

Public Transportation

JOURNAL OF

■ Mark W. Burris
Bill R. Stockton

HOT Lanes in Houston—Six Years of Experience

■ Paul Cozens
Richard Neale
David Hillier
Jeremy Whitaker

Tackling Crime and Fear of Crime While Waiting
at Britain's Railway Stations

■ Eric Dumbaugh

Overcoming Financial and Institutional Barriers to TOD:
Lindbergh Station Case Study

■ Vikki Ngan
Tarek Sayed
Akmal Abdelfatah

Impacts of Various Traffic Parameters
on Transit Signal Priority Effectiveness

■ John Pucher
Nisha Korattyswaroopam
Neenu Ittyerah

The Crisis of Public Transport in India:
Overwhelming Needs but Limited Resources

Public Transportation

JOURNAL OF

Volume 7, No. 3, 2004

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

Gary L. Brosch, *Editor*
Laurel A. Land, AICP, *Managing Editor*

EDITORIAL BOARD

Robert B. Cervero, Ph.D.
University of California, Berkeley

William W. Millar
American Public Transportation Association

Chester E. Colby
E & J Consulting

Steven E. Polzin, Ph.D., P.E.
University of South Florida

Gordon Fielding, Ph.D.
University of California, Irvine

Sandra Rosenbloom, Ph.D.
University of Arizona

David J. Forkenbrock, Ph.D.
University of Iowa

Lawrence Schulman
LS Associates

Jose A. Gómez-Ibáñez, Ph.D.
Harvard University

George Smerk, D.B.A.
Indiana University

Naomi W. Ledé, Ph.D.
Texas Transportation Institute

The contents of this document reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation, University Research Institute Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

SUBSCRIPTIONS

Complimentary subscriptions can be obtained by contacting:

Laurel A. Land, *Managing Editor*
Center for Urban Transportation Research (CUTR)
University of South Florida
Phone: 912•654•9314
Fax: 813•974•5168
Email: land@cutr.usf.edu
Web: www.nctr.usf.edu/journal.htm

SUBMISSION OF MANUSCRIPTS

The Journal of Public Transportation is a quarterly, international journal containing original research and case studies associated with various forms of public transportation and related transportation and policy issues. Topics are approached from a variety of academic disciplines, including economics, engineering, planning, and others, and include policy, methodological, technological, and financial aspects. Emphasis is placed on the identification of innovative solutions to transportation problems.

All articles should be approximately 4,000 words in length (18-20 double-spaced pages). Manuscripts not submitted according to the journal's style will be returned. Submission of the manuscript implies commitment to publish in the journal. Papers previously published or under review by other journals are unacceptable. All articles are subject to peer review. Factors considered in review include validity and significance of information, substantive contribution to the field of public transportation, and clarity and quality of presentation. Copyright is retained by the publisher, and, upon acceptance, contributions will be subject to editorial amendment. Authors will be provided with proofs for approval prior to publication.

All manuscripts must be submitted electronically, double-spaced in Word file format, containing only text and tables. If not created in Word, each table must be submitted separately in Excel format and all charts and graphs must be in Excel format. All supporting illustrations and photographs must be submitted separately in an image file format, such as TIF, JPG, AI or EPS, having a minimum 300 dpi. Each chart and table must have a title and each figure must have a caption.

All manuscripts should include sections in the following order, as specified:

- Cover Page* - title (12 words or less) and complete contact information for all authors
- First Page* of manuscript - title and abstract (up to 150 words)
- Main Body* - organized under section headings
- References* - *Chicago Manual of Style*, author-date format
- Biographical Sketch* - of each author

Be sure to include the author's complete contact information, including email address, mailing address, telephone, and fax number. Submit manuscripts to the Managing Editor, as indicated above.

CONTENTS

HOT Lanes in Houston—Six Years of Experience
Mark W. Burris, Bill R. Stockton 1

**Tackling Crime and Fear of Crime While Waiting at Britain’s
Railway Stations**
Paul Cozens, Richard Neale, David Hillier, Jeremy Whitaker 23

**Overcoming Financial and Institutional Barriers to TOD:
Lindbergh Station Case Study**
Eric Dumbaugh 43

**Impacts of Various Traffic Parameters on Transit Signal Priority
Effectiveness**
Vikki Ngan, Tarek Sayed, Akmal Abdelfatah 71

**The Crisis of Public Transport in India:
Overwhelming Needs but Limited Resources**
John Pucher, Nisha Korattyswaroopam, Neenu Ittyerah 95

*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

HOT Lanes in Houston— Six Years of Experience

Mark W. Burris and Bill R. Stockton
Texas Transportation Institute

Abstract

High occupancy/toll (HOT) lanes allow travelers to pay a toll to enter a high occupancy vehicle (HOV) lane when they do not meet the minimum occupancy restrictions of the lane. In cases where HOV lanes are not utilized to their full capacity, this provides an effective, and controlled, use of that spare capacity along with a revenue source to offset expenses. Although this is a promising concept, and many cities around the United States are examining the potential development of a HOT lane, only four HOT lanes currently exist. This research documents the findings of six years of experience with two HOT lanes in Houston, Texas. This includes an examination of the daily number of paying customers on the HOT lanes, benefits of the HOT lanes, socioeconomic and commute characteristics of HOT lane users, and their mode of choice when electing not to use the HOT lane.

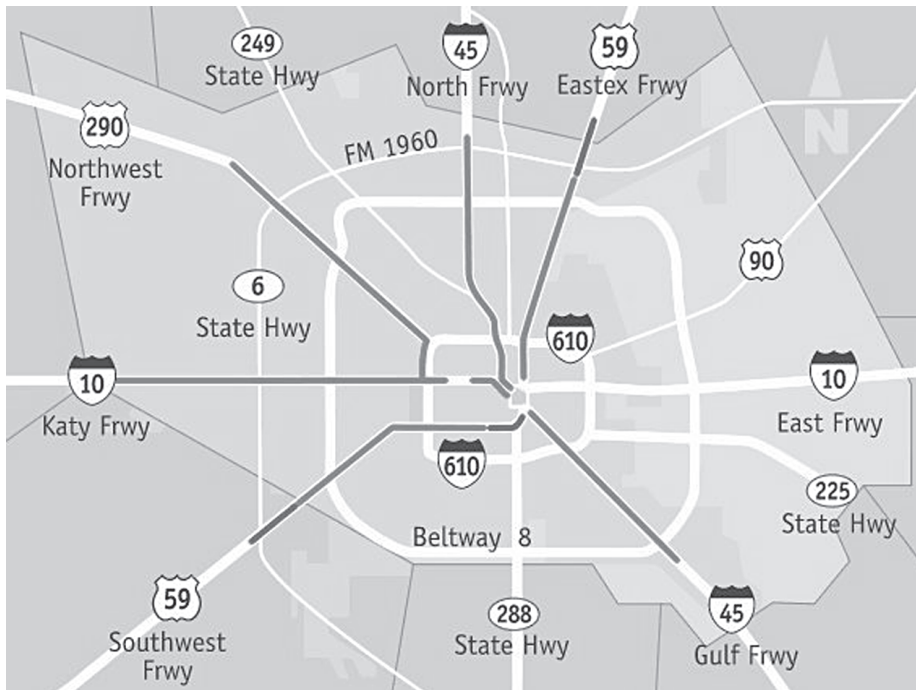
Introduction

The Houston metropolitan area has had a long and successful history of using high-occupancy vehicle (HOV) lanes to move travelers quickly and efficiently. The first HOV lane opened to buses and registered vanpools in 1979 on the North Freeway (I-45). Despite these occupancy restrictions the lane was highly successful and carried nearly as many people in the peak period as the two adjacent freeway lanes

combined (Turnbull 2003). As a result of this successful demonstration, this HOV lane was barrier separated and became a permanent fixture on this freeway.

Next, a permanent HOV lane was constructed on the Katy Freeway (I-10). Following this, HOV lanes were constructed on I-45 south of downtown Houston, US 59 both north and south of downtown Houston, and the Northwest Freeway (US 290) (see Figure 1). All of these HOV lanes are barrier separated, have adjacent park-and-ride lots, and have significant transit usage; many have direct freeway access (see Figure 2). The result is a system of bus rapid transit (BRT) lanes.

Figure 1. Houston's HOV Lanes



Source: Houston METRO (<http://www.ridemetro.org/services/areahovmap.asp>).

Figure 2. Park-and-Ride Access to a Barrier-Separated HOV Lane via a T-Ramp



When the Katy HOV lane opened in 1984, only transit buses and registered vanpools could use it (Bullard 1991). To make better use of this road capacity, the restrictions were relaxed in stages until any vehicles with two or more occupants (HOV2+) were allowed. The lane soon became congested during peak traffic periods due to the high number of carpool vehicles using the lane. This prompted Houston METRO, the transit agency responsible for the operation of the HOV lanes, along with TxDOT, to restrict usage to HOV3+ during the morning peak period (6:45 a.m. to 8:15 a.m.) in 1988.¹ Soon after, congestion during the afternoon peak period (5:00 p.m. to 6:00 p.m.) necessitated HOV3+ restrictions then as well. Most recently, the morning peak period (6:45 a.m. to 8:00 a.m.) on the Northwest Freeway (US 290) also changed occupancy restrictions to HOV3+.

Not surprisingly, these occupancy restrictions (HOV3+) resulted in a considerable reduction in peak-period traffic and available capacity in the HOV lanes. However, less onerous restrictions (HOV2+) had resulted in excess demand and congestion on the lanes. One potential solution was to allow HOV2s to use the lanes for a

price during the peak periods. This would limit demand to an acceptable level, make more efficient use of the lane, and provide a revenue source to help pay for the program. Thus, Houston's QuickRide program was created.

QuickRide began in January 1998 on the Katy Freeway and then in November 2000 on the Northwest Freeway. To use the HOV lanes during periods normally restricted to vehicles with three or more occupants, vehicles with two occupants pay a \$2 toll and a \$2.50 monthly fee. This form of HOV lane is often referred to as a high-occupancy/toll (HOT) lane. As of June 2004, there were only four HOT lanes in existence (all in the United States—these two in Houston and two in California). However, many cities are exploring the option of converting HOV lanes to HOT lanes (Value Pricing Homepage 2004).

In addition to making more efficient use of roadway capacity, HOT lanes offer travelers the additional choice of paying for fast, reliable travel. Evidence from California and Houston HOT lanes indicates few drivers use the lanes on a frequent basis (Burriss and Appiah 2004; Sullivan 2000; Supernak et al. 2001). Rather, the majority of drivers use the lane infrequently, possibly when they are particularly pressed for time or cannot risk the unreliable travel times offered by the free lanes.

Travel options available to travelers using the Katy and Northwest corridors are therefore extensive. The options include:

- drive alone or with passengers on the main lanes (peak or off-peak);
- drive with one passenger on the HOV lanes:
 - for free in the off-peak or
 - for a \$2 toll in the peak/QuickRide periods (defined as 6:45 to 8:00 a.m. on both Katy and Northwest Freeways and 5:00 to 6:00 p.m. on Katy);
- drive with two or more passengers for free on the HOV lanes;
- use transit (coach buses, as shown in Figure 3) with fare levels ranging from \$1 to \$3.50; and
- join a casual carpool, which travels on HOV lanes for free.²

Figure 3. Houston METRO Commuter Bus on HOV Lane



This myriad of choices provides travelers in these corridors more opportunity to optimize their travel behavior, and increases the net societal benefits of travel in the corridor. However, there is room for improvement, and changes to the QuickRide program are under investigation to further optimize the use of the HOV lanes (see the section “The Future of QuickRide”). Prior to these potential improvements it was critical to understand driver behavior and current use of the HOV lanes. Therefore, this article examines the benefits of the QuickRide program, usage patterns, and socioeconomic and travel characteristics of QuickRide users.

Benefits of the QuickRide Program

QuickRide offers HOV2 vehicles additional travel options that had not been available to them. HOV2 options now include:

- travel on the congested main lanes at any time,
- travel on the HOV lane during off-peak periods, and
- travel on the HOV lanes during peak periods for a \$2 toll (QuickRide).

Therefore, HOV2s’ primary benefits derive from either

- travel-time savings versus travel on the main lanes, or
- travel at their preferred time of day instead of the off-peak period.

To simplify this discussion, the benefits derived from travelers who switched modes to take advantage of QuickRide were assumed to be similar to the HOV2 travelers. For example, assume a pair of transit users formed an HOV2 to take advantage of the QuickRide program. Their travel time on the HOV lane would not change, but the travelers must have perceived some benefits to make this mode switch. These benefits were assumed to be similar in size to those benefits derived from HOV2s who received a faster travel time.

Another difficult benefit to measure is the benefit of traveling at one's preferred time of day. There is an interesting body of research on this issue (Arnott et al. 1998; Arnott et al. 1996; Chen and Bernstein 1995; Chu 1995; Verhoef 2000; Small 1992), but empirical results are extremely limited. Therefore, the exact value of the disbenefit that occurs when a morning commute is taken at a suboptimal time is unknown but would include either a penalty for:

- leaving home early (lost sleep, reduced time with family, etc.), or
- arriving late to work.

Reducing either of these penalties is a direct benefit to the drivers, albeit one that is extremely difficult to estimate. In addition, it is difficult to determine what percentage of QuickRide trips are a result of shifting from the main lanes (resulting in travel-time savings) or shifting from the off-peak (resulting in the benefit of traveling at their preferred time of travel). Therefore, for the analysis outlined here, it was assumed that the benefits of those QuickRide users who altered their time of travel to the peak period (and therefore experienced no change in travel time) was approximately equal to the benefits obtained by those QuickRide users who reduced their travel time by shifting to the HOV lane (and therefore did not change their time of travel).

Although still an estimation, determining the value of travel-time savings is more straightforward. To estimate the travel-time savings offered by QuickRide, it was necessary to determine both the number of QuickRide trips and typical travel-time savings. Fortunately, Houston uses an extensive automatic vehicle identification (AVI) system on many of its freeways (main lanes and HOV lanes) to estimate vehicle speeds (Texas Department of Transportation 2004), and this data source provided millions of vehicle speeds. Surveys of HOV lane users and vehicle counts were used to estimate the average distance traveled on each HOV lane by QuickRide participants. These average travel distances were then divided by the average speed found using Equation 1 to determine average travel times for both the HOV lanes

and the main lanes. Additionally, the number of QuickRide trips per day was recorded by the same AVI system for toll collection purposes (see Table 1). Multiplying the difference in travel times between the HOV and main lanes by the number of QuickRide users resulted in the average travel-time savings shown in Table 1. The average time to form a carpool, 4.33 minutes as reported in a survey of QuickRide participants, was subtracted from these travel-time savings prior to determining the value of travel-time savings.

$$Average\ Speed = \frac{\sum_{work\ days} \left[\frac{\sum_{segments} \left[\frac{\sum_{users} observations}{\sum_{n=1} \frac{1}{speed_n} \times \#observations} \right] \times Length_{segment}}{\sum_{segments} lengths} \right]}{\# work\ days\ in\ year} \quad (1)$$

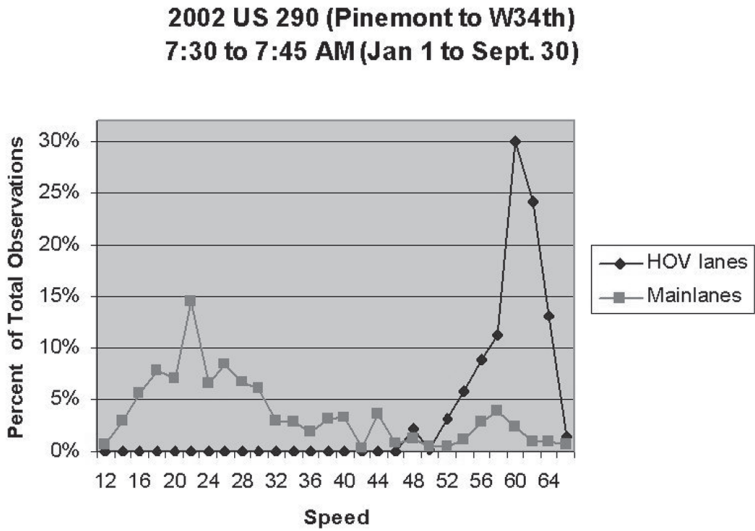
Combined with the benefit of travel-time savings, there is the benefit of a more reliable travel time. The HOV lane offers very reliable travel times where the travel time on the main lanes is much more unpredictable. For example, Figure 4 indicates average daily travel speeds from one section of the Northwest Freeway for the first nine months of 2002. On the main lanes, the speeds were most frequently between 15 mph and 30 mph but occasionally reached 60 mph. Traveling at these speeds—15 mph, 30 mph, and 60 mph—leads to greatly different travel times (40 minutes, 20 minutes, and 10 minutes, respectively) on a 10-mile section of highway.

Table 1. 2001 Travel-Time Savings

	<i>Time</i>	<i>Vehicles per Day</i>	<i>S_{main} (mph)</i>	<i>S_{HOV} (mph)</i>	<i>Time Savings (min/veh)</i>
Katy AM	6:45–7:00	11.11	29.76	53.98	11.58
	7:00–7:15	19.48	27.25	59.81	15.35
	7:15–7:30	23.61	24.48	60.21	18.62
	7:30–7:45	23.49	23.37	60.11	20.08
	7:45–8:00	10.18	24.79	59.48	18.06
Weighted Average (AM)			25.50	59.22	17.33
Katy PM	5:00–5:15	7.03	28.35	57.19	13.66
	5:15–5:30	14.15	26.13	58.34	16.23
	5:30–5:45	12.18	26.97	57.63	15.15
	5:45–6:00	6.71	28.61	58.70	13.76
Weighted Average (PM)			27.19	57.98	15.04
Northwest AM	6:45–7:00	2.83	34.36	53.01	6.27
	7:00–7:15	8.01	31.89	57.91	8.62
	7:15–7:30	14.02	28.72	58.85	10.91
	7:30–7:45	16.15	27.44	59.52	12.02
	7:45–8:00	7.25	30.09	59.82	10.11
Weighted Average (AM)			29.35	58.72	10.51

Average distance traveled on the Katy HOV lane was 12.8 miles, and on the Northwest HOV lane was 10.6 miles.

Figure 4. Example of the Speed Distribution on the HOV Lane and Main Lanes



Although it is difficult to estimate to exact value, there is clear evidence that travel-time reliability is valued at least as much as the travel-time savings itself (Small et al. 1999; Bates et al. 2001; Hensher 2001). To conservatively estimate this value of time and reliability, the average value of travel-time savings was assumed to be 35 percent of the QuickRide participant's wage rate (as reported in the survey discussed below). Research in this area has generally shown drivers to value their time in congested travel conditions at a higher rate than 35 percent of their hourly wage, so this should provide a conservative value of travel-time savings. Additionally, approximately 21 percent of carpools included a child, and that child's value of travel-time savings was assumed to be \$0. This resulted in an average value of travel-time savings of \$31.13 per hour per vehicle (or \$15.56 per hour per person). Using this conservative value of time, actual and predicted QuickRide trips over 10 years, and current travel-time savings minus carpool formation times, the net present value of the benefits of QuickRide travel-time savings were estimated to be approximately \$2.35 million.¹

QuickRide participants also experience reduced vehicle operating costs and reduced fuel usage. Based on fleet average fuel usage, and typical fuel prices,² the total fuel savings was estimated to be approximately \$13,500 over 10 years. This is an underestimation of actual fuel savings since these savings are based on MOBILE 5a modeling of the average speed readings recorded by the AVI equipment which is spaced at 3- to 5-mile intervals. These speed measurements fail to capture the fuel-intensive deceleration and acceleration patterns of vehicles that occurs on the main lanes during these peak periods. Even so, the value of fuel savings and emissions reduction was inconsequential when compared to the value of travel-time savings.

This brief analysis of benefits may considerably underestimate the true value of the QuickRide option. The 35 percent of wage rate personal value of time is an average, whereas the QuickRide users are mainly occasional users—presumably when their value of time is much higher than average. In addition, any benefit that may be experienced by main-lane users due to the small number of QuickRide participants leaving the main lanes is ignored.

Conversely, there are no costs experienced by either the existing HOV-lane users or the main-lane users. Since traffic on the HOV lane maintains free flow, users of the lane are not negatively impacted by the addition of the QuickRide vehicles. Therefore, despite the net societal benefit of the program being relatively small, it is beneficial since net societal costs to travelers are nonexistent.³

QuickRide Usage

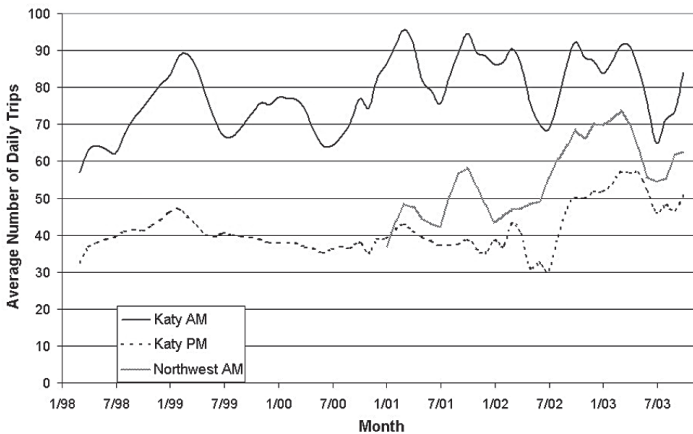
This section provides an in-depth examination of those travelers taking advantage of QuickRide due to the benefits discussed above. The data used in these analyses were from:

- billing records of all recorded QuickRide trips from the inception of the program in 1998, and
- a survey conducted in April 2003 of all current and former QuickRide enrollees.

QuickRide has experienced a slow and steady increase in usage since it began in 1998. Usage patterns include a significant decrease on Fridays⁴ and decreases that generally correspond to grade school holidays, including the summer break (see Figure 5). These latter decreases are primarily caused by the absence of carpools

where one member is a grade school child and to a lesser extent by decreased traffic levels in the main lanes, resulting in less congestion and less incentive to pay for QuickRide. For 2003, there were an average of 86.4 QuickRide users during the morning period on Katy Freeway, 54.9 during the afternoon period on Katy Freeway, and 66.8 during the morning period on the Northwest Freeway. This total of 208.1 QuickRide trips per day is relatively small, but with limited capacity on the single HOV lanes total usage must remain limited.

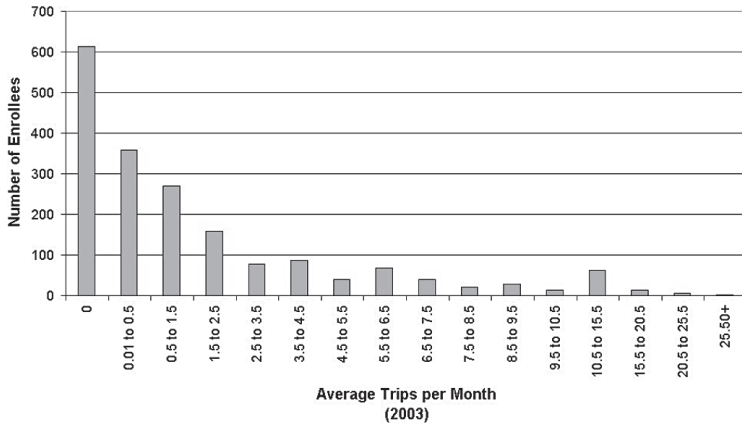
**Figure 5. QuickRide Billed Trips per Month
(Five-Month Moving Averages)**



QuickRide billing records for 2003 show that QuickRide enrollees take a QuickRide trip on an infrequent basis (see Figure 6).¹ In fact, the majority of enrollees made an average of fewer than 1.5 QuickRide trips per week. These results are similar to what has been recorded on the California HOT lanes (Shivashanker et al. 2004, Sullivan 2000).

These usage patterns appear to indicate that most drivers feel the travel-time savings is worth the \$2 toll (plus the need for a second occupant) only occasionally. They appear to use QuickRide only when they need the additional travel-time savings and it is convenient to carpool with one other person. The requirement for drivers to carpool is a larger deterrent to QuickRide usage than is the \$2 toll (Burriss and Appiah 2004). The following section takes an in-depth look at who is using the QuickRide program and their perception of travel-time savings.

Figure 6. Number of Monthly QuickRide Trips by Transponder Identification Number



Characteristics of QuickRide Participants

The results from two surveys were examined to determine the characteristics of QuickRide participants. The first survey was conducted in April 1998, shortly after QuickRide began. A total of 185 QuickRide enrollees, out of a total of 387 enrollees, completed and returned their survey for a response rate of 48 percent. The second survey was mailed in March 2003 to all 1,459 QuickRide enrollees. A total of 93 surveys were returned due to bad addresses. Of the remaining 1,366 surveys, 525 were completed and returned for a response rate of 38 percent.

The 1998 survey results provided insight into QuickRide participants' previous/alternate mode of travel (Stockton et al., 2000) (see Table 2). Similar results were obtained in the 2003 survey (see Table 3). As shown in Table 3, when not using QuickRide, the majority of trips are made by single-occupant vehicles (SOVs) followed by HOV2s in off-peak hours. These travelers use approximately 45 percent more vehicles when not using QuickRide. Therefore, the QuickRide program increases average vehicle occupancy on the corridor.

Table 2. Previous Mode and Time of Travel of QuickRide Enrollees

<i>Mode of QuickRide Enrollees Before QuickRide</i>	<i>AM</i>			<i>PM</i>		
	<i>Shoulders^a</i>	<i>Peak^b</i>	<i>Total</i>	<i>Shoulders^a</i>	<i>Peak^b</i>	<i>Total</i>
Drive Alone	12.7%	38.0%	50.7%	24.5%	33.2%	57.7%
Two-Person HOV, HOV Lane	7.0%	---	7.0%	6.8%	---	6.8%
Two-Person HOV, Freeway	10.7%	12.0%	22.7%	3.6%	25.7%	29.3%
3+ HOV	2.3%	2.4%	4.7%	-2.4% ^c	-3.7% ^c	-6.1% ^c
Vanpool	0.0%	2.0%	2.0%	0.0%	2.3%	2.3%
Bus	0.6%	10.0%	10.6%	1.6%	3.7%	5.3%
Other	0.0%	2.4%	2.4%	0.0%	4.7%	4.7%
Total	33.2%	66.8%	100.0%	34.1%	65.9%	100.0%

Notes: a=periods before and after the peaks.

b=peak periods defined as 6:45 a.m. to 8:00 a.m. and 5 p.m. to 6 p.m.

c=a negative value indicates increased 3+ carpool usage by QuickRide enrollees

Source: Stockton et al. 2000.

Table 3. Distribution of Vehicle Occupancy for Non-QuickRide Trips

<i>Occupancy During Non-QuickRide Trips (persons)</i>	<i>Percentage of Current QuickRide Participants</i>	<i>Corresponding Number of Vehicles</i>
1	53.6	53.6
2	30.4	15.7
3	6.6	2.2
4	2.0	0.5
5 or More	3.9	0.8
Bus	3.5	0
Total	100	72.8

The survey also examined commute characteristics of travelers while they were using QuickRide. Some of these results are discussed below. (For a more complete analysis of these survey results, see Burris and Appiah (2004)).

Travelers perceived QuickRide saved them approximately twice as much time as was typically saved on the HOV lane. For example, QuickRide participants who most often take advantage of QuickRide on the Katy Freeway in the morning estimated they saved an average of 34.7 minutes (± 1.13 minutes at a 95% confidence interval) where average savings (for the entire year of 2002) was approximately 17.3 minutes. This is probably a combination of QuickRide users (1) overestimating their time savings due to drivers' dislike of congested travel conditions (Small et al. 1999); (2) using QuickRide when they were particularly pressed for time, again causing them to overestimate their time savings; and (3) using QuickRide on days when main-lane congestion was worse than average. However, the third possibility is unlikely since the number of QuickRide trips was relatively constant on a day-to-day basis, regardless of main-lane congestion. For example, the average number of QuickRide trips during the Katy Freeway morning period for September 2003 was 93.9 ± 5.6 (at a 95% confidence interval) with a standard deviation of 12.7 trips per day.

QuickRide participants most frequently carpooled with a coworker (35%), followed by an adult family member (31%), a child (21%), a casual carpool (6%), a neighbor (3%), or other (4%). The 21 percent of carpools formed with a child was not surprising as significant drops in the number of QuickRide trips were observed to correspond with school holidays (see Figure 5). QuickRide participants estimated they required an average of 4.3 minutes to pick up their carpool partner. The majority of participants (73%) did not have the passenger help pay the \$2 toll. Finally, the majority of QuickRide trips (67%) were for commuting, followed by school (11%), recreation (10%), and other (8%).

A brief examination of the survey respondents' socioeconomic characteristics reveals a group who are primarily (61%) married with child(ren) or (30%) married without children. Most (65%) are in professional or managerial positions, 64 percent are between the ages of 35 to 54, 74 percent have a college degree, and 79 percent have a household income greater than \$75,000 per year. The number of males and females responding to the survey was similar.

Based on these survey findings it was clear that QuickRide users generally have high household incomes and placed a premium on their time. Additional research is currently underway to determine the differences between this group of commuters and other commuters along the Katy and Northwest Freeway corridors.

The Future of QuickRide

The QuickRide program may see significant changes in the near future, with alternate pricing and occupancy restrictions under investigation. The following actions are currently being considered:

1. expanding the HOV3+ restriction (and the QuickRide program) to the afternoon peak period on the Northwest Freeway,
2. expanding the HOV3+ restriction (and the QuickRide program) to the shoulders of each peak period in conjunction with time-of-day variable pricing where the shoulder toll is less than the peak-period toll, and
3. allowing SOVs to pay to use the lane during off-peak periods.

The first two options listed above include expansion of the current HOV3+ occupancy restrictions. This is under consideration due to building congestion on the two freeways during the shoulders of the peak and on the Northwest Freeway in the afternoon peak period. Figures 7 and 8 show average daily travel speeds on the HOV lanes for the year 2002. From these figures it is clear that demand during these periods is beginning to cause deterioration in the level of service on the HOV lane—which must be prevented to maintain the attractiveness of the lane and use of HOV and transit. The periods with the slowest speeds are just before and just after the QuickRide (and HOV3+ restriction) period. Based on analysis of the composition of vehicles during the day, it is clear that the demand and congestion is primarily caused by HOV2s who travel just before or just after the peak period.

To alleviate this congestion but still allow some HOV2s to use the lane, QuickRide may also be expanded to these shoulder periods. Research is underway to determine the proper QuickRide toll during the shoulder periods to smooth the demand for the HOV lane during the peak and shoulder times.

Figure 7. Vehicle Flow on the Katy HOV Lane

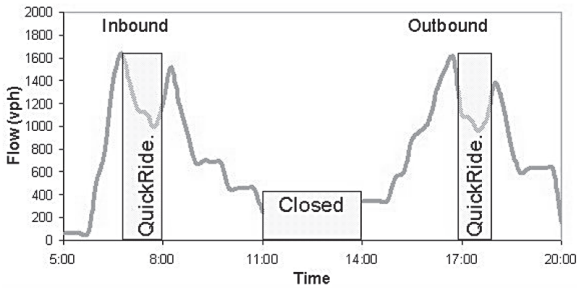


Figure 8. Vehicle Flow on the Northwest HOV Lane

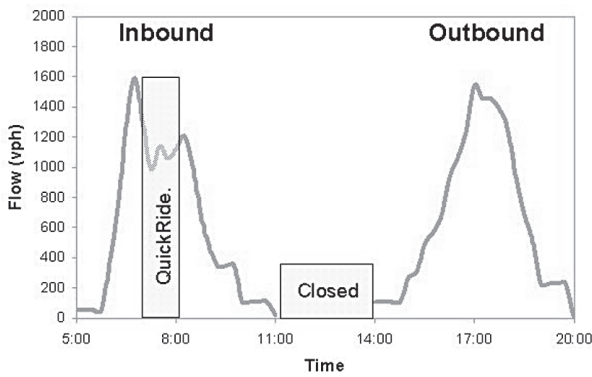
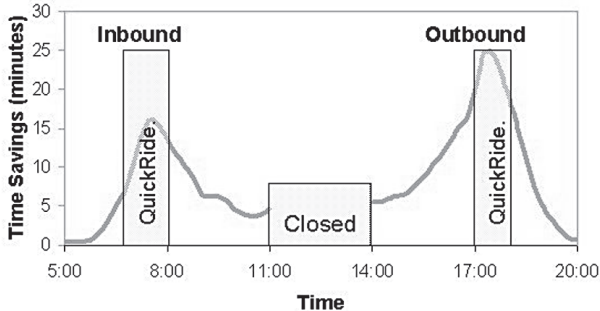


Figure 9. Average Travel-Time Savings Using the Katy HOV Lane Instead of the Main Lanes



Another option under investigation is allowing SOVs to use the lane during off-peak periods. Congestion on the main lanes is such that significant travel-time savings can be obtained well after the morning shoulder periods and before the afternoon shoulders (see Figure 9). Additionally, there is excess capacity in the HOV lanes during those periods.

Therefore, SOV vehicles may be willing to pay a toll to use the lanes during this period. Research is currently underway to determine the costs and revenue from this option. Particularly important is to determine the pricing mechanism and price levels for SOVs to ensure the HOV lanes remain free flowing during all periods of the day.

In the longer term, managed lanes are under construction and are slated to open on the Katy Freeway by 2010. In this scenario the middle four lanes (two per direction) will be toll lanes. These lanes represent new capacity on the Katy Freeway. The exact pricing scenarios are not set, but buses will not be charged a toll and carpools may be offered a reduced toll level.

Conclusions

The Houston QuickRide program currently offers HOV2s the option of traveling on the Katy and Northwest HOV lanes for \$2 when the lanes are normally restricted to HOV3+. This provides HOV2s another travel option, allowing its drivers to further optimize their travel behavior, and results in net societal benefits.

The QuickRide program receives relatively modest usage (an average of 208 trips per day in 2003) partially due to the limited amount of room available on either of the single HOV lanes. This relatively limited usage is comprised of a large number of users taking advantage of QuickRide on an infrequent basis (less than 2.5 trips per month). Despite the limited usage, the program provides a net societal benefit, primarily due to travel-time savings obtained by QuickRide participants.

The future of QuickRide holds several potential changes. Due to congestion on either side of the HOV3+ period (when HOV2+ is allowed), the HOV3+ period may be expanded. The expanded periods may have a lower toll, resulting in a variable HOT toll price based on time of day. Further into the future, SOVs may be charged for the privilege of using the HOV lane in the off-peak periods, using a dynamic pricing mechanism that will be priced based on the congestion level in the lane. Based on the findings from the first six years of operation, researchers are

examining the optimal configuration, pricing levels, enforcement methods, signage, and public awareness needed to successfully implement these changes and increase the net societal benefits of the program.

Endnotes

¹ The time period changed to 6:45 a.m. to 8:00 a.m. in 1990 and has not changed since.

² Casual carpoolers are well aware of the different occupancy restriction on the HOV lanes based on the time of day. In almost all cases, during peak periods two “slugs” (casual carpoolers who get a ride in another person’s vehicle) get into each vehicle, while during off-peak periods only one “slug” gets in each vehicle.

³ Using the federal government Office of Management and Budget’s real 10-year discount rate of 3.1 percent.

⁴ The typical fuel price is the price at the pump minus any taxes since taxes are a transfer of wealth and do not constitute a net societal benefit.

⁵ There were start-up costs and ongoing maintenance and operational costs paid by METRO. The toll revenues are used to pay the ongoing operational and maintenance costs.

⁶ Using time series analysis and an ANOVA analysis, it was found that Friday QuickRide volumes were significantly lower than the rest of the week at the 5 percent significance level.

⁷ Actual usage could be greater than that captured by the billing readers due to malfunctions of the equipment or willful violators. Research is underway to address this problem and minimize the number of violators on the lane. However, based on violation data, it is clear that not all enrollees are being charged when they take a QuickRide trip. Therefore, these violators are also benefiting from the program—but are not included in the benefit analysis.

References

- Arnott, R., A. De Palma, and R. Lindsey. 1996. Recent developments in the bottleneck model. Boston College, working paper.
- Arnott, R., A. De Palma, and R. Lindsey. 1998. Schedule delay and departure time decisions with heterogeneous commuters. *Transportation Research Record* 1197: 56–67.
- Bates, John, John Polak, Peter Jones, and Andrew Cook. 2001. The valuation of reliability for personal travel. *Transportation Research Part E* 37: 191–229.
- Bullard, D. L. 1991. *An assessment of carpool utilization of the Katy high-occupancy lane and characteristics of Houston's HOV lane users and nonusers*. Report 484-14F. College Station, TX: Texas Transportation Institute.
- Burris, M.W., and J. Appiah. 2004. An examination of Houston's QuickRide participants by frequency of QuickRide usage. Accepted for publication in *Transportation Research Record*.
- Chen, O., and D. Bernstein, D. 1995. AM/PM congestion pricing with a single toll plaza. *Transportation Research Record* 1498: 23–31.
- Chu, X. 1995. Endogenous trip scheduling: The Henderson approach reformulated and compared with the Vickrey approach. *Journal of Urban Economics* 37: 324–343.
- Hensher, David A. 2001. Measurement of the valuation of travel time savings. *Journal of Transport Economics and Policy* 35, part 1: 71–97.
- Shivashanker, P., D. Steffey, and J. Supernak. 2004. *I-15 FasTrak use patterns: The project versus post project period*. Presented at the Transportation Research Board 83rd Annual Meeting.
- Small, Ken. 1992. *Trip scheduling in urban transportation analysis*. The American Economic Review. Papers and Proceedings of the 104th Annual Meeting of the American Economic Association, New Orleans, LA. 482–486.
- Small, K.A., Robert Noland, Xuehao Chu, and David Lewis. 1999. *Valuation of travel-time savings and predictability in congested conditions for highway user-cost estimation*. National Cooperative Highway Research Program Report 431. National Academy Press, Washington, D.C.

- Stockton, B., N. Edmonson, P. Hughes, M. Hickman, D. Puckett, Q. Brown, A. Miranda, and W. Shin. 2000. *An evaluation of the Katy Freeway HOV Lane Pricing Project*. Report E 305001. College Station, TX: Texas Transportation Institute.
- Sullivan, E. 2000. Continuation study to evaluate the impacts of the SR 91 value-priced express lanes: Final report. Retrieved July 9, 2003, from the Department of Civil and Environmental Engineering, California Polytechnic State University at San Luis Obispo Web site: <http://ceenve.calpoly.edu/sullivan/sr91/sr91.htm>.
- Supernak, J., C. Kaschade, D. Steffey, and G. Kubiak. 2001. I-15 Congestion Pricing Project, monitoring and evaluation services, Phase II Year Three traffic study. Retrieved June 10, 2003, from San Diego's Regional Planning Agency Web site: http://www.sandag.org/fastrak/pdfs/yr3_traffic.pdf.
- Texas Department of Transportation. 2004. Houston real-time traffic map. Retrieved February 9, 2004, from the Houston Transtar Web site: <http://traffic.houstontranstar.org/incmap/>.
- Turnbull, K.F. 2003. *Houston managed lanes case study: The evolution of the Houston HOV system*. U.S. Department of Transportation, Federal Highway Administration, Washington, DC.
- Value Pricing Homepage. 2004. Retrieved February 6, 2004, from the Web site: <http://www.hhh.umn.edu/centers/slp/projects/conpric/index.htm>.
- Verhoef, E. 2000. Time-varying tolls in a dynamic model of road traffic congestion with elastic demand. Department of Spatial Economics, Free University Amsterdam, working paper.

About the Authors

MARK W. BURRIS (mburris@tamu.edu) is an assistant professor of civil engineering and assistant research scientist at the Texas Transportation Institute. Dr Burris's main area of interest is congestion (or value) pricing. He has primarily served in an evaluation and monitoring role for the Houston Value Pricing Project, Lee County Variable Pricing Pilot Project, Queue Jump Value Pricing Project, Fort Myers Beach Cordon Toll Study, and Traveler Credit Based Pricing. Dr. Burris is a member of the American Society of Civil Engineers, the Institute of Transportation Engineers, and

the Transportation Research Board's Economics Committee and Congestion Pricing Subcommittee.

BILL R. STOCKTON (*b-stockton@ttimail.tamu.edu*) is an associate director and research engineer at the Texas Transportation Institute. In addition, he leads the Economics and Policy Program at TTI and is a senior lecturer in civil engineering at Texas A&M University. He has more than 30 years of experience in transportation issues including experience with various high occupancy vehicle (HOV) and high occupancy toll (HOT) lane projects dating back to the early 1980s. Mr. Stockton has worked the last eight years on pricing-related projects in Texas, Colorado, and Georgia.

Tackling Crime and Fear of Crime While Waiting at Britain's Railway Stations

*Paul Cozens, Crime Prevention Through Environmental Design Consultant
Richard Neale and David Hillier, University of Glamorgan
Jeremy Whitaker, Wessex Trains*

Abstract

Crime on the railways in Britain is an increasing concern for train operating companies, the British Transport Police (BTP), passengers, and local residents. Significantly, rail users consistently perceive their risks from crime to be considerably higher than official crime statistics indicate, having a negative affect on levels of patronage. This article presents an exploratory study of passengers' fear of crime while waiting at railway stations using Quick Time Virtual Reality (QTVR) walkthrough scenes. QTVR arguably represents an innovative, dynamic, and interactive environmental stimulus for gaining insights into passengers' fear of crime. Visibility at stations was identified as a crucial factor in determining levels of fear of crime. The design of the station shelter is analyzed as an example of how crime prevention through environmental design (CPTED) is being implemented on railway stations by Valley Lines (Wales and Borders Trains) on its network in South Wales (UK).

Introduction

The recent environmental and social concerns associated with an increasingly car-reliant society have provided a new impetus for promoting public transport. Rail travel represents 5 percent of all passenger journeys in the UK (Hamilton and Jenkins 2000) and is currently subject to a large-scale regeneration program with health and safety issues representing a critical focus in the light of recent tragedies at Paddington and Hatfield. The industry is certainly striving to encourage potential passengers to “let the train take the strain.” However, crime on the railways has recently emerged as a high profile priority requiring scrutiny and attention. Indeed, media reports of the murder of Liz Sherlock at Euston station have certainly raised public awareness and one headline in the *Independent* newspaper read “Robberies on the Rise in Britain’s Dark, Dangerous Train Stations” (Lashmar 2001). Railways represent a vital part of Britain’s public transport system and one of the UK government’s stated policy objectives is to provide safe travel for the public; “We want people to travel safely and to feel secure whether they are on foot or bicycle, in a car, on a train, or bus, at sea or on a plane” (DETR 2000, p75).

According to the British Transport Police recorded crime on the railways rose by 5.6 percent in 2001–2002 (Guardian 2002). Crucially, however, recorded crime statistics represent only a fraction of total crime (Mirrlees-Black et al. 1998). The “dark figure of crime” (Maguire et al. 1997) represents the missing data that may not be witnessed or discovered, or remains either unreported or unrecorded—for a variety of complex reasons. This issue also applies to the transport environment as the UK government acknowledges: “a large proportion of crime on public transport is not reported” (DETR 1998a). Reluctance to delay one’s journey, a lack of confidence that the offender will be apprehended, the absence of someone to actually report an incident to, and the belief that a reported incident will not be taken seriously are examples of nonreporting behavior.

This article discusses crime prevention through environmental design (CPTED) and the fear of crime as it relates to the railway station and its immediate access routes and presents an exploratory study of passenger’ fear of crime using Quick Time Virtual Reality (QTVR) as the environmental stimuli. The performance of one specific CPTED modification, the introduction of the transparent railway station shelter, is compared with its predecessor.

Crime Prevention Through Environmental Design (CPTED)

CPTED (pronounced sep-ted) asserts that “the proper design and effective use of the built environment can lead to a reduction in the fear of crime and the incidence of crime, and to an improvement in the quality of life” (Crowe 2000, p1). The urban environment can be designed or modified to reduce opportunities for crime and fear of crime by promoting:

- *Natural Surveillance.* The placement of physical features, activities, and people in such ways as to maximize visibility. This also involves the lighting of public spaces and walkways at night.
- *Natural Access Control.* The physical guidance of people entering and exiting a space by the judicious placement of signs, entrances, exits, fencing, landscaping, and lighting.
- *Territorial Reinforcement.* The use of physical attributes that express ownership, such as fences, pavement treatments, artwork, signage, landscaping, and placement of buildings.
- *Image/Maintenance.* Allows for the continued use of space for its intended purpose and serves as an additional expression of ownership. This also involves supporting a positive image through the selection of materials, design, and scale.

CPTED strategies continue to be implemented in a wide range of urban settings at an international level and there is increasing volume of research activity seeking to evaluate real-world applications of CPTED (e.g., Levine et al. 1986; Loukaitou-Sideris and Banerjee 1994; La Vigne 1996; Hunter and Jeffery 1997; Sloan-Hewitt and Kelling 1997). However, Eck (1997) has reviewed various studies of public transport (Kenney 1987; Poyner 1988; Carr and Spring 1993; La Vigne 1997) and claims that despite such studies, little is currently known about the effectiveness of design interventions. The variety of crimes, number of different settings in the transport system, and the diversity of victim types effectively means that “we cannot therefore, identify with reasonable certainty, any specific tactic against specific crimes, that can be said to ‘work’ across similar settings in other cities” (Eck 1997, p16). Indeed, Schneider and Kitchen (2002, p293) argue that “approaches need to be tailored to specific local circumstances.” Clearly, although many CPTED measures may have been successful (or not) in any one context, a site-specific approach to analysing crime and the fear of crime at Britain’s railway stations and their immediate access routes appears to be vital.

Fear of crime in the built environment can result in the withdrawal of the community and a reduction of crucial “eyes on the street” that can actively contribute to policing a neighbourhood (Jacobs 1961; Newman 1973). Similarly, perceptions of crime on the railways will undoubtedly affect levels of patronage. Recorded crime on the railways is low while the perception of crime has consistently been found to be significantly higher (Brantingham et al. 1991; Crime Concern and Transport and Travel Research 1997). Crucially, Clarke (1996, p3) observes “...the fear of crime that stops many people using public transport has a serious impact on revenues.” Crime Concern and Transport and Travel Research (1997) suggested that there might be as much as a 15 percent increase in passengers for all rail journeys if a range of anticrime initiatives were successfully implemented.

Understanding the perceptual dimension to CPTED is clearly crucial, and has been explored with regard to residential housing (Tijerino 1998; Ham-Rowbottom et al 1999; Cozens et al. 2001). Regarding public transport, perceptions are no less important, as noted by the Legislative Assembly of Queensland (Australia): “...the public’s perception of crime is an important determinant of people’s usage of public transport” (Parliamentary Travel Safe Committee 1998, p16).

UK Government Policy for Tackling Crime on the Railways

The UK government is committed to providing an effective, safe, and thriving public transport network (DETR 2000; DETR 2001) and clearly recognizes the contribution of design in facilitating or discouraging criminality (DOE 1994; Crime and Disorder Act 1998). Indeed, it has been asserted that “there is now an established link both between design and crime and the reduction of fear” (DETR 1998b).

One initiative specific to the railways is the Secure Station Scheme. This scheme is operated jointly by Crime Concern and the British Transport police (BTP) and is arguably central to the government’s strategy for reducing crime and the fear of crime in and around railway stations. It focuses on implementing CPTED strategies at individual stations to reduce crime and the fear of crime. Currently, more than 150 railway stations in the UK have been accredited by the BTP and offers “... an opportunity for Britain’s rail companies to improve security at their stations and display to customers their desire to reduce crime” (DETR 1998a, p1). The number of accredited railway stations continues to rise and the British government intends this number to increase (DETR 2000), although currently this only represents 3 percent of Britain’s 2,500 or so railway stations (Lashmar 2001).

Significantly, the accreditation can only be awarded to railway stations that exhibit a threshold level of reported crime as a proportion of passenger throughput—ignoring those railway stations with either high crime rates or low throughput levels—or both. Furthermore, to date no study has evaluated the effectiveness of this scheme. Therefore, for railway stations outside the scope of the Secure Stations Scheme (the majority of stations on the Valley Lines network), train operating companies (TOCs) must develop an alternative framework for tackling crime and the fear of crime.

Indeed, Clarke (1996) has called for more studies to be funded by transit authorities and therefore, more communication between railway managers and CPTED theorists and practitioners. Furthermore, the Head of Rail Research UK, Keith Madelin (2003, p31), recently remarked that the rail industry “has ignored the potential benefits of academic research into new technologies and systems that could help to solve some of its problems.”

The Valley Lines Study in South Wales (UK)

The Valley Lines rail network (part of the Wales and Borders franchise) is located in South Wales and serves the communities of the Rhondda, Cynon, and Taff Valleys, in addition to stations in Cardiff, Barry, and Penarth (see Figure 1). BTP statistics reveal that 459 crimes took place on the Valley Lines' railway stations which operated 7.3 million passenger journeys annually (2000–2001). This does not include crimes that may have occurred on the train itself and equates to 6.26 crimes per 100,000 passenger journeys. Although not strictly comparable, the recorded crime rate per 100,000 population for the South Wales police force area in 1999 was 10,251 (Home Office 2000).

In a recent Valley Lines' Customer Satisfaction Survey (Pengwyn Services 2001) 1,000 rail users were interviewed while traveling on the network. To monitor passengers' fear of crime, specific questions were included to probe the issue of fear of crime while waiting at the station. Table 1 presents some of the preliminary findings. Clearly, a significant percentage of passengers experienced fear of crime at their local station.

Table 1. Passengers' Fear of Crime During Daytime (All Stations)

<i>Station Activity</i>	<i>% of Respondents Experiencing Fear of Crime</i>
Approaching the station	4
Waiting inside the platform shelter	7
Waiting on the platform	7
Using the station car park	10

Source: Pengwyn Services, February 2001. Customer Satisfaction Survey for Cardiff Rail Company Ltd.

Such feelings also varied considerably from station to station (Cozens 2002). Many stations on the network did not generate substantial levels of fear of crime, although as many as 39 percent of respondents at certain stations stated that they experienced fear of crime while waiting inside the brick platform shelter. Furthermore, various design measures were suggested by respondents as potential improvements that would reduce their sense of fear of crime (see Table 2).

Table 2. Perceived Effectiveness of Improvements

<i>Improvement</i>	<i>% of Respondents Stating Fear of Crime Would be Reduced</i>
Enhanced visibility (cctv, lighting, transparent shelters)	87
More rail staff visibly in attendance	87
Reliable information system	81
More passengers on the station	77
A cleaner environment	63

Source: Pengwyn Services, February 2001. Customer Satisfaction Survey for Cardiff Rail Company Ltd.

Clearly, fear of crime was experienced across the network and improved visibility was identified as a dimension that, if amended appropriately, respondents indicated would reduce their fear of crime while waiting at the railway station.

The study systematically collected data from respondents relating to the design and management of specific railway stations and their immediate access routes. The analysis of this data would facilitate the evaluation of the effectiveness of CPTED modifications in reducing crime and the fear of crime while waiting at railway stations. The use of QTVR technology to probe passengers' perceptions of personal safety in and around the railway station environment is presented as an innovative and constructive way forward. This article presents some of the initial findings and discusses the specific CPTED modification of the shelters provided at stations across the Valley Lines network.

The QTVR Study Methodology

To investigate fear of crime across the network, a representative sample of six railway stations was selected. These were chosen to reflect the diversity of stations on the network in terms of affluence/deprivation, geographical location (urban/rural), physical and security features, and usage levels.

Representations of the stations using QTVR provided a standardized, dynamic and interactive stimulus for the often complex station layouts and access routes, which could repeatedly be reemployed in various locations.

QTVR involves the photography of several 360 degree panoramas at various points in the environment. These panoramas are subsequently stitched together to create a QTVR walk-through scene, whereby respondents can virtually travel through the standardized environment of the station and its approaches, view in and out, and pan left or right at any stage of their journey. Each focus group was shown the same standardized walkthrough panoramas of stations in the controlled setting of an interview room. This approach not only reduces the problems associated with physically walking groups of people around several stations at different times and under variable conditions (e.g., weather, lighting conditions, noise, usage patterns), it also allowed for a more focused analysis of the physical detail of each station by the respondents. The QTVR approach has been critically reviewed at conference (Cozens et al. 2002) and widely received as a highly innovative approach at peer review sessions and at subsequent presentations to groups of academics, planners, and the police. Queensland Police in Australia and West Yorkshire Police in the UK are already using QTVR for investigations at crime scenes. It is presented here as an example of how QTVR can be operationally applied to underpin the systematic analysis of the railway station environment and its immediate access routes.

A total of 47 respondents (26 females and 21 males) were interviewed and asked to complete a structured questionnaire following the presentation of QTVR walk-through panorama scenes of the six selected railway stations and their immediate access routes. Their comments during group discussions were also noted and later analyzed.

The QTVR Study Findings

The initial findings from this study clearly indicate that there are specific times, geographical locations, and design features at stations that elicit fear of crime. A range of potential solutions was suggested by respondents to reduce fear of crime which included improved lighting (mentioned by 68% of respondents), CCTV (62%), more staff (43%), transparent shelters (43%), cleaner stations (38%), and cutting back vegetation (30%). Although such findings may appear similar to those that might be obtained with more traditional approaches, the QTVR approach has provided detailed site-specific insights into the design and management of the six representative railway stations on the Valley Lines network. The QTVR approach also provides potential scope in that the identical QTVR scenes can be shown to other specific stakeholder groups (e.g., tourists, young, elderly, disabled, nonrail user). A more detailed explanation of the wider findings have been discussed at length elsewhere (Cozens et al. 2002; Cozens et al. 2003) and this article specifically focuses on passengers waiting on the platform and the design characteristics of the station shelter, identified in this study as being particularly problematic for rail users. Various phased improvements are being implemented throughout the network and the replacement of the previous solid, low visibility brick shelters with high visibility transparent shelters is nearing completion of its first phase and provides an early opportunity for evaluation and critical review of this particular CPTED modification.

Visibility of and by others was mentioned by respondents in all the focus groups as being a crucial dimension to their fears of crime. The proximity of others (e.g., people in nearby houses and those engaged in activities overlooking the railway station) emerged as an important issue for those waiting on the platform.

People feel safer on a station that other people can see. (Female Respondent 12)

Visibility is the key—you've got to feel safe, otherwise you're not going to use it are you? (F3)

Similarly, when waiting on the platform, visibility of and by other rail users was regarded as inadequate. Significantly, 93 percent of females (compared to 53% for males) stated that they experienced fear of crime when waiting on the platform at night. Repeatedly, reference was made to the enclosed brick shelters, and respondents stated a marked preference for the high visibility transparent shelters that they had noticed being introduced at some local bus stops.

Do something about the concrete shelter. (Male Respondent 8)

It's enclosed on three sides...it would be better if they had the new clearer ones... like the bus shelters. (M19)

It smells like a toilet— and even looks like one! (F20)

Figure 2. A Typical Brick Shelter Found on a Valley Lines Railway Station



Clearly, visibility to others and opportunities for surveillance of the station platform are currently severely limited. The enclosed nature of the brick shelter encourages congregating youths who are not subject to any formal or informal surveillance by rail staff, rail users, or community members while concealed inside the shelter.

I don't like that brick shelter— it's just a gang hang-out, it needs to be see-through. (F25)

It should never be totally enclosed like that. (F4)

Stations attract young people as places to go. In the brick shelters there's underage drinking and drugs and stuff— it's an ideal hangout. (F27)

Respondents were also mindful of the lack of visibility and coverage by CCTV when waiting inside the brick shelters.

The cameras can't see inside the brick shelter. (M14)

As soon as you get into the brick shelter you're hidden. (M16)

Impaired visibility was clearly associated with fear of crime.

From inside that shelter I can't see homes, roads, or other passengers— you need to see and be seen—just for peace of mind, that's all you need. (M21)

Valley Lines has initially installed transparent shelters at seven stations to evaluate the effectiveness of this design modification in reducing fear of crime and increasing passenger flows. Figure 3 presents the transparent shelter design, which considerably enhances the opportunities for surveillance of the station by passengers waiting for trains and the visibility of the waiting passengers to others in the vicinity.

Figure 3. Transparent Shelter



That transparent shelter is tidy— you can see all around. (F6)

I feel much safer in transparent shelters where you know people can see you.(M1)

You can see people coming from everywhere. (M12)

Respondents also recognized that the transparent shelter would discourage youths from gathering and indulging in antisocial behavior, alcohol consumption, and vandalism.

The kids don't want to hang out in the glass shelters— they can be seen. (F17)

Most respondents clearly welcomed the enhanced opportunities for surveillance that the transparent shelters provide.

That's one of those new shelters you see...which are open and security-wise they are better because if you can be seen, you don't feel so unsafe. (F10)

In a customer satisfaction survey of more than 2,000 respondents (Wales and Borders Trains 2002), 18 percent commented that they had noticed physical improvements at the stations (which had thus far been installed at only a minority of stations). However, at railway stations where the transparent shelters had been installed, 93 percent of respondents stated that they had noticed the recent improvements to the physical fabric. Furthermore, of those, 71 percent stated that transparent shelters reduced their fear of crime due to improved visibility; being able to see around-and-about at all times and also the enhanced potential to be seen by others.

Conclusions

This study indicates that QTVR is clearly useful customer-focused approach for investigating crime and passengers' fear of crime at railway stations. Brick shelters were repeatedly identified as being problematic by rail users and transparent shelters clearly represent a significant improvement for rail users. Undoubtedly, the installation of transparent shelters has been well received by rail passengers as a surveillance-enhancing design feature that can tackle crime and the fear of crime. Indeed, the findings suggest that if transparent shelters work to enhance surveillance and visibility and to reduce fear of crime, careful consideration should be given to other design features that might impair or reduce visibility. Indeed, in the after-dark railway station environment visibility is certainly reduced and a study of lighting at Valley Lines stations is now underway. A more extensive, longer-term study of the perceived impact of design and management changes is essential to verify these positive preliminary findings, but the approach adopted and the results thus far seem most encouraging.

Significantly, the Valley Lines network has witnessed an increase in annual passenger flows of some 33 percent during the period 2000–2003. It would not be inappropriate to suggest that a significant proportion of this increase in patronage is attributable to Valley Lines' ongoing passenger-led station improvement program.

Indeed, the new high visibility shelters not only reduced fear of crime but appear to have also produced higher levels of consumer confidence, and in the short term, higher levels of patronage.

In relation to the transparent shelters, it will certainly be interesting to gauge how long these continue to provide "shelter from the storm" and whether the perennial problem of vandalism on the railways reinvents itself in new guises. The train oper-

ating company Wales and Borders Trains (2003) recently announced that during the next 12 months, rail passengers in Wales will benefit from a £2.5m Welsh Assembly Government grant for improvements to railway stations. This funding will allow Wales and Borders Trains to modernize railway station facilities and enhance passengers' safety and in doing so, continue to increase levels of patronage. Welsh Assembly Environment Minister, Ms. S. Essex (Wales and Borders Trains 2003) stated, "This funding will improve essential facilities such as toilets, waiting rooms and shelters, and better passenger safety will be tackled through CCTV and lighting." Indeed, prioritizing expenditure on physical improvements will be a crucial task for the train operating companies and they are now beginning to acquire a more detailed understanding of passengers' fear of crime at railway stations in which the use of technologies, such as QTVR, is making a substantial contribution.

References

- Brantingham, P. J, P. L. Brantingham, and P. S. Wong. 1991. How public transit feeds private crime: Notes on the Vancouver "Skytrain" experience. *Security Journal* 2, 2: 91–95.
- Carr, K. and G. Spring. 1993. Public transport safety: A community right and a communal responsibility. *Crime Prevention Studies* 1, 147–155.
- Clarke R. V. G. 1996. Editorial introduction: Crime and the economics of mass transit. In Clarke, ed., *Preventing Mass Transit Crime*. Crime Prevention Studies Volume 6, 1–4. Willow Tree Press, New York.
- Cozens, P. M. 2002. Exploring crime and the fear of crime within the railway environment. *Public Transport International* 51: 20–24.
- Cozens, P. M., D. Hillier, and G. Prescott. 2001. Crime and the design of residential property. Exploring the theoretical background. *Property Management* 19, 2: 136–164.
- Cozens. P. M., J. Waters, and R. H. Neale. 2002. A virtual reality approach to personal safety and the design of built environment facilities. *Proceedings of the ARCOM (Association of Researchers in Construction Management) 18th Annual Conference*. Volume 2: 461–473.
- Cozens, P. M., R. H. Neale, J. Whitaker, and D. Hillier. 2003. Investigating personal safety at railway stations using 'virtual reality' technology. *Facilities* 21, 7/8: 188–194.
- Crime and Disorder Act. 1998. *Crime and Disorder Act 1998*. Crown Copyright, London.
- Crime Concern and Transport and Travel Research. 1997. *Perceptions of safety from crime on public transport*. Crime Concern and Transport and Travel Research for DETR.
- Crowe, T. D. 2000. *Crime prevention through environmental design: Applications of architectural design and space management concepts*, 2nd ed. Butterworth-Heinemann.Oxford.
- DETR. 1998a. *Personal security on public transport. Guidelines for operators*. DETR Mobility Unit. Crown Copyright, London.

- DETR. 1998b. *Secure Stations Scheme. Guidelines for Operators*. Crown Copyright, London.
- DETR. 2000. *Transport 2010*. The Stationery Office, London.
- DETR. 2001. *PPG13 Transport*. Home Office, London.
- DOE. 1994. *Planning out crime circular 5/94*. Home Office, London.
- Eck, J. E. 1997. Preventing crime at places. Chapter 7 in Sherman, L.W, D. Gottfredson, D. MacKenzie, J. Eck, P. Reuter, and S. Bushway, *Preventing crime: What works, what doesn't, what's promising*. Report to the United States Congress, Prepared for the National Institute of Justice.
- Guardian. 2002. Police report rise in rail crime. Guardian Website <http://www.guardian.co.uk/Print/0%2C3858%2C4467190%2C00.html>. Visited 10/03/03.
- Hamilton, K., and L. Jenkins. 2000. A gender audit for public transport: A new policy for tackling social exclusion. *Urban Studies* 37, 19: 1793–1800.
- Ham-Rowbottom, K. A., R. Gifford, and K. T. Shaw. 1999. Defensible space theory and the police: Assessing the vulnerability of residences to burglary. *Journal of Environmental Psychology* 19: 117–129.
- Home Office. 2000. *Criminal statistics, England and Wales*. Government Statistical Service, London.
- Hunter, R. D and C. Ray Jeffery. 1997. Preventing convenience store robbery through environmental design. In Clarke, R.V., ed. *Situational Crime Prevention: Successful Case Studies*, 2 ed. Harrow and Heston, New York, 191–199.
- Jacobs, J. 1961. *The death and life of great American cities*. Vintage, New York.
- Kenney, D. J. 1987. *Crime, fear and the New York subways: The role of citizen action*. Praeger, New York.
- La Vigne, N. G. 1996. Safe transport: Security by design on the Washington Metro. In Clarke, ed. *Preventing Mass Transit Crime. Crime Prevention Studies Volume 6*: 163–198.
- La Vigne, N. G. 1997. Visibility and vigilance: Metro's situational approach to preventing subway crime. *National Institute of Justice—Research in Brief*. U.S. Department of Justice.

- Lashmar, P. 2001. *Robberies on the rise in Britain's dark, dangerous train stations. Independent*, 30 April, p7.
- Levine, N., M. Wachs, and E. Shiraz. 1986. Crime at bus stops: A study of environmental factors. *Journal of Architectural and Planning Research* 3: 339–362.
- Loukaitou-Sideris, A. and T. Banerjee. 1994. *Form follows transit? The Blue-line Corridor's development potential*. Los Angeles, CA: Department of Urban Planning, University of California, Los Angeles.
- Madelin, K. 2003. The research connection. *The Engineer*. March, 31–34.
- Maguire, M., R. Morgan, and R. Reiner, eds. *The Oxford Handbook of Criminology* (2nd ed.). Oxford: OUP.
- Mirrlees-Black, C., T. Budd, S. Partridge, and P. Mayhew. 1998. *The 1998 British crime survey*. HMSO, London.
- Newman, O. 1973. *Defensible space: People and design in the violent city*. Architectural Press, London.
- Parliamentary Travel Safe Committee. 1998. *Brisbane's Citytrain Network—Part—Passenger Security*. Report No.24. Legislative Assembly of Queensland.
- Pengwyn Services. 2001. *Customer Satisfaction Survey, 2001*. Cardiff Rail Company Ltd.
- Poyner, B. 1988. Video cameras and bus vandalism. *Journal of Security Administration* 11, 4–51.
- Schneider, R. H. and T. Kitchen. 2002. *Planning for crime prevention: A transatlantic perspective*. Routledge, London and New York.
- Sloan-Hewitt, M., and G. L. Kelling. 1997. Subway graffiti in New York City: Gettin' up vs. meanin' it and cleanin' it." In Clarke, R.V., ed. *Situational Crime Prevention: Successful Case Studies*, 2nd ed. Harrow and Heston, New York, pp. 242–282.
- Tijerino, R. 1998. Civil spaces: A critical perspective of defensible space. *Journal of Architectural Planning Research* 15, Part 4 (Winter): 321–337.
- Valley Lines. 2001. *Valley Lines network map*. Valley Lines, Cardiff.
- Wales and Borders Trains. 2002. *Customer satisfaction survey*. Unpublished, Wales and Borders Trains, Cardiff.

Wales and Borders Trains. 2003. All change for railway stations, states Ms. Sue Essex (Welsh Assembly, Environment Minister). Press Release, W030228-TP. 5 March.

About the Authors

PAUL COZENS (*pmcozens@yahoo.com*) is a consultant for crime prevention through environmental design (CPTED) and principal policy officer at the Office of Crime Prevention, Department of the Premier and Cabinet, Western Australia. He obtained a first class BA (Hons) degree in sustainable environments and a Ph.D. in crime and design, both from the University of Glamorgan, UK. He has experience as a CPTED researcher and consultant, conducting major projects for a national community regeneration partnership and a national railway network. Dr. Cozens' research on CPTED and designing out crime, lighting, CCTV and creating sustainable urban communities has appeared in more than 50 academic and trade journals. He is an ICA-certified CPTED practitioner.

RICHARD NEALE is professor of construction management and head of the School of Technology at the University of Glamorgan (UK). As head of the School of Technology, Dr. Neale promotes the institute's broadly-based curriculum, which embraces built environment, design, engineering, human geography, and mathematics. He established the Wales Transport Research Centre and the Suzy Lamplugh Trust Research Institute for Personal Safety. Prior to joining the university, Dr. Neale worked with civil engineers and construction contractors. He received an MSc in construction management. His research interests include the practical application of construction management theory. He has authored in more than 100 publications and has undertaken assignments for UN agencies in 10 developing countries.

JEREMY WHITAKER is commercial director of Wessex Trains and external professor at the University of Glamorgan. He is a chartered marketer with a postgraduate diploma in marketing. Dr. Whitaker is a founding member of the Wales Transport Research Centre and former director of National Rail Enquiry Service. He is active in the Association of Train Operating Companies where he has overseen the introduction of National Ticket on Departure (ToD) and is currently chairing the project board for the implementation of the industry's new fares system. Dr. Whitaker graduated from Birmingham University with a first in engineering and economics.

DAVID HILLIER is head of geography in the School of Technology, University of Glamorgan (UK). He has published on topics as diverse as urban regeneration, the changing retailscape of the British city, the Slow City movement, lighting levels in the British city, use of CCTV in town and city centers, and on the relationship between the design of the urban environment and its criminogenic capacity. His teaching focuses on the evolution of the post-industrial city.

Overcoming Financial and Institutional Barriers to TOD: Lindbergh Station Case Study

Eric Dumbaugh

Abstract

While transit-oriented development has been embraced as a strategy to address a wide range of planning objectives, from minimizing automobile dependence to improving quality of life, there has been almost no examination into the practices that have resulted in the actual development of one. This study examines Atlanta's Lindbergh Station TOD to understand how a real-world development was able to overcome the substantial development barriers that face these developments. It finds that transit agencies have a largely underappreciated ability to overcome the land assembly and project financing barriers that have heretofore prevented the development of these projects. Further, because they provide a means from converting capital investment into positive operating returns, this study finds that development projects provide transit agencies with a unique means of overcoming the capital bias in funding apportionment mechanisms. This latter factor will undoubtedly play a key role in increasing the popularity of transit-agency sponsored TOD projects in the future.

Introduction

Transit-oriented development (TOD), which seeks to encourage transit and walking as a travel mode by clustering mixed-use, higher density development around transit stations (Calthorpe 1993), has become popularly embraced as a strategy for mitigating a host of social ills, such as sprawl, automobile dependence, travel congestion, air pollution, and physical health, among others (Belzer and Autler 2002; Cervero et al. 2002; Frank et al. 2003). Despite these potential benefits, there has been little examination into the development practices that result in the actual occurrence of a TOD.

The literature addressing the topic of TOD implementation typically details developmental and regulatory barriers to TOD (Boarnet and Compin 1999; Belzer and Autler 2002; Leinberger 2001; SMARTRAQ 2001; Cervero et al. 2002), and then concludes by providing general guidelines and best practices, such as “Collaboration Is Key” (Renne and Wells 2002) or “Revise Development Codes” (Arrington 2003). While such “best practices” are useful as a conceptual starting point for encouraging TOD, they fail to consider the complicated financial and institutional arrangements needed to finance and construct these developments.

The absence of real-world project information is widely recognized as one of the major deficiencies in the literature on TODs. Indeed, the most comprehensive literature review on TODs to date, published by the Transit Cooperative Research Program, concludes that:

Research into the institutions, politics, methods, and impacts of TOD and TJD [transit joint development] is needed now more than ever... There is a huge pent-up demand for best-case practices that others can imitate and learn from. (Cervero et al. 2002, 89)

To help address this research need, this study provided a detailed examination into the financial and institutional practices that led to the development of a TOD project. Specifically sought is an understanding of TOD implementation strategies that can be used to inform development strategies in other regions. For many advocates of transit-oriented design, this information is essential for understanding how to move TOD from a development concept to a development reality.

Study Methodology

This research employs a case study approach to better understand how project finance and land assembly barriers can be meaningfully overcome in practice. By examining a real-world development, this study is able to move beyond theoretical best practices. Nevertheless, the use of a case study as a research approach necessarily raises questions regarding the appropriateness of the identified case in meeting the stated research objective, as well as the ability to generalize from an individual observation. Both of these research concerns are addressed below.

Case Selection

Several factors led to my selection of the Lindbergh Station TOD for this analysis. First, many of the projects that have been heralded as TOD successes are in fact nothing of the sort. They either lack functional integration to nearby transit service, and thus are, in fact, “transit-related developments” (Belzer and Autler 2002) or else they, like Laguna West, were designed to support future transit service, but currently lack a transit connection (Calthorpe 1993). While such developments are notable, they cannot be adequately understood as models on which to understand TOD implementation since they are not fully realized TODs. Once one distinguishes these types of developments from actual TODs, very few representative developments are available for study.

Second, MARTA’s Lindbergh Station Development was the first development selected to pilot the Federal Transit Administration’s 1997 Policy on Transit Joint Development, giving it intrinsic value for this analysis. The FTA’s policy revisions were intended to encourage transit agencies to take a more active role in the development of station-area lands. Lessons emerging from this pilot project would seem to be of great practical importance for other transit agencies throughout the United States.

Third, while several studies on transit-oriented developments have asserted that transit agencies can play an important role in the implementation of these projects (Porter 1997; Cervero et al. 2002), there has been little examination into the nature of this role. As described in the literature, this role is largely that of the advocate (Cervero et al. 2002; Belzer and Autler 2002). These assertions are principally made on theoretical grounds, rather than from detailed examinations into the practices of transit agencies. I believed that a focused study on a transit agency-sponsored project was essential for adequately understanding the role these agencies could play.

Finally, and perhaps decisively, my institutional connections with the planning agencies in the Atlanta region afforded me a high level of access to the key actors involved in making the decisions that resulted in the Lindbergh TOD. Beyond their willingness to both be interviewed and to respond to subsequent follow-up questions, these individuals also allowed me to review highly sensitive internal documentation and materials, materials which would have otherwise been impossible to obtain. Access to this material allowed me to understand this development in a level of detail that would have been impossible in other areas.

Addressing Generalizability

Generalizability is often the major design shortcoming of case study research (Yin 2003). To ensure that the results of this study are relevant to other areas and regions, this study is conducted with an eye toward identifying those policies and practices that could be transferred to address similar barriers in other regions. In this study, the Lindbergh development was examined to determine the following:

- What were the development incentives of the project sponsor?
- How did the project overcome land assembly barriers?
- How did the project overcome financial barriers?
- What financial and ridership benefits does the project create for its public-sector partners, if any?

The answers to these questions are of great relevance to other areas that are contemplating a TOD development strategy.

The Lindbergh Station TOD

In 1997, the Metropolitan Atlanta Rapid Transit Authority (MARTA) announced its plan to develop a 47-acre site surrounding its Lindbergh Station into a transit-oriented development. The site seemed ideal for the project. Located along Piedmont Avenue between the City of Atlanta's rapidly growing Midtown and Buckhead districts, and with superior access to the region's downtown and Perimeter Center employment hubs, the parcel appeared ripe for redevelopment. At the time of the announcement, the Lindbergh station area consisted of aging, low-density strip development, and MARTA's landholdings around its Lindbergh station was serving primarily as a park-and-ride lot for local commuters (see Figure 1).

Figure 1. The Lindbergh Station-Area (top) and Its Location in the City of Atlanta (bottom)

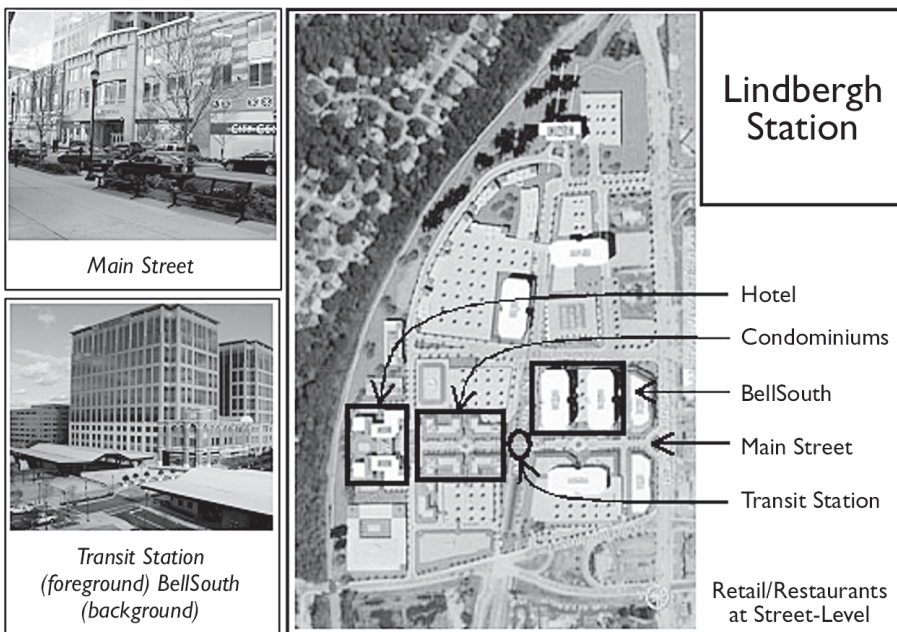


While the project plan went through several iterations, MARTA's final plan for the site would include roughly 2.5 million square feet of commercial office space, 2.2 million of which was reserved for BellSouth, 300,000 square feet of retail, roughly 1,300 residential units, as well as a 160-room hotel (see Figure 2 and Table 1).

Table 1. Land-Use Elements of the Final Lindbergh TOD

Component	Size	Partner
BellSouth Office	2,200,000 sq ft	BellSouth
Speculative Office	225,000 sq ft	Federal Realty
Retail	300,000 sq ft	Federal Realty
Hotel	160 rooms	Federal Realty
Rental Residential	916 Units	Post Properties
For Sale Residential	382 Units	Post Properties

Figure 2. The Final Lindbergh Station Site Plan



Overcoming Developmental Barriers

This study examines the Lindbergh TOD across four major areas. First, it identifies the sponsor for the project, as well as their incentives for encouraging the development. Second, it considers how the project overcame the land assembly barriers that hinder these developments. Third, it outlines the mechanism used to address the capital infrastructure costs of the development's financial barriers. Finally, this study considers the financial benefits the project generates for its public-sector partners in return for their investment in the development.

Project Sponsor Incentives

In the case of the Lindbergh development, MARTA was not only the champion of the project, it was the project's primary sponsor. MARTA's interest in encouraging TOD is obvious: Each additional rider increases the agency's bottom line. The agency has an inherent interest in encouraging station-area developments that funnel new riders into the transit system. What makes MARTA's involvement in the Lindbergh development unique is that, for the first time, a transit agency took the primary role in developing the properties *surrounding* a transit station.

The reason for this unique shift is not due to any unique innovation on the part of MARTA itself, but instead due to recent revisions in federal policy. While the Common Grant Rule had previously prevented transit agencies from developing federally assisted properties for purposes other than those directly related to transit,¹ the FTA had recently revised this policy to permit these landholdings to be developed into transit-oriented developments. MARTA's landholdings around its Lindbergh station—much of which had been acquired with federal aid—were suddenly available for development. Rather than use this regionally central location as a park-and-ride lot, MARTA was suddenly presented with the opportunity of transforming it into a significant point of both transit origin and destination.

While MARTA's interest in the project is clear, it leads to a broader consideration of the role transit agencies can play in the development of similar projects. Considering the role of transit agencies more generally, it is obvious that they, more than either local governments or private developers, are the logical sponsors of such projects (Cervero et al. 2003). While private developers are motivated by net profit, and municipalities by increased tax revenues, transit agencies receive a direct benefit from each new system rider. To successfully achieve the agency's transit ridership objectives, transit agencies have a strong incentive to encourage mixed-use, pedestrian-oriented developments at station ends that enable individuals to ac-

comply with a variety of travel objectives without the use of an automobile. Pedestrian-friendly design and the related benefits it can generate are consequently of great practical importance to the agency's measurement of success; any deviation from these development objectives detracts from the agency's overall performance.

Land Assembly

Not only did federal policy revisions provide MARTA with the incentive for undertaking joint development projects, they provided it with the means for overcoming land assembly barriers as well. Transit agencies typically accumulate excess landholdings as part of developing their regional transit system;² the FTA's Policy on Transit Joint Development suddenly made these formerly "undevelopable" lands available for development, thus, at least in part, removing major land assembly barriers to TODs.

The use of these properties was not unrestricted, however. As a criterion for evaluating development projects, the FTA introduced the concept of *highest and best transit use*. The concept is similar to the theory applied in conventional real estate analyses, except transit effectiveness is factored into the analysis. As defined by the FTA, the highest and best transit use is "that combination of residential, retail, commercial and parking space that results in the *highest level of transit support from a combination of project revenues and increased ridership*" (Federal Register 1997). While no minimum project benchmarks have been established, the FTA does require a proposed development to meet an informal three-part test (Marx 2002):

1. Is the development functionally related to transit?
2. Does the development generate revenue for the transit provider?
3. Does the development improve access to the system, accounting for the affects of new riders?

In short, development projects that generate a net profit to the transit provider and that demonstrate meaningful increases in system ridership are exempt from federal repayment obligations. As a result, MARTA suddenly had a large tract of developable land, and a strong incentive to develop it.

An interesting, and perhaps unrecognized aspect of the FTA's joint development policy was that it not only absolved transit agencies from their obligations for repaying the federal government for federally acquired properties, it also provided a means for utilizing federal capital funds for acquiring *new* landholdings for TOD projects as well. Since the policy revision regarded lands used for joint develop-

ment projects as transit capital investments, transit agencies could now apply for federal capital funding to acquire additional properties needed for a proposed TOD project. Indeed, MARTA, as the first agency selected as part of the FTA's pilot program for its joint development policy, utilized this flexibility to acquire \$1.6 million in new funds that were used not only for project planning, but also for the acquisition of 1.5 additional acres for the project (MARTA 1999).

Financing Mechanisms

Federal policy revisions gave MARTA both the incentive and the ability to undertake the Lindbergh development. What was by no means clear, however, were the financial arrangements that would enable the development to be constructed.

Under MARTA's development plan, the agency would finance the project's streetscape, sewer, and structured parking facilities, thereby absorbing the project's front-end capital needs, as well as most of the project's risks. In return, MARTA's development partners agreed to sign 99-year ground leases on the property, and to construct their buildings in conformity with MARTA's master plan for the site.

To fund its share of this arrangement, the MARTA board of directors authorized an \$81 million bond issuance (Vespermann 2001). Thus, in one fell swoop—a simple majority vote of its board of director—MARTA was able to bypass the financial barriers that have traditionally made the financing and implementation of these projects so difficult. While it is tempting to immediately herald this development as a success, several questions emerge. First, what was the means by which MARTA was able to make such a substantial public commitment without subjecting the bond issuance to a public referenda? Second, what are the actual benefits that this project creates for MARTA? Transit agencies are not principally land developers, yet, in the case of the Lindbergh development, MARTA has elected to undertake a project that the private sector, left to its own financing practices, would not.

This necessarily raises questions about the financial arrangement underpinning this development. If the Lindbergh TOD is to serve as a model for subsequent transit joint-development projects, what revenues does the project generate in return for MARTA's investment? The following sections detail what is perhaps of greatest interest to TOD advocates. First, it examines the institutional mechanisms that enabled MARTA to finance its share of this arrangement. And, second, it details the new ridership and developmental revenues that the project is expected to generate in return for MARTA's \$81 million investment.

Transit Agencies as Public Authorities

The key to understanding MARTA's ability to finance requires an understanding of the historical creation of transit agencies. Transit service was originally provided not by public agencies, but by private transit operators (Warner 1978; Jackson 1985). The advent of the private automobile and the lower-density development patterns that it generated made providing this service unprofitable, forcing private transit companies to discontinue service (Calthorpe 1993; Duany et al. 2000; Glacel 1983; Jackson 1985). The concept of "public transit" was the result of the realization that transit service was essential to meeting regional mobility needs, and thus merited public subsidies to continue its operation. While the public sector could have decided to provide this service directly or to contract this service to private operators, they instead opted to create special "public authorities"³ that were authorized with the ability to construct and operate transit systems.

Public authorities are unique institutions created through state enabling legislation. While they are funded through public revenues, they resemble private corporations more than they do any purely public-sector entity. Public authorities are governed by a board of directors whose membership is typically not determined through public proceedings such as a general election, but through appointees specified in its enabling legislation (Axelrod 1992).⁴ Because of their semiprivate characteristics, the actions of public authorities are typically not subject to public review unless they are explicitly required to do so in their enabling legislation, or unless they use federal funds for a project that has explicit public involvement requirements.

Despite their private-sector characteristics, the charters under which transit authorities are created typically supply them with many of the powers reserved for public agencies, including the ability to exercise eminent domain, to create laws and establish a police force,⁵ as well as the ability to finance projects using bonds backed by public revenues. Unlike municipalities however, transit authorities are not required to submit bond issuance to a public referendum (Walsh 1978). In practice, as Robert Caro observed in *The Power Broker*, public authorities have the ability to function as a "sovereign state" (623), making transit authorities, such as MARTA, potentially powerful forces in regional development. Indeed, MARTA's ability to synthesize its institutional power as a

public authority is key to understanding its ability to finance the Lindbergh TOD.

The major financial barrier to TODs, from the perspective of the private-sector developer, is that current financial evaluation methodologies, such as discounting and internal rate-of-return, favor short-term investments, typically over periods of five to seven years. Because TODs have high front-end capital costs, these developments typically take longer than seven years to mature, making them undesirable from an institutional lender's perspective (Leinberger 2001; Danielsen et. al., 1999; SMARTRAQ 2001).

As a public authority, MARTA is consequently able to use dedicated public revenues to backstop low-interest bonds. Thus, the agency does not need to conform to conventional lending practices to finance a project, nor does it need to seek public approval for their use. MARTA can consequently finance the Lindbergh development's infrastructure, and hence most of its risks, thereby offering its private-sector partners with the ability to distinguish their products in the market without accepting the corresponding risk associated with substantial front-end infrastructure investments. While this resolves an important barrier to TODs, it does not ensure that the project is a meaningful investment of public resources. The key question remains: What are MARTA's returns for this investment?

Project Benefits

Before analyzing the project's investment returns, it is important to first specify the sources of revenue the project will generate. First, and most obviously, MARTA's investment will generate revenues from ground leases and condominium sales. Nevertheless, evaluating the project solely on the returns from these sources would neglect MARTA's real incentive in investing in the project—the generation of new system riders. Correspondingly, the following analysis accounts for the projected revenues that will occur from new system ridership in addition to land development revenues.

Financial Assumptions

Reviewing the financial practices that underpinned the Lindbergh development proved difficult. While MARTA staff was largely cooperative in providing basic information on the Lindbergh project, contractual agreements with its development partners prohibited MARTA from disclosing the details of its

financial arrangements. Still, certain elements, such as the application it submitted to the FTA and its development-phasing plan, were public record, and MARTA was willing to provide its financial assumptions regarding transit ridership, as well as its anticipated aggregate revenues for the project at completion. Using these data sources, it was possible to approximately reconstruct the development’s financial model.

Project revenues from new transit ridership were approximated by making basic assumptions about the number of employees and residents for each of the project elements, as well as their trip-making behavior,⁶ while accounting for vacancy rates (Table 2), and then using MARTA’s transit capture⁷ (Table 3) and farebox assumptions to arrive at transit ridership revenues. MARTA’s financial assumptions assumed that the base fare of \$1.75 would be reduced by 25 percent to account for the use of special fare rates, such as monthly passes. Further, MARTA projected a consistent 2 percent annual fare increase through the life of the project.

Table 2. Ridership Assumptions

Project Element	Vacancy Rate	Unit	Annual Travel Days	Annual Trips
BellSouth Office	0%	150 s.f. per employee	244	7,157,496
Office	5%	150 s.f. per employee	244	695,400
Retail	5%	52 persons per 1,000 s.f.	360	11,737,440
Hotel	5%	1.1 persons per room	360	101,152
Residential	5%	1.3 persons per unit	360	1,155,600

Table 3. Estimated Transit Ridership for Trips Generated by the Lindbergh TOD

Project Element	Element Size	Annual Trips	Transit Capture	Transit Riders
Bellsouth Office	2,200,000 sq ft	7,157,496	30%	2,147,246
Speculative Office	225,000 sq ft	695,400	10%	69,540
Retail	300,000 sq ft	11,737,440	5%	586,872
Hotel	160 rooms	101,152	10%	10,152
Residential	1,298 units	1,155,600	10%	115,560

The joint development application MARTA submitted to the FTA indicated its intention to build 120 condominium units at the Lindbergh site, providing MARTA with conservative sales proceeds of \$5 million and placing the per unit proceeds at \$41,667. Later revisions to the development plan increased the number of units to 382. This analysis assumed that MARTA's per unit sales proceeds remained unchanged; revenues from condominium sales were determined by multiplying by \$41,667 by the number of units scheduled to be sold each development year.

Once values for these data points were determined, deriving estimates of ground lease revenues was simply a matter of subtracting transit ridership estimates and condominium sales from total revenues. While such an approach did not permit the revenues from specific project components to be identified, it nevertheless provided an approximate measure of aggregate revenues derived from ground leases.⁸

Project Revenues

To finance the Lindbergh TOD, MARTA issued \$81 million in bonds to be repaid over a 30-year period at 4 percent interest, compounded annually. Because MARTA did not disclose the time periods at which these bonds would be issued, the following analysis assumes that the full \$81 million was issued on day one, to be repaid in equal annual payments of \$4,684,238 over the 30-year period. Under this accounting scheme, MARTA's Lindbergh project will produce roughly \$293 million, in 2001 dollars, of new revenue during the 30-year period over which the project is financed. Less the cost of repaying the bonds, this provides MARTA with almost \$153 million in net new revenues (see Table 4). While such a return would seem profitable, on the surface, the longer-term period over which these returns are realized makes these benefits misleading. If one considers investing the same

Table 4. Lindbergh TODs Revenues and Benefits

Year	Costs		Estimated Revenues				Estimated Benefits		
	Bond Repayment		Ground Leases	Ridership	Condo Sales	Annual Benefits	Net Annual Benefits	Net Profit	
2001	\$4,684,238		\$950,000	\$0	\$0	\$950,000	(\$3,734,238)	(\$3,734,238)	
2002	\$4,684,238		\$1,920,000	\$0	\$0	\$1,920,000	(\$2,764,238)	(\$6,498,476)	
2003	\$4,684,238		\$1,401,326	\$1,278,674	\$0	\$2,680,000	(\$2,004,238)	(\$8,502,714)	
2004	\$4,684,238		\$1,340,701	\$2,259,299	\$0	\$3,600,000	(\$1,084,238)	(\$9,586,952)	
2005	\$4,684,238		\$730,321	\$2,979,679	\$4,375,035	\$8,085,035	\$3,400,797	(\$6,186,155)	
2006	\$4,684,238		\$1,047,517	\$3,052,483	\$0	\$4,100,000	(\$584,238)	(\$6,770,393)	
2007	\$4,684,238		\$1,813,262	\$3,113,533	\$4,375,035	\$9,301,830	\$4,617,592	(\$2,152,801)	
2008	\$4,684,238		\$1,955,806	\$3,797,783	\$0	\$5,753,590	\$1,069,352	(\$1,083,450)	
2009	\$4,684,238		\$2,706,645	\$3,873,739	\$3,000,024	\$9,580,408	\$4,896,170	\$3,812,721	
2010	\$4,684,238		\$3,455,965	\$3,951,214	\$0	\$7,407,179	\$2,722,941	\$6,535,662	
2011	\$4,684,238		\$3,683,025	\$4,550,950	\$0	\$8,233,974	\$3,549,736	\$10,085,398	
2012	\$4,684,238		\$4,418,800	\$4,641,968	\$0	\$9,060,769	\$4,376,531	\$14,461,929	
2013	\$4,684,238		\$5,138,281	\$4,749,282	\$4,166,700	\$14,054,264	\$9,370,026	\$23,831,955	
2014	\$4,684,238		\$5,870,090	\$4,844,268	\$0	\$10,714,359	\$6,030,121	\$29,862,076	
2015	\$4,684,238		\$6,600,000	\$4,941,154	\$0	\$11,541,154	\$6,856,916	\$36,718,991	
2016	\$4,684,238		\$6,600,000	\$5,039,977	\$0	\$11,639,977	\$6,955,739	\$43,674,730	
2017	\$4,684,238		\$6,600,000	\$5,140,776	\$0	\$11,740,776	\$7,056,538	\$50,731,268	
2018	\$4,684,238		\$6,600,000	\$5,243,592	\$0	\$11,843,592	\$7,159,354	\$57,890,622	
2019	\$4,684,238		\$6,600,000	\$5,348,463	\$0	\$11,948,463	\$7,264,225	\$65,154,847	

2020	\$4,684,238	\$6,600,000	\$5,455,433	\$0	\$12,055,433	\$7,371,195	\$72,526,042
2021	\$4,684,238	\$6,600,000	\$5,564,541	\$0	\$12,164,541	\$7,480,303	\$80,006,345
2022	\$4,684,238	\$6,600,000	\$5,675,832	\$0	\$12,275,832	\$7,591,594	\$87,597,940
2023	\$4,684,238	\$6,600,000	\$5,789,349	\$0	\$12,389,349	\$7,705,111	\$95,303,050
2024	\$4,684,238	\$6,600,000	\$5,905,136	\$0	\$12,505,136	\$7,820,898	\$103,123,948
2025	\$4,684,238	\$6,600,000	\$6,023,239	\$0	\$12,623,239	\$7,939,001	\$111,062,949
2026	\$4,684,238	\$6,600,000	\$6,143,703	\$0	\$12,743,703	\$8,059,465	\$119,122,414
2027	\$4,684,238	\$6,600,000	\$6,266,577	\$0	\$12,866,577	\$8,182,339	\$127,304,754
2028	\$4,684,238	\$6,600,000	\$6,391,909	\$0	\$12,991,909	\$8,307,671	\$135,612,424
2029	\$4,684,238	\$6,600,000	\$6,519,747	\$0	\$13,119,747	\$8,435,509	\$144,047,934
2030	\$4,684,238	\$6,600,000	\$6,650,142	\$0	\$13,250,142	\$8,565,904	\$152,613,838
Total	\$140,527,140	\$142,031,742	\$135,192,442	\$15,916,794	\$293,140,978	\$152,613,838	

amount of money—\$81 million—in a savings account that yielded 5 percent per year, MARTA's returns over the 30-year cycle would be \$350 million—more than twice that realized by the Lindbergh development.

When one considers the time value of money, the Lindbergh project looks even less desirable. Assuming a generous discount rate of 4 percent and accounting for discounted costs and revenues, the net present value of the project at the end of the 30-year investment period is only about \$71 million—\$10 million less than MARTA's initial investment. MARTA's returns also do not account for the inherent risk of this development. These returns are based on the assumption that all of MARTA's revenue and ridership assumptions are realized. The failure of a project element to generate the anticipated financial returns can have a dramatic impact on the project's overall profitability. MARTA, by financing the infrastructure costs of this development, has largely underwritten most of the project's risks. High-risk projects should return high yields. Nevertheless, MARTA's annual yield on this investment is, under the best circumstances, only about 2.1 percent—well below national interest rates, despite the project's risks.

An issue that potentially compounds this problem is the project's performance over the short term. For MARTA, the Lindbergh station development operates largely at a loss through year six, although condominium sales help to offset the magnitude. The project only begins showing net annual benefits in its seventh year, and does not show a net profit until year nine (see Table 4). MARTA is currently running a \$20 million operating deficit that has forced the agency to cut-back route frequency and to eliminate underperforming routes (*Atlanta Journal Constitution* 2001). The decision to undertake a major development project that operates at a significant net loss during this critical period, and that ultimately generates few long-term benefits seems at first confusing. Considering the relatively low yield on this high-risk investment, MARTA's decision to invest in the development makes little sense.

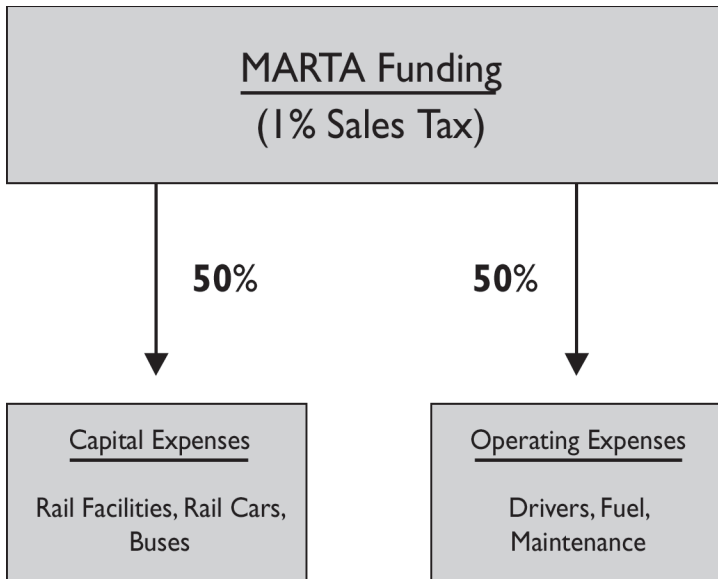
Circumventing the Operations Dilemma

Clearly, the key factor in MARTA's decision to undertake this project is not the project's overall profitability. The key lies in what the project secures for the agency—a continuous, \$13.3 million annual revenue stream that will continue indefinitely. Development projects, such as Lindbergh, also provide a means to bypass the major financial hurdle that confronts transit agencies—operating costs. Understand-

ing the financial significance of these projects requires a brief discussion of the financial structures of transit agencies.

When transit authorities are created, their enabling legislation allocates public funds to sustain them, but also specifies the apportionment that can be used for capital purposes, such as constructing new rail lines or purchasing buses, and that which can be applied to operations, which is the cost of actually providing transit service on a day-to-day basis. MARTA, for example, is funded by a 1 percent local sales tax that is split evenly between capital and operations⁹ (see Figure 3).

Figure 3. MARTA Funding Allocations



While system expansion, particularly new rail facilities, requires substantial capital investments, transit authorities are able to pool significant resources together to finance these projects. In addition to their direct public sources of revenue, transit authorities are able to apply for federal funding, which covers up to 80 percent of the actual capital acquisition costs. Beyond this federal contribution, transit agencies can also appeal to local governments to supply some or all of the additional 20

percent local match required to fund the project. It is consequently possible (although unlikely) for a transit authority to fully finance a new capital project without using a dollar of dedicated agency funding.

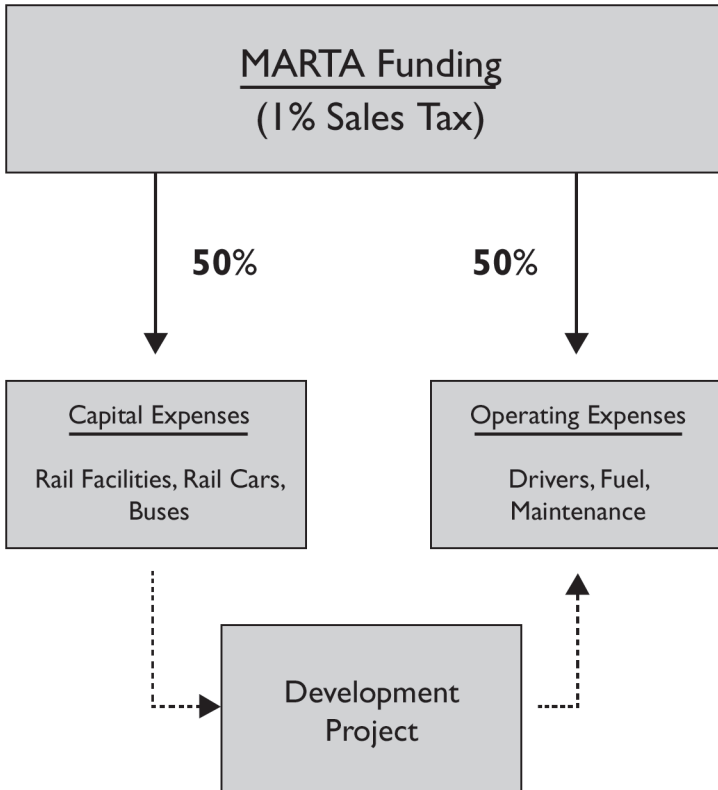
Operations are more difficult to finance. While each dollar derived from ticket sales can be used to cover operations, transit service always operates at a loss. Nationally, farebox revenue accounts for only 35 percent of the cost of operating transit service (American Public Transportation Association 2003), and MARTA recovers only 38 percent of its operating costs (Georgia Department of Transportation 2003).

Because operating costs are not recovered in farebox revenues, transit operators are forced to identify alternative sources of revenue to cover the costs of operating transit service. Development projects, such as the Lindbergh development, have the ability to provide an important means of supplying this critical operating revenue.

For transit authorities, development projects, such as Lindbergh, are *capital* projects, similar to the construction of a new rail line or the provision of a new bus route. The revenues they generate, however, are *operating* dollars. As a consequence, even a development operating at a net fiscal loss can provide a transit authority with new funds that it can use to expand transit service (see Figure 4). To illustrate using the Lindbergh project as an example, in 2003 the Lindbergh project operates at a net loss of slightly more than \$2 million dollars (see Table 4). From a private sector perspective, the loss of \$2 million dollars is a real loss. This is not the case with MARTA's Lindbergh project. The loss for MARTA is solely in capital dollars, which are much easier to come by than operating dollars. Indeed, for a transit authority, *all* capital projects operate at a loss—undertaking financially unprofitable investments are central to its business approach. What is unique about development projects is that the losses are absorbed entirely on the *capital* side. While the project may operate at a net loss during 2003, it nevertheless provides MARTA with \$2.6 million dollars in *new operating* revenue—revenue that can be used to increase service frequencies and reestablish routes it was forced to eliminate during its current budget shortfall.

Although this finding would appear to have surface appeal to TOD advocates, it nevertheless leads to an unappealing conclusion. Transit agencies have a strong incentive to undertake financially unprofitable development projects, a problem that is exacerbated when transit agencies are running substantial operating deficits. Projects that are able to generate net positive operating revenues will com-

Figure 4. Using Development Projects to Shift Capital Dollars into Operating Dollars



pete favorably with other projects, such as new transit lines, which run at a continuous operating loss. Since the costs are absorbed on the capital side, and the benefits realized on the operating side, the ultimate question for transit agencies is not whether a development makes sound financial sense, but instead, what capital losses are acceptable for new gains in operating revenue.

Subsequent Revisions to the Transit Joint Development Policy

While the FTA’s 1997 Policy on Transit Joint Development permitted transit authorities to use development revenues from federally assisted properties for either capital or operating purposes, this freedom was later revoked when the policy was formally incorporated into the U.S. Code through the Transportation Equity Act for the 21st Century (TEA-21).¹⁰ TEA-21 indicated that “the net income from asset

sales, uses, or leases (including lease renewals) under this section shall be used by the recipient to reduce the gross project cost of other capital projects carried out under this chapter” (49 U.S.C. 5334(g)). In other words, revenues coming from federally assisted properties could no longer be used to subsidize operations.

While this would seem to resolve the issues surrounding capital losses for operating gains, the likely result of this policy revision is simply to encourage transit agencies to undertake creative site configurations. Agencies seeking to increase their operating revenues have a powerful incentive to design these projects so that the revenue-generating uses are located not on the individual parcels that work best for the TOD as a whole, but instead on those parcels that provide the agency with the greatest fiscal flexibility in the use of revenues. Further, if operating revenues will not be generated through the development of the property, many agencies may be unwilling to even consider undertaking the complicated and uncertain federal review process needed to develop the property.

While there is no direct evidence to suggest that these considerations influenced the configuration of MARTA’s Lindbergh development, it is nevertheless interesting that all of the project’s revenue-generating uses—its commercial, retail, and residential elements—are located on properties acquired *solely* with local funds; the federally funded properties are being used for nonrevenue-generating uses, such as parking facilities and the relocation of the agency’s headquarters. The Lindbergh development will consequently allow MARTA to apply the project’s revenue to cover operating expenses, should MARTA choose to do so.¹¹ Regardless of whether the Lindbergh site configuration was designed to circumvent federal requirements or simply a matter of coincidence, it is nevertheless clear that the decision to allow development on federally assisted properties, but to restrict the use of the revenue, does little more than to provide transit agencies with a barrier to optimizing the usefulness of a site.

Conclusions

The FTA’s 1997 Policy on Transit Joint Development is a milestone for advocates of transit-oriented development. By relaxing federal restrictions on the use of transit-area properties, this policy gave transit agencies a powerful incentive to see station-area properties developed into TODs.

When one examines the actions MARTA undertook to realize this development, the potentially central role of transit agencies in the implementation of these

projects emerges. As a public authority, transit agencies can synthesize many of the powers of the public sector to bring a project to fruition. First, transit agencies often have excess, and in many cases substantial landholdings surrounding their transit stations. The new ability to develop these properties can allow these agencies to bypass the land-assembly barriers that have previously made developing TODs difficult. Further, where land assembly is needed, transit agencies often have the ability to exercise eminent domain to acquire these properties, and may further be eligible to use federal funds for their acquisition.

Transit agencies can also overcome the second major barrier to TOD implementation: project finance. Transit agencies have the ability to use bond finance to cover the capital infrastructure costs that have made these projects undesirable to the private sector. In the case of the Lindbergh TOD, MARTA used \$81 million in bond finance to cover the streetscape, transit infrastructure, and structured parking costs of the development.

While this significant, high-risk investment would seem to merit a correspondingly high return, MARTA will receive only \$153 million over the 30-year bond repayment period, assuming all of its financial assumptions are met. Accounting for the time value of money, and applying a nominal 4 percent discount rate, the present value of MARTA's investment is only about \$71 million—\$10 million less than MARTA's initial investment.

The apportionment mechanisms applied to finance transit service explain MARTA's decision to undertake this development. While transit authorities were initially created as a means for the public to underwrite the provision of transit service, local and federal transit policies have been increasingly oriented toward reducing operating subsidies. This mixed policy mandate—whether to treat transit as a public good or to encourage it to be operationally efficient—currently makes transit agencies hard-pressed to identify projects that generate positive operating revenues that can be used to cover the costs of operating socially desirable, but financially unprofitable transit service.

TOD joint development projects, even while operating at a net fiscal loss, provide transit agencies with a means for transferring capital dollars into this much-needed operating revenue. Revenues from new riders, ground leases, and property sales can be applied toward covering operating costs (assuming the agency can circumvent more recent federal restrictions on the use of these revenues). Thus, even a development that is operating at a substantial net loss would appear to enhance

overall transit performance since the development would generate new operating revenue that advances the agency's core mission—providing transit service.

Acknowledgments

The author wishes to thank Michael Meyer and David Sawicki for their invaluable review of earlier drafts of this article, as well as MARTA staff and management, who, while under severe time and budgetary constraints, were nevertheless extremely generous with their time. Thanks also to Dahshi Marshall, who supplied market information used in this research.

Endnotes

¹The Common Grant Rule, which outlined federal policy regarding the disposition of property, relieved a transit agency of its obligation to the federal government for projects developed for transportation projects, but was unclear about what federal obligations, if any, would be required for federally funded properties used for real estate development. To avoid potential federal obligations, transit authorities have correspondingly limited their joint development ventures to projects built on the air rights of existing stations because the property is already being used for the intended transportation purpose, fulfilling the agency's obligation to the federal government under the Common Grant Rule.

² MARTA has roughly 280 acres of excess station-area landholdings.

³ The concept of a public authority dates back to Elizabethan England. The term "authority" is derived from the Parliamentary act that authorized them, which began with the phrase "Authority is hereby given..." (Caro 1974, p. 615).

⁴ MARTA's board of directors includes appointees from the City of Atlanta, Fulton, DeKalb, Gwinnett, and Clayton Counties, as well as members from the Georgia Department of Transportation, Georgia Regional Transportation Authority, State Properties Commission, and State Department of Revenue

⁵ MARTA's police force, with 304 sworn officers, is the ninth largest in the State of Georgia (Source: MARTA).

⁶ ITE's *Trip Generation Handbook* is the conventional reference used to estimate trip generation. This reference, however, pertains to automobile trips, and the method used to derive its trip generation estimates are regression results based on

observations of single-use suburban developments, rather than the more urbanized development models represented by transit-oriented developments (Ewing and Dumbaugh 2001). To develop a more meaningful estimate of total trip generation, as well as to make the ridership assumptions transparent, I elected to develop independent estimates for each of the project elements that were consistent with the developmental mix of the project. My assumptions further account for travel variations associated with weekends, vacations, and holidays, factors not considered in the regression results shown in the *ITE Trip Generation Handbook*.

⁷ While the Bellsouth component has what would appear to be a high transit capture rate, this assumption is supported by the characteristics of the development. As part of a mediation agreement with the neighborhood groups, BellSouth agreed to undersupply its on-site parking, forcing a third of its employees to use an alternate mode to work. To further encourage transit use, Bellsouth is combining transit pass subsidies with parking fees. Under the Metro plan, a monthly parking permit will cost \$60 per month, while a transit pass, after Bellsouth subsidies, will cost \$12. BellSouth's North Avenue building, built on the air rights of MARTA's North Avenue Station and employing a similar combination of parking restrictions and transit pass subsidies, currently has a 30 percent transit capture rate (Gilbert 2001; Vespermann 2002).

⁸ MARTA provided me with a spreadsheet outlining their aggregate revenues through 2007, as well as its aggregate revenue for the build-out year of 2013. Revenues from ground leases through 2007 could consequently be determined by simply subtracting my estimates of condominium sales and ridership revenue from total revenues. To determine ground lease revenues for the 2007–2013 period, I estimated the sum of the difference between known ridership and sales revenues from the total revenues for the period, and then distributed it equally along each year of this period. While the distributions of ground lease revenues doesn't exactly match the development phasing cycle, this approach should not affect the accuracy of the results presented.

⁹ To help minimize MARTA's current operating deficit, the state legislature recently adjusted this apportionment to allow MARTA to flex up to an additional 10 percent of state sales tax revenues for operating purposes.

¹⁰ The federal government reauthorizes transportation funding through a multiyear legislative act. The two most recent transportation reauthorization packages, ISTEA and TEA-21, have been funded for six-year intervals.

¹¹ According to Paul Vespermann, former director of Transit-Related Developments, increasing system operating revenues is indeed the primary objective of this development (2002).

References

- American Public Transportation Association. 2003. *Public transportation fact book*. Washington DC: American Public Transportation Association.
- Arrington, G. B. 2003. Light rail and the American city: State-of-the-practice for transit-oriented development. *Transportation Research E-Circular E-C05*:. 9th National Light Rail Transit Conference. Washington DC: Transportation Research Board.
- Atlanta Journal Constitution*. 2001. "MARTA to Discuss Tough Financial Choices," November 16.
- Axelrod, Donald. 1992. *Shadow government: The hidden world of public authorities and how they control \$1 trillion of your money*. New York: John Wiley and Sons, Inc.
- Boarnet, Marlon G., and Nicholas S. Compin. 1999. Transit-oriented development in San Diego county: The incremental implementation of a planning idea. *Journal of the American Planning Association* 65 (1) 80–95.
- Belzer, Dena, and Gerald Autler. 2002. Transit Oriented Development: Moving From Rhetoric to Reality. Discussion paper prepared for the Brookings Institution Center on Urban and Metropolitan Policy and The Great American Station Foundation. Washington DC: The Brookings Institution
- Caro, Robert A. 1974. *The power broker*. New York: Vantage Books.
- Calthorpe, Peter. 1993. *The next American metropolis: Ecology, community, and the American dream*. New York: Princeton Architectural Press.
- Cervero, Robert, Christopher Farrell, and Steven Murphy. 2002. Transit-oriented development and joint development in the United States: A literature review. *Transit Cooperative Research Program Research Results Digest* 52. Washington DC: Transportation Research Board.
- Danielsen, Karen A., Robert E. Lang, and William Fulton. 1999. Retracting Suburbia: Smart Growth and the Future of Housing. *Housing Policy Debate*, 10, 3: 513–540.
- Duany, Andres, Elizabeth Plater-Zyberk, and Jeff Speck. 2000. *Suburban nation: The rise of sprawl and the decline of the American dream*. New York: North Point Press.

- Ewing, Reid, and Eric Dumbaugh. 2001. Internalizing travel by mixing land uses: A study of master-planned communities in South Florida. *Transportation Research Record* 1780: 115–120.
- Federal Register*. 1997. Federal Transit Administration Policy on Transit Joint Development. 62: 50, March 14, p. 12266.
- Frank, Lawrence, Peter Engelke, and Tom Schmid. 2003. *Health and Community Design*. Washington DC: Island Press.
- Georgia Department of Transportation. 2003. *Georgia transit programs fact book*. Atlanta: Georgia Department of Transportation.
- Gilbert, Richard (Spokesperson for BellSouth). 2001. Telephone Interview, December 5.
- Glacel, Barbara Pate. 1983. *Regional transit authorities: A policy analysis of Massachusetts*. New York: Praeger Publishers.
- Jackson, Kenneth T. 1985. *Crabgrass frontier: The suburbanization of the United States*. Oxford University Press: New York.
- Leinberger, Christopher. 2001. *Financing progressive development*. Article prepared for the Brookings Institution Center for Urban and Metropolitan Policy and the Harvard University Joint Center for Housing Studies. Washington DC: The Brookings Institution.
- MARTA. 1999. Development Application Submitted to the Federal Transit Administration, June 4.
- MARTA. 2001. Transit oriented-development: The sMARTA way to development. Atlanta: The Metropolitan Atlanta Rapid Transit Authority.
- Marx, Paul (Economist with the Office of Policy Development, Federal Transit Administration). 2002. Telephone Interview, January 15.
- Porter, Douglas R. 1997. *Synthesis of transit practice 20: Transit-focused development*. Washington DC: Transportation Research Board, National Research Council.
- Renne, John, and Jan Wells. 2002. *State of the literature: Transit-oriented development*. New Jersey: Vorhees Transportation Policy Institute.

- SMARTRAQ, Georgia Institute of Technology, Metro Atlanta Chamber of Commerce, and Robert Charles Lesser & Co. 2001. Trends, implications & strategies for balanced growth in the Atlanta region: Synthesis Report, SMARTRAQ.
- Vespermann, Paul. 2001. "MARTA's Lindbergh City Center Project is Good for Metro Atlanta." Opinion Letter submitted to the Atlanta Business Chronicle. Atlanta Business Chronicle. January 26.
- Vespermann, Paul (Director of Transit-Related Development, MARTA). 2002. Telephone Interview, February 26.
- Walsh, Annmarie Hauck. 1978. *The public's business: The politics and practices of government corporations*. Cambridge, MA: MIT Press.
- Warner, Sam Bass. 1978. *Streetcar suburbs: The process of growth in Boston (1870–1900)*. Harvard University Press: Cambridge, MA.
- Yin, Robert K. 2003. *Case study research: Design and methods*, 3rd ed. Thousand Oaks: Sage Press.

About the Author

ERIC DUMBAUGH (edumbaugh@aol.com) is a doctoral candidate in the School of Civil and Environmental Engineering at the Georgia Institute of Technology. He holds joint master's degrees in city and regional planning and civil engineering, also from Georgia Tech. His recent research focuses on nonmotorized travel, performance measurement, and safety-conscious planning. His dissertation, scheduled for completion in 2005, examines strategies for incorporating context-sensitive solutions into the design practices of state and local departments of transportation.

Impacts of Various Parameters on Transit Signal Priority Effectiveness

Vikki Ngan, IBI Group

Tarek Sayed, University of British Columbia

Akmal Abdelfatah, American University of Sharjah

Abstract

This research examines the impacts of a number of traffic parameters on the effectiveness of a Transit Signal Priority (TSP) application. TSP is tested with the 98 B-line rapid buses along Granville Street in the City of Vancouver as a case study. VISSIM, a micro-simulation software (PTV 2002), is used to simulate TSP operation on the corridor. The traffic parameters studied include: bus approach volume, cross street volume/capacity (v/c) ratio, bus headway, bus stop location, bus check-in detector location, left turn condition, and signal coordination. Based on results from these experiments, recommendations are provided for TSP application on Granville Street. In general, it is found that a TSP application would be most effective under a traffic condition that has moderate-to-heavy bus approach volume, little or no turning volume hindering bus movement, slight-to-moderate cross street v/c ratio, farside bus stop, and signal coordination for traffic running in the peak direction.

Introduction

Transit Signal Priority (TSP) is an Intelligent Transportation System (ITS) measure that modifies the normal signal operation process to better accommodate transit vehicles. It aims to reduce the delay and travel time of transit vehicles, thereby increasing the quality of a transit service; meanwhile, it attempts to provide these benefits with minimal impact on other road users and cross street traffic in particular. TSP has been widely tested and deployed around the world, especially in the United States and Europe, as a tool to improve transit performance. However, previous research has shown that the impacts and effectiveness of a TSP application is subjective and depends on its surrounding traffic environment (such as signal timing settings, congestion levels, etc.). Consequently, it is important to study the influences of various traffic and transit parameters on the impacts and effectiveness of a TSP application.

This research studied the effects of seven traffic and transit parameters on the effectiveness of TSP. These parameters include: bus approach volume, cross street volume/capacity (v/c) ratio, bus headway, bus stop location, bus check-in detector location, left turn condition, and signal coordination. The 98 B-Line bus route, along the Granville Street corridor, Vancouver, British Columbia, is used as a case study. Based on the results, some generic guidelines and recommendations for TSP applications are proposed.

Previous Work

Several studies investigated the relationship between the effectiveness of a TSP application and the surrounding traffic environment. The studied traffic parameters can be categorized into four main areas: vehicular volume, bus headway, bus stop locations, and signal coordination.

Garrow and Machemehl (1998) used CORSIM to simulate several green extension measures on the Gaudalupe corridor in Austin, Texas. They reported that there would be a severe negative impact on the cross-street traffic if the cross-street saturation level is above 1.0 with a 10-second green extension, or if the cross-street saturation level is above 0.9 with a 20-second green extension. Under these conditions, they reported that the cross-street traffic would require 2 to 3 cycles to recover. Balke, Dudek and Urbanik (2000) examined the impacts of a proposed "intelligent bus priority concept" on the bus and general traffic performance at bus approach v/c ratios of 0.50, 0.80 and 0.95. Their results illustrated that the intelli-

gent priority system could improve bus travel time by more than 25% at three bus approach v/c ratios; meanwhile, it slightly reduced the travel time of general traffic running on or opposite to the bus approach. However, Balke, Dudek and Urbanik also reported that the proposed system would have a substantial negative impact on the average stop delay of traffic traveling on the non-priority approaches with v/c levels greater than 0.95.

Little work had addressed the question of optimal bus headway for TSP operations. Khasnabis and Rudraraju (1997) examined the possible consequences of different headways on a TSP operation. A major bus route in Ann Arbor, Michigan was selected for demonstration and was simulated using NETSIM. Route-level analysis illustrated that a 10-minute headway would produce the highest effectiveness in reducing delay of the target direction and both directions of the main street. They also reported that if a reduction in the delay of the cross street or the combined main street and cross street was the objective, a 7.5-minute headway would be considered as the best alternative. Agrawal, Waller and Ziliaskopoulos (2002) examined the impact of bus frequency on a TSP application. From a 30-minute simulation, they reported the following observations on the impact of bus frequency:

- Total system travel times of “no preemption” strategy and “preemption” strategy converge when the number of buses rises above 30 per 30 minutes.
- The least difference in total system travel times with and without preemption was observed at a bus frequency of 15 per 30 minutes or 2-minute headway. The authors claimed that the difference did not remain constant at a higher bus frequency because of the vehicle route changing that occurred after preemptions.
- The benefit from preemption on bus trip time increased when there were fewer buses; above approximately 20 buses per 30 minutes, the benefit decreased and leveled off.

With regard to bus stop location, there was a clear preference for the use of far-side bus stops for the implementation of active TSP, for which real-time detections of buses are required. This is because the uncertain passenger loading and unloading time at a near-side bus stop would increase the uncertainty in predicting arrival time of a bus at an intersection (Daniel 1997). It was also believed that a far-side

bus stop could maximize the efficiency of a signal priority operation, as there would be less influence from the dwell time at the bus stop (Huffman, et al. 1998).

Several studies investigated the effect of incorporating transit signal priority into a coordinated network. Skabardonis (2000) proposed that transit signal priority should only be granted if there is sufficient spare green time in a signal cycle. This would mean that little or no transit vehicles would be given priority along a congested corridor or during the peak hours. According to Skabardonis (2000), the spare green time was computed as:

$$G_{Spare} = \sum_{i=1}^N G_i * (1 - X_i)$$

where

G_i = green time for phase i ,

X_i = degree of saturation of the critical link in phase i , and

N = total number of phases in a cycle.

Chatila and Swenson (2001) proposed to set the maximum green extension time to 20% (or one-fifth) of the cycle length. To return to coordination, every 5th second in the cycle is skipped until the local clock (with adjusted time for green extension) and the master clock (with original reference time) are back in synchronization. Whereas, Duerr (2000) attempted to use a sophisticated algorithm called DARVIN (with static optimization by Genetic Algorithm and dynamic adaptation by Neural Network) to minimize the interference between public transit vehicles and other vehicles and to maintain the existing signal coordination as much as possible.

Methodology

As described earlier, the main objective of this article is to investigate the impact of various traffic and transit parameters on the effectiveness of TSP. To achieve this, Transit Signal Priority (TSP) application of the 98 B-line rapid transit buses along Granville Street in the City of Vancouver is used as a case study and is simulated by VISSIM.

Experiment Site

The Granville Street corridor, where the 98 B-Line buses run, is one of the busiest traffic and transit corridors in the Greater Vancouver Regional District (GVRD). The studied section along the Granville Street corridor stretches approximately 6km, from Broadway to 70th Avenue. All traffic data are based on morning peak period data of year 2000. Granville Street morning peak hour entering volumes are around 2,000 vehicles per hour (Veh/hr) and 1,000 Veh/hr in the northbound and southbound directions, respectively. The 98 B-Line buses operate in mixed traffic at 10-minute headways during the morning peak period. There are 19 signalized intersections along the section.

The B-Line bus check-in detectors are located approximately 100 meters from the intersection stop bars for real-time detection of the buses. Five on-street bus stops for the 98 B-Line are placed on each Granville Street approach. Most of them are on the farside (i.e., downstream) of the intersections, except the northbound bus stop at the intersection of Granville Street and Broadway where a nearside bus stop is placed because of a high transit stop demand that already exists on the farside of the intersection. The TSP strategies experimented in this study are:

- (i) Green extension: Extension of the green time when a bus checks in during the bus-approach green phase and cannot check out before the original green phase elapsed. The green phase for the bus would be extended until either the bus checks out or when the maximum green extension of 14 seconds is reached, whichever comes first. Beyond the 14-second green extension, the green phase of the bus-approach phase would end. To maintain coordination, the cross street green time reduces accordingly after a green extension call.
- (ii) Red truncation (or Early Green): The green time of the cross street phases would be truncated (or shortened) when a bus checks in during the bus-approach red phase, subjected to the required flash don't walk (FDW) time and a 3-second minimum walk time of the pedestrian phase (conflicting to the TSP-eligible bus approaches); and
- (iii) Restriction of TSP calls in two successive cycles.

VISSIM Simulation and Calibration

VISSIM, a micro-simulation software, is used to simulate TSP operation on the Granville Street corridor. VISSIM has a number of features that make it a useful tool for modeling transit operation and transit priority:

1. VISSIM allows the development of user-defined signal logics to test different TSP strategies. The user-defined signal logics are coded with VAP, a C-like programming language that offers traffic-related functions such as detector calls, switching of signal phases, and transit phasing (PTV 2002)
2. VISSIM allows the assignment of detailed priority rules to model yielding movements at signalized and non-signalized intersections.
3. VISSIM has a wide range of user-customizable output files for measures-of-effectiveness such as volume, mean speed, travel times, delay, queue lengths, and number of stops. Detailed signal records can also be logged.

As with every modeling exercise, a calibration process of the base network is performed. A geometric network calibration is performed by looking at the VISSIM graphical user interface for any unusual behavior of the traffic, which may be due to inexact coding of the network construction or traffic signal logics. Additionally, the model is calibrated to isolate unrelated traffic factors, which could influence the impact of the studied traffic parameters.

The VISSIM network was compared with the real-life network. The existing geometric conditions, actual input volumes, and actual signal timings on the Granville Street corridor were used as the base of the model.

VISSIM Modeling

After calibration, a traffic simulation model, named "NoTAC," is developed as the base model (with no TSP) of the 98 B-Line buses on Granville Street.

Since the goal of this article is to investigate the individual impact of traffic parameters on TSP effectiveness, the NoTAC model assumes **No Turning** to and from Granville Street, no **Actuation** from pedestrians at the pedestrian signals (or half signals), and no turning from the **Cross Streets**. Two-phase fixed time signals are tested along the corridor. In addition, it neglects actual gradient of the corridor, actual exclusive HOV and bus lanes, and actual on-street parking on Granville Street during the morning peak hours. These assumptions create a hypothetical case that eliminates factors that might affect performance, and is used as a base for comparison and for evaluating one traffic variable at a time.

Total simulation time is 1 hour and 15 minutes, including a normalization period of 15 minutes at the beginning to fill the network with vehicles, and a simulation period of 1 hour to collect data for analyses. Each experiment is performed with five different random seeds to account for the stochastic traffic input. This is required to ensure the validity and stability of the results.

Results from the five simulation runs are averaged using a “Trimmed Average” approach, which excludes the highest and the lowest results of the runs, then averaging the remaining. This aims to reduce the effect of randomness in the simulation results. The trim-averaged simulation results are used to test the sensitivities of TSP impacts or effectiveness to the studied parameters.

Evaluation

Two measures of effectiveness (MOEs) used in the evaluations are the impact of TSP and the green extension success rate. The impact of TSP compares the B-Line bus and/or cross street performance (i.e., travel time or delay) with and without TSP implementation; and the green extension success rate measures the rate at which a bus might clear the intersection successfully with a green extension. Additionally, results of the simulations are presented in one of the two levels of aggregation: corridor-level presents the traffic performance along the Granville Street corridor, and approach-level focuses on the traffic performance on an approach to an intersection.

Bus Approach Volume (Corridor-Level)

The B-Line buses operate at a default headway of 10 minutes and the Granville Street (or bus approach) volumes considered for this experiment are 500, 1,000, 1,500, 2,000, 2,500, and 2,700 veh/hr/3-lanes. These Granville Street volumes represent average v/c ratios from 0.2 to 1.0 (i.e., at capacity). The v/c ratio for the corridor is calculated based on the generated volume and capacity value, which is estimated using the average green times of all signalized intersections along the corridor. The Highway Capacity Manual Model procedure is used for the calculation of the v/c ratio. When considering a change in v/c ratio and fixing all other factors, as summarized in Figure 1, the following remarks can be made:

Figure 1. (a) Impact on Bus Travel Time

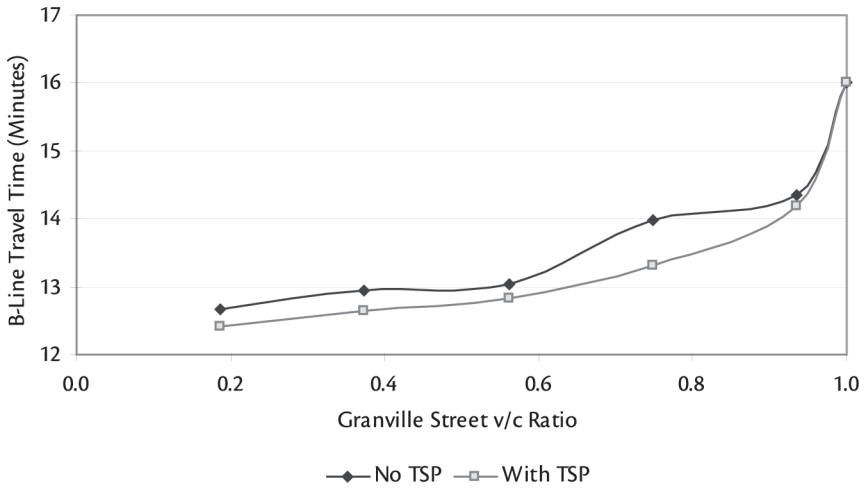
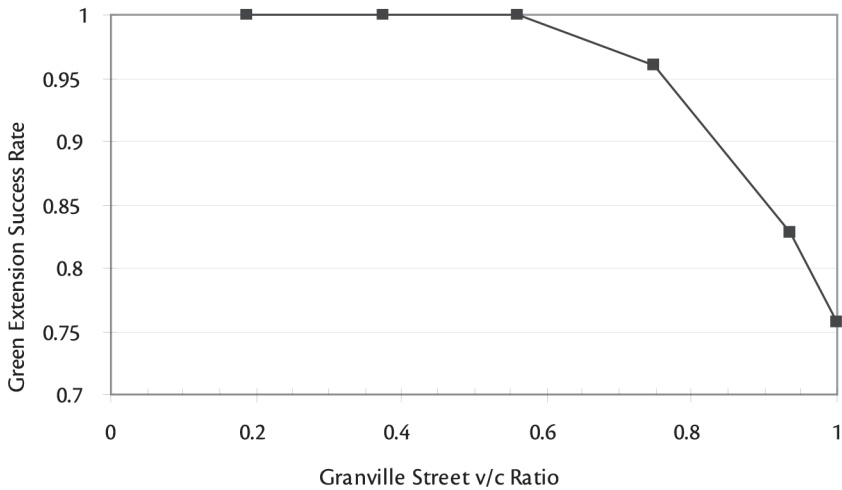


Figure 1. (b) Impact on Green Extension Success Rate



- TSP application would be most effective under moderate-to-heavy traffic condition. TSP's improvement on the B-Line bus performance decreases at low bus approach v/c ratios, at which the buses would not encounter too much traffic delay. The improvement also decreases as the traffic condition approaches capacity, because congestion would hinder bus movement.
- The green extension success rate would be reduced as bus approach volume increases. The reduction in green extension success rate could be attributed to an increasing traffic volume on Granville Street, which lengthens the time required by the buses to enter the intersection after checking in, making the buses less likely to clear the intersection during the green extension phase.

Cross Street Volume/Capacity Ratio (Approach-Level)

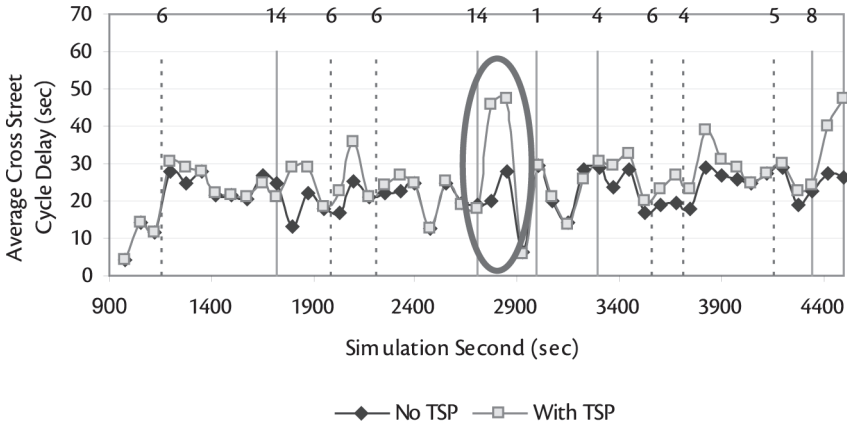
This experiment examines the impact of TSP on cross street delay for various cross street v/c ratios. The result shows that the impact of TSP on cross street performance is minimal at low cross street v/c ratios. Whereas, TSP has a moderate impact on cross street performance at cross streets with a v/c ratio above 0.8, it has a significant impact on cross street performance (i.e., causes high cross street delay and increases delay recovery cycles) at cross streets with v/c ratios above 0.9. Figure 2 shows the simulated cross street delay trends with and without TSP application under the approach v/c ratios of 0.8, 0.9, and 1.0. The v/c ratios are obtained using the procedure described in the previous section. The numerical value on top of each vertical line represents the duration of green extension (solid line) or red truncation (dotted line) conferred to the B-Line bus approach, which is the difference between the actual green time and the maximum green time of the fixed time signal phases. The circle identifies the maximum number of recovery cycles required for each cross street v/c ratio scenario.

Bus Headway (Corridor-Level)

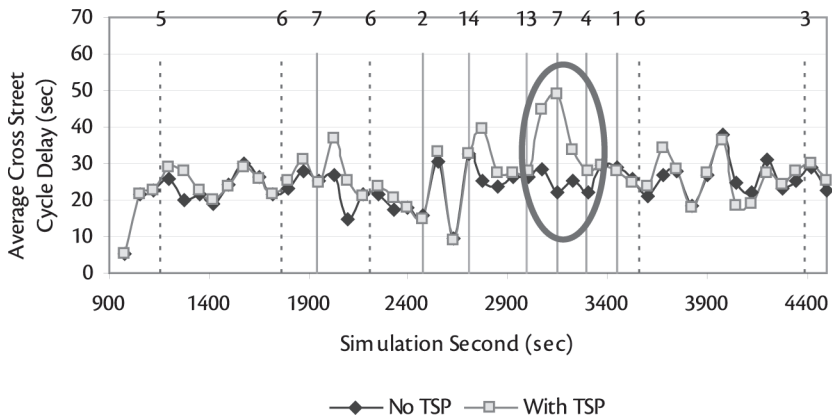
The B-Line bus travel time along the Granville Street corridor is also assessed under five headway scenarios, with and without the allowance of TSP calls in successive cycles. Figure 3 shows the improvement in bus travel time under different headways when TSP is implemented.

Based on the results of this analysis, 10 minutes is the optimal bus headway at which TSP brings the highest improvement (or reduction) in bus travel time. At headways greater than the optimal headway (i.e., > 10 minutes), fewer TSP requests limit the benefits of TSP on the B-Line bus performance. Whereas, at headways smaller than the optimal headway (i.e., < 10 minutes), the improvement of TSP on

Figure 2. Average Cross Street Cycle Delay (with and without TSP) at:
(a) v/c Ratio = 0.8



(b) v/c Ratio = 0.9



(c) v/c Ratio = 1.0

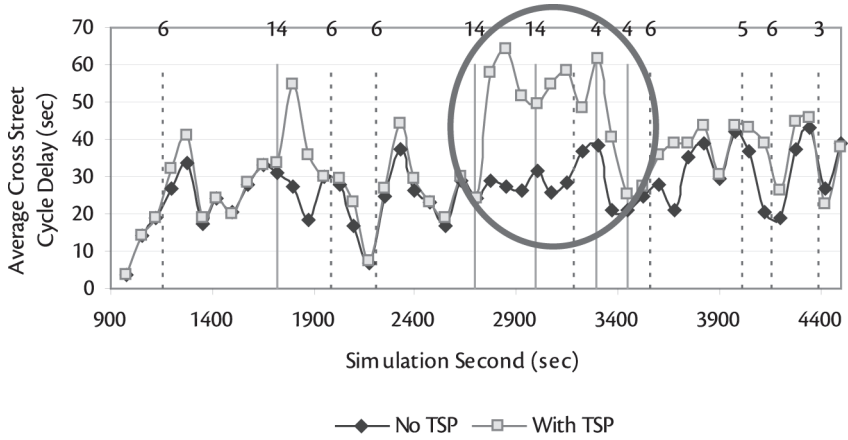
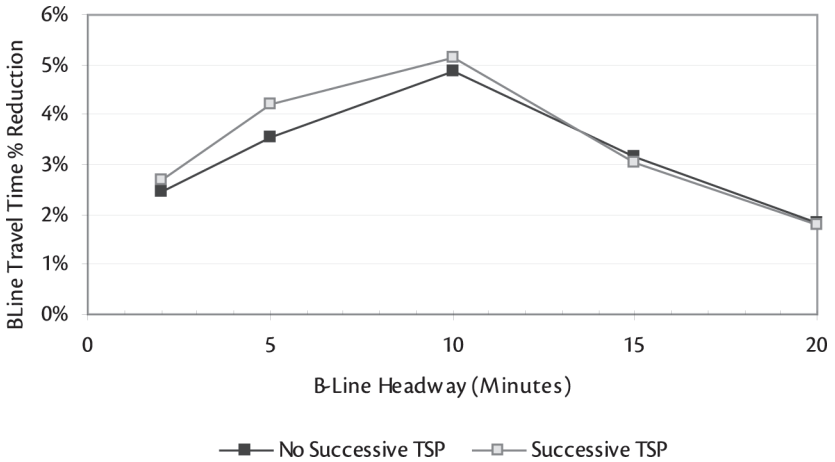


Figure 3. Bus Headway Impact (with TSP)



bus travel time is reduced, because a higher bus volume increases delay of the buses.

Results also show that allowance of TSP calls in successive cycles would bring a higher improvement in bus travel time at smaller headways, at which a higher number of TSP calls would be triggered in successive cycles. However, at B-Line bus headway of 2 minutes, the improvement decreases, because a higher bus volume would increase B-Line bus delay in the network.

Bus Stop Location (Approach-Level)

For this experiment, an “isolated-intersection model” is used because the B-Line bus performance on an approach is studied. The model assumes a 4-minute bus headway, allowance of TSP calls in successive cycles, and provision of TSP only to the northbound B-Line buses. Two bus stop scenarios are considered in this experiment:

- Farside Bus Stop Scenario: Stops are placed on the farside (or downstream) of a signalized intersection.
- Nearside Bus Stop Scenario: Stops are placed on the nearside (or upstream) of a signalized intersection.

The above bus stop location scenarios are examined under various Granville Street traffic volumes: 500, 1000, 1500, 2000, and 2500 Veh/hr/3-lanes, representing v/c ratios from 0.2 to 0.95. Figure 4 shows the comparison. The B-Line bus delay value expresses only the traffic delay of the buses, i.e., bus dwell time delay has been excluded.

Figure 4 illustrates that a nearside bus stop would cause a higher delay to the B-Line buses than a farside bus stop. This is because a significant portion of the green extension would be wasted while passengers board and alight at a nearside bus stop, thereby lowering the green extension success rate of the buses. This lengthens the bus waiting times at a signal and causes higher delays to the B-Line buses. This result is in agreement with the findings of Daniel (1997) and Huffman, et al. (1998) that a farside bus stop is more preferred when TSP is implemented. However, it should be noted that it is possible to address some of the nearside bus stop conditions for the implementation of TSP, such as placing the detector immediately downstream of the stop or using delay timers if dwell time at a bus stop is consistent.

Figure 4. Bus Stop Location Impact on Average Bus Delay (with TSP)

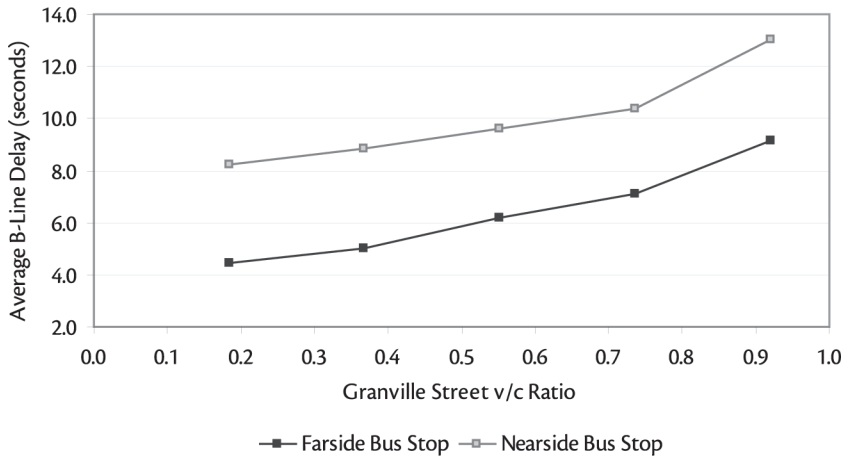
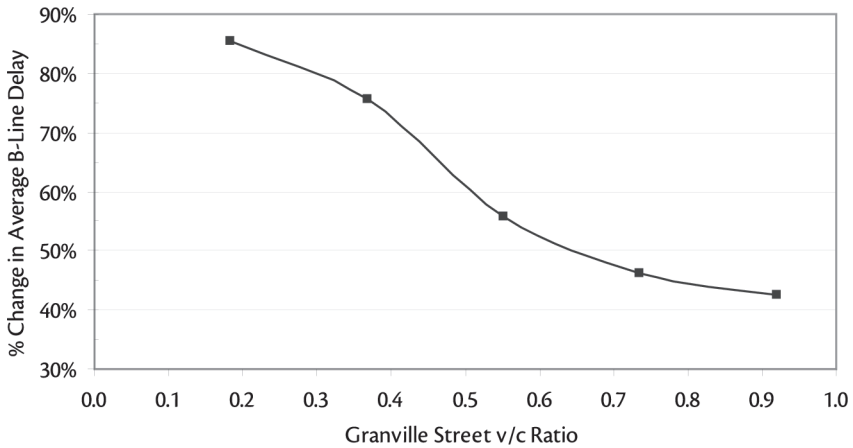


Figure 5 shows the percentage increase in the average B-Line bus delay under different Granville Street (or bus approach) v/c ratios when a bus stop is moved from the farside to the nearside of an intersection. In general, the bus delay would increase when a farside bus stop is converted to a nearside bus stop, and the deterioration in the bus delay would reduce as the bus approach v/c ratio increases. This is likely due to a higher influence on bus delay by traffic congestion than by bus stop location, when the bus approach v/c ratio increases.

Figure 5. Nearside Bus Stop Impact on TSP Effectiveness



Bus Detector Location (Approach-Level)

An “isolated-intersection model” is deployed for this experiment because only the B-Line bus approach delay is examined. For this experiment, seven B-Line bus check-in detector location scenarios are analyzed for a farside and a nearside bus stop, when TSP is implemented. Figure 6 shows the comparison. The bus delay value only expresses the traffic delay of the buses, i.e., dwell time delay has been excluded.

As discussed earlier, a farside bus stop would give a lower bus delay than a nearside bus stop. Additionally, the result shows that the bus delay is less sensitive to the check-in detector location when a nearside bus stop is placed. This is because the performance of the B-Line buses would be more influenced by dwell time at nearside bus stops than by the location at which the buses are detected. When a farside bus stop is used, the improvement of TSP on bus delay would increase when check-in detectors are placed further from the intersection stop bar. This is because placing the detector further from the intersection would allow the red truncation or green extension to start earlier. However, the check-in detector cannot be placed too far from the intersection because of greater uncertainty in bus travel time from the check-in detector to the intersection. It should also be noted that the optimal detector location might vary with different signal conditions (e.g., cycle length, maximum and minimum green times) and bus arrival pattern.

Figure 6. Comparison of Detector Location Impact on Average Bus Delay for Farside and Nearside Bus Stops (with TSP)

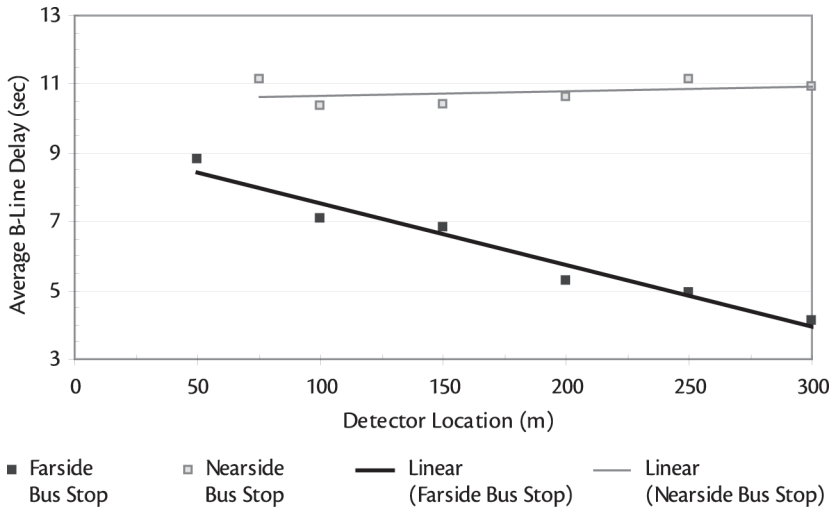


Table 1 compares the number of green extensions calls granted, the number of green extension failures (i.e., the number of B-Line buses that cannot check-out after the maximum green time elapsed), and the green extension success rates for various bus stop location and bus detector location scenarios. Results show that a higher number of green extensions are called when a nearside bus stop is used or when the check-in detectors are placed further from an intersection. Under these conditions, the B-Line buses require more time to enter the intersection after checking in; therefore, more B-Line buses would require a green extension to clear the intersection. In addition, the green extension success rate would decrease as the bus detector is placed further from the intersection, because this lengthens the time required for the bus to enter an intersection after checking in.

Table 1. Green Extension (GE) Effectiveness for Farside and Nearside Bus Stops

Detector Location	Total # of GE		# of GE Failure		GE Success Rate	
	Farside	Nearside	Farside	Nearside	Farside	Nearside
50 / 75 m	2	6	0	2	100%	61%
100 m	3	6	0	2	100%	61%
150 m	3	6	0	2	100%	61%
200 m	4	7	0	3	100%	52%
250 m	6	9	2	6	71%	37%
300 m	6	9	2	6	71%	37%

Left Turn Volume/ Lane/ Phase (Approach-Level)

The “isolated-intersection model” is used for this experiment. Effects of the left-turn traffic (in direction parallel to the through-traveling buses) on TSP effectiveness of through-traveling buses at a signalized intersection are studied. The opposing-through v/c ratio is set to different values to generate different dissipation conditions for left-turn traffic. The influence of left-turn volume on TSP effectiveness is compared under three left-turn conditions:

- i. Shared through-left-turn (TH-LT) lane with permissive left-turn phase
- ii. Exclusive left-turn (LT) lane with permissive left-turn phase
- iii. Exclusive left-turn (LT) lane with protected-permissive left-turn phase.

In this analysis, the scenario of no left-turn traffic is used as the benchmark condition because this scenario is expected to give the highest effectiveness of TSP. The TSP effectiveness of each left-turn scenario is measured by the change in bus approach delay relative to this benchmark left-turn volume (i.e., no left-turn).

The B-Line bus approach delay is examined under the three aforementioned left-turn conditions for left-turn (LT) volumes (in direction parallel to the through-traveling buses) of 25, 50, 100, 150, and 200 Veh/hr and opposing-through (Opp-TH) volume of 1,000 Veh/hr, 1,500 Veh/hr and 2,000 Veh/hr, representing v/c ratios of 0.37, 0.55 and 0.74, respectively. It should be noted that high left-turn volume and high opposing-through volume scenarios might not be realistic for a permissive left-turn phasing scheme, but are performed to illustrate the theoretical

trend of the change in B-Line bus delay and to compare results with other left-turn conditions.

Table 2 shows a comparison of bus approach delay results for various left-turn conditions, when TSP is implemented. The result shows that, without the use of a

Table 2. Left Turn Traffic Impact on Bus Average Approach Delay (with TSP)

Opp-TH Vol	LT Vol	Change in Average B-Line Bus Approach Delay (Seconds)		
		Permissive LT Phase, Shared LT-TH Lane	Permissive LT Phase, Exclusive LT Lane	Protected LT Phase, Exclusive LT Lane
1,000 <i>v/c=0.37</i>	0	0.0	0.0	0.0
	25	0.5	-0.3	-0.1
	50	0.9	-0.4	-0.2
	100	3.0	0.0	-0.4
	150	7.2	0.6	0.0
	200	32.3	2.0	0.4
1,500 <i>v/c=0.55</i>	0	0.0	0.0	0.0
	25	1.2	-0.1	-0.4
	50	2.2	-0.2	0.1
	100	25.2	2.3	-0.1
	150	63.2	22.2	-0.1
	200	83.9	49.8	-0.1
2,000 <i>v/c=0.74</i>	0	0.0	0.0	0.0
	25	1.2	0.0	0.2
	50	5.6	0.2	0.1
	100	54.4	11.1	0.0
	150	90.3	42.9	0.5
	200	103.2	58.7	0.0

Note:

- All changes are compared to the “No Left-Turn” scenario for their corresponding opposing-through volume and left turn condition.
- Bolded values represent scenarios that cause significant increase in B-Line bus approach delay.
- Italic values represent results that might have caused by some fluctuation in the VISSIM simulation from one scenario to another. The changes are assumed negligible when the absolute change is less than 1.0 second.

left-turn lane or a protected left-turn phase, a high left-turn volume would significantly increase the average delay of the buses when TSP is implemented. A high left-turn volume and queue would increase the traffic usage on the center and rightmost lanes, thereby increasing traffic hindrances to B-Line buses that run on the rightmost lane. Additionally, the v/c ratio of opposing-through volume would also significantly impact bus delay because the dissipation of left-turn traffic is controlled by the availability of an adequate gap of the opposing-through traffic. The result also demonstrates a need for a protected left-turn phase and an exclusive left-turn lane at an intersection with high left-turn and opposing-through volumes, in order to maintain the effectiveness of a TSP application.

Signal Coordination (Corridor-Level)

This experiment tests the signal coordination impact on the effectiveness of TSP. Default parameters and the NoTAC model are deployed to evaluate the Granville Street corridor performance. Two coordination scenarios are compared:

- Granville Street with Signal Coordination: To maintain coordination, the green time of the cross street approaches is shortened accordingly when a TSP call (i.e., green extension or red truncation) is granted. In addition, TSP calls are not responded for two successive cycles to reduce the adverse effect on cross street traffic.
- Granville Street without Signal Coordination: No signal coordination is maintained along the Granville Street corridor (NTCIP 1211 standard violated). The cycle length at an intersection could fluctuate with the length of a green extension or red truncation; and the length of the cross street green time could be maintained after a green extension is conferred. For this scenario, TSP calls do not respond for successive cycles, because the cross street green time is not shortened after a TSP call.

The TSP effectiveness is expressed as the change in traffic delay in the “with coordination” scenario, the benchmark condition. The evaluations are performed at a corridor-level and are disaggregated by the following categories: the entire corridor (i.e., major and cross streets traffic combined), major traffic approaches, cross street approaches, and individual major traffic approach. Table 3 shows that removing signal coordination from Granville Street would increase the entire corridor delay, which is attributed to an increase in the major traffic delay on Granville Street. Meanwhile, removing the coordination would result in minimal improvement in the cross street total delay, because green time for the cross street approaches is allowed to be maintained after a TSP call. These results suggest that, for

the objective of maximizing TSP improvement in the total delay of the entire corridor, TSP would be more effective when applied with signal coordination. This result agrees with Daniel's (1997) proposal that providing priority for transit vehicles in a non-coordinated network would increase the overall delay of vehicles in the network.

Table 3. Signal Coordination Impact on TSP Effectiveness

Total Delay (Seconds)	Delay with coordination *	Delay with No Coordination *	Delay Change **	Delay Change (%) **
Entire Corridor	8458	8607	+149	+2%
Major traffic (vehicle)	6216	6341	+125	+2%
Cross Street traffic	2260	2250	-10	-0%
Northbound Only				
Northbound B-Line Buses	209	223	14	6%
Northbound All Traffic	3820	4460	640	17%
Southbound Only				
Southbound B-Line Buses	299	299	-0	0%
Southbound All Traffic	2396	1899	-497	-21%

* The delay values are of scenarios with the implementation of TSP.

** The change or percentage change in delay is with respect to the "with coordination" scenario, which is the actual scenario on the Granville Street corridor.

The result also shows that removing signal coordination from Granville Street would worsen the delay of the northbound general traffic and the northbound B-Line buses, which the default signal coordination heavily favors. On the other hand, removing coordination along Granville Street is observed to bring about minimal improvement to the southbound B-Line buses and significant improvement to the southbound general traffic, which the original signal coordination does not favor.

It should be noted that during the period studied (i.e., AM peak), northbound volume was almost double the southbound volume. Therefore, it would not be acceptable to deteriorate northbound traffic performance for the benefit of southbound traffic. As a result, coordination should be maintained with TSP application for the benefit of the majority of traffic on Granville Street.

Conclusion

Based on the results of the analyses in this research, the following general recommendations can be made:

1. TSP application would be most effective under moderate-to-heavy bus approach traffic condition.
2. The allowance of TSP should be carefully considered at cross street with high v/c ratio.
3. Left-turn volume (in the direction parallel to the through-traveling TSP-eligible buses) and its associated queue could impact the effectiveness of TSP. For the highest effectiveness of TSP, exclusive left-turn lane and protected left-turn phase for the left-turn traffic should be considered when applying TSP at signalized intersection with heavy left-turn and opposing-through volumes.
4. TSP is more sensitive to the location of check-in detectors when a farside bus stop is placed than when a nearside bus stop is placed.
5. Placing the bus check-in detector further from the intersection to a certain limit (i.e., within the clearance distance for the maximum green extension interval) could improve B-Line bus performance and maintain the effectiveness of green extension.
6. For the best performance of the entire corridor, coordination should be maintained when implementing TSP.

Based on the results of the analyses in this research, the following recommendations are specific to the TSP application of the 98 B-Line buses on Granville Street:

1. TSP application would be most effective at Granville Street v/c ratios between 0.6 and 0.9.
2. 10 minutes would be the optimal bus headway that brings about the highest effectiveness of TSP in improving the bus travel times.
3. TSP could have significant adverse impacts on cross street traffic at cross street v/c ratios above 0.9.

Acknowledgements

This research was funded by the National Sciences and Engineering Research Council of Canada (NSERC) and the Department of Civil Engineering at the University of British Columbia. Much of the data of this research were obtained from the City of Vancouver and IBI Group.

References

- Agrawal, B. B., S. T. Waller, and A. Ziliaskopoulos. 2002. *A modeling approach for transit signal preemption*. Paper presented at the 81st Annual Meeting of the Transportation Research Board.
- Balke, K. N., C. L. Dudek, and T. Urbanik, II. 2000. *Development and evaluation of intelligent bus priority concept*. *Transportation Research Record* 1727: 12-19.
- Chatila, H. F., and M. J. Swenson. 2001. *Transit signal priority along State Route 522*. Paper presented at the ITE Quad Conference, Vancouver, B.C..
- Daniel, J. 1997. *Bus signal priority along congested corridors*. *Proceedings of the ASCE conference on Traffic Congestion and Traffic Safety in the 21st Century*.
- Duerr, P. A. 2000. *Dynamic right-of-way for transit vehicles: An integrated modeling approach for optimizing signal control on mixed traffic arterials*. Paper presented at the 79th Annual Meeting of the Transportation Research Board.
- Garrow, M., and R. Machemehl. 1998. *Development and evaluation of transit signal priority strategies*. Paper presented at the 77th Annual Meeting of the Transportation Research Board.
- Huffman, B., J. Paquet, J. Weesner, and M. Pitstick. 1998. *Signal priority demonstration in suburban Chicago*. *Proceedings of the APTA 1998 Bus Operations, Technology and Management Conference*.
- Khasnabis, S., and R. K. Rudraraju. 1997. *Optimum bus headway for preemption: A simulation approach*. *Transportation Research Record* 1603: 128-136.
- PTV Simulation – VISSIM. 2002. www.english.ptv.de/cgi-bin/produkte/vissim.pl
- Skabardonis, A. 2000. *Control strategies for transit priority*. Paper presented at the 79th Annual Meeting of the Transportation Research Board.

About the Authors

VIKKI NGAN (vikki@telus.net) is a junior transportation engineer at the Vancouver office of IBI Group. She obtained her B.A.Sc. in civil engineering and a M.A.Sc. from the University of British Columbia. Ms. Ngan has particular interest in intelligent transportation systems, rapid transit, and transit priority systems.

TAREK SAYED (*tsayed@civil.ubc.ca*) is a professor in the department of civil engineering at the University of British Columbia. He obtained his B.Sc. in civil engineering from Ain Shams University in Egypt, and his M.A.Sc. and Ph.D. from the University of British Columbia. He teaches graduate and undergraduate courses in traffic engineering and safety. Dr. Sayed's research interests include several areas in transportation engineering, traffic operations and safety, intelligent transportation systems, and economic analysis of transportation projects. He was recently appointed as a distinguished university scholar.

AKMAL ABDELFAH (*akmal@aus.ac.ae*) is an assistant professor in the school of engineering at the American University of Sharjah in the United Arab Emirates.

The Crisis of Public Transport in India: Overwhelming Needs but Limited Resources

*John Pucher and Nisha Korattyswaroopam, Rutgers University
Neenu Ittyerah, Indian Railways, Chennai, India*

Abstract

The rapid growth of India's urban population has put enormous strains on all transport systems. Burgeoning travel demand far exceeds the limited supply of transport infrastructure and services. Public transport, in particular, has been completely overwhelmed. Most bus and train services are overcrowded, undependable, slow, inconvenient, uncoordinated, and dangerous. Moreover, the public ownership and operation of most public transport services has greatly reduced productivity and inflated costs. India's cities desperately need improved and expanded public transport service. Unfortunately, meager government financial assistance and the complete lack of any supportive policies, such as traffic priority for buses, place public transport in an almost impossible situation.

Introduction

Public transport faces severe problems in almost all countries of the developing world, although the situation varies from one country to another, and even from one city to another (Vasconcellos 2001). Perhaps most important, the lack of financial resources prevents necessary investments in maintaining and upgrading

existing bus and rail systems and building new ones. Likewise, many advanced technologies long available in Western Europe are simply not affordable in most developing countries. Public transport systems in the Third World are plagued by chronic corruption and inefficiency, overcrowded and undependable service, congested roadways that slow down buses, and an operating environment that is often chaotic and completely uncoordinated.

Those problems of public transport occur within the broader context of daunting urban transport problems in general. Air pollution, noise, congestion, and traffic fatality levels are often much more severe than those of developed countries. One might expect the much lower incomes in developing countries to assure a huge potential market of public transport riders. In fact, many city residents are so poor that they cannot afford even low fares, and routes are not designed to serve the poor at any rate. Thus, the poor in developing countries suffer even more than those in the Western World from low levels of mobility and accessibility, especially to jobs.

In many respects, the situation in India is typical of other developing countries. The most important commonality is India's low per-capita income—only US \$2,540 in 2002, less than a tenth of the average incomes of countries in North America and Western Europe (Central Intelligence Agency 2002). With 23 percent of its urban population living in poverty, India has been forced to keep its public transport fares extremely low. That has sharply restricted the operating revenues of all public transport systems, making it difficult to afford even routine maintenance and vehicle replacement, let alone system modernization and expansion.

Poverty is not only a problem at the individual level, but also in the public sector, with cities and transport systems desperately lacking the necessary financial resources for investment in infrastructure, vehicles, new technologies, and fare subsidies. The financial problems stemming from India's low per-capita income are probably the most important challenges facing Indian public transport, but there are many others as well: inefficiency, roadway congestion, traffic accidents, lack of planning, overcrowding, noise, and total lack of coordination of any kind.

Trends in Population and Land Use

The rapid growth of India's urban population—as in other developing countries³⁴—has generated an enormous need for efficient public transport services to carry high volumes of passengers through dense, congested urban areas. By 2001 over 285

million Indians lived in cities, more than in all North American cities combined (Office of the Registrar General of India 2001). There has been especially rapid growth of the very largest metropolitan areas such as Mumbai (Bombay), Kolkata (Calcutta), and Delhi, which now exceed 10 million residents each. Chennai (Madras), Hyderabad, Ahmedabad, and Bangalore each have more than 5 million residents. And 35 metropolitan areas have populations exceeding 1 million, almost twice as many as in 1991. Since large cities are far more dependent on public transport than small cities, the need for public transport services has increased faster than overall population growth.

Moreover, the lack of effective planning and land-use controls has resulted in rampant sprawled development extending rapidly in all directions, far beyond old city boundaries into the distant countryside. That also has greatly increased the number and length of trips for most Indians, including those by public transport.

Most public policies in India actually encourage sprawl. In an explicit attempt to decongest city centers, government regulations limit the ratio of floor areas to land areas for buildings in the center, and thus restrict the heights of buildings and density of development in the center. For example, the so-called “floor space index” in sampled city centers in India was only 1.6, compared to indices ranging from 5 to 15 in other Asian city centers (Bertaud 2002; Padam and Singh 2001). By contrast, government regulations permit higher floor space/land area ratios in suburban developments, yet more inducement for firms to decentralize. Indeed, local governments even advertise the less stringent regulations in the suburbs to promote more development there. Such land-use policies obviously discourage development in the center and force both firms and residences to seek locations on the suburban fringe. Moreover, local governments have permitted scattered commercial and residential development in outlying areas without the necessary infrastructure such as roads, utilities, hospitals, shopping, and schools. That generates long trips between residences and almost all other trip destinations.

Just as in North America, most new commercial development is in the distant suburbs. For example, Tidal Park is a software center on the outskirts of Chennai; Gurgaon is a large new industrial area outside Delhi; and Pimpri-Chinchwad is a similar center outside of Pune (Bertaud 2002). Similarly, Bangalore is planning several technology parks on its fringe as well as several circumferential highways in the suburbs, both of which will induce further decentralization. In most cases, there is inadequate infrastructure to serve these new suburban developments and the residences locating around them. Ramachandran (1989) characterizes Indian sub-

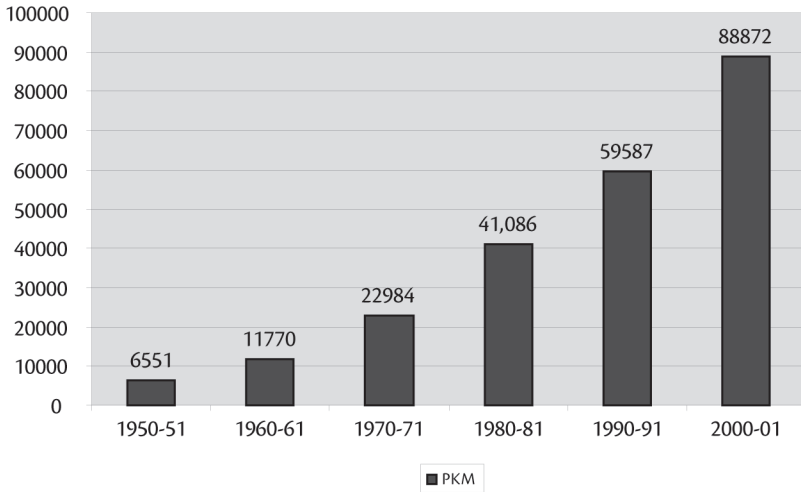
urbs as an “uncontrolled mix of industrial development, dumps and obnoxious uses,” with the “extension of urban settlement causing conditions in the overtaken villages to deteriorate, both physically and socially.” The leap-frog development typical of suburban sprawl tends to follow major highways out of Indian cities to the distance countryside.

There are important consequences of such low-density, sprawled decentralization for public transport. Just as in North America and Europe, it generates trips that are less focused in well-traveled corridors and thus more difficult for public transport to serve. In India, it has led to rapid growth in car and motorcycle ownership and use and thus increasingly congested roadways that slow down buses, increase bus operating costs, and further discourage public transport use.

Trends in Public Transport

The best statistics for public transport in India are for suburban rail, because it is centrally owned and operated by Indian Railways. As shown in Figure 1, suburban rail usage has sharply increased over the past five decades, with a 14-fold growth in passenger km of travel (Indian Railways 2001). There are no comprehensive national statistics on bus service supply, let alone the number of riders, but the fragmented statistics for individual cities suggest substantial growth. For example, in the 10 years from 1990 to 2000, there was an 86 percent increase in the size of Mumbai’s bus fleet, and a 54 percent increase in Chennai’s bus fleet. While the size of Delhi’s public bus fleet actually fell, the number of private buses rose by almost twice as much, yielding a net 28 percent increase (Association of State Road Transport Undertakings 2002).

**Figure 1. Growth in Suburban Rail Travel in Indian Cities
1951 to 2001 (in millions of passenger km)**



Source: Indian Railways 2002

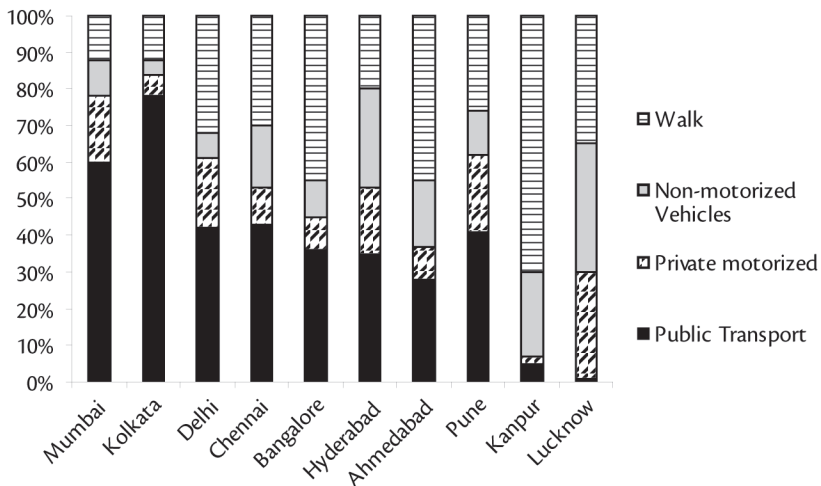
Buses carry more than 90 percent of public transport in Indian cities. Indeed, most Indian cities have no rail transport at all and rely instead on a combination of buses, minivans, auto rickshaws, cycle rickshaws, and taxis. Even in most of the largest cities, rail transport carries less than a third of public transport passengers. The only exception is Mumbai, which has India's most extensive suburban rail network, carrying more than 5 million passengers a day³48 percent of total public transport passengers in the region (v. 42% by bus) and 80 percent of total passenger km (v. 20% by bus) (Brihanmumbai Electric Supply and Transport 2003; Indian Railways 2002).

In general, the larger the city size, the higher the percentage of urban trips served by public transport in India: 30 percent in cities with population between 1 and 2 million, 42 percent for cities with populations between 2 and 5 million, and 63 percent for cities with populations over 5 million (Sreedharan 2003). Thus, the especially rapid growth of large cities suggests a further rise in future demands for public transport in India.

As shown by Figure 2, however, there is substantial variation among cities of the same size category. Almost 80 percent of all trips in Kolkata are by some form of

public transport, compared to about 60 percent in Mumbai, and 42 percent in both Chennai and Delhi. Differences in land use and roadway supply explain some of the variation. Delhi and Chennai are lower density, more polycentric, and more spread out than Mumbai and Kolkata. Delhi also has a particularly extensive roadway network, while the supply of roadways in other large Indian cities is much more limited. For example, 21 percent of Delhi's total land area is devoted to roads, compared to only 11 percent in Mumbai and 5 percent in Kolkata. Mumbai and Kolkata also have more restricted geographies, since both are situated on peninsulas that channel travel and land-use development in only a few directions. Such focused travel corridors especially encourage suburban rail use, as in Mumbai. Delhi has no such geographic restrictions and sprawls out in all directions. Thus, Delhi currently relies primarily on auto rickshaws, motorcycles, taxis, and private cars to serve the multidestination, less focused travel patterns of its residents.

Figure 2. Percent Distribution of Urban Trips by Means of Travel for Selected Indian Cities, 2002



Sources: Pendakur 2002 and World Bank 2002

The range of public transport services available also varies considerably, even among the largest categories of cities. Only Mumbai, Kolkata, and Chennai have extensive suburban rail services. Delhi has limited suburban rail services. Until recently, Kolkata had India's only underground metro system (16.5 route km), but Delhi is currently constructing a far more extensive metro (62.5 route km) (Delhi Metro Rail Corporation 2003a). Chennai has a hybrid surface and elevated metro, designated as Mass Rapid Transport System, which currently extends 8.6 km and is being expanded by another 11.2 km (Southern Railway 2003). Finally, Kolkata has India's only remaining tram system, a 68-km double-track network of old, seriously deteriorating tracks and vehicles.

As noted previously, buses account for most public transport services, even in these large cities, and for virtually all public transport services in cities with less than 5 million residents. Moreover, all Indian cities feature large numbers of auto rickshaws (3-wheeled motorized, minicars), taxis, and cycle rickshaws (human-powered carts).

Problems and Challenges

The sharply rising demands for public transport have overwhelmed the existing public transport systems in India. Trains and buses in most cities are dangerously overcrowded. On suburban rail lines in Mumbai, peak-hour trains must carry more than twice their maximum design capacity, leading to inhuman traveling conditions, with so-called "super dense crush loads" of 14 to 16 standing passengers per square meter of floor space (Varshneya, Jain, and Sahai 2002; Ministry of Railways 2002)! On peak-hour trains, many passengers are forced to hang out doors and windows or to ride between train cars or even hang on the outsides of cars. Suburban trains and stations seem hopelessly overcrowded and desperately need expanded capacity.

Buses in Indian cities are doubly disadvantaged by congested conditions. Buses themselves are seriously overcrowded, with some passengers forced to ride on the outsides of vehicles. In addition, however, buses must negotiate extremely congested, narrow streets, with no separate rights-of-way at all, having to fight with a mixed array of animal-drawn carts, minivans, cars, taxis, motorized two-wheelers, auto rickshaws, pedestrians, cyclists, and street vendors. Severe roadway congestion has slowed down most buses to a crawl during much of the day—as slow as 6 to 10 km per hour in many large cities (Gakenheimer and Zegras 2003).

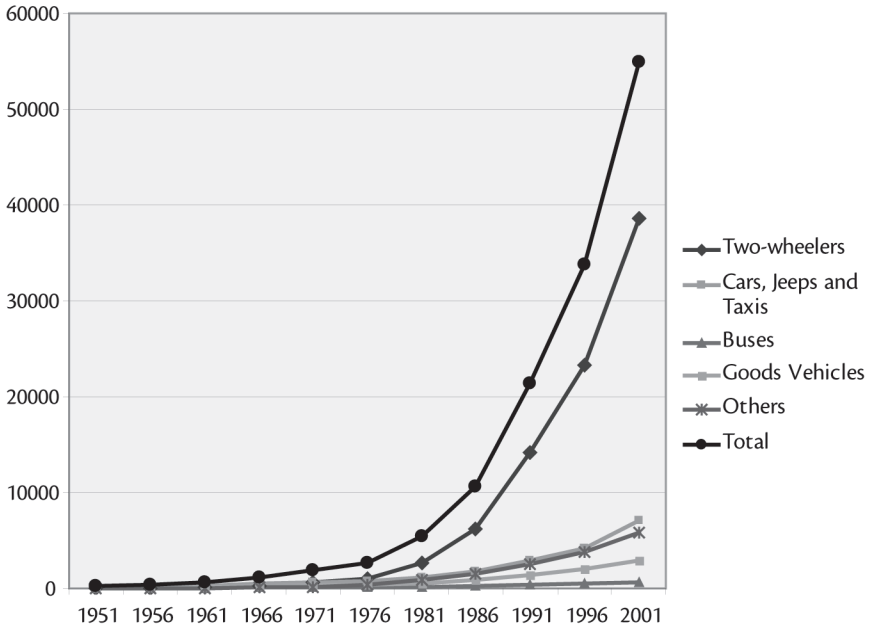
These congested conditions in public transport vehicles, stations, and rights-of-way not only slow down travel but make it outright dangerous. Tens of thousands of public transport passengers are killed or injured every year in accidents. Many buses and trams do not even have doors and windows that can be closed, and that only encourages passengers to ride by protruding from inside the vehicle or by hanging on from outside. Clearly, riding on the roofs or sides of buses and trains is inherently unsafe and results directly from the severe undercapacity of public transport systems in India. Slow, uncomfortable, undependable, and unsafe conditions in the early 1990s led to riots of passengers protesting these inhumane conditions, forcing some of the service expansion efforts described later in this article (Acharya 2000).

One consequence of insufficient service quantity and terrible service quality is that public transport has been losing market share in many cities. Dissatisfied public transport passengers are increasingly turning to the private car, and even more dramatically, to the relatively low-cost motorized two-wheelers, which have experienced a boom in ownership and use in the past 10 years. As shown in Figure 3, the total number of private cars and motorized two-wheelers increased roughly four times faster than the number of buses over recent decades (World Bank 2002; Ministry of Road Transport and Highways 2003). For much of the Indian middle class, the motorcycle offers an affordable, far more flexible, convenient, faster, and more dependable way of getting around than public transport. For affluent Indians, the private car offers an even higher level of comfort and greater prestige, although it is more likely than two-wheelers to be slowed down by roadway congestion.

The deteriorating quality of public transport service reinforces the impact of the rapid decentralization of Indian cities. Both trends encourage a shift away from space-saving public transport toward individual motorized transport. That has greatly increased roadway congestion, further reduced travel speeds, and aggravated traffic safety problems. Perhaps because of its separate rights-of-way and thus higher speeds, suburban rail continues to experience strong growth in passenger levels, in spite of crowded vehicles and stations and undependable service. By comparison, bus systems in some cities have suffered losses of passengers in recent years, as their overcrowded buses get bogged down in slower and slower traffic.

Another crucial problem of Indian transport is inefficiency, lack of productivity, overstaffing, excessively high operating costs, and large subsidy needs. Especially

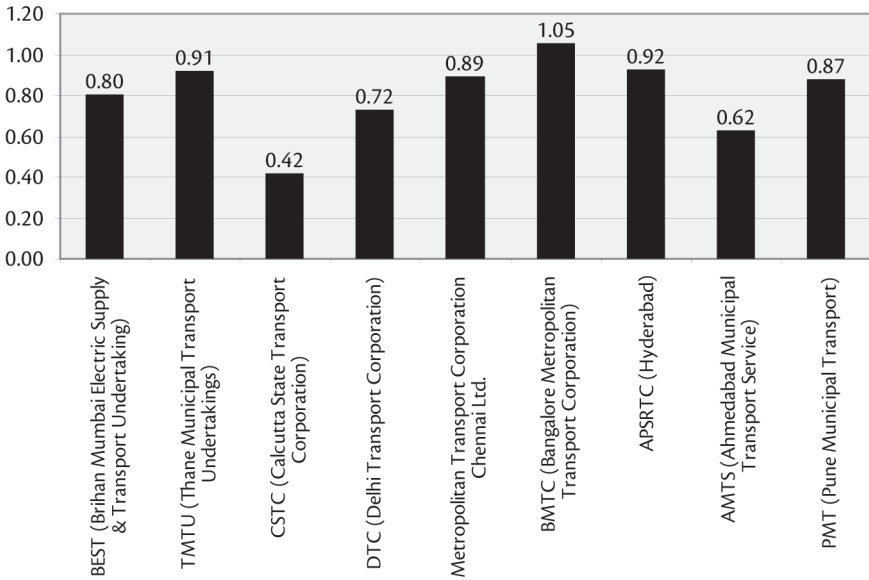
Figure 3. Growth of India's Motor Vehicle Fleet by Type of Vehicle 1950-2001 (in thousands of vehicles)



Source: Ministry of Road Transport and Highways 2003

since the mid-1990s, operating deficits have been rising rapidly. For bus systems in the largest cities, the combined operating deficit quadrupled (Association of State Road Transport 2002b), and for Indian Railways, the annual operating deficit tripled. As shown in Figure 4, most publicly owned bus systems in large cities generally cover about 70 to 90 percent of operating costs, much higher than large public transport systems in Western Europe. The most unprofitable bus system is in Kolkata, which covers only 42 percent of costs through passenger fares, while Delhi (72%) and Mumbai (80%) cover about three-fourths of costs. At the high end of the scale, Bangalore (105%) is actually profitable, and Hyderabad (92%) almost breaks even. It is notable that both of the publicly owned bus firms in Bangalore and Hyderabad contract many of their services to privately operated companies, which probably explains the better economic performance.

Figure 4. Proportion of Operating Expenses Covered by Passenger Revenues for Selected Cities in India, 2000–2001



Source: Association of State Road Transport Undertakings 2002

Clearly, much could be done to improve the efficiency of both bus and rail operations, most of which are publicly owned, operated, and regulated. There are many institutional obstacles to any fundamental changes, including powerful labor unions representing employees, which have blocked changes that would disadvantage them.

Privatization

One possible solution to many of these problems might be the selective privatization of India's public transport sector. That could be done either through opening up the market to private firms (who would own, manage, operate and finance their own systems) or by having public agencies contract with private firms to operate services on a systemwide basis, for selective routes, or for selected functions (like maintenance). Rail systems have only rarely been privatized anywhere in the world (except for certain narrow functions), while there is considerable experience with

bus privatization. Thus, privatization seems an option only for bus services, but they account for more than 90 percent of India's public transport.

Privatization of public transport in India was strongly encouraged by the World Bank (2002), which accused publicly owned and operated systems of being inefficient and highly unprofitable, providing insufficient and low-quality services, and failing to respond to market demands. Although there were some minor attempts at privatization in the 1980s, the first large-scale privatization of buses occurred in Delhi in 1992, when numerous small, private bus firms entered the market. Unfortunately, the new private operators were not adequately regulated and coordinated, leading to complete chaos. The new private services tortured passengers with lengthy, zig-zag routes, long waiting times, completely unreliable service, extreme overcrowding, unqualified drivers, speeding and reckless driving, fights among competing buses, and even running down passengers waiting at bus stops. Moreover, the private buses were often poorly maintained, unsafe, noisy, and highly polluting, adding to the already severe congestion, safety, and air pollution problems in Delhi.

In the years since 1992, regulations have been strengthened and better enforced. Moreover, the many private bus operators are now much better coordinated than at the outset. Service quality problems still remain, but privatization appears to have brought some substantial economic benefits. In a comparison of public and private bus operators in Delhi, the World Bank found that private bus firms carried twice as many passengers per bus per day (1,584 v. 751), earned twice as much revenue per bus per day (2,700 v. 1,321 Rupees), required less than half the staffing per bus (4.6 v. 9.6 employees), cost less than half as much per bus km (7.7 v. 17.2 Rupees), and actually made a profit (3.2 Rupees per bus km) while the public bus firms ran a loss (11.0 Rupees loss per bus km) (Marwah, Sibal, and Sawant 2001).

These financial comparisons between public and private buses are somewhat exaggerated, since private firms can usually select profitable routes, while public firms are often required to provide unprofitable services on lightly used routes to achieve social objectives and ensure comprehensive coverage to the entire city. Moreover, private bus companies offer their employees much lower wages, less job security, and less generous fringe benefits such as pensions and health insurance. Thus, to some extent, the private bus firms have lower costs due to lower salaries for their workers.

Kolkata currently has a large number of privately operated buses as well (about 1,800 private v. 1,200 public), and as in Delhi, they have fewer employees per bus, lower costs, and much higher cost coverage through fare revenues than the publicly operated buses. Privatization in Bangalore and Hyderabad has so far been limited to the contracting out of certain routes to private operators, but still with the overall coordination of a public agency.

It appears that privatization does indeed have much potential to improve efficiency, but that it must be accompanied by strict regulations, performance standards, and overall coordination to ensure an integrated network of services. In light of the transport funding crisis in Indian cities, they may have little choice but to seek the cost savings possible with privatization and increased competition.

Funding

Since passenger revenues do not cover the full costs of operation and capital investment of public transport, government financial assistance is obviously crucial. As owner of Indian Railways, the Central Government must bear whatever operating deficit remains after the substantial cross-subsidies from profitable freight services. In the past, the Central Government also bore most of the costs of capital investment, but in recent years, state governments have financed growing portions of these costs, especially for the expansions and improvements of suburban rail systems in Mumbai, Chennai, Kolkata, and Hyderabad (Ministry of Railways 2002). To encourage more state contributions, Indian Railways now gives priority to projects with up to two-thirds state government funding.

Funding for new and expanded metro rail systems comes from the Central Government as well as state and local governments, but there is no exact formula, and the distribution of contributions varies from case to case. The World Bank, the Japanese Bank for International Cooperation (JBIC), and other international lending agencies have also provided loans for large infrastructure projects. For example, a JBIC loan is funding two-thirds of the capital cost of building the Delhi Metro (Delhi Metro Rail 2003b). Rail system operating deficits, however, are primarily borne by local governments.

Most bus services are still publicly owned and operated by STUs (State Transport Undertakings), whose operating and capital investment costs are covered by a combination of state and local government subsidies, grants, and loans that vary from state to state.

Significantly, no government level has any dedicated taxes whose proceeds would be automatically earmarked for public transport. Thus, financial support for public transport is tenuous, depending on annual budgetary appropriations. With critical shortages of revenues at every government level, public transport must compete each year with many other urgent needs for public funds. The willingness of the Central and state governments to fund public transport can vary substantially over time, making long-term planning very difficult.

Recent and Planned Improvements

In spite of severe shortages of both public and private financing for improving public transport, several Indian cities have been trying to provide more and better services to meet burgeoning travel demands. The most extensive improvements are in Mumbai. For example, Indian Railways has already opened two new suburban rail lines and has plans for additional extensions. Several existing lines have been vastly improved by constructing additional tracks (from one to two tracks and from two to four tracks) to permit separation of local and express trains. Moreover, cars have been added to trains, average speeds have increased, and frequency of service has also risen—measures aimed at mitigating the overcrowding problem. By relocating more than 6,000 illegal slum dwellings that encroached on land directly adjacent to railway tracks, Indian Railways increased service dependability, speed, and safety (Mumbai Metropolitan Region Development Authority 2003).

An especially innovative initiative is the planned Sky Bus system, which will feature several lines of express buses on elevated guideways. The initial phase, which extends 8.3 km, scheduled for completion by 2006, should help to relieve the most congested suburban rail and bus routes in the same corridors (Konkan Railway Corporation Ltd. 1999). Finally, the main bus operator in Mumbai (BEST) has already introduced smart cards for fare collection on some premium bus services and also plans to introduce low-floor buses to facilitate travel by passengers with disabilities (Brihanmumbai Electric Supply and Transport 2003).

Delhi has been innovative on at least three different fronts. It has been constructing a new metro system with three lines, but only a small section is currently in service. When completed, it will have 12.5 km of underground lines and 50 km of surface or elevated lines. By the year 2005, the Delhi Metro is expected to carry more than two million passengers a day (Delhi Metro Rail Corporation 2003c). Delhi has also been at the forefront of innovations in bus services, both by requir-

ing a complete switchover to nonpolluting CNG buses and by introducing privatization and increased competition among bus firms to reduce costs. As noted earlier, both of those policy changes caused enormous disruptions in service for several transitional years, but the overall result has been positive.

Kolkata is currently extending its existing 16.5 km underground metro by another 8.5 km (Metro Railway Kolkata 2003)

Chennai completed the first phase of its Mass Rapid Transit System in 1997, which includes 6 km of elevated track and 2.6 km of surface track. Currently, the system is being extended by another 11.1 km, with at least 40km of future expansions planned (Southern Railway 2003). The initial phase was disappointing because it was not well coordinated with bus and suburban rail services, but those problems are currently being handled through significant improvements in parking and better connections to bus and suburban rail. Connections are also being improved between three of the suburban rail lines in Chennai, with physical links now possible thanks to gauge conversions for compatibility. Finally, Chennai has plans to introduce privatized, competitive bus services on roughly half its bus routes, following the example of Delhi and the recommendations of the World Bank.

Bangalore had planned a new light rail system, but it has been indefinitely postponed due to a shortage of funds. Instead, a less expensive system of grade-separated busways and high-capacity articulate buses is being considered (Gaur 2002).

The suburban rail services in Hyderabad are being expanded and improved, with a special focus on upgrading station areas and enhancing safety. In addition, transfers between bus and rail services are being facilitated by better coordination between the city bus services and Indian Railways.

Recommended Policy Shifts

Given the rapid growth of India's largest cities and the desperate need for better and expanded public transport, it is crucial that policies change to improve the entire range of public transport services offered. Unfortunately, the Indian government has been emphasizing instead the need to further develop the nascent automobile industry in India and has actually encouraged more private car ownership and use. Indian cities are simply not equipped to handle increased volumes of private vehicle use. Roadways are already hopelessly congested, with average speeds declining each year. Even for automobile users, it will be important to improve

public transport, if only to remove some traffic from the streets and thus reduce congestion to manageable levels and increase travel speeds.

Clearly, public transport must be given priority attention to avoid further deterioration of air quality, traffic safety, congestion, and noise in Indian cities. While some improvements can be made even with existing funding levels, most would require massive infusions of new funding for expanded and modernized bus and rail systems. Equally important, state and local governments must give traffic priority to buses, both through special bus lanes and signal priority over private transport.

With more than 90 percent of public transport passengers in Indian cities relying on buses, it is especially important to upgrade bus services through modern, safe vehicles and priority on the congested roadways. The heavy, high-floor buses currently in service in most cities are noisy, polluting, fuel-inefficient, and unsafe. They are built on truck chassis with such high floors that boarding is slow and difficult. Moreover, they have slow acceleration as well as poor fuel economy due to their weight, and are inappropriate to urban use. Many buses do not even have closable windows and doors to protect passengers from the weather and from falling out of the vehicle. It is essential to replace these outdated buses with modern, safe, clean, and fuel-efficient vehicles.

Improving and expanding rail systems is also crucial, since they are insulated from the congestion delays caused by roadway traffic. Unfortunately, they are usually very expensive, and it is not realistic to expect that even most large Indian cities will be able to afford new rail systems. Moreover, for medium and small cities, where public transport services are either nonexistent or very infrequent, as well as slow and crowded, improved bus service is the only feasible option. Private vehicles have a much higher share of total trips in small and medium-sized cities precisely because the bus services there are so inadequate.

Within the current funding limits, it would still be possible to vastly improve the transfer connections between rail and bus lines, as well as to introduce integrated ticketing for all public transport modes. In addition, the privatization and increased competition among bus services already implemented in Delhi and a few other cities might be adopted more widely, as it would increase efficiency and reduce costs. That would, however, have to be accompanied by strict regulation and enforcement of safety and pollution standards combined with overall regionwide coordination of all public transport services. It was the failure to regulate and coor-

dinate the new private bus operators in Delhi that led to the serious problems of unsafe, overcrowded, unpredictable, and uncoordinated private buses.

The main problem in Indian cities, however, is financial. To some extent, operating revenues of public transport firms could be greatly enhanced by targeting fare subsidies to low-income passengers and raising considerably the fares for the middle and upper classes. As noted earlier, fares on most systems are extremely low and passenger volumes are extremely high so that even modest increases might yield substantial revenues for system maintenance, modernization, and expansion. Fares cannot be raised too high, however, even among middle-class riders, since they might then be diverted to private transport modes, which cause the most urban transport problems. Thus, larger subsidies from the public sector will be essential.

Until all levels of government in India devote the necessary funding to expanding and improving public transport, it will remain overcrowded, unsafe, undependable, and unpleasant, thus encouraging ever more Indians to turn instead to the private car and motorcycles, which would lead to even more serious congestion and pollution problems in Indian cities. The ideal source of such funding would be some sort of dedicated gasoline or private motor vehicle tax whose revenues would be devoted specifically to the improvement of urban transport conditions, including better roadways, better bicycling and walking facilities, and above all, better bus and rail services. Many of the world's developed countries have used such dedicated gasoline and motor vehicle taxes for decades to fund their public transport improvements. In India, it would be doubly beneficial. Such a tax would discourage nonessential private car ownership and use. Moreover, the burden of the tax would fall on relatively affluent Indians, so that the overall impact would be quite progressive. The solution to public transport's financing problem in India seems quite clear, but does the Indian government have the political will to implement it?

References

- Acharya, R. 2000. Indian railways: Where the commuter is king. *Japan Railways and Transport Review* 25, October: 34–45.
- Association of State Road Transport Undertakings. 2002. *The performance of STUs at a glance for the period 1989–90 to 2000–01*. Delhi, India: ASRTU. Accessible at: <http://www.asrtu.org/data-00-01.PDF>.
- Association of State Road Transport Undertakings. 2002b. *STU policy issue*. Delhi, India: ASRTU. Available at: http://www.asrtu.org/stu_policy.htm. Accessed: November 2003.
- Bertaud, A. 2002. The economic impact of land and urban planning regulations in India. Unpublished manuscript accessible at: http://www.alain-bertaud.com/images/AB_%20India_%20Urban_Land_Reform.doc.
- Brihanmumbai Electric Supply and Transport. *Organisational information*. Mumbai, India: Available at: http://www.bestundertaking.com/org_info.asp. Accessed: November 2003.
- Central Intelligence Agency. 2002. *The CIA world fact book*. Washington, DC: CIA. Accessible at: <http://www.cia.gov/cia/publications/factbook/geos/in.html>.
- Delhi Metro Rail Corporation Ltd. 2003a. *Project update*. New Delhi, India: Delhi Metro Rail Corporation. Available at: <http://www.delhimetrorail.com/home/projectUpdate.htm>. Accessed: November 2003.
- Delhi Metro Rail Corporation 2003b. *Cost and funding plan*. New Delhi, India: Delhi Metro Rail Corporation. Available at: <http://www.delhimetrorail.com/home/MetroFastFactsCost.htm>. Accessed: January 2004.
- Delhi Metro Rail Corporation Ltd. 2003c. *History*. New Delhi, India: Delhi Metro Rail Corporation. Available at: <http://www.delhimetrorail.com/home/history.htm>. Accessed: November 2003.
- Gakenheimer, R. 2002. *Planning transportation and land use for cities in India*. Cambridge, MA: Massachusetts Institute of Technology.
- Gakenheimer, R., and C. Zegras. 2003. *Travel demand drivers: Mumbai and Chennai, India*. Geneva, Switzerland: World Business Council for Sustainable Development.

- Gaur, M. 2003. Delhi to get new busway. In Institute for Transportation and Development Policy. *Sustainable Transport e-update*. No.1. May–June 2002. Available at: <http://www.itdp.org/STe/STe1/index.html#delhi>. Accessed: November 2003.
- Indian Railways. 2002. *Annual statistical statements, 2001–2002*. New Delhi: Indian Railways.
- Indian Railways. 2001. *Year book 2000–2001*. New Delhi: Indian Railways.
- Konkan Railway Corporation Ltd. 1999. *Sky bus: The urban transport technology for the new millenium*. Navi Mumbai, India: The Konkan Railway Corporation Ltd. Available at: http://www.konkanrailway.com/website/ehtm/sky_bus.htm. Accessed: January 2004.
- Marwah, B. R., V. K. Sibal, and S. Sawant. 2001. Bus transport in Delhi. In Morris, Sebastian, ed., *India Infrastructure Report 2001*. New Delhi, India: Oxford University Press.
- Metro Railway Kolkata. 2003. *Status of ongoing projects*. Kolkata, India: Metro Railway Kolkata. Available at: <http://business.vsnl.com/metro/rly/status.html>. Accessed: November 2003.
- Ministry of Railways. 2002. *Status paper on Indian railways: Issues and options*. New Delhi: Government of India, Ministry of Railways, May 2002. Available at: <http://www.indianrailways.gov.in/railway/status-paper.pdf>. Accessed: January 2004.
- Ministry of Road Transport and Highways 2003. *Motor transport statistics*. New Delhi, India. Available at: <http://morth.nic.in/mts.htm>. Accessed: November 2003.
- Ministry of Road Transport and Highways. 1999 and 2000. *Handbook on transport statistics in India*. Delhi, India: Transport Research Office, Ministry of Road Transport and Highways.
- Mumbai Metropolitan Region Development Authority. 2003. *Mumbai urban transport project*. Mumbai, India: MMRDA. Available at: <http://www.mmrdamumbai.org/mutp2.htm>. Accessed: November 2003.
- Office of the Registrar General of India. 2001 “Urban agglomerations/cities having population of more than one million in 2001” in *The Census of India 2001*. New Delhi, India. Available at: http://www.censusindia.net/results/miillion_plus.html. Accessed: November 2003.

- Padam, S., and Singh, S. K. 2001. *Urbanization and urban transport in India: The sketch for a policy*. Pune, India: Transport Asia Project Workshop. Accessible at: http://www.deas.harvard.edu/TransportAsia/workshop_papers/Padam-Singh.pdf.
- Pendakur, V. S. 2002. *A policy perspective for sustainable cities: Non-motorized transport in Asia*. Vancouver, Canada: University of British Columbia.
- Ramachandran, R. 1989. *Urbanization and urban systems in India*. Oxford University Press, Oxford, England.
- Southern Railway. 2003. *Projects*. Chennai, India: Southern Railway. Available at: <http://www.southernrailway.org/aboutus/projects.asp>. Accessed: November, 2003.
- Sreedharan E. 2003. *Need for urban mass transport system for our cities*. New Delhi, India: Press Information Bureau, Government of India.
- Varshneya, Jain, and Sahai. 2002. *Strategy for solving transport problems in Mumbai*. Mumbai, India: Indian Railways.
- Vasconcellos, E. 2001. *Urban transport, environment and equity: The case for developing countries*. London, UK: Earthscan Press.
- World Bank. 2002. *India's transport sector: The challenges ahead*. Washington, DC: The World Bank.

About the Author

JOHN PUCHER (pucher@rci.rutgers.edu) is professor of urban planning and public policy at Rutgers University in New Brunswick, New Jersey. He specializes in comparative research on transport systems, travel behavior, and public policies in the United States, Canada, and Europe.

NEENU ITTYERAH (neenuittyerah@hotmail.com) is a senior transport manager for the Indian Railways, currently in charge of the freight operations and information system in the Southern and Southwestern Zones. She spent the 2002–03 academic year at Rutgers University as a Humphrey Fellow of the U.S. State Department.

NISHA KORATTYSWAROOPAM (nishak@eden.rutgers.edu) is a Ph.D. candidate at Edward J. Bloustein School of Planning and Public Policy, Rutgers University, New Brunswick, New Jersey. Her research interests include urban public transportation and transportation in developing countries.