in policies aimed at solving environmental problems of transportation?

This article describes whether and to what extent countrywide fare-free transit schemes —aside from small pilot projects—are able to induce a large-scale modal shift from car travel to public transportation and, therefore, mitigate externalities. After presenting the theoretical background, the article discusses the experiences in Templin from an economist's point of view. The article ends with a summary and an overall assessment of fare-free transit schemes.

Second-Best Pricing Solution

From an individual firm's point of view, it is evident that the implementation of fare-free schemes always entails financial deficits for the transportation company: There is no payment in return for a service anymore. In fact, the financial situation of public transportation companies is traditionally precarious even without fare-free schemes. To provide and maintain an effective public service of an appropriate size, the mobilization of considerable subsidies has been required for decades. In the United States the Federal Transit Administration (FTA) collects and disseminates data on the state of mass transportation via the National Transit Database (NTD) program. As reported by the FTA (2002), total federal, state, and local subsidies have risen from \$0.9 billion in 1970[2] to about \$25.6 billion in 2002. Subsidies for mass transit in Germany, as reported in "Bericht über die Folgekosten des öffentlichen Personennahverkehrs" (Deutscher Bundestag 1997), account for about \$6 billion (Ratzenberger 1997; WIBERA 1996; Storchmann 1999). Often, the level of subsidies is not only regarded as an indicator of a lack of efficiency, in fact, they are deemed as the main cause of ineffectiveness (Pucher et al. 1983). This may be correct for the vast majority of private companies. Mass transportation companies, however, are mainly public companies and thus pursue a different goal. In general, they do not aim at the goal of profit maximization but want to maximize welfare; in financial terms only is cost recovery desirable (e.g., Bös 1986; Turvey 1971). Therefore, the term "efficiency" focuses on the questions:

- What level of service should be provided?
- How should it be priced?

Since the early 1970s, several welfare-oriented models have been developed to determine the optimal service and price level for mass transit under first-best conditions (e.g., Mohring 1972; Turvey and Mohring1975; Jansson 1980).[3] All of these studies refer to the term "social cost" which, aside from the companies cost, particularly accounts for time costs of third parties (externalities). On the base of first-best marginal pricing rules, a deficit can, in fact, be compatible with the achievement of the welfare optimum. However, since costs should be borne by those transit passengers who cause them, peak fares should be significantly higher than off-peak fares. Whereas marginal costs caused by off-peak passengers tend to zero, an incremental peak passenger requires considerable resources. By law, the size of capital stock and staff has to be dimensioned according to the transportation needs in rush hours.

Under first-best conditions, service and price level are calculated and optimized for each mode of transportation separately. This solution is welfare optimal only if substitute modes to public transportation follow the same rules and also charge first-best prices. However, these conditions are not always readily fulfilled. If a relevant substitute mode deviates from the marginal cost-pricing rule due to imperfect markets or externalities, transit fares should deviate from this rule as well in order to guarantee a welfare maximum. This new optimal fare is called the "second-best optimal" price. The theory of the second best, thus, aims at answering the question whether and to what extent a deviation from first-best prices can be beneficial to reach welfare gains. In its general form, the second-best theory was first introduced in the 1950s by Lipsey and Lancaster (1956/57); later it was applied in several specific fields. Given the extent of automobile-caused externalities, such as congestion and environmental damage, and the fact that public transportation and automobile travel are relatively close substitutes, the consideration of second-best arguments for mass transit pricing is almost compelling.[4] This leads to the question whether public transportation should deviate from first-best pricing rules and charge lower (deficit-causing) second-best fares. In this context, the introduction of fare-free transit has been discussed since the early 1970s.[5]

In its simple version, the second-best approach distinguishes only between the two modes of public transportation (t) and automobile (a). The second-best optimal fare is then calculated according to the following formula (Gómez-Ibáñez 1999):

$$P_t = MC_t - \left[\left(\frac{E_{ta}}{E_t}\right) \cdot \left(\frac{Q_a}{Q_t}\right) \cdot (P_a - MC_a) \right] \qquad (1)$$

where:

P_t, MC_t, and Q_t stand for fare, marginal cost, and quantity consumed of transit services.

P_a, MC_a, and Q_a denote the respective variables for automobile travel.

E_{ta} denotes the cross-price elasticity of automobile travel in response to changes of transit fares.

E_t is the own-price elasticity of public transportation.

According to the logic of second-best pricing, the reduction of transit fares pays as long as the marginal reduction cost of automobile-caused externalities by converting automobile users to mass transit is smaller than the actual marginal damage. Or more concretely, subsidies to public transportation are worthwhile as long as every additional dollar avoids a marginal damage higher than a dollar. Thus, the optimal amount of the subsidy is reached when marginal damage and marginal reduction costs are equal.

As can be seen from equation (1), the second-best optimal transit fare equals marginal cost (MC_t) minus the term in brackets. Only if the term in brackets is equal to zero, should public transportation charge marginal cost prices (i.e., first-best prices); otherwise a deviation is worthwhile. Given that automobile-caused externalities are predominantly negative, this "deviation" translates into a fare reduction. This reduction will be larger the more the cross-price elasticity dominates the own-price elasticity; that is, the easier it is to attract automobile users compared to transit users. On the one hand, fare reductions are inefficient and useless if the cross-price elasticity is equal to zero. In this case not a single car driver will be attracted by low transit fares. On the other hand, an automobile dominated modal split as well as high marginal externalities per passenger mile ($MC_a > P_a$) induce low second-best transit fares.

The actual amount of the fare reduction is dependent on the value of each variable, i.e., the price and cross-price elasticities, the current modal split, and the respective marginal costs. In general, any transit fare is possible, including zero fares or even negative fares. However, a second-best optimum of exactly zero requires a very specific constellation. Hence, the economic justification of a fare-free transit regime demands high empirical requirements. General fares of zero, therefore, are to be taken as rule of thumb rather than as an exact second-best optimal outcome. They are not much more than an approximation to a second-best optimum.

Generally, equation (1) can be applied for different service times, such as peak and off-peak. However, in this case we are able to consider intermodal substitution between automobile and transit for one service time only (peak or off-peak). For instance, a shift from peak-automobile travel to off-peak transit cannot be depicted. To account for intertemporal interrelations, more complex approaches have been developed (Glaister 1974). Empirical studies, however, suggest that modal substitutions clearly prevail over temporal substitutions (Table 1). The odds to turn peak into off-peak travel—regardless of the mode—tend to be close to zero.

Table 1. Transit Fares and Price Elasticities

	Automobile		Transit	
	Peak	Off-peak	Peak	Off-Peak
Peak	0.03	0.00	-0.35	0.04
Off-peak	0.00	0.02	0.03	-0.87

Source: De Borger et al., 1996; Glaister and Lewis, 1978.

From a theoretical point of view, second-best prices, and thus fare-free transit, is associated with several implications. First, a change in relative prices gives the necessary incentive for a modal switch from automobiles to environmentally friendly public transportation; this is the intended substitution process. Second, they will also induce additional demand by former transit users. This undesired side effect will be the greater the more the own-price elasticity dominates the cross-price elasticity. Since transit is a substitute not only to passenger cars but also to nonmotorized modes, a shift of bicyclists and pedestrians to transit is likely. Third, fare-free transit is likely to generate new travel demand (induced traffic). Finally, fare-free transit will entail an income effect: Consumers who use mass transit and automobiles will face an increase in real income. This can lead to more automobile travel.

According to empirical studies, there is only a very small potential for shifting automobile travel to public transportation. As shown in Table 1, cross-price elasticities of car travel with regard to transit price changes are almost zero. For instance, a decrease in peak fares by 10 percent will lead to an increase in peak ridership by 3.5 percent. Automobile travel, however, will be reduced by only 0.3 percent. Hence, the vast majority of new riders consists of former transit users, pedestrians, bike riders, or is newly induced traffic. There will also be a moderate intertemporal shift from off-peak transit to peak transit.

In addition, increasing ridership will require adjustments in the capital stock—regardless whether this is due to shifted or induced demand. This will entail an impact on the marginal production cost, which as MC_t is an implicit part of equation (1). However, investment decisions are not to be made only using a partial cost-benefit analysis. In fact, if alternative applications were considered, one has to account for opportunity costs. Given market imperfections within one segment, the second-best optimum should not be determined partially but rather for the overall economy; peripheral piecemeal policy and second-best optimum are incompatible (e.g., Bös 1986). Otherwise, the reference to second-best solutions could justify any suspension of competition.

Experience in Templin

Templin, a health resort town with about 14,000 inhabitants, is located in east German Brandenburg, about 60 miles northeast of Berlin. Its bus system in relatively small. There are two main lines and two auxiliary lines. The "fare-free bus service" project was launched on December 15, 1997. Since then the usage of public transportation has been free for everybody. Financial means are provided by the city of Templin, the Land Brandenburg, the county, and the local transportation authority *Uckermärkische Verkehrsgesellschaft mbH*. The declared goal of this policy was to reduce automobile usage and its main externalities such as noise, pollution, and the risk of accidents (Stadt Templin 2000).

Within a year after the transit scheme's introduction, transit ridership increased by almost 750 percent —from 41,360 to 350,000 passengers per year. Two years later, in 2000, ridership was above 512,000—almost 13 times its original amount (Stadt Templin 2000).

A study carried out on behalf of the Federal Ministry of Transportation investigated transit ridership before and after the fare-free program by surveying passengers (Keuchel et al. 2000). The study found that the vast majority of new transit riders are children and adolescents. This agrees with experiences in fare-free transit programs launched more than 30 years ago. As early as 1973, Baum reported on "additional demand accruing from useless and senseless journeys by children" (Baum 1973). A similar "adverse selection" occurred in early fare-free programs in the United States. Aside from joy-riding kids, transportation authorities were especially worried about increasing vandalism. The best-known U.S. fare-free project was launched in 1989 in Austin, Texas. It was abandoned after only 15 months. One of the issues was the increase in incidents involving intoxicated passengers (Hodge 1994).

When asked what means of transportation would be replaced, most people answered they would substitute public transportation for nonmotorized travel. The study found that 35 to 50 percent of transit passengers would walk less, 30 to 40 percent would replace bicycle rides, and 10 to 20 percent would reduce automobile trips. However, it is unclear whether this refers to the driver or the passenger. Nor is the length of the respective trip mentioned. Hence, conclusions regarding passenger miles cannot be drawn. Using simulation techniques Keuchel et al. evaluated the impact of the program on the modal split. It turned out that own-price elasticities for the trip purposes school, work, and shopping are significantly higher than those for leisure related trips.[6] Cross-price elasticities are considerably lower and worth mentioning only for the trip purposes to school or work. This matches empirical results drawn from an econometric transportation model for Germany as a whole (Storchmann 2001). According to these numbers, a moderate modal shift potential can be expected only for school and work trips (see Table

2). The vast majority of these trips occurs during peak hours which will entail increasing marginal production cost.

Table 2. Price Elasticities of Public Transportation[a] and Automobile Travel[b] by Trip Purpose

	Own-Price Elasticities	
Public transportation	Work	-0.321
	School	-0.121
	Business	-0.052
	Shopping	-0.087
	Leisure	-0.076
	Total	**-0.150**
	Cross-Price Elasticities	
Automobile travel	Work	0.045
	School	0.136
	Business	0.001
	Shopping	0.015
	Leisure	0.005
	Total	**0.017**

a. Comprising subways, tramways, and buses.

b. Measured in passenger kilometers.

Source: Storchmann, 1999.

What are the benefits of fare-free transit for the town of Templin? Could the goal of mitigating private automobile travel be achieved? Keuchel, et al. (2000), distinguish the four benefit components - production, infrastructure, image, and externalities - and quantify the respective effects.

Production

Generally, fare-free transit schemes make all activities associated with collecting fares unnecessary. Depending on the system, the cost savings can be considerable. However, for small bus systems, as in Templin, these savings can be neglected. Keuchel et al., therefore, assume no cost reduction. On the other hand, all activities associated with checking tickets can be abandoned also. In Templin, this leads to cost reductions of • 5,000 to •10,000.

It is questionable whether the time spent at bus stops can be reduced by letting passengers board without having to buy a ticket. This would lead to an increase in the velocity and could save considerable cost. Even though this seems to be the case at first glance, we have to account for the increasing number of passengers which could offset any time saving. Given an increase in ridership by more than 1,200 percent, this effect will prevail. In addition, fare-free transit will not only increase the number of passengers, it will entail a changing structure as well. According to the elasticity figures mentioned above, an above-average increase in peak riders can be assumed. Peak travel is characterized by significantly higher marginal production costs than off-peak travel. This may lead to a blowing-up of the capital stock only to accommodate peak demand. Hence, a considerable increase in average costs will be the consequence. For Templin, the respective costs were estimated at • 20,000.

Infrastructure

Infrastructural benefits can be subdivided into those for flowing and for parking traffic. Due to the minimal modal shift, almost no cost or benefits are to be expected. Road construction cannot be avoided nor are new parking facilities (e.g., for "park and ride") to be built.

Image

Without doubt, the introduction of the fare-free transit scheme brought much media attention and contributed to the fact that the City of Templin is well-known in all of Germany and beyond. According to city officials, this advertisement effect was crucial for the 33 percent increase in overnight stays (Stadt Templin 2000). However, it is doubtful that this increase is caused only by popularity of the fare-free bus service. The role of the overall economic growth in the late 1990s should not be neglected. To separate the effects, econometric models should be applied. Hence, Keuchel et al., did not quantify this point. In addition, it has to be pointed out that any advertisement effect is based on the sole position of the City of Templin. With an increasing number of towns introducing the same fare scheme, the marginal advertisement effect will move close to zero.

Externalities

Since the introduction of the fare-free transit program in Templin was aimed directly at reducing car-related externalities, this point is of paramount interest, especially in terms of environmental costs and road safety. In the context of fare-free transit, the mitigation of environmental costs is caused by the reduction of specific emissions per passenger kilometer (i.e., by a shift from automobiles to less polluting public transportation). Since there is only a small reduction in automobile travel, the environmental effect is very moderate. Keuchel et al., estimate the value of avoided environmental cost (noise, CO, NO_x, SO_2, HC, particulate matter, CO_2) at • 5,000. Because of the chosen money value per unit of pollution, this is the maximum limit.[7]

In contrast, the benefits with respect to road safety are considerably higher. Because fare-free transit is particularly attractive to pedestrians and bicyclists, it helps to reduce the usage of the most dangerous means of transportation. As shown in Table 3, the fatality ratio as well as the casualty ratio of pedestrians and bicycle riders exceeds that of automobiles and buses by a multiple. However, there is a wide range in the valuation of the prevention of fatalities and casualties. Table 4 shows that the figures used by the German Bundesanstalt für Straßenwesen (BASt) are considerably lower than those used by the British Department of Environment, Transport, and the Regions (DETR). Depending on the value chosen, fare-free transit induced cost reductions between • 43,000 and 120,000.

Table 3. Fatalities and Casualties by Transportation Mode (per billion passenger kilometer 1999)

	Pedestrian	*Bicycle*	*Auto*	*Bus*	*Total*
Fatalities	39.1	25.1	8.9	0.1	9.0
Casualties, serious	481.6	664.4	109.4	3.1	119.5
Casualties, light	864.8	2094.8	381.2	23.2	386.5

Source: Bundesministerium für Verkehr, Bau- und Wohnungswesen , 2000.

Table 4. The Valuation of Road Accidents

	BAS[t]	***DETR***[a]	
Fatalities	• 1,200,000	• 1,790,000	£ 1,207,670
Casualties, serious	• 82,150	• 209,400	£ 141,490
Casualties, light	• 3,730	• 20,630	£ 13,940

Source: Baum and Höhnscheid, 1999; Department of the Environment, Transport and the Regions , 1998. a. Euro values were calculated using the 1998 exchange rate 1.48 •/£.

To assess whether fare-free transit schemes are an appropriate policy to reduce automobile caused-externalities, the experiences in Templin are very useful. They can be summarized as follows:

- Overall, fare-free transit induced benefits ranging from • 33,000 to • 115,000. On the other hand, total fare revenue of • 90,000 had to be abandoned. Whether there is a positive net effect, therefore, depends on the value chosen for reduced environmental and safety costs.
- Even though the abolition of tickets saves costs associated with selling and checking, production costs will increase. This is due to the fact that demand, especially within cost intensive peak times, will increase significantly.
- A considerable modal shift from automobiles to mass transit cannot be achieved. The cross-price elasticity of car travel with respect to bus fares is extremely low. However, a massive shift of pedestrians and bicycle riders to public transportation will increase ridership enormously. In addition, current transit users will ride more often and thus lead to a further increase in service demanded.
- Due to the low substitution potential between automobile travel and mass transit, there is virtually no reduction in automobile-induced environmental costs.
- Almost all induced benefits of fare-free transit schemes are safety related. According to second-best logic this is explained by the existence of a strong undesired side effect: Pedestrians and bicycle riders switch to public transportation and, therefore, escape automobile induced perils.

Conlcusion and Assessment

Following the extraordinary growth in automobile travel over the last few decades, transportation externalities have risen to an alarming level. Policies aimed at reducing external costs (e.g., accidents, noise, pollution) can be distinguished into two different approaches: the automobile burdening *push policy* and the transit favoring *pull policy*. Against this background the introduction of general fare-free transit schemes appears to experience a renaissance in several European cities; best known are the Belgian Hasselt and the German City of Templin. The staggering increases in ridership in both cities seem to be a clear indication of the overwhelming success of this policy approach. In addition, a study carried out for the German Federal Ministry of Transportation found that the benefits of fare-free transit in Templin could offset the costs. According to the study, the positive net benefit shows that fare-free transit is a viable policy instrument to curb automobile caused externalities. Is this the first step toward a paradigm shift in transportation and environmental policies?

Fare-free schemes are based on the economic theory of the second best. Under first-best conditions, service level and prices of transportation modes were optimized separately; the price should be equal to the respective marginal cost. However, since the private marginal costs of automobile travel lie below the social marginal costs, a welfare improving second-best approach suggests a reduction of transit fares below the first-best optimum. Under particular conditions, this even allows to derive a fare of zero. The objective of this policy is to encourage automobile users to shift to environmentally friendly public transportation. An undesired side effect of fare-free transit, however, may be an increase in the demand by former transit users and the attraction of users of nonmotorized transportation.

This could be confirmed in the City of Templin. A study aimed at quantifying the benefits of fare-free transit found that ridership increased by 1,200 percent. The vast majority of this additional demand consisted of former transit users and attracted pedestrians and bicycle riders. The shift from automobile to transit was only minimal. Depending on the values chosen for intangibles, a positive net benefit may result. This is due mainly to a reduction in fatalities and casualties. Since pedestrians and bicycle riders belong to the most endangered road users, every decrease in these modes will necessarily lead to a reduction of automobile caused costs. The undesired side effect thus becomes the main effect.

This astounding result appears to be cynical. Should it be the goal of transportation policies to minimize external automobile costs by converting nonmotorized travel into motorized travel? Using the same argument one could introduce a tax on pedestrians and bicycle riders as well. The effect would be more direct and more efficient. In fact, this would be a paradigm shift. Overall, we can state that automobile-caused externalities should not be answered by transit fare reductions. Externalities should better be countered at the source, by internalizing policy approaches.

Endnotes

[1] For instance, the PDS is demanding fare-free transit for major German cities such as Mainz (200,000 inhabitants) and Munich (1.2 million inhabitants).

[2] This is equal to $4.1 billion in 2002 prices.

[3] A comprehensive literature survey is provided by Small (1992).

[4] In general, uncovered costs of accidents or infrastructure can lead to inefficient prices as well. Second-best analyses are to be found, e.g., in Calabresi (1970). The relationship between road accidents and transit pricing was investigated by Allsop and Robertson (1994) and Evans and Morrison (1997). , S. 117 ff. For a comprehensive approach encompassing infrastructure, congestion, environmental, safety, and distribution effects see De Borger et al. (1996).

[5] Compare for instance, the discussion lead in the then German language journal *Kyklos* by Bohley (1973) and Blankart (1975). Also, in English, Baum (1973).

[6] Encompassing holiday hotel city center, private errands, and other trip purposes.

[7] The following values per avoided automobile kilometer driven were assumed: noise • 0.030; CO, NO_x, SO_2, HC and particulate matter • 0.022; CO_2 • 0.008.

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About the Author

Karl Storchmann (*Karl-heinz.storchmann@yale.edu*) is a lecturer in the Economics Department at Yale University. His main research interests are applied microeconomic issues related to environmental and resource economics, transportation, energy, and agriculture. His most recent articles have appeared in *Transport Policy* and *Agricultural Economics*.