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Editor's Note: An inadvertent error was made in the last issue that misidentified the authors of this paper on the cover and in the table of contents. That error is corrected in this issue with a reprint of the paper. We extend our sincere apology to the authors and to our readers.

Development of a Mode Choice Model for Bus Rapid Transit in Santa Clara County, California

*Chun-Hung Peter Chen and George A. Naylor
Santa Clara Valley Transportation Authority*

Abstract

Bus Rapid Transit (BRT) is an enhanced bus service that offers many of the same service attributes as rail transit, such as specialized vehicles, large stations, real-time passenger information, and more frequent and reliable operations. The Santa Clara Valley Transportation Authority (VTA) intends to develop an integrated BRT network throughout Santa Clara County, California, to provide high quality service to areas not well served by the VTA Light Rail (LRT) system. Past research showed that many transit agencies in North America considered BRT the same as LRT in their demand models, and a few agencies treated BRT and local bus identically. Realistic BRT ridership forecasts are essential for selecting and sizing facilities, preparing service plans, estimating capital and operating costs, and assessing cost-effectiveness. This study applied the results of the transit preference survey in a Market Research Model prepared for the VTA and built the improved mode choice model that explicitly included the BRT mode in the VTA demand model. Instead of considering BRT the same as either LRT or local bus, the improved VTA model with an explicit BRT mode is expected to forecast more reasonable future BRT boardings. Eleven scenarios in the BRT strategic plan for Santa Clara County were developed using the BRT forecast results from the improved VTA model.

Introduction

Bus Rapid Transit (BRT) is an enhanced bus service that offers many of the same service attributes as rail transit, such as specialized vehicles, large stations, real-time passenger information, and more frequent and reliable operations. A more detailed definition developed by the Transit Cooperative Research Program (TCRP) as part of TCRP Report 90 (2003) is that “BRT is flexible, rubber-tired rapid transit mode that combines stations, vehicles services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image ... In brief, BRT is an integrated system of facilities, services, and amenities that collectively improves the speed, reliability, and identity of bus transit.”

Vuchic (2002) defined BRT based on combining mode performance (speed, reliability, capacity, image) and investment cost per kilometer of line for three categories of transit modes—rapid transit (Metro), semi-rapid transit (light rail transit, LRT), and street transit (regular bus)—and expresses the definition of BRT as the transit mode between LRT and regular bus. Levinson et al. (2002) proposed the comparisons of BRT and other transit modes as follows: “1. where BRT vehicles (buses) operate totally on exclusive or protected rights-of-way, the level of service provided can be similar to that of full Metrorail rapid transit; 2. where buses operate in combinations of exclusive rights-of-way, median reservations, bus lanes, and street running, the level of service provided is very similar to LRT; 3. where buses operate mainly on city streets in mixed traffic, the level of service provided is similar to a limited-stop tram/streetcar system.” In general, BRT operating in combinations of exclusive bus lane and mixed traffic is considered to be a transit mode between LRT and local bus.

BRT is now a major trend in the development of public transportation systems worldwide. In the U.S., several BRT systems are in service, such as in Eugene (Oregon), Los Angeles, and Cleveland, and there are also other BRT systems under construction, in development, or planned. According to a Federal Transit Administration’s study (2005), in areas with new BRT systems, about 24 to 33 percent of BRT ridership is new to transit. BRT ridership—and transit ridership forecasting in general—is an integral part of transportation planning. Realistic estimates of BRT ridership are essential for selecting and sizing facilities, preparing service plans, estimating capital and operating costs, qualifying benefits, and assessing cost-effectiveness (TCRP 2006). TCRP (2006) implemented BRT ridership surveys for 20 transit agencies in North America to ascertain how BRT was treated in their travel

demand forecasting. This study found many agencies considered BRT the same as LRT in their demand models, and only a few agencies treated BRT and local bus identically. It was also found that no transit agencies had built new specific BRT modes in their models for analyzing BRT in the study survey.

The Santa Clara Valley Transportation Authority (VTA) intends to develop an integrated BRT network throughout Santa Clara County, California, to provide high quality service to the areas not served by LRT. VTA has developed the Santa Clara County BRT Strategic Plan (2009) in which different BRT alternatives, potential corridors, operating and infrastructure strategies were proposed. Near-term and long-term BRT corridors integrated with the existing transit system and road system within the county, including Caltrain, LRT, bus, and exclusive lanes with signal priority, will provide the community with more comprehensive and convenient transit service. Future BRT ridership forecasting is one critical element for BRT planning. The current VTA countywide model does not include a BRT mode in the mode choice model. Based on the current structure of the VTA models, if BRT is considered the same as LRT, the forecast ridership may be overestimated. Conversely, if BRT is considered the same as a local bus, the forecast ridership may be underestimated. Given the anticipated need for the level of detail required in developing future BRT plans, it was necessary for the VTA to develop a refined mode choice model that included the mode of BRT.

The purpose of this study was to develop an enhanced mode choice model including the mode of BRT into the VTA model so that the model can forecast future BRT ridership for the planning, development, and implementation of the BRT system in Santa Clara County. The model proposed in this study also is used for alternatives analysis, prioritizing BRT corridors, analysis of new transit trips, and examining impacts to background local bus services. The “previous model” used in this paper represents the original VTA countywide model without applying the procedures of the BRT mode choice model developed in this study; the “improved model” represents the revised model using the new BRT mode choice model.

Previous VTA Model

VTA has developed and maintained a countywide travel demand model for at least a decade, which has been applied to various countywide transportation planning and engineering projects. The VTA model initially was structured to be consistent with the Metropolitan Transportation Commission (MTC) regional model, BAY-

CAST (1997). MTC is the metropolitan planning organization (MPO) for the nine-county San Francisco Bay area. The VTA countywide model is an enhanced version of the MTC nine-county regional model, with the addition of more traffic analysis zones (TAZs) and more detailed highway and transit network coding within Santa Clara County. The MTC mode choice model also was enhanced for application in Santa Clara County and the greater modeling region. In the original MTC model, trips were first split into motorized modes and bicycle and walk-only modes. Motorized trips were then split into drive alone, shared ride 2, shared ride 3 plus, and transit. Last, transit trips were split into transit walk access versus transit auto access. All transit modes were treated identically in the MTC mode choice model, and the choice as to whether the trip used heavy rail, commuter rail, light rail, or express or local bus was dependent on the shortest time path. The enhancements from the MTC model to the VTA model included the implementation of a transit submode nest, allowing the models to estimate ridership on the different transit submodes of commuter rail, express bus, local bus, BART (heavy rail), and light rail as distinct choices based on relative costs and travel times that occur for each submode. The constants of the utility functions for commuter rail, express bus, local bus, BART (heavy rail), and light rail were calibrated based on the transit on-board survey data and transit boarding data. With the inclusion of distinct transit submodes as choices in the model structure, it was possible to calibrate mode specific constants in the VTA mode choice models for each submode. Typically, submode specific constants capture the importance of modal attributes not typically included in the mode choice utility equations, such as reliability, passenger comfort, and safety. During base year calibration, for home-based work trips, the addition of transit submode constants improved the level of validation for each submode. Home-based work calibration results yielded a less negative constant on light rail, followed by heavy rail, commuter rail, local bus, and express bus, in that order. This implies that, all things being equal with respect to travel times and costs, there is a higher probability that a trip will use rail over bus. For the non-work purposes, transit submodes behave in a much more generic manner, with only slight biases for rail in the home-based shop/other and home-based social recreational models. The exception in the non-work models was with the non-home-based trip purposes, as both heavy rail and light rail were shown to have less negative constants as compared to commuter rail or bus modes. Figure 1 without the dashed line box shows the mode choice structure at the previous VTA model.

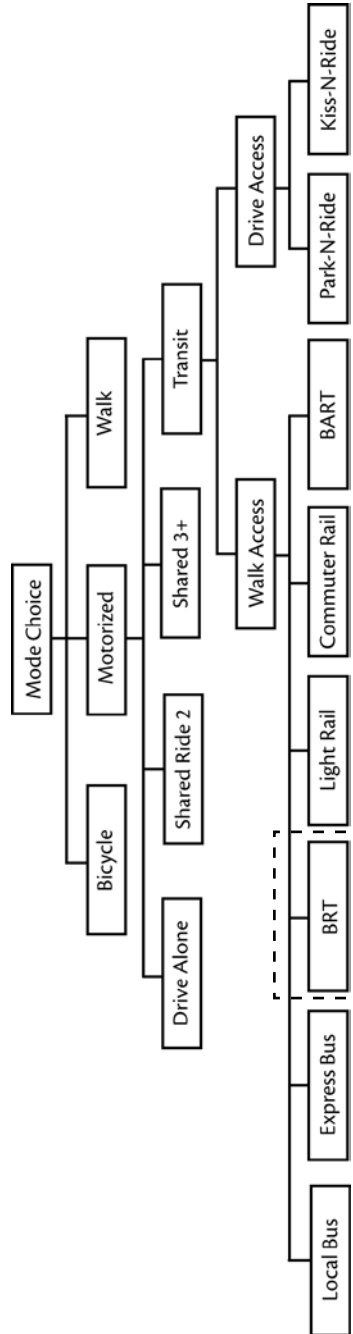


Figure 1. Mode choice structure of the previous and improved VTA models

Improved VTA Model

The BRT mode was added into the VTA mode choice model for developing the BRT ridership forecasts to support the Santa Clara County BRT strategic plan. Figure 1 with the dashed line box of the BRT mode shows the mode choice structure of the improved VTA model. The important parameters used in the improved VTA mode choice model, i.e., BRT constants, were derived from the Transit Market Research Model (2007) developed for the VTA. This section addresses how the BRT mode was developed by applying the Transit Market Research Model into the VTA demand model while BRT was still in development and planned without any observed BRT operating data.

Transit Market Research Model

VTA developed a transit market research project, implemented by Cambridge Systematics, Inc., to support the Comprehensive Operational Analysis (COA), a major service redesign plan for the entire VTA bus system that was implemented in January 2008. Transit market research is used to develop market segments based on travelers' attitude towards everyday transportation experiences. The VTA transit market research project consisted of three distinct tasks: data collection, attitudinal-based market segmentation modeling, and mode choice modeling. Data collection included a stated-preference survey of 819 households throughout Santa Clara County. The survey collected attitudinal, demographic, and travel behavior data. The attitudinal-based market segmentation uses cluster analysis techniques to group individual travelers according to their attitudes toward transportation to identify market segments, and then expands the survey records to the entire population of Santa Clara County.

The importance of Transit Market Research Model introduced here is because a new mode of travel—BRT—was estimated in the market research mode choice models. Market research-based mode choice models were developed with the data collected from the market research household travel surveys, specifically from four customized mode choice experiments. Four experiments in the surveys have different values of time, costs, and amenities. Three transit service amenities to address packages of BRT and other transit modes include an electronic sign showing minutes until next train, distinctive-looking buses with comfortable interior, and well-lit, covered stations equipped with benches, maps, and guides. Because BRT was not in service currently, through attitudinal and stated preference surveys, the ridership of BRT likely transferred from current transit systems and potential new ridership from auto modes could be estimated by the market research-based mode

choice models. The market research-based mode choice models are multinomial logit models for work and non-work trip purposes. The results of the mode choice models, including the coefficients of different variables in the utility functions and the bias constants for each transit mode (rail, BRT, and bus) are shown in Table 1.

Table 1. Market Research-Based Mode Choice Models

Categories	Variables	Home-Based Work/University	Non-Work
IVTT	In-Vehicle Travel Time	-0.0330	-0.0091
OVTT	Walk time-Access/Egress	-0.0650	-0.0233
	Wait time <= 7 mins	-0.0650	-0.0233
	Wait time > 7 mins	-0.0500	-0.0179
	Drive-Access Time	-0.0650	-0.0233
	Transfer Time	-0.0650	-0.0233
Cost	Cost	-0.0770	-0.0718
Attitudinal Factors	Pro-environment	0.5750	-
	Social Perception	-0.2430	-0.5512
	Travel Flexibility	-0.1450	-
Social-Economic Variable	Workers/ Household	-0.0630	-
	Vehicle/ Household	0.0000	-0.0670
	Age 18 to 24	1.5180	1.8589
	Income < \$25,000	1.0360	1.4565
	Income \$25,000 to \$50,000	0.2520	-0.2244
	Female	-0.6210	-0.3754
Transit Amenities	Amenities -Signs	0.2140	0.5281
	Amenities -Buses	0.2930	0.0187
	Amenities Stations	0.4220	0.5100
Modal Constants	Drive Alone - base constant	0.0000	0.0000
	LRT- constant	0.0000	-1.7593
	BRT – constant	-0.0340	-1.8115
	Bus – constant	-0.7810	-1.8025
Perform Measures	Value of Time	\$25.37	\$7.64
	OVTT(wait time <= 7 mins) /IVTT	2.0	2.6
	OVTT(wait time > 7 mins) /IVTT	1.5	2.0

Note: OVTT: out-vehicle travel time; IVTT: in-vehicle travel time

Source: Santa Clara Valley Transportation Authority, 2007.

Translation of BRT Constants

Though the purpose of the market research project was to support the transit comprehensive operational analysis, and the market research-based mode choice models were not directly applied in the VTA demand model, the bias constants of BRT compared to (light) rail and bus can be applied to add the new BRT mode in the VTA demand model. Constant coefficients can be converted into bias time constants by dividing constant coefficient by in-vehicle time coefficient

$$b_m = \frac{c_m}{c_{ivt}} \tag{1}$$

where b_m is bias time constant for mode m ; c_m is constant coefficient for mode m and c_{ivt} is in-vehicle time coefficient in Market Research Model. Bias time constants present the relative waiting time among different transit modes. For home-based work trips, the rail, BRT, and bus constants are 0, -0.034, and -0.781. Using Eq. (1), the bias time constants for rail, BRT, and bus are 0, -1.03 and -23.67 minutes, respectively. For non-work trips, the rail, BRT, and bus constants are -1.7593, -1.8115, and -1.8025. The bias time constants for rail, BRT, and bus converted to equivalent minutes of in-vehicle travel time are -193.33, -199.07 and -198.08 minutes, respectively. Due to home-based work passengers having a higher value of time at \$25.37 compared to non-work passengers' value of time at \$7.64, potential BRT passengers from home-based work trips consider BRT more like LRT, while non-work passengers consider BRT more like local bus. For home-based work passengers, BRT only provides one less minute travel time than light rail and 23 minutes travel time over local bus; for non-work passengers, BRT and local bus almost have no significant difference for equivalent time, -199.07 and -198.08 minutes. It was, therefore, assumed that BRT and local bus have the same bias time constants for non-work trips.

Bias time constants derived from Transit Market Model were used to estimate the BRT constants in the VTA demand model. Table 2 shows the coefficients of utility functions of the previous VTA mode choice model without BRT constants. Because the BRT mode is considered to be service between that provided by light rail and local bus, BRT constants are calculated by the linear interpolation method using the light rail constants, local bus constants, and bias time constants obtained above.

$$\Delta_{BRT} = \Delta_{LB} + (\Delta_{LRT} - \Delta_{LB}) \left(\frac{b_{BRT} - b_{LB}}{b_{LRT} - b_{LB}} \right) \tag{2}$$

where Δ_{BRT} is BRT constant; Δ_{LB} is local bus constant; Δ_{LRT} is LRT constants; b_{BRT} is BRT bias time constant; b_{LB} is local bus bias time constant; and b_{LRT} is LRT bias time constant.

Table 2. VTA Mode Choice Models—Transit Walk Access

Variables	Home-Based Work	Home-Based Shopping	Home-Based Social/ Recreation	Non-Home Based	Home-Based School (Grade School)	Home-Based School (High School)	Home-Based School (College)
BART (heavy rail)	-0.86301	1.14089	2.48260	4.74364	0.59115	1.11067	0.76854
Commuter Rail	-0.86301	1.02982	2.22221	3.57032	0.59115	1.11067	0.76854
Light Rail	-0.96318	1.02982	2.22221	4.84000	0.59115	1.11067	0.76854
Express Bus	-1.84149	1.02982	2.22221	3.57032	0.59115	1.11067	0.76854
Local Bus	-1.70196	1.02982	2.22221	3.57032	0.59115	1.11067	0.76854
EMPD	0.546100						
Zero VHHD	0.550100	3.2910					
VHH		-0.3352	-0.7475				
PHH^3					0.004436		
Rurali					1.544		
Total Time		-0.05815					
IVT	-0.033260		-0.02745	-0.03232	-0.05855	-0.03228	-0.02731
Wait	-0.052330			-0.07836			
Walk	-0.093050			-0.07583			
Transfer	-0.033260						
OVTT			-0.06806		-0.06384	-0.03463	-0.03923
Cost	-0.002067						
LnCost		-0.2262	-1.1600	-0.9862	-1.9300	-2.0340	-0.6920
Corej		2.3750	0.9694				
LnAreaDen			0.3217				
Net ResDen						0.1442	
Value of Time	\$9.65	\$6.58	\$0.78	\$1.08	\$0.36	\$0.23	\$0.67
Ratio of Wait/IVTT	1.57	-	-	2.42	-	-	-
Ratio of Wait/IVTT	2.80	-	-	2.35	-	-	-

Note: EMPD: employment density; Zero VHHD: zero vehicle per household; VHH: vehicle per household; PHH: population per household; Rurali: rural in production zone; Corej: core zone (CBD) in attraction zone; LnAeraDen: natural log of area density; Net ResDen: net residential density.

Source: Santa Clara Valley Transportation Authority, Valley Transportation Plan 2035, 2009; Transit Cooperative Research Program Report, Appendices to TCRP Report 118, 2006; VTA Model

Table 3 shows the results of BRT constants by applying Eq. (2). Estimated BRT constant for home-base work is -0.99530, close to the light rail constant -0.96318. For home-based shopping, home-based social/recreation, home-based grade school, and home-based high school, light rail constant and local bus are considered as the same mode in VTA model, so that the estimated BRT constants are the same as light rail and local bus constants. For non-home-based trips, BRT constant is equal to local bus constant because BRT and local bus has the same bias time constant for non-work trips.

Table 3. BRT Constant Calculation

Variables	Home-Based Work	Home-Based Shopping	Home-Based Social/ Recreation	Non-Home Based	Home-Based School (Grade School)	Home-Based School (High School)	Home-Based School (College)
Light Rail Constant Δ_{LRT}	-0.96318	1.02982	2.22221	4.84000	0.59115	1.11067	0.76854
Local Bus Constant Δ_{LB}	-1.70196	1.02982	2.22221	3.57032	0.59115	1.11067	0.76854
Light Rail Bias Time b_{LRT}	0	193.33	193.33	193.33	193.33	193.33	193.33
BRT Bias Time b_{BRT}	1.03	198.08	198.08	198.08	198.08	198.08	198.08
Local Bus Bias Time b_{LB}	23.69	198.08	198.08	198.08	198.08	198.08	198.08
Estimated BRT Constant Δ_{BRT}	-0.99530	1.02982	2.22221	3.57032	0.59115	1.11067	0.76854

BRT Strategic Plan

BRT ridership estimates for VTA’s BRT Strategic Plan were developed based on the results of the improved VTA model with the added BRT mode in the mode choice model. Eleven different BRT alternatives and operating and infrastructure strategies were proposed. Six potential BRT corridors were identified by the recent Comprehensive Operations Analysis and from VTA’s Long-Range Countywide Transportation Plan (Valley Transportation Plan 2035) (VTA 2009), and these included the Alum Rock, El Camino, King Road, Monterey Highway, Stevens Creek, and Sunnyvale-Cupertino BRT corridors, all shown in Figure 2. Six lines show the potential BRT corridors, which are not covered by the LRT. An assessment of new

BRT services was conducted on three corridors within the county as the most promising alignments for near-term BRT implementation. The three corridors included:

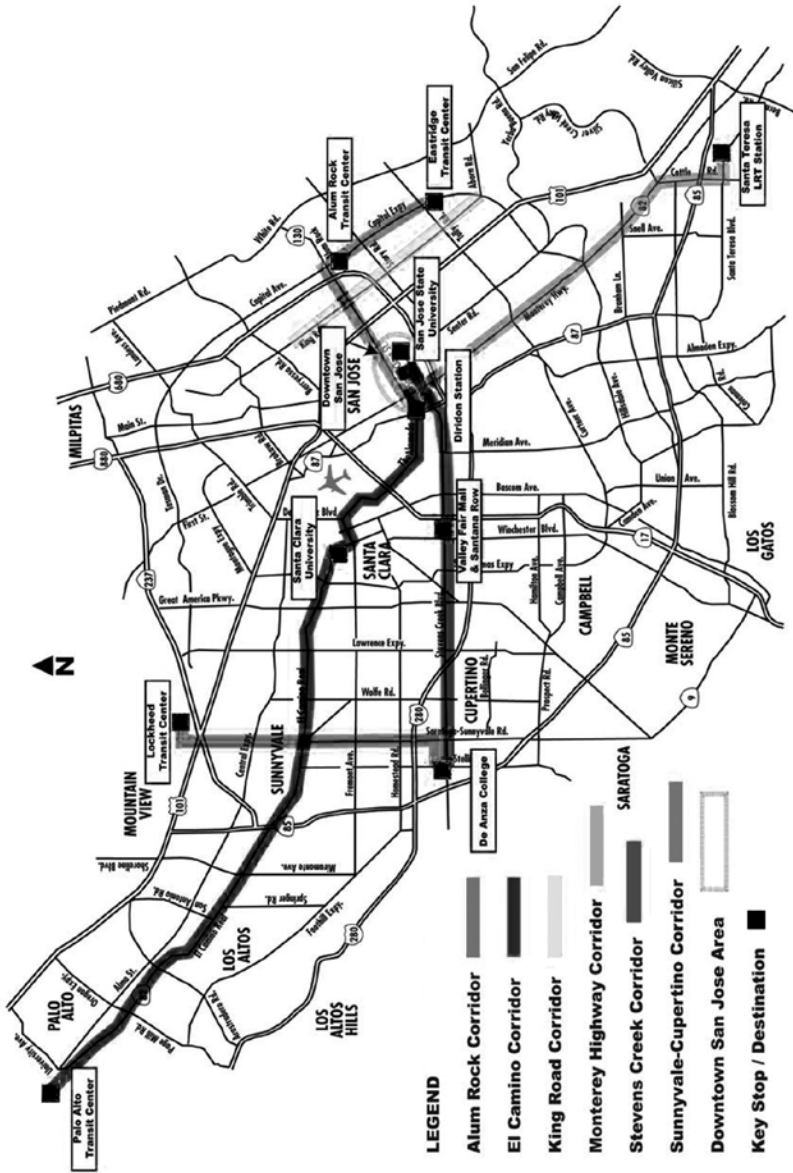
- Alum Rock—stretching from HP Pavilion to Eastridge Mall (6.9 miles) and currently served by Rapid 522 (15-minute headways), Local Route 22 (12-minute headways), and Local Route 23 (12-minute headways).
- El Camino—stretching from Palo Alto Transit Center to HP Pavilion (16.6 miles) and currently served by Rapid 522 (15-minute headways) and Local Route 22 (12-minute headways).
- Stevens Creek—stretching from De Anza College to Downtown San Jose (8.6 miles) and currently served by Local Route 23 (12-minute headways).

Rapid 522 has the same route alignment as Local Route 22 with less headway but longer stop spacing. In the previous model, all Rapid 522, Local Route 22, and Local Route 23 are considered as local bus mode. The operating plan in these three corridors is shown in Figure 3.

Two new BRT services were proposed in these three corridors: BRT 522 to replace Rapid 522 and overlay on the Local Route 22, and BRT 523 to overlay and complement Local Route 23. Eleven operating plans were developed seeking to achieve enhanced transit market share in the corridor, while making transit more efficient and effective at serving riders. The No Project and 10 operating plans were proposed based on different combinations of BRT and local bus service areas and headways. Note that:

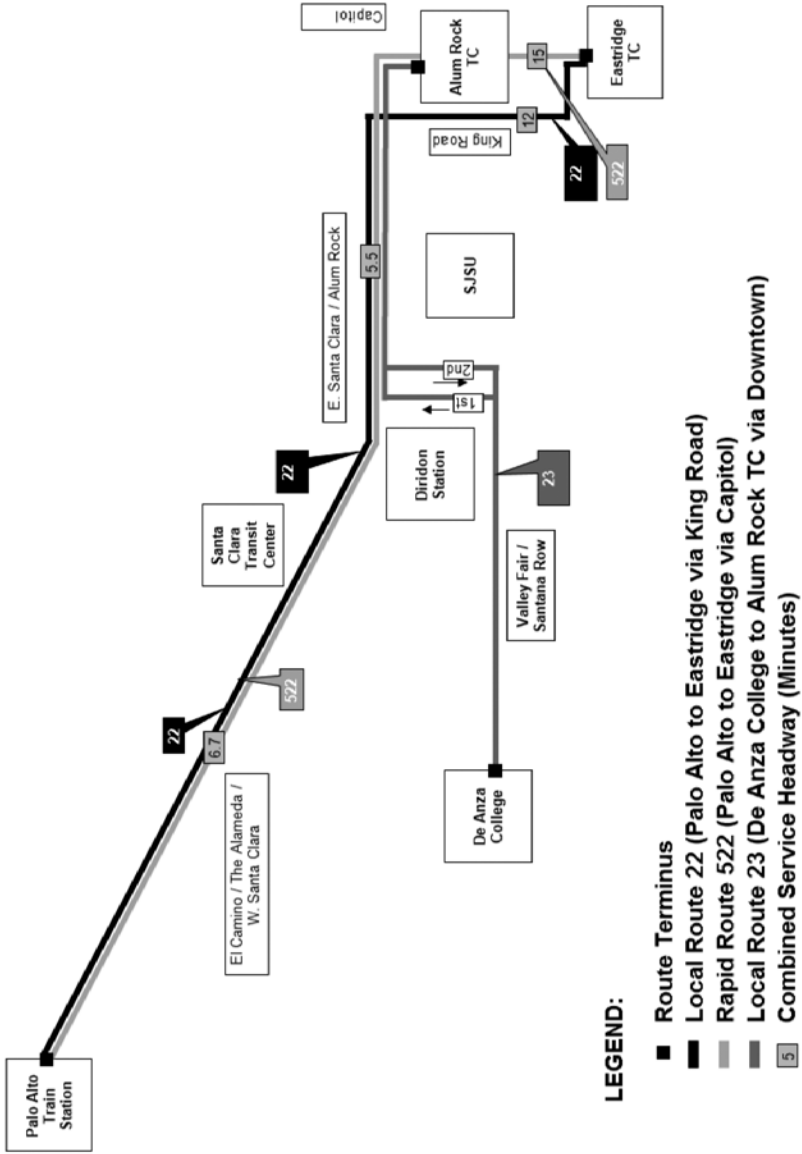
- (1) Option 6 considers BRT 522 and 523 modeled as an LRT mode using Option 4 as a base.
- (2) BRT 522 in the No Project is the existing Rapid 522. The existing Rapid 522 currently provides 15-minute headways and fewer bus stops than Local Route 22 and is considered as a local bus in the previous VTA model;
- (3) BRT would operate a premium service with 10-minute headways.
- (4) Local Route 22 service would be fixed at 15-minutes, a slight reduction in service from existing 12-minute, and Local Route 23 service would have a variable headway (between 15-30 minutes) to be tested in various service scenarios to gauge its impact on demand.

It also was assumed that in order to claim the full BRT constant, the amount of capital infrastructure required to provide the travel time savings, through either



Source: VTA, Congestion Management & Planning Division

Figure 2. Six potential VTA BRT corridors



Source: VTA, Congestion Management & Planning Division

Figure 3. Existing Rapid 522, Local Route 22, and Local Route 23

dedicated lanes with signal priority, and vehicle and station passenger amenities must be accounted for in the BRT alternative definition and costs.

Table 4 shows the No Project and 11 operating plans by different operating combinations of BRT 522, Local Route 22, BRT 523, and Local Route 23 that were modeled. Table 5 shows the 2030 boardings for the No Project and the 11 BRT operating plans. Option 6 has the highest boardings for the 522/523 BRT corridors at 91,769 daily boardings, with VTA total transit system boardings of 409,859, because BRT was assumed to have the same constant as LRT in this option plan. Option 4 modeled as a BRT mode results in 79,494 daily boardings for the 522/523 BRT corridors; this translates to a 15 percent decrease in BRT ridership if BRT is treated as a separate BRT mode and not the same as LRT. Option 4a with BRT modeled as a local bus mode results in 65,985 daily boardings for the 522/523 BRT corridor routes and 375,713 VTA total transit system boardings. This represents a 17 percent decrease in BRT ridership over the BRT constant model if BRT is treated as a local bus mode.

Table 4. No Project and Eleven BRT Operating Plans

	BRT Route 522	Local Route 22	BRT Route 523	Local Route 23
No Project	Rapid, Palo Alto to Eastridge via Capitol (15-min headways)	Palo Alto to Eastridge via King Road (12-min headways)	N/A	De Anza College to Alum Rock via Downtown (30-min headways)
Option 1	Palo Alto to Eastridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	Valley Fair/Santana Row to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to SJSU via Downtown (30-min headways)
Option 2	Palo Alto to Eastridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	Valley Fair/Santana Row to Eastridge via SJSU/Capitol (10-min headways)	De Anza College to SJSU via Downtown (30-min headways)
Option 3a	Palo Alto to SJSU via Downtown (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	Valley Fair/Santana Row to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to Alum Rock via Downtown (30-min headways)
Option 3b	Palo Alto to SJSU via Downtown (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to Alum Rock via Downtown (30-min headways)

Table 4. No Project and Eleven BRT Operating Plans (cont'd)

Option 4 (modeled as BRT)	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	N/A
Option 4a* (modeled as Local Bus)	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	N/A
Option 5	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	Valley Fair/Santana Row to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to SJSU via Downtown (30-min headways)
Option 6** (modeled as LRT)	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	N/A
Option 7 (BRT 10-20)	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to SJSU via Downtown (20-min headways)
Option 7a (BRT 10-15)	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to SJSU via Downtown (15-min headways)
Option 7b (BRT 10-30)	Palo Alto to East-ridge via Capitol (10-min headways)	Palo Alto to Eastridge via King Road (15-min headways)	De Anza College to Eastridge via Downtown/Capitol (10-min headways)	De Anza College to SJSU via Downtown (30-min headways)

Note: * Option 4a considers BRT 522 and 523 as Local Bus mode using Option 4 as the base.

** Option 6 considers BRT 522 and 523 as LRT mode using Option 4 as the base.

Table 5. 2030 Daily Boardings by Eleven BRT Operating Plans

Operator/Route	No Project	Opt 1	Opt 2	Opt 3 a	Opt 3b	Opt 4	Opt 4a	Opt 5	Opt 6	Opt 7	Opt 7a	Opt 7b
Route 22 (Local)	29,830	20,782	21,067	21,373	21,383	20,908	15,709	20,651	19,562	20,667	20,557	20,788
Route 23 (Local)	16,966	3,497	3,498	4,269	2,715	0	0	6,678	0	4,386	6,474	2,061
Route 522 (BRT)	12,883*	35,479	36,297	26,597	23,941	32,568	26,738	35,103	40,497	32,549	32,533	32,565
Route 523 (BRT)	0	15,568	12,278	18,469	28,049	26,018	23,538	15,415	31,710	24,834	24,013	25,450
Total BRT Boardings	12,883	51,047	48,575	45,066	51,990	58,586	50,276	50,518	72,207	57,383	56,546	58,015
522/523 BRT Corridor Routes	59,679	75,326	73,140	70,708	76,088	79,494	65,985	77,847	91,769	82,436	83,577	80,864
LRT System	122,466	118,906	119,721	119,737	119,920	119,146	120,692	119,008	123,658	119,120	119,084	119,134
VTA Local Bus (not including Routes 22/23)	145,358	153,280	153,658	152,198	151,005	153,152	147,636	151,923	152,807	150,983	150,525	152,295
VTA Community Bus	23,670	24,026	24,406	23,945	23,907	24,060	24,085	23,937	24,476	23,935	23,878	24,018
VTA Express Bus	16,545	16,323	16,312	16,339	16,239	16,226	17,315	16,314	17,149	16,216	16,213	16,223
VTA Total System	367,718	387,861	387,237	382,927	387,159	392,078	375,713	389,029	409,859	392,690	393,277	392,534

The ultimate preferred BRT Option 7a has the second highest boardings for the 522/523 BRT corridors at 83,577 daily boardings, with VTA total transit system boardings of 393,277, by using the BRT constants derived from Table 3 in the improved VTA model. Option 7a also would generate the second largest total new transit trips, including home-based work and non-work trips, as shown in Table 6. The potential new transit riders would be up to 36 percent of BRT ridership in the preferred operating plan Option 7a, which is a little higher than the 24 to 33 percent from the FTA's study of BRT systems currently in operation (Peak et al. 2005).

The operating costs and capital costs for the 11 BRT operating plans are listed in Table 7. Detailed operating and capital cost analysis can be found in the VTA BRT Strategic Plan (2009). Without considering Option 6 (BRT treated as LRT mode), after demand, operating cost, and capital cost analysis, Option 7a was selected as the preferred BRT operating plan, which would generate the highest demand and the largest number of new riders, but include the highest operating costs as well. The operating and routing plan of Option 7a is shown in Figure 4.

Conclusions

A state-of-the-practice travel demand model with a new BRT mode included in the mode choice model was developed by the Santa Clara VTA and now is used in planning and design phases for countywide BRT projects. Instead of considering BRT the same as LRT or local bus, the BRT constants derived from the Market Research Model fall between LRT and local bus constants. The application of the BRT constants results in BRT ridership between ridership estimates prepared with BRT having a local bus constant and for BRT having a LRT constant, with a variation of approximately 15 percent higher or lower, depending on which constant BRT employed in the forecasts. The improved VTA model was expected to forecast more reasonable future BRT boardings, which were an important consideration in light of the relatively high capital and operating costs associated with BRT services. The potential new transit riders after BRT lines open would be up to 36 percent of BRT ridership in the preferred operating plan.

Future extensions of the present work might include developing a peer review of before-and-after BRT implementation studies and an evaluation of how actual ridership compares to forecasted ridership for areas implementing BRT, either through passenger counts or on-board surveys reflecting the situation at least one year after BRT lines opens. The Alum Rock segment of the BRT lines 522/523 is currently in final design and scheduled for completion by 2013. The remainder

Table 6. 2030 Daily Linked Transit Trips – Santa Clara County

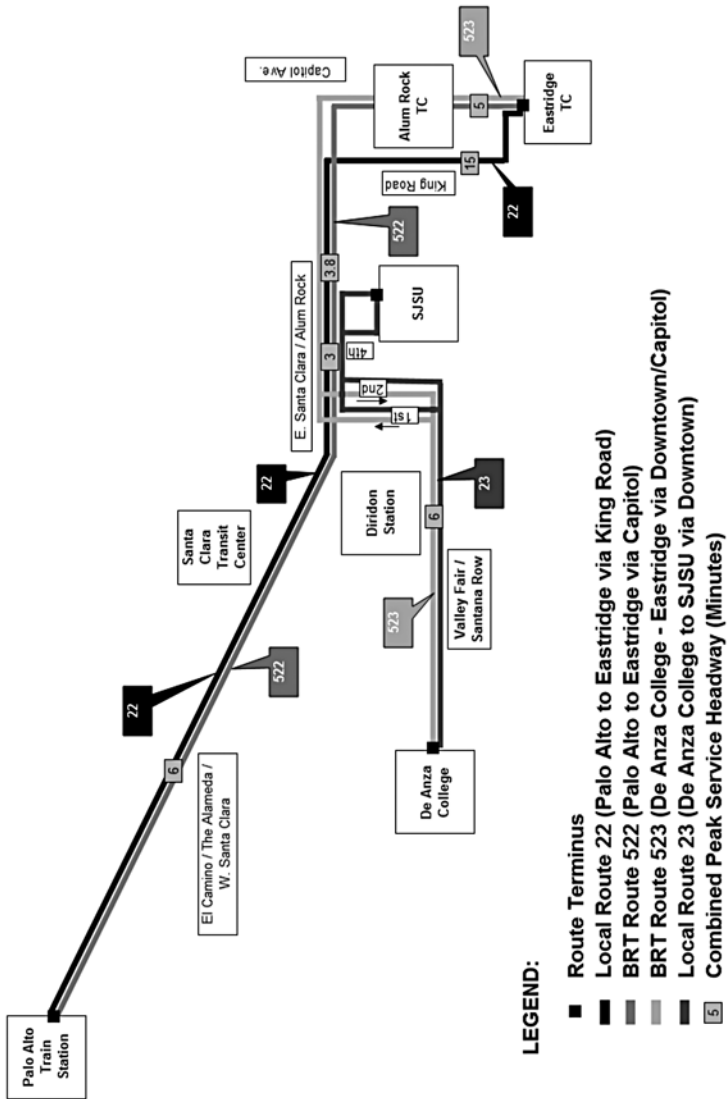
Linked Transit Trips	No Project	Opt 1	Opt 2	Opt 3a	Opt 3b	Opt 4	Opt 4a	Opt 5	Opt 6	Opt 7	Opt 7a	Opt 7b
Home-based Work	113,800	118,819	118,716	118,134	119,067	119,638	114,256	118,954	119,854	119,794	119,835	119,737
Non Work	204,865	216,234	216,238	215,262	217,945	218,552	208,659	216,727	224,524	219,107	219,154	218,877
Total	318,665	335,053	334,954	333,396	337,012	338,190	322,915	335,681	344,378	338,901	338,989	338,614
New Home-based Work Transit Trips (relative to No Project)		5,019	4,916	4,334	5,267	5,838	456	5,154	6,054	5,994	6,035	5,937
New Non Work Transit Trips (relative to No Project)		11,369	11,373	10,397	13,080	13,687	3,794	11,862	19,659	14,242	14,289	14,012
Total New Transit Trips (relative to No Project)		16,388	16,289	14,731	18,347	19,525	4,250	17,016	25,713	20,236	20,324	19,949
Percent New Transit Relative to Total BRT Boardings		32.1%	33.5%	32.7%	35.3%	33.3%	8.5%	33.7%	35.6%	35.3%	35.9%	34.4%

of the BRT 522 corridor along El Camino Real is scheduled for completion by 2015. Based on this schedule, it is expected that the VTA will be able to implement BRT in the county within three years, which will provide an opportunity to refine the BRT models in the relative near term and develop before and after studies of actual local experiences.

Table 7. Annual Operating and Maintenance Costs and Capital Costs for Eleven BRT Operating Plans

	Annual Operating and Maintenance Cost	Capital Cost
No Project	-	-
Option 1	\$62,700,000	\$412,200,000
Option 2	\$62,600,000	\$420,900,000
Option 3a	\$58,900,000	\$417,900,000
Option 3b	\$64,600,000	\$495,700,000
Option 4	\$64,400,000	\$490,000,000
Option 4a	\$64,400,000	\$490,000,000
Option 5	\$64,700,000	\$412,200,000
Option 6	\$64,400,000	\$490,000,000
Option 7 (BRT 10-20)	\$70,400,000	\$490,000,000
Option 7a (BRT 10-15)	\$72,300,000	\$490,000,000
Option 7b (BRT 10-30)	\$68,400,000	\$490,000,000
Option 7b (BRT 10-30)	\$68,400,000	\$490,000,000

Source: VTA BRT Strategic Plan, 2009.



Note: Assumes Transit Center at San Jose State for layover and turnaround.

Source: VTA BRT Strategic Plan, 2009

Figure 4. Preferred BRT operating plan – Option 7a (BRT 10-15)

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Modeling Access Mode Choice for Inter-Suburban Commuter Rail

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Abstract

This paper presents an analysis of access mode choice by riders of one of the first U.S. suburb-to-suburb commuter railroads, the Westside Express (WES), in the Portland, Oregon metropolitan area. The study uses on-board survey data collected by the region's transit agency, Tri-Met, during WES's first year of operation. The data include observed access mode choices, historical mode usage, and subjective assessment of WES attributes. A hierarchical choice model was estimated, using attributes of the access trip, station areas and rider characteristics. The estimation results revealed pre-WES-mode inertia effects in choosing drive access, pro-sustainability attitudes in choosing bike access, the importance of comfort to light rail and auto users, and strongly positive station-area effects of feeder bus lines and parking provision. The hierarchical choice model revealed significant substitution effects between drive and light rail modes and between bike and walk modes. This study provides potentially valuable insights to agencies for the purposes of station-area planning and targeted marketing efforts.

Introduction

In recent years, transit agencies have been trying more aggressively to attract suburban choice riders by extending rail service to areas traditionally dominated by automobile travel. Understanding the needs and preferences of current and potential transit riders is fundamental to developing and providing an attractive

service, but little is known about inter-suburban commuters and how they differ from more familiar hub-and-spoke commuter rail riders and urban transit riders.

Transit access and egress experiences are one important difference. Walk access dominates city transit and, consequently, most urban access mode choice studies focus on walking (Cervero 1995; Loutzenheiser 1997). Commuter rail riders, however, often live or work, or both, in the suburbs and depend on non-walk modes for train access. Access modes for commuter rail have received scant attention to date, and even less is known about the preferences and sensitivities of inter-suburban commuter rail riders.

This study applies discrete choice modeling to data from an onboard survey conducted by TriMet in 2009 on the Westside Express Service (WES), an inter-suburban commuter rail serving the western suburbs of Portland, Oregon. The objective is to learn more about suburban commuter rail access in general and WES riders in particular by estimating models of access mode choice with the aim of supporting targeted marketing and station-area planning efforts. The analysis covers both home and non-home origins and considers socio-economic, trip-context, station area and service variables, as well as survey respondents' attitudes. To our knowledge, this is the first study of access mode choice for suburb-to-suburb commuter rail.

Background

WES began operations in January 2009 as a single suburb-to-suburb line with five stations over 14 miles of existing freight tracks serving the heavily-traveled I-5 and OR Highway 217 corridor during rush hours. With only one connection to TriMet's light rail network, WES deviates from the conventional hub-and-spoke structure, making commuter rail transit available to those who both live and work in the suburbs.

Previous studies have found that access and egress factors, such as easy access to additional transportation, adequate parking, centrally-located stations, and attractive pricing, play important roles in attracting commuter rail riders (Cervero and Kockelman 1997; MARC 2002; Taylor and Fink, 2001). In terms of access mode shares, the majority of riders using Toronto's GO Rail system drove and parked (56%), followed by bus at 16 percent and walk at 11 percent (Wells 1996). In their study of Chicago's Metra system, Kurth et al. (1991) likewise found park-and-ride to be the dominant access mode (47%), but found higher walk access than bus access (22% and 11%, respectively). A 1994 survey of Florida's Tri-Rail revealed an access mode split of 48 percent park-and-ride, 38 percent transit, and 14 percent walk (Hadj-Chikh 1998).

Compared to city transit, commuter rail riders' tolerance for walking tends to be higher. Walking dominates short access trips of 0.5 to 0.7 miles, accounting for up to 80 percent of the mode split (Evans 2007; Debrezion 2009). For longer access distances, car or feeder transit services dominate. A BART survey found that 80 percent of access trips exceeding one mile to suburban stations were made by car (Cervero 2001).

Urban form, station-area factors, and area demographics also can affect access mode choice. In Washington, D.C., transit station area population density and walk access mode share were positively correlated (Kurth et al. 1991). Loutzenheizer (1997) found that availability of additional transit positively influenced transit access to BART commuter rail, but noted that individual characteristics such as gender, ethnicity, age, and car availability explained access mode choice better than land use and urban design variables. A 2003 study in California found that high-income transit riders residing close to rail stations were more likely to walk and bike to rail transit than other income groups (Evans 2007).

Access and egress mode choices differ, as fewer modes are typically available for the egress trip. Even so, findings from an *egress* mode study on Metra commuter rail trips in Chicago may be instructive. Kurth et al. (1991) found average egress walk time was 0.6 miles (12 minutes), noting that this was longer than the half-mile often used as a maximum walk distance for light rail transit. Moreover, the estimated value of time for the egress mode choice model was about half the value of time for the regional mode choice model.

About the WES Survey

In the summer of 2009, after WES had operated for six months, TriMet conducted an extended on-board origin-destination survey (TriMet 2009), collecting data on origins and destinations, previous travel modes, socioeconomic variables, pass holder status, and respondent attitudes. It should be noted that the survey was trip-based, not person-based, so some individuals may have taken it more than once. Highlights include:

- Before WES existed, 42 percent of respondents made the same trip by car and 47 percent by bus.
- 90 percent of trips were made by self-reported frequent or regular transit users.

- 35 percent of trips were made by people whose fares were subsidized by employers.
- Respondents' income distribution was bimodal, with a larger share of high-income riders than is typical for peak hour trips on TriMet overall.
- 63 percent of WES trips were made by males, and 75 percent of trips by Caucasians.
- WES riders agreed somewhat or strongly with all image statements about WES, such as freedom from stress and traffic, reliability and good connection with other transit modes. Riders described WES as "fast" and "comfortable," but wished for extended hours of operation and higher frequency.

Access Mode

Nine out of ten WES trips were home-based, (i.e., home was either the origin or destination). Home was the origin for 56 percent of home-based trips. Commuting (one end being work or school) comprised 77 percent of trip purposes. In general, the survey showed that WES attracts high proportions of bus and walk access for both home and non-home origins and relatively low proportions of car access trips, compared with the other commuter rail access model studies reviewed above. Figure 1 shows access mode shares for home origins, in which bus (28%) and car (27%) dominate, followed by walk (20%). For non-home access trips, car tends to be unavailable, and bus is the dominant access mode, distantly followed by walk and light-rail transit (LRT), as shown in Figure 2.

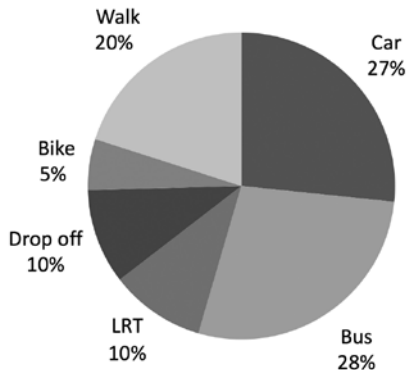


Figure 1. Access mode shares from home origins

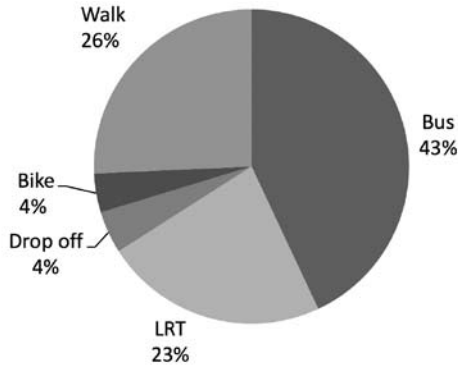


Figure 2. Access mode shares from non-home origins

Table 1 shows travel times by chosen access mode. Here, travel time is defined as the sum of in-vehicle, walking, initial wait, and transfer wait times for motorized modes, as derived from modeled network times used in the mode choice analysis described below. For reasons discussed below, this excluded observations in which walk and bike times exceeded the 85th and 95th percentile cutoffs, respectively. The long median travel times for bus and LRT suggest that, when coupled with other transit modes, WES represents one of two or more legs of a longer trip and is not necessarily the principal mode.

Table 1. Median, Mean and Max WES Access Times

Time (minutes, including wait and transfer)

	Median	Mean	Max
Car	7	11	51
Bus	30	34	121
LRT	22	24	73
Drop-off	5	7	25
Bike	13	19	55
Walk	8	13	59

Figure 3 shows access mode shares by distance. The median access trip was 1.7 miles (mean 2.75 miles). Walk access is the dominant mode at distances shorter than one-half mile, but drops sharply thereafter. Between one-half and one mile, mode shares are relatively equal between car and bus. For distances of one to five miles, bus is the major access mode. LRT holds the largest share for trips greater than five miles, but this is limited to trips accessing WES at the Beaverton station. In contrast to previously mentioned studies, WES auto access is notably low even at longer distances.

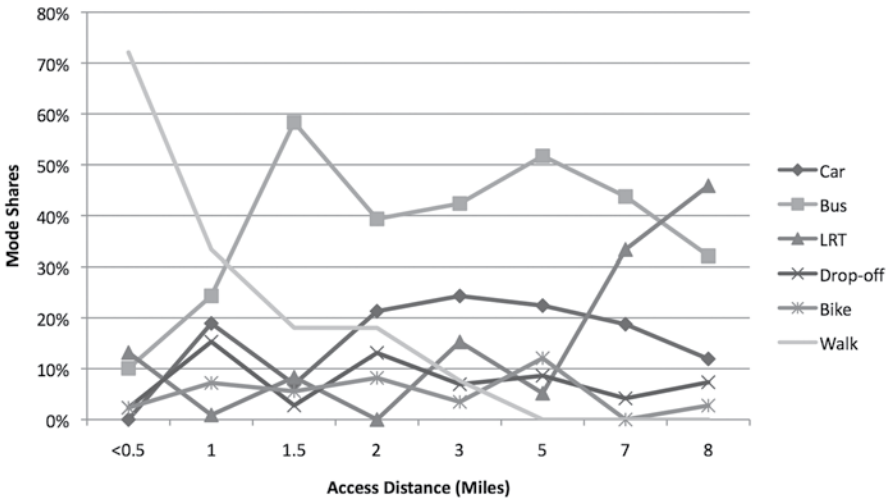


Figure 3. Access mode by distance

The survey used the three income categories listed in Figure 4. As expected, bus is a dominant mode share among the low income group, whereas car has the largest mode share in the high-income group, just below 30 percent. In contrast to the low income group, walk and bus access have equal mode shares among high-income riders.

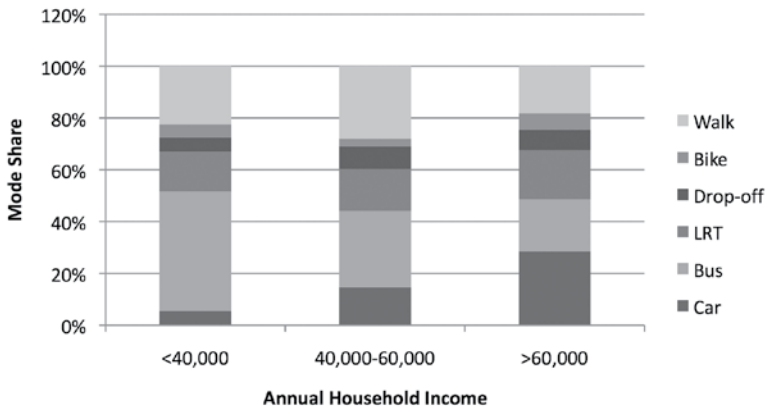


Figure 4. Access mode by annual household income

Access mode choice also varied substantially by WES station. For example, Beaverton is the only station with LRT access, which is the main access mode, but has no parking spaces and consequently supports very little (5%) car access. Tigard has the highest share of bus access (36%), while Tualatin is characterized by walk access (39%).

Methodology

To explore the behavior of individuals making a choice between alternative access modes, this study used discrete choice modeling methods (McFadden 1974; Ben Akiva et al. 1985). In discrete choice models, the probability of choosing a particular alternative is proportional to the difference between its estimated utility and the estimated utility of other available alternatives. Utility is defined as a linear function including variables representing attributes of the modes (e.g., travel time, cost, frequency), decision maker (e.g., income, auto ownership, age) or attributes of the environment in which the decision is made (e.g., population density). Utility function coefficients are estimated using maximum likelihood methods.

The multinomial logit (MNL) model is the simplest form, assuming that random error terms are identically and independently distributed (IID). A consequence of this restriction is the assumption of equal competition among alternatives. For example, in the MNL, the introduction of service improvements to an existing mode reduces the probability of other existing modes in proportion to their probabilities before the change. In reality, however, some alternatives are likely to be closer substitutes than others. The IID property can be overcome by using more flexible, complex model forms. In this study, we also estimated a Nested Logit (NL) model, which relaxes the independence assumption and can accommodate different degrees of similarity between subsets (nests) of access model alternatives.

Choice Set Creation

Logit mode choice models require the analyst to account for not only the observed choice, but also the set of alternatives that could have been chosen by each respondent. We supplemented the WES survey with trip-specific data on motorized and non-motorized travel times, transit availability and transfer times, costs, and previous on-board surveys. We defined a universal choice set consisting of six access-mode alternatives: car (drive and park), bus (with walk access), LRT (with walk access), drop-off (ride share), bike, and walk. From this universe of alternatives, we then created a set of "available" alternatives for each respondent in the survey.

Auto distances and travel time skims for pairs of traffic analysis zones (TAZ) were retrieved from the Portland regional travel demand model for all motorized modes (Metro 2005). Car was made available only for trips where the origin was home. The WES survey did not recover information on auto ownership. Based on auto ownership information gathered from onboard bus and express bus surveys in the WES corridor before WES existed, car was set as an available mode to 90 percent of trips in the dataset. Car was removed from the choice set for the one-tenth of surveys

for which all of the following was true: *Low income household (<\$40,000 per year)+ trip start at home + chosen access mode not car or drop-off + travel mode before WES existed not car or drop-off.*

Because fares paid for WES also cover transit access modes, only Car was assumed to have an additional monetary cost, calculated based on an average fuel consumption of 23 miles per gallon and a summer 2009 gasoline price of \$2.73 per gallon (US DOE 2009; Oregongasprices.com 2009).

The cost for drop-offs was set to 0.75 of drive and park cost, to reflect the two possible scenarios where a person can be dropped off on the driver's way (shared cost) or where the driver goes out of his or her way to drop off the WES rider (extra cost).

In Metro's transit travel time skims, bus is available if the distance from a TAZ centroid to the nearest bus line is under 0.25 miles. For LRT, the cutoff is 0.5 miles. Initial and transfer waits are calculated as half the headway of the nearest bus line, and walk access time is based on the distance from the TAZ centroid to the nearest bus line (Metro 2008). LRT was available only for trips accessing WES at Beaverton transit center.

A model developed by Broach et al. (2009) was used to produce least-cost path distances and travel times for bike and walk access. The model used a detailed network with bike paths. Utility-weighted distances, taking into account factors such as grade, presence of bike facilities, and car traffic volumes, were used instead of network distances. The 95th percentile, 8.5 miles, was chosen as a cutoff for availability for the universal choice set to retain a sufficiently large number of observations. The reported median access distance was 1.7 miles (mean 2.6 miles).

The fine level of detail in the bike network also made it useful for estimating shortest path distances for walk access. Median walk distances to WES were long: 0.54 miles (over 10 minutes), further than typically assumed walk distances to urban rail transit. The 85th percentile, 3 miles or 1 hour of walking, was set as the upper limit for walk availability.

The final dataset in the access mode choice estimation model retained 732 observations, or 77 percent of the original. Reasons for exclusion included missing information, origins outside the study area, and unrealistically long walk or bike distances.

Independent Variables

Explanatory variables used in the model estimation are listed in Table 2.

Table 2. Final Model Variables

Travel Time Variables	Definition	Median	Mean
TOTAL TRAVEL TIME			
CAR	Single occupancy in-vehicle time (AM or PM 2-hour peak)	6.9	10.55
BUS	Bus transit in-vehicle time (AM or PM 2-hour peak)	30.45	34
LRT	LRT transit in-vehicle time (AM or PM 2-hour peak)	22	23.63
DROPOFF	Single occupancy in-vehicle time (AM or PM 2-hour peak)	4.77	7.43
BIKE	Bike network utility-weighted distance/10 mph * 60 minutes per hour	12.66	18.61
WALK	Bike network shortest path distance/3 mph * 60 minutes per hour	8.4	13.34
OUT OF VEHICLE TRAVEL TIME	Walk time to transit + Initial transit wait (incl car) + Transfer transit wait	5.7	8.2
WES Station Variables			
PARKING	Natural log of number of car parking spaces at boarding WES station	103	125
BUS ROUTES	Natural log of number of bus routes serving the boarding WES station	10	7.6
POPULATION	Natural log of population within one-mile radius of WES station	8650	9900
Decisionmaker Variables			
ORIGINISHOME	Trip origin is home		0.56
FEMALE	Gender dummy (1=female)		0.37
EMPLOYER SUBSIDIZED TRANSIT PASS	TriMet transit pass is paid or subsidized by employer		0.29
INERTIA	Used to make this trip by car before WES existed		0.42
LOW INCOME	Annual household income less than \$40,000		0.35
COMFORT	Used the word "comfortable" when listing reasons for liking WES		0.43
LIFESTYLE	Agreed "somewhat" or "strongly" with the statement "Riding WES is part of my commitment to a sustainable lifestyle"		0.67

Model Results

Findings from previously published studies of access to urban rail transit and commuter rail, together with knowledge of WES and its service area, were brought together to form hypotheses about factors influencing the choice of all included access modes. Hypothesized relationships were tested in the model and typically retained at a 95% confidence level. While the final model specification includes mainly statistically significant variables, the discussion of the model results includes mention of a few theoretically plausible, yet statistically insignificant effects. Parameter estimates for the preferred multinomial and nested logit model specifications are presented in Table 3, and the preferred nesting structure illustrated in Figure 5.

Table 3. Preferred MNL and NL Models

Preferred MNL and NL models	MNL		NL	
Log Likelihood at zero coefficients	-1038.02		-1038.02	
Log Likelihood at constant	-816.06		-816.055	
Log Likelihood at convergence	-699.87		-679.467	
Rho-squared w.r.t. zero	0.326		0.345	
Rho-squared w.r.t zero Adjusted	0.326		0.324	
Rho-squared w.r.t. constants	0.142		0.167	
Rho-squared w.r.t. constants Adjusted	0.142		0.146	
Number of cases	732		732	
	Parameter	t-stat	Parameter	t-stat
Constants:				
Car				
Bus	1.253	2.065	0.935	1.049
LRT	3.684	6.621	5.216	6.478
Drop off	0.505	0.863	-0.889	-1.865
Bike	0.946	1.395	-0.015	-0.016
Walk	-1.64	-0.84	-2.273	-0.89
Generic variables:				
Travel cost (\$, car only)	-0.602	-1.453	-0.911	-1.932
Total travel time (minutes)				
In-vehicle travel time motorized modes	-0.023	-1.772	-0.049	-2.453
Travel time non-motorized modes	-0.049	-6.745	-0.079	-4.07
Out of vehicle travel time (walk time, initial and transfer wait)	-0.005	-0.428	-0.027	-1.308

Table 3. Preferred MNL and NL Models (cont'd)

	Parameter	t-stat	Parameter	t-stat
Mode specific variables:				
Log of car parking spaces at WES station				
Car	0.34	3.944	0.365	2.897
Used to drive this trip before WES existed (inertia)				
Car	1.507	5.045	2.536	5.465
Employer paid or subsidized transit pass				
Car	0.642	2.259	1.181	2.673
"Comfort" as main reason for liking WES				
Car	0.685	2.38	0.734	1.726
LRT	1.1	3.066	1.282	2.644
Low income household (<\$40,000 annual income)				
Bus	0.62	3.194	0.698	2.137
Log of bus routes at WES station				
Bus	0.697	4.286	1.447	4.236
Origin is home				
Drop off	1.128	3.426	1.079	3.326
Female				
Bike	-1.341	-2.7	-1.421	-2.559
"Riding WES is part of my sustainable lifestyle"				
Bike	1.127	2.429	1.229	2.271
Log of population density within one mile of WES station				
Walk	0.586	2.927	0.611	2.249
Nested test (against MNL model)				
Number of nests				2
Chi-squared vs MNL, -2*(LL_R-LL_U)				40.813
Critical chi-squared (95%)				5.99
Rejection significance				<.0001
Nesting coefficients				
Motorized 1 (drop off)			1(*)	
Motorized 2 (car,bus,LRT)			0.353	8.371
Non-motorized (bike, walk)			0.586	3.063

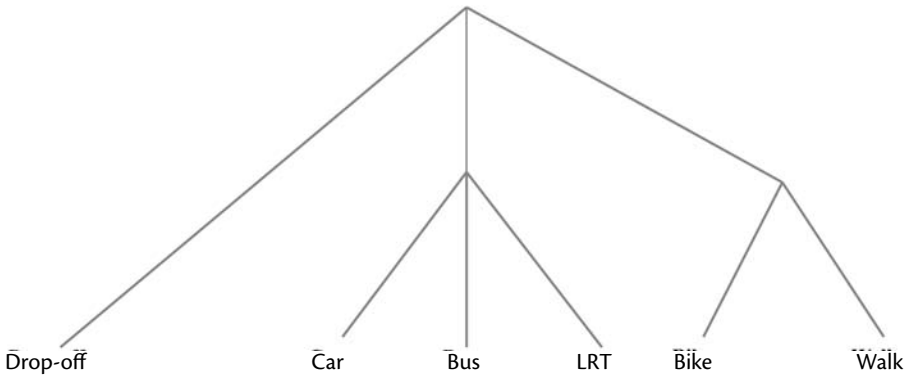


Figure 5. Preferred nesting structure

Model Fit Statistics

The NL model with the highest log likelihood value, -679.47, predicted access mode choice better than the multinomial logit specification ($p < .0001$). The rho-squared value is a log likelihood ratio between 0 and 1, used to indicate goodness of fit of the model, where a value of 1 implies all mode choices are predicted correctly. The rho-squared with respect to 0, 0.324, is an acceptable model fit considering limitations of the data. The adjusted rho-squared with respect to constants, 0.146 indicates that the independent variables provided explanation in addition to the model constants.

After testing several nesting structures, the preferred nesting structure illustrated in Figure 5 was chosen, based on goodness of fit, reasonableness of parameter estimates and theoretical validity. In this structure, car, bus and LRT belong to the same nest because they share more unexplained variance, while drop-off differs from the motorized modes. Similarly, bike and walk were closer substitutes and were placed in the same nest. The two nesting coefficients were estimated at the lowest level in the model. Nesting parameters with values closer to 0 represent greater similarity between alternatives within that nest, while values closer to one are statistically more independent. A Wald test demonstrated that the motorized and non-motorized nests were significantly different from 1 (0.353, t 8.371 and 0.586, t 3.063, respectively), thereby validating this structure.

Time and Cost Variables

In mode choice models, it is assumed that shorter travel times and lower costs increase the utility of an alternative. Therefore, we expect the coefficients to be negative for in-vehicle travel time, walk time to transit, initial wait for car and

transit, transfer wait for transit, and out-of-pocket costs. In preliminary estimation attempts, walk time, initial wait and transfer wait performed closest to these expectations when estimated together as out-of-vehicle travel time. En-route travel time was also separated into motorized and non-motorized modes to reflect the expectation that walking and biking are more physically demanding travel modes.

The coefficient on out-of-vehicle time was negative but, contrary to expectations, not significant (-0.027, t -1.308). The coefficient on cost was negative and barely significant at the 95% confidence level (-0.911, t -1.932). As expected, the in-vehicle travel time coefficient for motorized modes was negative and significant (-0.049, t -2.453), while the non-motorized travel time coefficient had a stronger negative magnitude and significance (-0.079, t -4.07). These results have implications for the value of time implied by the model.

Implied Value of Time

To test the reasonableness of the time and cost coefficients, the implied value of time was calculated, in dollars per hour, as follows:

$$\frac{\beta \text{ In-Vehicle Travel Time}}{\beta \text{ Cost}} \times 60 = \text{Dollar value of time per hour}$$

For models in which one predicts the main mode, not just the access mode, this value is expected to be roughly one-quarter to one-half of an hourly wage rate (Koppelman and Bhat 2006). Table 4 shows the in- and out-of-vehicle value of time in dollars for motorized and non-motorized modes for the nested logit model.

Table 4. Preferred NL Model Implied Value of Time

Preferred NL model	
Value of time	
In-vehicle travel time \$ per hr (motorized)	3.20
Travel time \$ per hr (non-motorized)	5.20
Wait and transfer time \$ per hr	1.77

Detailed information on WES rider incomes was not available. More riders were included in the below \$40,000 and above \$60,000 bins than in the middle income category. If the median hourly wage is taken to be \$20 per hour, the motorized in-vehicle travel time value of time would be one-sixth of the hourly wage, which is low compared with the ratios expected for main mode choice models. The implied value of time for non-motorized modes is closer to expectations at approximately

one-fourth of the hourly wage. The out-of-vehicle time parameter is problematic, not only because it is statistically non-significant, but also because it implies a lower value of time than in-vehicle travel time. Best practices in mode choice modeling hold that travelers regard waiting, transfer, and walk access times as two to three times more onerous than in-vehicle time (Koppelman and Bhat 2006).

The non-significance of the out-of-vehicle parameter and hence low value of time estimate may be partially due to a lower overall value of time for WES riders. Unlike the larger auto-oriented population, they seem to tolerate longer line-haul travel times and longer walk and bike access distances. These results seem to be consistent with the study by Kurth et al. (1991) on Chicago-area commuter rail egress trips, which reasoned that low values of time for egress trips might reflect lower willingness to pay additional costs for travel from commuter rail stations to final destinations. Another contributing factor is that the zone-based nature of the transit networks and aggregation of peak and off-peak average headways is likely to produce imprecise measurements of the experienced waiting times and inaccurate assumptions regarding bus stops used.

Rider Characteristics

It was hypothesized that riders may have formed habitual preferences for the modes they used for this trip prior to the existence of WES. This "inertia effect" was found to be significant only for ex-car drivers, who comprised 42 percent of the sample. The ex-driver dummy variable was strongly positive and significant (2.536, t 5.465), indicating that people who had previously driven the entire trip were now more likely to drive to and park at the WES boarding station. We theorized that WES riders with employer-sponsored transit passes would be more prone to accessing WES by transit modes. Contrary to our expectations, riders with employer-sponsored passes (35% of sample) were found to be significantly more likely to drive to WES (1.181, t 2.673). This likely is related to motivations behind employer sponsored pass programs, such as targeting former car commuters.

While low-income riders were expected to access WES by bus, LRT, walk, or bike (i.e., modes that incur no extra cost in addition to the WES fare), the estimation results supported this hypothesis only for bus (0.698, t 2.137). Unlike the Bay Area study by Evans (2007), our study did not find a significant relationship between walk-access propensity and high-income earners whose trips originated within a mile of the WES boarding station. Nor did we find a significant relationship between walk access propensity and ex-drivers with origins within a mile of WES stations. It may be argued that the suburban environment combined with the strong "car inertia"

effects discussed above, makes walking and biking less attractive and that this has a stronger influence on the disutility of walking than distance alone.

Ride sharing tends to be more common among members in the same household. We tested for this by including a dummy variable for trips originating at home, and found that WES riders starting from home were more likely to be dropped off than trips starting elsewhere (1.079, t 3.326). Home-origin proved to be the only significant predictor of the drop-off mode. In urban mode choice studies, females often are found to be less likely than males to travel by bike (Broach et al. 2009). Likewise, gender had a significant effect on choosing bike access for WES riders (-1.421, t -2.559).

WES Attributes

We theorized WES riders' subjective ratings of WES attributes could reveal preferences for certain access modes. We detected a "comfort factor," where riders who described the commuter rail as "comfortable" and cited this as the main reason they liked WES were significantly more likely to access it by LRT (1.282, t 2.644). The relationship between comfort and the choice of car as the access mode also was significant in the MNL model (0.685, t 2.38), but the significance of this parameter dropped to the 90% confidence level (0.734, t 1.726) in the NL model, suggesting this is not a well-defined variable. Nonetheless, it was retained in the model as an interesting value statement seemingly shared between LRT and car users.

Further, the survey probed WES rider sustainability values with the statement, "Riding WES is part of my commitment to a sustainable lifestyle." We hypothesized that those who agreed with this sustainability statement would be more likely to access the train by all non-automobile modes. Interestingly, this effect was found significant only for bike access (1.229, t 2.249).

Station Area Variables

Based on findings from other studies, it was hypothesized that greater parking supply would lead to more car access trips and more transit line connections would produce more bus access trips. To account for the non-linear and diminishing effect of additional car parking spaces, the natural log of car parking spaces was specified and yielded a positive and significant coefficient (0.365, t 2.897), confirming the hypothesis. Using the natural log of bus routes serving each station, it was found that the probability of riding the bus to access WES increases with the number of connecting bus routes (1.477, t 4.236).

In the aforementioned Washington, D.C. study (Kurth et al. 1991), stations with higher population densities were found to have higher proportions of pedestrian access. We

found that WES riders are more likely to walk to the train in areas with higher population density (0.611, t 2.249). More direct measures of urban design, such as number of intersections, traffic volumes, or even percentage streets with sidewalks, would likely produce a stronger indicator of “walkability” (Schwanen and Mokhtarian 2005); however, creating these variables was beyond the scope of our study.

As WES is a small commuter rail line with only five stations, attributes or travel behaviors associated with individual stations could have an unduly large influence in the model. To control for this, station dummy variables were tested, but no significant relationships between access mode and station were found. Nevertheless, the estimated constant for LRT is likely to pick up some station-specific effects due to it being available only at the Beaverton WES station.

Elasticities: Employing the Model

Elasticity computations can show how the probability of choosing an access mode changes in response to a change in an observed variable. This is useful for analyzing service or station attributes, over which the agency has some control. For example, if the number of car parking spaces at a WES station were increased, we could calculate the impact of this change on car-access mode share (direct elasticity) and could predict the extent to which other access modes would lose shares (cross-elasticity).

Using the estimated coefficients from the NL model, we tested the purely hypothetical situation of adding up to 100 car parking spaces at the Beaverton WES station, which has no park-and-ride today, despite the fact that nine survey takers drove and parked near this station. Because the elasticity computation requires a starting value above 0, it was assumed that the station starts out with four car parking spaces. The log of car parking spaces variable was used to capture the diminishing effect of adding more spaces. Table 5 shows the outcome of this exercise. Expanding to a total of 100 parking spaces would result in a 319 percent increase, or 29 additional car access trips to that station. The new car access mode share would be 13.7 percent, and the shares of other modes would be reduced. Following from the structure of the nested model, the largest effect would be on LRT and bus, which share the same nest as car, with smaller negative effects on the probability of choosing alternative drop-off, bike, and walk.

It is important to note that, due to the scope of this study, these elasticity calculations assume that total demand is fixed, and do not account for the possibility of attracting new WES riders, which might occur if additional parking were provided.

Table 5. Changes in Mode Shares Resulting from Addition of Parking Spaces

Beaverton Transit Center

Current parking spaces	4
Total spaces after addition	100

Beaverton WES access mode shares	Car	Bus	LRT	Drop-off	Bike	Walk	Total
Original mode shares	3.30%	31.60%	41.80%	8.00%	2.90%	12.40%	100%
Elasticity	1.377	-0.056	-0.056	-0.017	-0.017	-0.017	
Percent change	319.80%	-13.03%	-13.03%	-3.85%	-3.85%	-3.85%	
New mode shares	13.70%	27.50%	36.40%	7.70%	2.80%	11.90%	100%

Conclusion

The objective of this study was to learn how WES commuter rail riders choose access modes. This study found that station area attributes such as car parking spaces, connecting bus routes, and population density are some of the most important predictors of WES access mode choice, which is consistent with other urban rail transit access studies. In addition, we found significant relationships between certain rider attitudes and access mode choice, namely a link between appreciation for comfort and the propensity to access WES by LRT or car, and a link between pro-sustainability attitudes and bike access. Moreover, this study showed clear evidence for the preferences of ex-car commuters for driving to and parking at commuter rail stations. Employer-sponsored pass holders were also significantly more likely to access WES by car.

This type of study could be improved by including in future surveys questions related to auto and bike availability, which is critical to accurate construction of choice sets. In addition, some measurement problems related to transit sub-mode access, walk and wait times, and transfers could be remedied by point-to-point routing of transit trips and increased attention to schedule detail, which would require a more advanced transit network modeling tool than is currently available for the Portland region. As shown by Krizek and El-Geneidy (2007) in a Minneapolis-St. Paul transit market analysis, system reliability is also an important factor in travel mode choice. This could be explored for WES through additional survey questions related to its importance and respondent travel time buffers.

Current WES riders are similar to commuter rail riders elsewhere in their tolerance for long access travel times, irrespective of access mode, but differ in their

greater propensity to use non-auto access modes, particularly bus and walk. This preference for non-auto access modes, combined with the fact that WES is the only commuter rail line in the region, is just 14 miles in length, and is designed to connect suburbs, suggests that it may function more like a link in the regional transit network than a distinct primary mode. The study of a single suburb-to-suburb commuter rail line is not enough, however, to make any conclusive statements about the extent to which suburb-to-suburb commuter rail riders may differ from conventional hub-and-spoke commuter rail.

At the time of the study, WES had operated for only six months and was characterized by a small and enthusiastic group of riders, some of whom were likely trial users. Future analysis is likely to find a more established ridership. It would be especially interesting to follow car-accessing employer-sponsored transit pass holders over time to find out if they can be retained. Future work of this type should expand the scope of analysis to consider the entire mode choice decision and include the joint choices of access, main and egress modes together with other main modes, such as the automobile.

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Characteristics of Age-Friendly Bus Information

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Abstract

Bus information is an important element to consider when developing and implementing age-friendly bus systems. Little is known regarding the bus information needs and preferences of older people. This study aims to illuminate characteristics of age-friendly bus information. Participant observations with stimulated recall interviews (n=40) were used to identify older peoples' (age 60 and over) perspectives on bus information. The data were analyzed using qualitative content analysis. A printed information location checklist also was conducted. Categorical analysis identified that older people used a variety of information sources including printed information, telephone, Internet, bus drivers, word of mouth, and experience. Positive and negative characteristics of each source were identified. Older people also required a range of levels of information complexity. Popular locations for sourcing printed information included post offices, news agents, tourist information centers, and libraries. Transport providers and policy makers should consider the needs and preferences of older people when providing bus information. Effective information provision requires a range of media, covering a broad spectrum of information complexity and through a variety of locations.

Introduction

With aging populations in many western countries, there is an imperative to provide transport services that are accessible for older people. In Australia, for instance, the proportion of older people is expected to at least double in the first half of this century (Alsnih and Hensher 2003). Older people have a greater risk of difficulty catching buses and other forms of public transport, despite an increased reliance on public transport for community mobility (Glasgow and Blakely 2000; Dent et al. 1999; Davey 2007). In a study involving 620 older Australians (age 75 and over), a third reported difficulty using public transport (Dent et al. 1999). Fifteen percent of the sample had difficulty with both private and public transport and had no access to transport assistance.

Using buses is a complex process requiring multiple stages such as planning the trip, moving to and from the bus stop, getting on and off the bus, and interacting with bus drivers and other passengers. Significant attention has been given to researching low floor buses and other physical accessibility innovations, with relatively little consideration of other aspects of the bus system such as information and communication needs (Ashton et al. 2008). Finding, understanding, and processing information to plan a bus journey is a key step to using a bus system that has been relatively unexplored in the literature. The quality of bus information has been identified by older people as a potential barrier to their ability to use buses (Department for Transport UK 2001; Broome et al. 2009). Providing appropriate information and training has been identified as a core priority in providing an age-friendly bus system (Broome, Worrall et al. 2010). Indeed, older people have specific requirements for information that differ from the needs of younger adults (Broome, Nalder et al. 2010). Existing systems that may be designed without the explicit needs of older people in mind may not be appropriate.

It has been noted that the current generation of older bus users has a preference for printed materials over online or telephone information (Environment Victoria 2004; Fiedler 2007). Various recommendations exist for the provision of usable and accessible printed materials regarding font size (minimum of 10 pt, 14 pt recommended), font type (sans serif), color contrast (preferably black on white), and the need for information to be clear and concise (Environment Victoria 2004; Fiedler 2007; Shaheen and Rodier 2006; Texas Transportation Institute and Nustats International 1999). These recommendations, however, rarely are reported alongside evidence-based justifications. The most comprehensive sources (Texas Transportation Institute and Nustats International 1999) also are not age-specific. It is likely

that the recommendations simply have been drawn from disability literature, given their similarities. There are many potential shortcomings when applying disability standards to older people, as disability standards rarely take into account the cognitive, social, and generation-specific needs of older people (Harrison 2004).

There also are discernible shortcomings in the literature related to the provision of bus information to older people. The provision of information involves more than text and readability of written timetables. General guidelines for information provision for older people (not specific to bus information) have been suggested, including providing appropriate, clear and concise information and using a variety of sources for dissemination (Everingham et al. 2009). The role that the Internet and telephone services play for some older people is relatively uncharted, although they may be increasingly applicable with the growth of smart phones. Bus drivers are one of the most available sources of information during a bus journey. Despite this, the friendliness and helpfulness of bus drivers, the second highest priority for older people (Broome, Worrall et al. 2010), also has attracted minimal research attention. Similarly, the availability of printed information attached to bus stops signs (as opposed to printed timetables) has received little consideration. In regards to printed timetables, a review of the literature found no research that recommends where older people would prefer to source printed timetables.

Given these gaps in the research, a mixed-methodology approach has been adopted in the present study to further our understanding in a number of areas of bus information provision for older people. The aims of the current study are to 1) elicit experiences of older people using various forms of information, 2) elucidate the specific information needs of older people, and 3) determine sources of printed information used and preferred by older people.

Methodology

Multiple methods were used to establish the bus information needs of older people. The study used qualitative analysis of stimulated recall interviews (associated with an actual bus trip) to garner older peoples' perspectives on bus information. A quantitative analysis of the stimulated recall interviews is covered in a previous paper (Broome, Worrall et al. 2010). This information was supplemented by a checklist to establish known and preferred sources of printed information.

Sampling

Volunteer sampling and maximum variation sampling were used to attain a sample of 40 older people age 60 and over. The sample targeted in this study is drawn from a larger volunteer sample from a previous study (Broome, Worrall et al. 2010). Two sample sites from Queensland, Australia, were used. Participants from Hervey Bay provided perspectives on a regional bus service, and participants from Brisbane represented users of a metropolitan bus service. The two sites were selected to provide divergent perspectives, as transport disadvantage is known to differ between metropolitan and more rural contexts (Glasgow and Blakely 2000).

To minimize self-selection bias, maximum variation sampling (to reflect diversity) was used to select 40 participants from a volunteer sample of 227 older people who took part in the larger research study (Broome, Worrall et al. 2010). Maximum variety aims to attain a broad spectrum of perspectives by purposively selecting participants who reflect various combinations of parameters. Parameters used in this study were frequency of bus use, difficulty of bus use, and sample site. Each of the 40 participants took part in a bus trip followed by a stimulated recall interview. Of these participants, 33 also completed the checklist on printed information sources. Eligibility criteria for the study were community-dwelling, age 60 or over, and with sufficient cognitive and language skills to complete the interview. No incentives were provided for participation in the study.

Outcomes Measures

All participants, as part of the previous study (Broome, Worrall et al. 2010), completed an initial questionnaire including demographics and car use, as well as frequency (3-pt scale) and ease (10-pt scale) of bus use. Higher scores represented greater ease of bus use. The previous study used the nominal group technique to identify and prioritize barriers and facilitators to bus use for older people. The importance of information accessibility was identified at this stage. Following selection from the larger sample, the 40 participants were invited to take part in observations of their bus use and stimulated recall interviews. Stimulated recall interviews are used to elicit participants' recalled experience of actual events or situations (Davidson et al. 2006; Skovdahl et al. 2004). Stimulated recall interviews uncover the subjective experience of participants in relation to observed events. The stimulus material may be, for example, a video, audio recording, or verbal prompts related to a recent activity. In this case, the stimulus was a return bus trip. A researcher accompanied each participant on a bus trip of the participant's

choosing. Prior to the bus trip, the stimulated recall interview was initiated using a semi-structured interview to elicit participants' perspectives on planning the bus trip. Participants were asked to identify what helped (facilitators) or hindered (barriers) planning the bus trip. Following the bus trip, the stimulated recall interview was continued with stimuli including phases of the bus trip, such as getting to and from the bus stop, embarking and disembarking the vehicle (e.g., "then you stepped on to the bus"), and moving on and around the vehicle. Participants were asked what helped or made it more difficult to catch the bus at each phase. Additional prompts based on observations by the researcher (e.g., "then a person on the bus moved off a seat for you to sit down") also were used. Interviews averaged approximately 105 minutes in duration. Each interview was audio recorded and transcribed.

Participants also completed a checklist on sources of printed information and were asked where they knew timetables were available or where they thought timetables should be available. The checklist was completed at the end of the interview. Stimulus questions included, "You have mentioned places where you have got timetables. Is there anywhere else you know you could get a timetable?", "Is there anywhere else you think would be a good place for you, an easy place to pick up a timetable?" and "What is it about the place that makes it good, that would make you think it is there or should be there?" Prompt locations included timetables on the bus and at the library, the council, news agencies, post offices, community groups/venues, bus depot/booking centers, and tourist information centers. Participants were encouraged to mention other applicable locations. Comments relating to the locations—for example, how easy they were to get to—also were recorded.

Data Analysis

Demographics were described using descriptive statistics. Qualitative content analysis (Graneheim and Lundman 2004) was used to identify categories and themes from the stimulated recall interviews. Salient comments related to bus information were identified within the transcripts. These comments were organized into subcategories, with subcategories then grouped under overarching categories. A review of the data as a whole, as well as categories and subcategories, was used to uncover themes related to bus information that permeated the transcripts. A peer review process, where the qualitative content analysis was reviewed by a second researcher, was used to improve the rigor of data analysis. In the peer

review process, the second researcher was provided with the raw qualitative data relating to bus information and coded these into categories. Where discrepancies in categorization existed, discussion continued until a consensus was reached. When consensus could not be reached, a third researcher was available to mediate categorization, but was not required. Supplementary data from the checklist were analyzed using descriptive statistics to highlight frequently known and frequently preferred sources of printed timetables.

Findings

Demographics

Participant characteristics are shown in Table 1. The sample represented a diversity of transport situations and self-rated ease of bus use. There were more females than males who took part in the study, which may limit the generalizability of findings.

Table 1. Participant Characteristics

Characteristics		Mean (SD) n=40
Age		72.4 (6.5)
Self-rated ease of bus use (out of 10)		5.8 (3.3)
		N (%)
Gender	Male	11 (27.5)
	Female	29 (72.5)
Sample site	Hervey Bay	20 (50)
	Brisbane	20 (50)
Length of residence in area	Five years or over	22 (55)
	Less than five years	18 (45)
Driving Status	Current driver	25 (62.5)
	Retired driver	9 (22.5)
	Never driven	6 (15)
Frequency of bus use	Frequent user	18 (45)
	Occasional user	12 (30)
	Non user	10 (25)

Qualitative Content Analysis

An outline of the categories and subcategories is shown in Figure 1 and described in more detail in the following sections. The comments relate to barriers and facilitators to using bus information identified by older people.

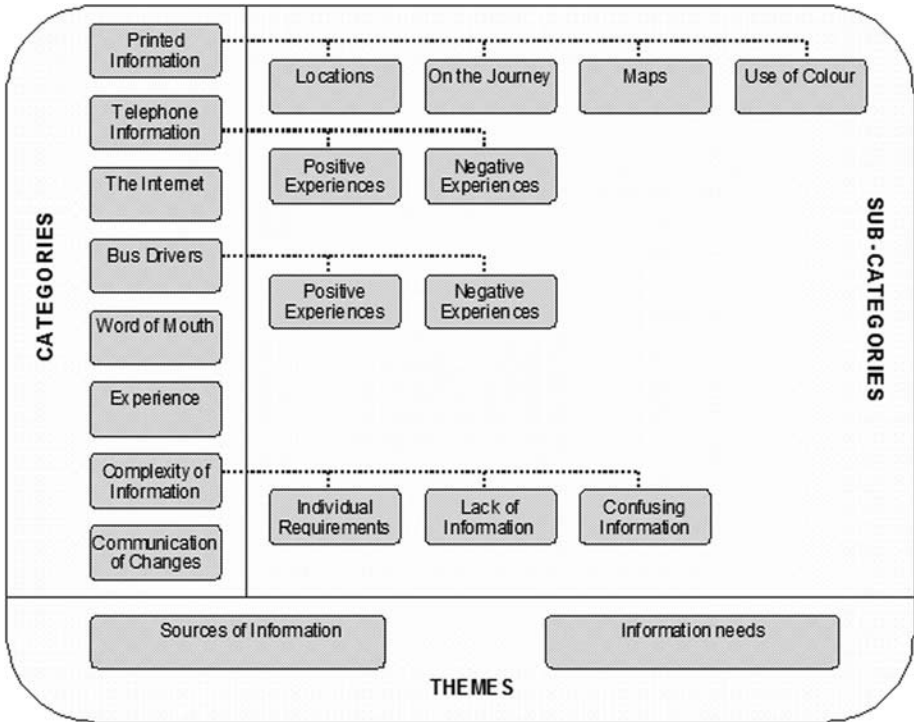


Figure 1. Categories and themes relating to barriers and facilitators to bus use for older people

Categories of bus information included printed information (both printed timetables and at the bus stop), word-of-mouth (friends, family, neighbours, strangers), bus drivers, telephone services (bus company or information line), and the Internet. Some participants did not use information sources, and these were categorized as “experience” (e.g., previous experience, just turned up, previously saw that a bus with a destination sign had come past). Other categories included the complexity of information required and communication of changes to the bus system.

Printed Information

Printed information was the most common source of information and attracted the most comment. This included both printed timetables that were carried on the person as well as information at the bus stops. The ability to source printed timetables as a prerequisite to using buses was identified as a barrier by some participants. Often timetables were difficult to access. As one participant stated:

Just the non-availability of schedules, [1] found that frustrating. I guess they work on the premise that the people that use the buses are frequent travelers and they have the schedules memorized. The lady at the corner knew exactly when her bus was due along the esplanade the other day and on Saturday.

One new bus user noted that when she was new to the area and she did not know where to look for printed timetables.

The provision and locations of printed timetables needed to be intuitive to new buses users. As one user noted, "You've got to think in the customer's mind, not your own. So where would you go, you go to a new town ... go to Centro. Or go into a news agent or one of the tourist shops.... That's where I'd go, but a lot of people don't think that way."

In many cases, the sources of printed timetables were not intuitive, as described by one participant: "That's what sort of got me, they drop off ... [their schedules] to hotels and motels in the bay.... They don't ... put them into banks." One site, Hervey Bay, had initiated an effective approach of using a letterbox drop, which overcame this issue of finding printed timetables.

Often, participants also needed to access information during the journey or used the information at bus stops rather than planning ahead. In this situation, portable printed timetables or information attached to the bus stop sign became invaluable. A number of participants commented on the ability to have pocket-sized folded timetables, highlighting the need for small and durable timetables. Other participants preferred information at bus stops. Information at bus stops needed to be consistent across stops, as was noted: "There's not information at the stops here, not all the stops have got information.... I think all stops should have a timetable."

With respect to the content of the timetable, the importance of the map was predominant. The majority of participants who used printed information relied on the map:

Definitely those maps were essential, substantial. The way they set them out, separating the routes out. It leaves no doubt in a person's mind where the pickup points are and how they move around, and that's very important.

The map was often the first point of reference to decide whether a bus route was applicable for the person's journey. One participant, while planning her trip, dem-

onstrated increased understanding of her journey after referring to the map. Maps were not included on timetables in all jurisdictions:

Getting that timetable made all the difference, and being able to see where the buses actually went. Having those pictures of the route on it ... I think it's an excellent timetable, much better than the ones we had in the city. They were just a sort of a typed sheet and that was about it.

When designing the map itself, including each route and marking the direction of routes with arrows was valuable. Also, maps have the potential to communicate more than just routes. Where relevant they can give important information on zones related to ticket prices:

I find the ones we have adequate because they have a map. They show you the zones so you can follow where you're going. But I picked up a timetable I was using the other day and it didn't have that on. And I said to my husband, "Isn't that strange, we don't know what zone we're in."

Color is an important facilitator in timetable design to orientate the reader to the map and routes. Many participants discussed the use of color in a positive manner, often using color to link timetables to maps. Consideration should be given to ensuring high contrast between the color and the background, as well as a preference for using matte paper to avoid glare. Use of color should be accompanied by a key to illustrate the meaning of each color. On the subject of color, one participant drew parallels with the London Tube system, where the colored route map has become iconic:

I think having the different colored routes [helps], I mean, we were struck on the tube in London, you know, the routes were different colored and you knew what routes you needed. It makes it so much easier to look up.

Telephone Information

Telephone information was also a popular source for participants. Depending on the type of phone system and the quality of staff, some participants had very good experiences with telephone information. Two participants described very positive experiences, as one mentioned:

I found that very helpful. I found the staff helpful. I was enquiring particularly just a couple of weeks ago to visit my brother and I didn't know how to get there. They were very helpful, they gave the bus stop to wait at, they

gave me all the information that I required, and I thought that was very helpful.

In contrast, some participants had negative experiences with telephone information. One participant noted that “I don’t do many calls on the phone, only what I have to, because I’ve got a deaf phone, and it’s very hard sometimes even hearing the deaf phone.” This highlighted not only the need for multiple sources of information to cater for sensory impairments, but also the potential role for effective communication strategies used by staff. Automated telephone systems also were negatively perceived. One participant called the automated system “a little bit of a pest ... because you’re not actually talking to a person at times and they don’t always know what I’ve said to that machine.” She went on to describe an illustrative situation where “I had to repeat myself three times to answer the question, ‘Did you say so and so’ and I said, ‘No! So and so’ and that went on for a bit and then I think probably they did put me on to somebody.”

The Internet

While many participants did not use the Internet to find bus information, a few did. Many participants did not use the Internet at all. One participant stated, concerning computers, “The fact that my life doesn’t seem to need one. At nearly 81, I might find it a bit difficult. I have friends who have trouble with the, uh, machines.” Some had access to the Internet but did not use it as a source of bus information. As one participant described, he would “much rather use the little paper one, [it] wouldn’t occur to me to go on the web, it’s just there, it’s handy.” This lack of familiarity with computers and the Internet is likely to change as successive generations age. Therefore, the provision of accessible bus information via the Internet should become part of a long-term strategy for age-friendly information provision.

Familiarity with the Internet also may be influenced by the local demographic and may differ in other areas of the world where Internet use by older people may be more common. Additional factors affecting Internet use, include changes in vision, prompted one participant to mention:

I found that out from the Internet, and then I found it a bit difficult to read it on the computer. My eyes are getting old. But I worked out an itinerary. I thought, I’d better go and get a timetable. So I went and got a [printed] timetable then so that I could just check that what I read on the computer was up to date.

Bus Drivers

Bus drivers were also a commonly consulted and very convenient source of bus information. As one participant stated, “The bus drivers were helpful with their information. They’d say, well, where do you want to go? And I’d tell them, and they’d give me the information. All you’ve got to do is open your mouth and ask the drivers or get on the phone and ring the bus service.” In many cases, this information was in addition to using timetables for trip planning. Bus drivers often knew specific information that was not in timetables—for example, how the bus system worked, where specific locations were—and could assist when timetables were not available or were outdated.

The effectiveness of bus drivers as a source of information was strongly influenced by their friendliness, helpfulness, and knowledge. As one participant stated, “I’ve found bus drivers at all levels. The two bus drivers [today] were very good. I mean they knew where we wanted to go and they knew what we were about and that’s I think the role of the bus driver—to get a passenger to and from the point of embarking to the point of disembarking.” Many bus drivers, especially in regional Hervey Bay, were very friendly and helpful. A positive experience recounted by one participant was that:

They’ll say, well, I want to go to such and such, and then the bus driver will say the closest, and then he’ll call out whoever wanted to go to such and such a place, this is where you get off. And then as they get off, they’ll point and say, then you go up that street. And they’re very helpful that way.

In contrast, some older people also had negative experiences with bus drivers. “There’s one grumpy one I don’t like. I thought, I won’t ask him again (laughed).”

Word-of-Mouth

It was not uncommon for participants to also use less formal sources of information, such as word of mouth. Other service providers (such as shop assistants), neighbours, and strangers at the bus stop were common sources of information. One participant elaborated on her experience, saying that, “I’d walk down and catch the bus and listen to people talking on the bus; if they’re talking about something, your ears pick up. So the bus goes from here to there, and all this sort of thing, but times were more of a problem because I didn’t know how many buses we have a day or anything.” Word-of-mouth often could provide additional information not available in timetables, such as recommendations from experience on

the best connections to take. At times, word-of-mouth was limited: “And I think it’s pretty fair to say that most people that don’t use buses don’t talk buses.”

Experience

Some participants did not use any sources of information to plan the trip, as they had extensive experience using buses and were already familiar with routes, systems and timetables. From experience, others have confidence that they do not need to plan the trip and can wait for buses at stops that they already know. One participant stated, “As I go to the shops. I see the bus stop. I can stop and read the number of which bus it is and the route is drawn there on the bus stop sign at the shopping center.”

Complexity of Information Required

Participants reported a wide range of depth of information required that were both barriers and facilitators. For some, information requirements were simple, for example, “Well, they gave me the bus routes, the times, and the connections, which is basically all I needed to get there.” Others performed more extensive planning, with one participant stating;

Mostly before I go, I know when I’m going and when I’m coming home, in which case I know which bus, and I try to work out before I go, which bus is going to be the most convenient to come home on. If you don’t do that, you’re going to have to wait an extra hour, very simple. Saturdays are really the only day that I can’t do that because there’s not as many buses, so I’ve got to wait until 11 o’clock to after 12 to get a bus, but I usually get one at Centro.

In many cases, the information provided, either on printed timetables or via the Internet, was insufficient. In the simplest terms, one participant said, “I don’t think there’s enough information yet to tell me when I can leave this house and catch a bus, what time to catch a bus.” Specific shortcomings include lack of details in roads and maps, as well as lack of information on ticketing. Two participants relayed their experiences of lacking information: one found that the map did not indicate a major street near her; the other found that the Internet source did not have sufficient information to work out fares and ticket types available.

It can be a perpetual challenge for transport operators to provide information that is both detailed and concise and meets standards in text size. This dilemma often requires a suite of publications, including both a network route map (to assist bus users to select appropriate routes) and separate timetables for each route. In

some cases, the information provided was confusing or could have benefited from greater clarity. As one participant described, "It needs to be clearer, and I think it would be better if all the buses did the same thing; some do one thing, others another; when you get on, you have no idea." Another stated, "This later addition where they give the times throughout the day is a little easier, rather than when you had to add you half hours or quarter hours."

Communicating Changes to the Bus System

Unexpected changes to the bus system were barriers to using buses raised by a number of participants. Not all experiences were negative. In one positive example, the council that runs the local bus service was proactive. As a participant states, "Yes, it was in our local papers. It was advertised, and we had been informed that we would be getting the bus by the local council."

Themes

Two specific themes emerged from the qualitative content analysis. The first related to multiple *sources of information*. The participants who were interviewed accessed a wide range of information sources, including printed information, telephone information, the Internet, bus drivers, word-of-mouth, and experience. Some participants used only one source of information, while others used multiple sources. Therefore, transport providers should provide information through all forms of media and at many different sources. The source of information was frequently based on personal preferences. Sources of information not only are influenced by participants' preferences, but also can be limited by changes associated with aging (such as a visual impairment) or geographic factors (such as difficulty travelling to locations where printed timetable can be found). These findings are aligned to previous findings from other age-friendly literature focusing on supermarkets, GPs, financial planners, and tourism operators, which identified that older people used a variety of information sources, but commonly had a preference for printed information (Pettigrew et al. 2002).

The second overarching theme was that there was individual variation in the information needs of each participant. Some were experienced users and required only bus times. Others were new to the system and required additional background information on how the system works or how fares are structured. While there is variation in the type and depth of information that older people are seeking, there are core aspects or "questions" from the user's side, such as "How do I get to the bus stop?", "When will it come to my bus stop?", "Will it take me to where I need to go?", and "How much will it cost me?" As one participant aptly put, "You've got

to think in the customer's mind, not your own." These findings also are aligned to previous literature that identified that older people may be served best by multiple levels of complexity of information; for example, some required limited information focused on the present situation while others preferred detailed information (Pettigrew et al. 2002).

Printed Information Location Checklist

In addition to completing the participant observations with stimulated recall interview, 33 of the participants completed the checklist on sources of printed timetables. The most common places that participants knew timetables were kept included the library (11), shopping centers (10), on the bus (9), from the council (9), at bus depots/interchanges, (7) and at tourist information centers (5). As no single location was listed by more than a third of participants, this represents a relatively low general awareness of where timetables are available. The most common places that participants thought it would be a good place to keep timetables included the post office (24), news agents (17), tourist information centers (13), libraries (13), shopping centers (9), councils (8), on the bus (8), community centers/groups (8), and bus depots/interchanges (7). As can be seen, there is a discrepancy between where participants knew timetables were kept and where they preferred timetables to be located.

The most consistent comments regarding barriers to accessing printed information locations were that libraries and councils were often out of the way or not frequently accessed. As one participant mentioned, "You have to catch a bus to get to the library." In contrast, the post office and shopping centers were regularly frequented by older people.

Discussion and Conclusion

The results of the qualitative content analysis and the checklist neither support nor refute the previous literature on bus information that focused on fonts, contrast, and other parameters of printed materials. The participants rarely commented on these aspects and focused more on aspects not mentioned in previous literature, namely the sources and qualities of bus information. The themes fit in well with the considerations suggested (Everingham et al. 2009) for the general provision of information in age-friendly communities. The positive experiences associated with telephone information and bus drivers implicate these media as important

aspects of a comprehensive suite of bus information sources, while the negative experiences suggest potential areas for improvement. Transport providers should reconsider their current delivery of information and whether it meets the needs and preferences of older people in terms of sources, quality and depth.

As a result of this study, the following recommendations should be an initial guide for transport providers and policy makers when designing bus information suitable for older people:

1. Transport providers should continue to use multiple media in their communication plans, including printed timetables, timetables at bus stops, telephone information lines, and Internet sources.
2. Printed timetables should be designed using clear vibrant colors with high contrast and a white background.
3. Printed timetables should include clearly marked maps and, where possible, have a separate map for each route.
4. Printed timetables should be distributed to post offices, news agents, tourist information centers, libraries, shopping centers, councils, carried on the bus, community centers/groups, and bus depots/interchanges, and in smaller jurisdictions where there is greater cost-effectiveness, a letterbox drop might be used.
5. Printed information should be available at all bus stops.
6. The effectiveness of bus drivers as information providers should be enhanced, for example, through communication training and/or age-friendliness training or through the recruitment of bus drivers with effective communication skills.
7. Telephone information should be in person or, where possible, there should be an option to go directly to an operator.
8. Similar to bus drivers, training or recruitment processes also should be applied to bus information telephone information providers to enhance their age-friendliness.
9. Improving Internet information should be part of the medium- to long-term strategy for assisting older people.
10. Changes to the bus system should be communicated through various modes, including, for example, advertising, notices at bus stops, and bus drivers.

The findings from this study extend on the existing literature, specifically proposing recommendations for providing age-friendly bus information based on older people's preferences. However, this study also experienced a number of limitations due to the design of the study. The study focuses on a limited sample, drawn from

one country. This may lead to peculiarities in the findings, such as the limited mention of Internet use and no mention of smart phones, within this study. Therefore, the study should be replicated in other jurisdictions to increase generalizability. Additionally, while qualitative research is beneficial for exploring a phenomenon when little or no knowledge exists on the topic, such as age-friendly bus information, it is prudent to conduct subsequent quantitative analyses to validate hypotheses raised and improve the generalizability of the data. A quantitative analysis also may allude to the relative importance of each information source and quantify the difference between the metropolitan and non-metropolitan samples used in this study, which could not be obtained in this study. Once the hypotheses have been explored, the next logical step is to evaluate the impact of implementing these recommendations on ease of trip planning for older people, as well as overall bus use, satisfaction, and community participation outcomes for older people.

Prior to this study, there was a dearth of published literature about the bus information preferences of older people. This study suggests that older people access a variety of information sources and require a range of levels of complexity regarding information. By catering to the needs and preferences of older people, it is likely that the barriers to bus use will be overcome or at least minimized and older people will have a greater opportunity to use transport later in life.

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A New Architectural Design of Elevated Small Group Automated Rapid Transit

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Abstract

Due to increased motorcar popularity, public transport use has declined while congestion costs billions in wasted time, fuel, accidents, air and water pollution. Proposed passenger transport projects have been cancelled in major cities, and completed projects have not attracted the private motorist. This study investigates reasons for this. As cities grow vertically and horizontally, they form three-dimensional mazes requiring special transport design solutions that enhance the city. Congestion can be alleviated by transferring passenger transport onto elevated solutions such as the presented Elevated Small Group Automated Rapid Transit (ESGART) SkyCabs system, which straddles the gap between Group Rapid Transit (GRT) and Personal Rapid Transit (PRT). This two-way monobeam is detailed, including ease of building through cities and low construction cost. Architectural and engineering aspects of eight-seater cabs, cab frequency, stations, and lines are described. This study also explores connectivity on two example lines in Auckland, New Zealand, within a SkyCabs network and to other modes of transport. Quantitative and qualitative attributes are considered. The result is a rapid transport system that is affordable

and attractive enough to draw significant numbers of auto users reducing congestion and CO2 emissions.

Introduction

As a consequence of increased motorcar popularity, public transport use has declined such that traffic congestion on our roads costs billions in wasted time, fuel, accidents, air and water pollution (Laird et al. 2001) Cities such as London, New York, Seattle, Chennai, Sydney, Melbourne, and Auckland have, in the last five years, delayed or abandoned planned rail, light rail, or monorail routes because of seemingly unjustifiable costs or costs well beyond budget.

Objectives

The objectives of this work are four-fold: (i) review briefly the interaction between city growth, public transport, and traffic congestion; (ii) propose a new passenger-transport mode solution to reduce congestion; (iii) describe the new solution in detail and compare it to traditional forms of public transport; and (iv) perform connectivity analysis of the new solution using qualitative and quantitative attributes. The final objective aims at preparing the ground for the construction of a demonstration track as part of a pilot study of the new passenger-transport mode solution.

Literature

Several publications present an overview of new technologies in public transport. In a very comprehensive review of advanced transit systems, the U.S. Department of Transportation (Federal Transit Administration 2000) divides these systems into five groups. The first group consists of fleet-management systems, which include automatic vehicle location, public-transport operations software, communication systems, geographical information systems, automatic passenger counters, and systems for traffic priority. The other groups are traveler-information systems, electronic payment systems, systems for demand management, and intelligent public-transport vehicles. The discussion of each group contains a description of the technology, its benefits, a review of the state of the art and existing systems, and examples of application.

In a separate publication, the U.S. Department of Transportation (Federal Transit Administration 2006) identifies and quantifies the benefits derived from cur-

rent applications of the advanced systems described in the previous publication (Federal Transit Administration 2000). A very detailed discussion of the various technologies addresses their benefits and costs, including monetary values based on actual experience. Applications of fixed bus routes, demand-responsive public transport, and various rail types are presented.

Blythe et al. (2000) presents an overview of intelligent transportation system (ITS) applications on public transport. The authors identify specific advantages that ITS can offer public transport in terms of travel-demand management, infrastructure management, vehicle management, information provision, and multi-modal ticketing.

The idea of intelligent public vehicles for private use has been discussed in the literature for a decade, but some small-scale cases of implementation have induced a new debate over practical issues. Anderson (2000) reviews the rationale for Personal Rapid Transit (PRT) and the process needed to develop it. Glazebrook and Subramania (1997) offer a detailed discussion of PRT, which is based on a concept similar to PRT.

City Growth and Transport

Urban expansion occurs in two ways. Easiest and lowest-cost expansion is spreading into newly available areas further from the city center. Closer to the central business district (CBD), expansion and development are more difficult and expensive. Vertical growth with ever taller buildings and higher occupancies in the CBD create a three-dimensional maze.

Global Factors Affecting Travel Demand and Service Provision

Global factors affecting travel demand and service provision (TranSystems et al. 2006) are summarized in the New Zealand (NZ) context:

- City/land development features and patterns such as geographic, topographic, ecological, zoning, density considerations.
- Population characteristics in zones, age distribution, activity-related travel.
- General and individual economic situation, household income, asset ownership.
- Features of travel mode, mode choice due to attractiveness and convenience.
- City/government intervention via regulation/assistance via subsidies.

Transport Difficulties with Buses and Traditional and Light Rail in the City

Providing passenger transport from the outer edges of the city with their own “hubs” but with very low population densities involves long trips by buses into the central areas along increasingly congested roads.

The use of exclusive bus lanes near the central city to overcome the disadvantage of multiple stops and slow trips has to be regarded as a problem. While allowing faster bus trips, an exclusive bus lane takes a minimum 1,800 to 2,000 passengers/hr auto users off the road. With 40-seater buses, up to 50 full buses per hour, one every 1.2 minutes, are required just to equal the lost capacity. A bus with 80 passengers gives a frequency of 2.4 minutes. Both are in the congestion-causing frequency (Nielsen et al. 2007). Buses alone on bus lanes do not seem to increase throughput of the roads.

Traditional rail services from the outer edges need exclusive rail corridors through the developed city, of necessity, do one or more of the following:

- Take over existing road space competing directly with cars and causing further congestion at intersections.
- Take land currently developed with housing and commercial land to provide the exclusive way (this still necessitates crossings at all roads at right angles)
- Raise the rail line above roads.
- Build tunneling underground with underground connections to the city above.

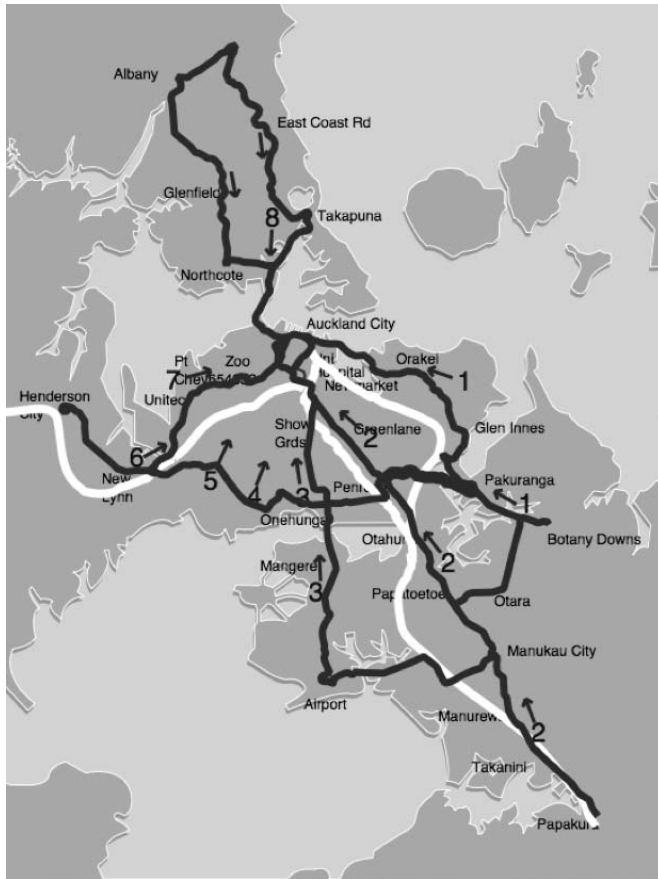
Rail lines are continually proposed to be placed directly along the simplest route, severing communities on either side. Any use involving crossing the rail lines is restricted, and accidents increase.

Light rail line costs are reduced by use of the roadway at the expense of previous use of the road. If light rail is to provide a service to attract auto users, as all new rail systems are expected to do, they need to be frequent and have a high operating speed. These two requirements cause a direct conflict with autos and pedestrians in any sharing of the road.

Time Frames Travel Patterns and Proposed Rail Expenditure

Congestion in cities normally shows up with the movement to the places of employment during 7:00 AM to 9:00 AM peak travel times at the start of business and the opening of schools and is at its worst usually in the CBD. Afternoon and evening peaks follow (Auckland Transport Models 1996).

In Auckland, the major morning peak traffic is heading to the CBD from approximately eight directions, as shown in Figure 1. The existing rail covers only two directions—the South and the West. As trains are full in peak hours, an expenditure of \$3.9 billion (NZ\$) currently is proposed to increase trains from 4 per hour to 6 per hour or at 10-minute intervals. Using 600 or 800 passengers/train, this could allow an increase of 1,200 to 1,600 passengers/hr. Even if allowing three directions of rail service, this will lead to a total of 3,600 to 4,800 passengers/hr extra into the city for the capital expenditure of \$3.9 billion, or minimum \$812,500 investment per new passenger. Figure 1 also demonstrates the new network of the proposed solution of this work.



SkyCabs Graphs

Figure 1. Existing rail corridor (white) stations at 2086m and proposed SkyCabs passenger-transport solution (black) stations at 750m

Reducing Traffic Congestion

There are two ways of achieving the reduction of congestion, and the two ways are best used together:

1. Using roads in a better manner than at present to facilitate peak traffic movement.
2. Improving passenger transport and its coverage so the auto user finds a better solution that does not use the present congested roadways.

The question then arises as to how to provide this attractive passenger transport without destroying the existing transport that has initiated and supported the life of the city.

Architectural Approach

During the last two centuries, except for the motor car, new means of urban transport have been designed on the mega structure philosophy. Many traditional transport systems, such as trains and monorails, need large stations and have large vehicles on the basis that they are cheaper to run if passengers are allowed to accumulate at stations so fewer vehicles are operated.

Architects design many different types of buildings from small to monumental—educational facilities to inspire the young, office and commercial complexes, and enduring mega structures that dazzle viewers with art galleries, theatres, recreational facilities and sport stadiums. In the 21st century, the architect’s approach to transport design has to be to design for the individual passenger. He/she needs a seat as soon as possible for a trip with as few stops as is reasonably possible and is as short as is reasonably possible.

Where to Place the Transport Expansion

The legally-defined road and the space above it are dedicated to transport. The space above the road is generally available for services with elevated components such as trolley buses, light rail, and monorail. There are fairly well reported capital costs when considering traditional rail and monorails. Bangkok’s elevated rail with massive structures has been in financial difficulty three times. Indonesia tried several times to build a traditional monorail, but the cost has thwarted them so far. Seattle planned for a 23 km traditional monorail but found in 2005 that the US\$2.1 billion cost was too high and that the system would take over whole blocks of the city to turn a corner (Seattle Monorail Project 2003).

The space under the road has been generally dominated by services and is available at a high cost. Few cities have found they can justify the funds for underground transport.

Analysis of the three-dimensional urban fabric shows that there is scope for an elevated transport system that has a relatively small structure and is able to carry considerable numbers of passengers at speeds better than the auto through a small, restricted envelope that can fit happily in the three-dimensional street context.

Analysis of all modes of road traffic in the city (Auckland Transport Models 1996) shows that the greatest pressure from congestion is normally on arterial roads leading to and from the CBD or major centers. The vehicles on such an elevated transport system need to be small and able to collect passengers requiring similar destinations traveling along such a main route (Bishop and Mole, 2001). These small vehicles also would need to be frequent to provide useful capacity, require far fewer stops because of their lower number of passengers, and have a speed close to or better than autos. Then, the individual passenger's traveling requirements could be met.

New Transport Systems

New systems have been developed over the last 10 to 20 years to improve urban passenger transport and reduce congestion. Many are still in the concept stage.

Personal Rapid Transit (PRT)

PRT focuses on totally personal trips for passengers. With the vast majority of passengers traveling alone, this necessitates many small vehicles. The smallness of the vehicle, the low number of passengers (1-4), and the short wheelbase restricting its speed, limit PRT in answering current urban needs. Hourly volume at three-second intervals, ranging from 1,200 single passengers/hr to around 1,700 passengers/hr, is below the capacity of a motorway lane. The small wheelbase restricts speed to around 30-40 km/hr, only slightly better than cars on a semi-congested motorway. However, elevated PRT can provide an additional transport option without the loss of existing road capacity on the ground, in the direction of the track. PRT has the advantage of not needing a timetable as long as there are sufficient vehicles available to answer the demand.

Austrans, although a nine-seater, is considered a PRT system by inventor Arthur Bishop. Taxi 2000, designed by Anderson USA (2000), and ULtra from Cardiff, UK,

are examples of PRT. Both use electric four-seater vehicles and run on rubber tires. All three require either two tracks or double-width tracks to achieve travel in opposite directions. Austrans had a 500-meter demonstration track in Sydney. Taxi 2000's demonstration still operates on a dedicated guideway at 2.5 seconds frequency. ULTra completed an inter-terminal connection at Heathrow Airport in 2009.

An increasing number of cities are investigating elevated passenger transport. For the European Commission's (EC) Key Action "City of Tomorrow," short PRT systems were examined by the Evaluation and Demonstration of Innovative City Transport (EDICT) team in five urban environments: Huddinge in Sweden, Ciampino in Italy, Eindhoven and Almelo in the Netherlands, and Cardiff in the UK. This three-year study found high user acceptance and strong support from stakeholders, but both the Cardiff and Eindhoven projects were hindered by political problems (European Commission 2004).

Small Group Rapid Transit

The next largest passenger transport system is the Elevated, Small Group, Automated, Rapid, Transit (ESGART) system SkyCabs, designed and patented in New Zealand.

SkyCabs is an elevated two-way monobeam carrying light eight-seater cabs on tracks on each side of the beam, available on demand, providing fast, pollution-free, unimpeded travel above the footpath with panoramic views of the city. It is a collector system distinct from PRT, with space for eight standing passengers per cab. The longer vehicle length facilitates design speeds up to 80 km/h and a 60 km/hr average operating speed, considerably faster than PRT and light rail. SkyCabs is illustrated in Figure 2.

SkyCabs is an automated electric system. Safety performances of established driverless systems have been reported to be excellent, better than manual systems (Fabian 2004). SkyCabs uses similar high frequencies to PRT systems and provides vehicles smaller than the buses and trains of Group Rapid Transit systems and thus gains advantages over both.

Capacity

A single two-way SkyCabs line with eight-seater cabs and frequency of up to six seconds between vehicles gives a capacity of 4,800 passengers per hour. Therefore, the single two-way line can match the capacity of a four-lane motorway and, with the additional eight standing passengers, i.e., 9,000+ passengers/hr, that of an eight-lane motorway.



Figure 2. Proposed small group rapid transit (SkyCabs) vehicle in simulated environment

Stations

Off-line stations in both directions provide the key to SkyCabs' capacity and operating speed. These switched stations allow stopping cabs to go off the main line into the station to one of four ports to unload or load passengers. The four ports, with two separate access and rejoin tracks, enable a four-port station to handle the full capacity of the line, ensuring the line is kept clear for thru traffic. Two of the four ports can be used at night or in off-peak times for parking of cabs. The elevation of the SkyCabs track allows unobstructed passage for the cabs but requires vertical connection with fast lifts for passengers from ground level.

There are very convenient positions for stations above or within car parking areas and shopping and commercial centers. Placing stations at or within existing centers provides an urban planning tool for increasing density by adding to single level centers. Stations on the second floor increase the pedestrian count and add further value.

Guideway

Architecturally, SkyCabs can blend into the street fabric with some changes in street lighting and some services in the footpath bypassed, straddled, or rearranged. The small, light eight-seater plus eight standing cabs require about one-tenth the concrete compared to guideways carrying heavy traditional monorails,

resulting in much lower capital cost. The slim SkyCabs guideway can turn street corners and is light enough to go on bridges. Guideway on the north side of east-west roads allows for any shadow from SkyCabs to be cast onto the street. With north-south roads, either side can be used, as any shadow passes very quickly. For engineering, the varying state of the ground can be catered for by adding additional depth to the drilled “pole” foundation. A flat surface foundation may be used in some circumstances, but a 1.5-meter diameter pile could provide the usual limit of the required surface area approximately every 30 meters. Allowing 5-6 meter clearance under the cabs, the track itself would be 8-9 meters above the footpath.

In some cities, the visual impact of the guideway may be raised. Stakeholders living along a line may need to choose between quiet SkyCabs above the footpath out of sight and a bus lane either replacing parking outside their residence or carving off the front of their property, with noisy buses emitting CO₂ and small particulates closer to their living and sleeping areas. In the European community report (2004) PRT study, reduction in car traffic and, hence, in air pollutants were valued highly. Visual impact as a result of the elevated track was raised only in Cardiff and in historic areas of Huddinge.

Service Frequency and Wait Times

The SkyCabs system is a collector system with automated vehicles. Calculations show that while a waiting time of less than one minute would be normal in a city such as Auckland, four minutes would be the longest wait to allocate a vehicle with available capacity approaching the stop during very low demand times. Parked vehicles can be activated to ensure minimal waiting.

Buses need timetables until six-minute interval is reached. As headway decreases from four minutes, traffic congestion and environmental pollution increase; this is shown in Figure 3.

Figure 3 shows the considerable difference between the service frequency possible with a SkyCabs system compared to buses and light rail. Waiting is similar to that of a lift. SkyCabs operate above the road space, so it does not cause congestion even at less than one minute headway or a 30-second waiting time.

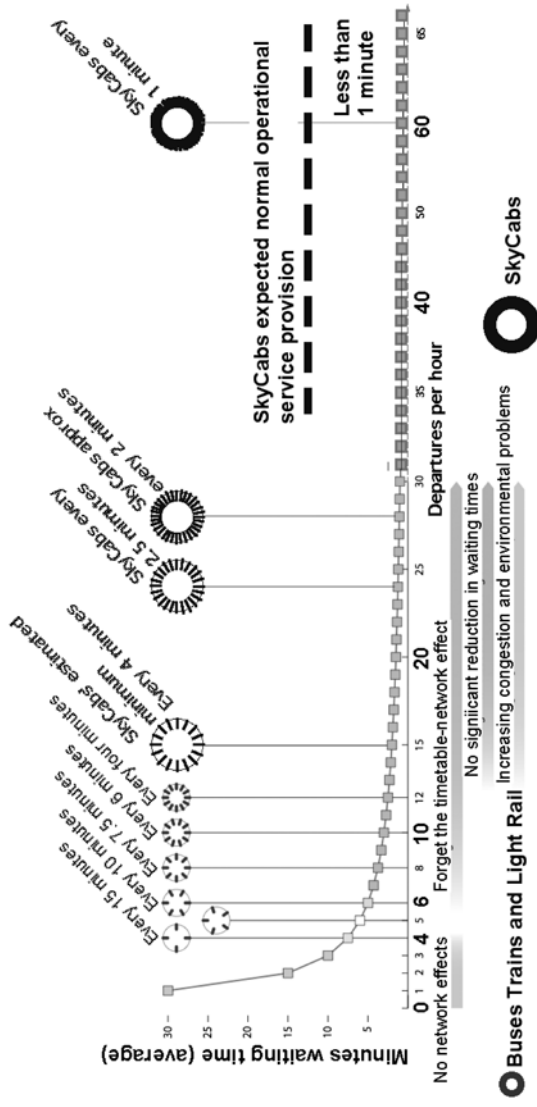


Figure 3. Waiting times vs. Departures per hour, with congestion and environmental effects for bus, train, light rail with SkyCabs information added

Operating Speed

Monorails, rail, and light rail cover the larger vehicle capacity systems. Large vehicles necessitate multiple stops. The Seattle monorail bid showed the fastest traditional monorail technically able to complete the end-to-end trip in 45 minutes or, at an operating speed of 30 km/hr, a speed only slightly faster than cars (Seattle Monorail Project 2003).

After cars on a flowing motorway, SkyCabs offers the next fastest trip times, followed by cars on flowing arterial roads and heavy rail. PRT, light rail, and buses are only slightly faster than cars on congested roads. These results are similar to mode comparisons presented by Lawson (2003).

In Figure 4, bus and train times from MAXX (operator of GRT in Auckland), actual in July 2009, light rail times from Phoenix Light Rail in 2009, and car and SkyCabs estimates for comparable 18 km journeys have been plotted against operating speed of the relevant mode.

Inter Mode Integration

Most elevated SkyCabs stations can be positioned easily above or close to bus and rail stations. Beginning any journey with SkyCabs, the “on demand” service means that the waiting for a cab starts when the passenger swipes his/her card and indicates a destination or stop. This would give a transfer time of around one minute and a waiting time of around another minute.

Energy Use and Environmental Effects

SkyCabs cabs are all-electric, lightweight eight-seaters. PRT vehicles generally are electric and lightweight four-seaters. The European community report (2004) found that PRT uses considerably less energy per passenger-km than cars or even conventional public transport. Even allowing for pollution caused by the production of the electricity required to run them, there is a net saving in both energy and emissions compared with the modes that their passengers would use otherwise. Furthermore, the expected reduction in car traffic will lead to further reductions in CO₂ emissions. Electric vehicles also are generally quieter than the alternative modes. Small vehicles can be run inside buildings, thus reducing visual intrusion or habitat destruction. The main issue of concern is when the system runs outside historic buildings or private residences (European Commission 2004). Concerns may be mitigated by sensitive architectural design. Figure 5 presents a comparison between the findings of the European Community Report (European Commission 2004) and SkyCabs estimated energy use.

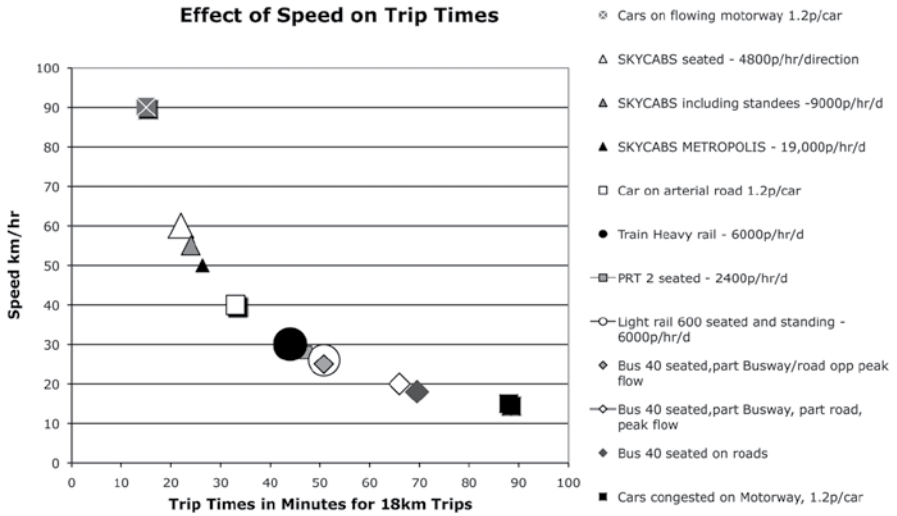
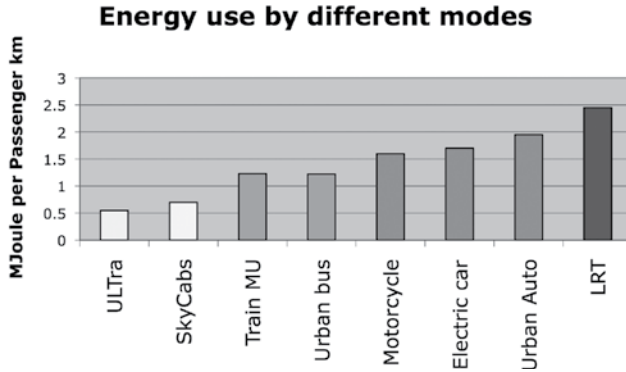


Figure 4. Effect of different mode operating speeds on trip time



Source: European Community Final Report (2004)

Figure 5. Energy use by different modes plus estimate of SkyCab energy use/passenger km

New Transport Systems/Modes in Auckland

Current Situation

A two-lane road with parking on each side changed to clearways at peak hours has a total capacity of two working lanes in the direction of peak time flow. The present approach in Auckland is to change peak-time clearway/daytime parking along the road to a bus lane. With peak-time exclusive bus lanes, the total capacity in the direction of peak-time flow is one working lane plus bus lane capacity. This configuration can be equal only to the two working lanes when the bus lane use equals the car-carrying capacity of the one road lane. In reality, this takes many years to occur, while the remainder of the increasing number of displaced cars is backed up along the remaining one road lane or its side streets.

Dominion Rd, Auckland

This road has been converted into two lanes of general vehicles, one per direction, with a bus lane on each side. It is claimed that nearly half of the trips are public passenger transport trips along this route. This illustrates that this bus lane with buses at 12 per hour does not add to the throughput of passengers, its main reason for existence, but is only close to the capacity of a general vehicle lane.

Onewa Rd, North Shore, Auckland

One of the two lanes connecting Onewa Rd to the motorway was specified as a transit lane for high occupancy vehicles (T3). The initial 45 percent of peak-time commuters using carpooling and buses increased to 55 percent, but congestion reportedly doubled for the 45 percent remaining car users. By 2008, carpooling increased from 9 to 28 percent, while bus use increased from 36 to 40 percent. The T3 lane accounts for only 27 percent of all vehicles using the two inbound lanes, giving an average of 2.7 people per vehicle across both lanes compared to overall average of 1.1 people per vehicle for car only travel in Auckland (Macbeth and Fowler 2008). The short length (1 km) of the T3 lane shunts buses and HOV vehicles to the front of the queue, encouraging carpooling and thus achieving a degree of increase in throughput. There is restriction on the motorway after Onewa Rd, and the congestion experienced still needs some solution to ease traffic in the car lane on Onewa Rd.

New Transport for Future Growth

What else could be done on these two routes to future proof for population growth and to increase capacity significantly and at what cost? PRT, light rail or SkyCabs line could be installed at varying effects and costs per mode. Figure 6 compares the different modes.

MODE	Type	Mode Capacity, Passengers/hour	Change in Road	Net Increase in Passengers/hour	Capital Cost NZ\$/km	Km Cost / extra passenger carried / hour
PRT	One Way Elevated	1,200 - 1,800	No decrease	1200 - 1800	\$14 million @ .67	\$7,780
LIGHT RAIL	Two Way On Ground	7,200 600p at 10mins	Lose two lanes	3200	\$64 million @ .67 \$43 million @ .79	\$16,720 average
SKYCABS	Two Way Elevated	9,600 seated 18,000 with standees	No decrease	9,600 18,000	\$16 million	\$1,670 \$890

Figure 6. Mode effect on road and on capital cost/km per extra traveler per hour

The costs associated with the three modes of Figure 6 are as follows:

- PRT cost is US\$9.4 million/km, adjusted from Ultra (www.ultraprt.com, 2010).
- Light rail average cost is US\$43 million/km. (Cox 2002)
 - Phoenix Light Rail as built in 2008, US\$43.5 million/km (www.azcentral.com/news/articles/2008/12/09), converted at 0.67 to NZ\$64 million.
 - City of Sydney Light Rail Extension A\$34.4 million/km (Price Waterhouse Cooper 2006), converted at 0.79 to NZ\$43 million.
- SkyCabs construction cost estimate of NZ\$16 million/km would convert to approximately US\$14 million/km overseas, including stations at 750m centers. SkyCabs figures are based on design parameters and construction cost estimates from consultants and manufacturers.

In Figure 6, three options are compared for providing greater capacity on either of the two roads examined. The light rail option would entail the loss of two road lanes. Allowing 2,000 travelers per hour per flowing arterial lane, the extra passengers carried reduce to 3,200. The capital cost related to this added capacity is an average \$16,720 per extra passenger per hour. Both PRT and ESGART (SkyCabs) show considerably lower capital cost per extra passenger, with PRT at less than 50 percent of the light rail cost and SkyCabs only 10 percent of the light rail cost per extra passenger per hour. If PRT travelers are prepared to accept four passengers in one vehicle and potentially detour for variable destinations, the resulting higher capacity would reduce the capital cost per extra passenger carried per hour, although volume carried in an hour may reduce due to longer routes traveled. For SkyCabs with fixed routes, an even lower potential capital cost of \$890 per extra

peak time passenger per hour is achieved when eight standees are added to the eight seated passengers. There is considerable advantage provided by the introduction of these new forms of transport.

A further comparison between SkyCabs and other modes concerning different characteristics appears in Table 1. Most characteristics and values for other modes are from Viability of Personal Rapid Transit in New Jersey (2007). The SkyCabs figures are from design parameters and consultant and manufacturer estimates.

Table 1. SkyCab Compared to Other Passenger Travel Modes

	Part Busway and Part Buslane	Light Rail	Standard Monorail	PRT (Personal Rapid Transit)	SkyCabs (Esgart)
Cost per km of 2-way track	US\$15 - \$25 million	US\$31 - \$43.5 million	Varies to US \$62 million	US\$18.6 - \$31 million	Below US\$20 million
Cost of stations and vehicles	Not included	Included	Included	Included	Included
Distance between stations	200 - 2000 meters off-lane	200 - 500 meters in-line	1000-1500 meters in-line	500-1000 meters off-line	750 meters off-line
Speed of construction	Two opposing "on ground" lanes by motorway	Two "on ground" tracks in road	Two large elevated tracks required	Two small elevated tracks required	Single small two-way elevated beam over footpath
Average speed of travel	30 km/hr	24 km/hr	42 km/hr	42 km/hr	60 km/hr
Capacity seated	2,400 people/hr/direction at 1 min intervals	3,000 people/hr/direction	3,000 people/hr/direction	1,200 – 4,800 people/hr/direction	4,800 people/hr/direction
Capacity seated and standing	Up to 7,200/hr crammed at 1 minute intervals	6,000/hr, up to 9,000/hr crammed	6,000/hr, up to 9,000/hr crammed	1,200 – 4,800 people/hr/direction	9,000 people/hr/direction
Peak-time service	2-10 min (6-30 veh/hr)	2-10 min (6-30 veh/hr)	4 - 6 min wait (10-15 veh/hr)	Time to arrange passengers	30 secs to max 4 min (15-120 veh/hr)
Off-peak service	15-30 min wait (2-4 veh/hr)	12 min wait (5 veh/hr)	12 min wait (5 veh/hr)	No waiting	30 secs to max 4 min (15-120 veh/hr)

Fiscally responsible choice of public transport modes should be governed by the selection of the most economical method of adding capacity to arterial roads to ensure congestion is significantly reduced.

A Well Connected Path

Besides SkyCabs being all-electric, non-polluting, and very quiet with soft wheels, further attributes are required for auto users to choose alternative public transport. One possible definition (Ceder 2007) of a prudent, well-connected transit path is this:

An advanced, attractive transit system that operates reliably and relatively rapidly, with smooth (ease of) synchronized transfers, part of the door-to-door passenger chain.

Interpretation of each component of this definition as it relates to SkyCabs includes:

Attractiveness

- Clearly visible SkyCabs stations with convenient shops, protected from elements.
- Easy route selection with map directory and electronic display.
- Easy fare payment with smart card.
- Kind to the environment, emission-free electric cabs.
- Comfortable airline-quality seats in cab.
- Panoramic elevated views from SkyCabs windows along the route.
- Provision for wheelchair, pram, and bicycles, on-board entertainment in cabs.

Reliability

- Short waiting time, on demand SkyCabs service, small variance in journey times as elevated route avoids intersections, traffic lights, and general road congestion.
- Safe, automated computerized controls, built-in double redundancy where needed.
- Complies with ASCE Standards (American Society of Civil Engineers 2002) for automated people movers.

Rapidity

- Easy access/egress to and from vehicle, door opening three meters wide.

- Fast travel at average 60km/hr operating speed, also express service available.
- Off line stations allow following traffic to bypass stationary cab.

Smoothness (ease)

- Approximate distance between off-line SkyCabs stations/stops is 750 meters.
- Fast lifts to transport platform, no timetables needed as service is on demand.
- Connects local communities otherwise bypassed or severed.

Synchronicity

- Can integrate with all other modes of transport via elevated stops.
- Cab allocation is computer controlled and demand responsive.
- On the SkyCabs network, one 1-4 minute transfer covers Greater Auckland suburbs.

Key areas of dissatisfaction with public transport were found to be timing, frequency, and destination (Bachels et al. 1999). Also, the need to transfer between routes generates a major cause of discomfort for transit users. Designing routes and schedules with a minimum amount of waiting time during a transfer may decrease the level of inconvenience. Many papers have been written from the 1970s to today about a variety of ways to design synchronized transit services. Improving transit connectivity is one of the most vital tasks in transit-operations planning (Ceder 2007).

Connectivity Measures

Eight quantitative attributes that can be measured to evaluate the quality of connectivity and three subjective qualitative attributes that can be survey-based are listed by Ceder (2007). The common denominator for all transit services are the following quality-of-connectivity attributes:

e_1 = Average walking time (for a connection)

e_2 = Variance of walking time

e_3 = Average waiting time (for a connection)

e_4 = Variance of waiting time

e_5 = Average travel time (on a given transit mode and path)

e_6 = Variance of travel time

e_7 = Average scheduled headway

e_8 = Variance of scheduled headway

These eight attributes, which can be measured, are termed quantitative attributes.

Other important attributes are not easily quantified and measured. Three of these include:

e_9 = Smoothness (ease)-of-transfer (on a given discrete scale)

e_{10} = Availability of easy-to-observe and easy-to-use information channels (on a given discrete scale)

e_{11} = Overall intra- and inter-agency connectivity satisfaction (on a given discrete scale)

These hard-to-quantify attributes are termed *qualitative attributes*.

Different perceptions of these by different passengers are captured in the average weighting of each attribute. The weight of each attribute is survey-based and/or based on the results of a mode (path)-choice model. Measuring transit connectivity involves various parameters and components, as described by Ceder et al. (2009).

Adding up all connectivity component measures along given paths will give overall connectivity value for those paths so a comparison can be made among paths. Destinations can be evaluated for access-connectivity. Introducing average passenger numbers using the paths gives exposure-connectivity, and paths can be evaluated for people-access-connectivity. Comparisons considering passenger flow can be made among paths and destinations. In addition, Ceder (2007) described how weaknesses and bottlenecks of transit connectivity can be found and corrected.

Connectivity of Some Bus and SkyCabs Paths

Inter-Route and Inter-Mode Path Comparison

Two sets of origins and destinations were chosen for comparison:

- (1) *Origin O6*: Browns Bay, North Shore; *Destination D3*: Onehunga, South Auckland
- (2) *Origin O8*: Onehunga, South Auckland; *Destination D1*: CBD, Auckland.

Some values of attributes were obtained from studies carried out at the Transport Research Centre, University of Auckland (Ceder et al. 2009). Several other paths and associated travel times were obtained from the MAXX Auckland website. For the SkyCabs connections on paths and for the Onehunga – CBD paths P5, P6, and P7, additional nomenclature is used for origin, destination, and arcs. Qualitative attributes e_9 , e_{10} , and e_{11} have been excluded in calculating connectivity.

On Browns Bay to CBD paths, nomenclature for origins, destinations, hubs, and arcs follows that of Ceder et al. (2009). Table 2 and Figure 7 show the resultant path with best connectivity during the morning 7:00-9:00 AM peak.

Table 2. Definitions and Path Description that Involves SkyCabs

Path	Origin	Destination	Arcs	Path Description
P1	O 6	D 3	A25+A10+A35	Walk-wait-Public Bus-wait-Public Bus-wait-Public Bus-Onehunga
P2	O 6	D 3	A32+ASC1+ASC2	Walk-wait-Public Bus-wait- SkyCabs -wait- SkyCabs -Onehunga
P3	O 6	D 3	A32+ASC3	Walk-wait-Public Bus-wait- SkyCabsExpress -Onehunga
P4	O 6	D 3	ASC3	Drop off-wait- SkyCabsExpress -Onehunga
P5	O 8	D 1	A33+A34	Walk-wait-Public Bus-wait-Public Bus-Queen St
P6	O 8	D 1	A35	Walk-wait-Public Bus-Queen St
P7	O 8	D 1	ASC2	Walk-wait- SkyCabs -Queen St

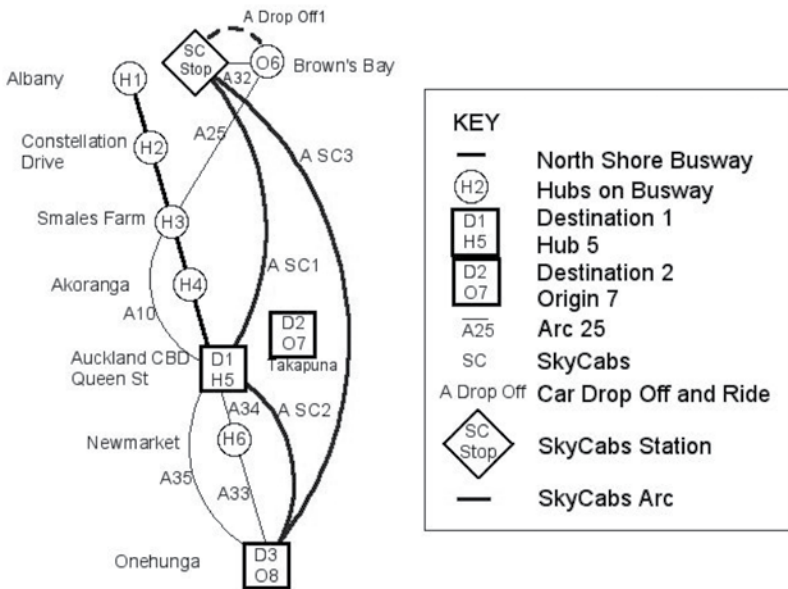


Figure 7. Schematic connectivity outline: Browns Bay to Onehunga, Onehunga to CBD

Based on the analysis of connectivity measures (Ceder 2007 and Ceder et al. 2009), Figure 8 introduces a comparison between different linked transit modes. The bold curves are associated with SkyCabs, and the value of the Y-axis is a normalized value of the connectivity a per passenger/hour basis. The lower the normalized value, the better the connectivity. The best connectivity is shown on paths that are uni-modal SkyCabs paths. The superior connectivity of the paths involving Sky-Cabs is due to faster unimpeded travel on an elevated guideway, shorter waiting times, and headways due to high frequency and on-demand service.

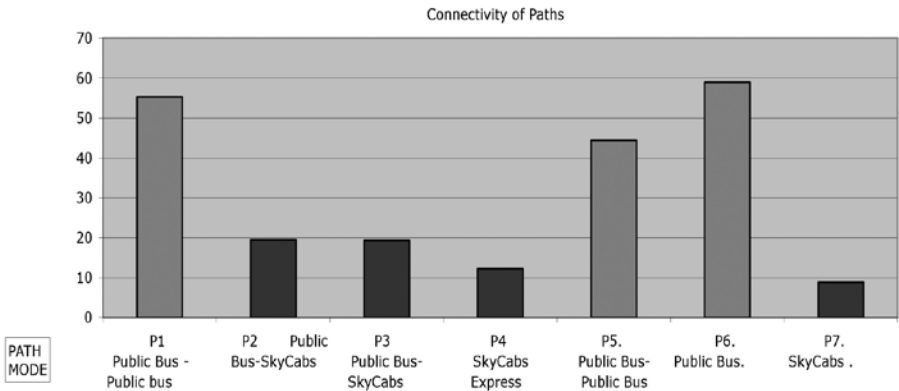


Figure 8. Normalized connectivity of busway, SkyCabs, and combined mode paths

Routes and schedules of superior connectivity with minimum amount of waiting time during a transfer are likely to decrease the level of inconvenience and discomfort for passengers and can be expected to encourage greater public transport use.

Economic Effects of Congestion and Pollution

As cars take longer and drive at a slower pace, engine inefficiencies increase dramatically. A car caught in traffic will operate at 400 percent less efficiency compared to operating at 60-80km/hr (Laird et al. 2001). Reduction of congestion that leads to reduced car travel times on city roads and motorways by 50 percent would reduce pollution by well over 50 percent through improved engine performance (Auckland Regional Council).

Auckland's local city councils together have a yearly budget of \$2.3 billion (Royal Commission on Auckland Governance 2009). Cost of congestion to Auckland city,

industry, and residents has been estimated by various bodies, including SkyCabs, at \$2 billion per annum. Auckland's growth per capita in real GDP grew by only 1.1 percent per annum over the five years to 2003 against an NZ average growth of 2.3 percent p.a. (New Zealand Round Table 2006). If congestion and the \$2 billion congestion cost were removed, and all time saved was used productively, the increase in Auckland's GDP would be 4.2 percent p.a., and New Zealand's GDP would increase by 1.2 percent.

Conclusion

Significant reduction of congestion can improve economic performance and reduce pollution, both vital areas of concern for cities around the world. Congestion can be alleviated by transferring passenger transport onto elevated solutions such as the presented Elevated Small Group Automated Rapid Transit (ESGART) SkyCabs system, which straddles the gap between Group Rapid Transit (GRT) and Personal Rapid Transit (PRT). This two-way monobeam is detailed in this study, including ease of building through cities and low construction cost. Architectural and engineering aspects of eight-seater cabs, cab frequency, stations, and lines also are described. In addition, this study explores connectivity on two example lines in Auckland within a SkyCabs network and other modes of transport in which quantitative and qualitative attributes are considered.

The SkyCabs ESGART system could provide an attractive and affordable passenger transport solution to congestion problems. Initial connectivity comparison of the SkyCabs paths to comparable paths on the North Shore busway in Auckland is favorable, due to faster unimpeded travel on SkyCabs elevated guideway and shorter waiting times and headways. Further studies should be carried out for an extended SkyCabs network (see Figure 1). A short \$5.5 million demonstration track needs to be funded and built to confirm the technology and the estimated low capital and operating costs. Finally, new bold thinking is needed to make our cities economically productive.

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Urban Bus Services in Developing Countries and Countries in Transition: A Framework for Regulatory and Institutional Developments

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Abstract

Urban passenger transport has experienced major change in many developing countries in Africa, Asia, and the Middle East, as well as in countries of political and/or economic transition in the Commonwealth of Independent States (CIS) and China. Such changes have included planned market opening to private operators and new entrants; unplanned market opening by the entry of unlicensed operators; privatization and other changes to the ownership base of large public-sector transport companies; emergence of large-scale minibuses and paratransit; and national and urban policies and programs to upgrade the transport supply and quality.

This paper presents a framework to understand regulatory and institutional changes in urban bus services in Africa, Asia, the Middle East, the CIS, and China. The framework identifies three types of changes: (i) changes in the role of the regulator and market structure; (ii) changes in the structure of the operator and of private sector participation; and (iii) changes in the transport supply. The paper then identifies critical factors leading to change in the urban transport sector, factors that can be identified with successful outcomes, and issues associated with the development of the minibus, paratransit, and the informal sector that have played major roles in the urban transport sector of developing countries and countries in transition.

Introduction

The mobility of people is fundamental to their ability to participate in society. In developed countries, mobility in urban areas is assured for the majority of the population, in part due to high levels of car ownership, and in part due to stable public passenger transport systems. In the urban areas of most developed countries, public transport is provided by public or private operators who have medium- to long-term agreements with a transport authority for a defined set of services, enforced legal protection against interlopers, and are usually subsidized to cover any losses due to the social and environmental dimensions of the services.

The situation in developing countries and countries in transition is more varied. For working purposes in this paper, “developing countries” are considered as those with a low average income and a low degree of industrialization. “Countries in transition” is used to include countries in which there have been major political and market shifts such as the Commonwealth of Independent States (CIS or former Soviet Union countries), changes to the structure of the economy (such as China), or fundamental change in the demographic or settlement patterns such as India’s and China’s migration to urban areas, and where institutions, markets, laws, and other frameworks are still in the process of adapting. Some countries can be both developing and in transition.

By their very nature, these countries, which account for the majority of the global population, face diverse challenges that involve change to society, economic and legal frameworks, and relationships between these (UITP 2003, Amos 2004, UN 2005). Further, many of these countries lack the financial resources, appropriate political/government structures, and sometimes the political stability to implement effective and efficient mobility services at affordable prices that meet the expectations of citizens (World Bank Group, 2008). These challenges are most concentrated in the urban areas and their hinterlands due to the scale of population and the intensity of activity.

There may also be extreme problems caused by lack of mobility for individuals and communities in rural areas, where it is estimated that 1 billion people in low-income countries have no access to an all-weather road (World Bank Group 2008).

The market for urban passenger transport has experienced major change in many developing countries in Africa, Asia, and the Middle East for a variety of economic, political, and societal reasons and due to fundamental political and economic transition in CIS and China. Such changes have included planned opening of the market

to private operators and/or new entrants; unplanned opening of the market by the entry of unlicensed operators, especially where the licensed services become inadequate; privatization and other changes to the ownership base of large public-sector transport companies; emergence of large-scale minibuses and paratransit; and national and urban policies and programs to upgrade the transport supply and quality.

This paper concentrates on developments in the urban bus services sector in developing countries and countries in transition that have recently occurred or which are currently taking place. The contribution is specifically to critically synthesize these changes which impact on both the mobility of the citizens and on the ability of the authorities and other stakeholders to influence the coverage, connectivity, intensity, and quality of mobility services that are available. This contrasts with the existing literature that either concentrates on a more macro approach (Amos (2004) or presents evidence from a single location.

For the purposes of this paper, the urban passenger transport sector can be considered to consist of three strands:

- Agencies that manage the market for the supply of transport services, which are referred to as “the regulator” (this includes transport authorities)
- Entities of public and private form that operate the transport services, which are referred to as “the operator”
- The transport offer, including the network, service types, coverage, intensity, and quality

The paper presents a framework to understand the three main types of development observed:

1. Changes to the market structure and the role of the regulator, and the basis of the relationships between the regulator and the operator
2. Changes to the nature, format, ownership, and structure of the transport operators and means of participation of the private sector
3. Changes to the type, structure, quality, and scale of passenger transport services.

The current paper focuses on positive developments; the approach has been to identify relevant developments from available published sources, supplemented by direct observation. A good analysis of failings and what to avoid is provided by Gwilliam (2003).

Since most of the developments are ongoing and are themselves changing, the focus has been on contemporary sources. Much of the evidence is drawn from papers presented at the Thredbo series of conferences on competition and ownership in passenger transport, a major source of information in this sphere, while unreferenced items are from the authors' direct experience.

Following an introduction to international trends in market structures and the role of the regulator, with emphasis on those in more mature systems, each of the three strands is considered in turn.

The final section discusses issues arising from the presented developments and key factors and/or enablers for evolution of an effective passenger transportation system.

International Trends in Market Structures and Regulatory Frameworks

Over the past two decades, there has been a very clear trend towards a more structured market for the provision of urban public transport. This section is derived from more extensive reviews by Finn and Nelson (2003a, 2003b). The main features include:

- restructuring institutional frameworks as a coherent supporting structure
- a clear separation of planning and operational functions
- opening of the markets to allow new entrants to offer services
- procuring subsidized services by transport authorities, using market processes
- corporatization of formerly public-sector operating entities, i.e., transformation into entities that are structured as companies with associated corporate, governance and accounting principles
- privatization, joint-ventures, and other means of modifying the ownership base of parastatal operators
- making public assets available to both public and private sector bidders
- mobilizing private investment for public infrastructure and services

These trends and motivations have led to different market frameworks emerging, with greater or lesser opportunities for transport operators to participate and with different relationships between the authorities and the operators. The market framework in a specific location usually reflects historical context, the national and local policies, and the capacity of the local government. In more mature systems, the various issues of policy, planning, development, and integration of passenger

transport, regulation, financing, etc., are handled by a transport authority either for the urban area or for a broader metropolitan area (Nielsen et al. 2005). The transport authority is usually accountable to the governance structures of the local government, but it can be at regional or national level.

Framework for Understanding Change in Urban Public Transport in Developing and Transition Countries

This paper concentrates on the connections between changes to the regulatory framework, changes to the nature and form of the operator, and the nature of transport supply. Examples of these are presented, then summarized in Tables 1, 2, and 3 in the following sections of this paper. These elements are clearly interconnected, and developing countries and countries in transition do not show a unique response. One common characteristic of the experience of developing countries and countries in transition is that the frameworks in which the urban transport sector exists change, and often change rapidly. In some cases, the main reason is because society itself is changing. In other cases, it is because a framework is lacking or contains inherent weaknesses that need to be adjusted. In contrast, in mature systems where the frameworks are stable, there is often no fundamental change for decades, and all participants understand the roles, relationships, opportunities, and boundaries among the various stakeholders (functionally and spatially).

Change in the Role of Regulator/Transport Authority and Market Structure

Regulation of urban passenger transport is introduced or restored. In Ghana, the passenger transport sector had been self-regulating since 1983, as the minibuses became the dominant form of transport supply while the state-owned Omnibus Service Authority (OSA) went into decline and was unable to meet growing demand. In 2008, the function of regulation was restored to Local Government. Bylaws were passed in each area to provide the legal basis (Finn 2008, 2009). In Manila (Philippines), while route franchising remains with LTFRB, since 2003 the city authority (Metropolitan Manila Development Authority, MMDA) regulates the flow of buses along the principal urban orbital (EDSA) and at both their terminals and stopping places along EDSA.

Regulation of passenger transport transferred to City. In Jordan, the Land Transport Regulatory Commission (LTRC) of the national Ministry of Transport is the regulator for all passenger transport services throughout the country. In November 2007, all responsibility for urban passenger transport in Amman, including the regulatory

role, was transferred to Greater Amman Municipality. LTRC continues to regulate services elsewhere in the kingdom.

Regulatory capacity is developed within local government. In Accra and Kumasi (Ghana), Amman (Jordan), and Tbilisi (Georgia), new municipal public transport departments have been established or existing general transport departments have been restructured to add public transport responsibilities. Specific public transport and regulatory expertise is engaged and developed (Finn 2008). For example, in Manila, the MMDA has developed a specific public transport unit, regulations, staffing, and supporting technical systems to manage the bus routes operating on EDSA, the megalopolis's primary ring road (30+ routes, 3000+ buses, ~50,000 daily bus trips). This system is called the Organised Bus Routes (OBR).

Changes are made to rules for market entry and/or procurement. Lagos (Nigeria) has and Accra will procure bus and feeder bus services for a BRT scheme under tendering, awarding route service contracts to the successful applicants. In Tbilisi, in 2001, the unregulated minibus operators were formalized by opening a competitive tender process and awarding operating permits to operators, who, in turn, were required to organize themselves into operating entities (some 64 entities were formed).

Regulators develop new models for procurement of services. In Recife (Brazil), a new model for competitive tendering has been developed to overcome three decades of wrangling among different government agencies. It established a basis for a specified service, regulation of quality, and financing (Filho 2007). This has been the basis to admit some 252 vehicles on 26 new lines that had previously been in direct competition with the state-owned transport operator.

Regulators develop new contractual basis for bus services or amend existing ones. In Kaunas (Lithuania), as part of major restructuring of the reorganization and finances of the municipal bus and trolleybus companies, the City entered into a 10-year public service contract with the municipal company based on committed service levels and quality, subsidies, and investment program (Bruggeman 2009). In South Africa, a system of contracts was established with private bus operators for subsidized commuter bus services. In total, there are about 115 such contracts, with differing payment bases. The government is currently attempting to amend all contracts to payment for kilometres operated (Walters 2009). In Santiago de Chile, as part of the TranSantiago BRT system, a new contractual and payment system was established for the operators so that they would participate in the integration of network and tariffs (Muñoz 2007).

Regulator makes direct intervention to restructure operator sectors. In Sri Lanka, in 2005, the 11 regional state public owned and operated bus companies were reformed into a single national entity, SLTB (Sri Lanka Transport Board). There are also approximately 19,000 private bus operators in addition. The National Transport Commission has initiated five pilot projects to cluster the private operators in pilot areas, to improve their organizational capacity, use of resources, and service quality (Kumarage and Jayarante 2007).

Transport authority makes vehicles available to operators. In Accra and Tbilisi, the transport authority or government acquired vehicles for the (quasi-) public sector bus operators that had all but ceased to have operational capacity. This allowed them to re-establish large-bus operations. The vehicles were initially second-hand buses that had limited benefit and many of these vehicles soon ended up out of service (Finn 2008). Subsequent purchases acquired new buses. In Dhaka (Senegal), the transport authority used government-negotiated loans to establish a special purpose company to acquire vehicles and lease them to private sector operators who agreed to be regulated and to operate under contract (IBIS 2008) in return.

Transport authority provides funding or financial incentives for bus purchase and/or technology upgrades. The City of Kaunas arranged financing through EBRD for the purchase of new buses and associated support systems for the municipal bus company (Bruggeman 2009). In South Africa, a scrappage grant has been implemented to incentivize bus operators to replace old vehicles, equivalent to about one sixth of the cost of a new vehicle (Walters 2009). In many rural areas in Brazil, school transport involves long journeys in difficult operating conditions. The Brazilian government has sponsored the development and deployment of more robust and suitable vehicles (Carvalho et al. 2009).

Transport authority finances new transport infrastructure to enhance public transport system and provide suitable facilities to operators. In Accra, Amman, Dar es Salaam (Tanzania, planned), Delhi (India), Mauritius (planned), and many other cities, the transport authority has funded or plans to fund the development of Bus Rapid Transit infrastructure and supporting facilities to improve the quality and level of service of passenger transport (Richmond 2006, Torres 2007, Finn 2008 2009). In China, many municipalities have constructed passenger interchanges, terminals, and overnight parking for use by corporatized state-owned operators (Dotson and Finn 2007). In Amman, the municipality has constructed bus and shared taxi terminals for private operators (Finn 2009).

Table 1 presents a summary of these changes.

Table 1. Summary of Changes in Role of Regulator/Transport Authority and Market Structure

Change in Role of Regulator/Transport Authority and Market Structure	Examples
Regulation of urban passenger transport introduced or restored	Ghana, Manila (Philippines)
Regulation of passenger transport transferred to the City	Jordan
Regulatory capacity developed within local government	Accra and Kumasi (Ghana), Amman (Jordan), Tbilisi (Georgia), Manila (Philippines)
Changes made to rules for market entry and/or procurement	Accra(Ghana) and Lagos (Nigeria), Tbilisi (Georgia)
Regulators develop new models for procurement of services	Recife (Brazil)
Regulators develop new contractual basis for bus services, or amend existing ones	Kaunas (Lithuania), South Africa, Santiago (Chile)
Regulator makes direct intervention to restructure private operators	Sri Lanka
Transport authority makes vehicles available to operator	Accra(Ghana), Tbilisi (Georgia), Dhaka (Senegal)
Transport authority provides funding or financial incentives for bus purchases and/or technology upgrades	Kaunas (Lithuania), South Africa, rural areas in Brazil
Transport authority finances new transport infrastructure to enhance public transport system quality and level of service and to provide improved operating and maintenance facilities to operators	Accra (Ghana), Amman (Jordan), China, Dar es Salaam (Tanzania), Delhi (India), Mauritius, many other cities

Change in Form of Operator

Public sector bus operators have their corporate and ownership basis changed. In China, the State Owned Enterprise bus companies in many cities have been transformed from administrative units of the municipality into joint-stock companies, and inward investment is now accepted either as direct investment or through the creation of joint-ventures (Dotson and Finn 2008). In Kazakhstan, the first wave of public transport reform in 1996-7 allowed municipalities to privatize their transport companies and to allow new market entrants. Most cities, apart from Almaty and Astana, privatized their bus companies. All cities allowed new market entrants (Finn 2005). In Tbilisi, the municipal bus company has been transformed into a corporate entity, placed at arms-length from the municipality, and has been considered for outright privatization while retaining the subsidized public service contract (Finn 2008).

Private operators are given controlled access to the market. In Rostov-on-Don (Russian Federation), the private sector had achieved 63 percent of the market by 2005 within a controlled competition structure (Zyryanov and Sanamov 2007).

Individual minibus operators form associations or cooperatives to gain route contracts or to have access to facilities or finance. In Samarkand and Bukhara (Uzbekistan), independent minibus operators formed associations at the initiative of the municipalities. This gave them access to operating permits and to maintenance and shared purchasing facilities (Gwilliam et al. 1999). In Tbilisi, in 2001, about 3,500 minibus operators consolidated into 64 companies to gain operating franchises from the municipality for 223 lines. The companies were shell companies (i.e., minimal staffing and functions, purely to meet permit compliance, vehicles and staff associated with the entity but remained independent) for convenience. There has not been further integration or consolidation of assets (Finn 2008). In Dhaka, minibus operators formed into cooperatives to be collectively responsible for loan repayments on minibuses made available under a vehicle-leasing scheme sponsored by government (IBIS 2008). The 17 East Jerusalem bus operators formed an association in 2002 and operate under common livery and coordination. This has given them access to two good-quality bus terminal facilities and bus purchase grants from the Israeli Ministry of Transport. In Cebu (Philippines), the jeepney association VUDTRASCO secures operating franchises from LTFRB, and its members then operate under an association franchise covering about 500 units.

Private sector participates directly in infrastructure and rolling stock development and financing. Various financing and investment instruments (PPP, DBOT, BOT, PFI) have been developed to mobilize private finance for major infrastructure projects, such as LRT in Manila. In Fuzhou (China), investors provided direct financing for buses without any participation in the companies or operations and received their payback over the life of the vehicles.

Private sector investors purchase vehicles and lease them to drivers. *Tro-tros* and taxis in Accra, jeepneys in Manila, marshrutkas in Tbilisi, and shared-taxis in Palestine (“service” taxis) are examples of private individuals purchasing vehicles (usually second-hand) and then renting them to drivers who must pay an agreed amount to the owner (typically per day). In Samarkand and Bukhara, extended families have pooled savings to purchase minibuses, since financing from banks is either not available to them or too expensive.

Operating companies change their business model to gain efficiencies. Bangalore Metropolitan Transport Corporation (India), while remaining in the public sector,

has restructured its business model along private sector lines. It has outsourced all non-core and many core activities, increased efficiency, and become profitable (Torres 2007). In Indore (India), the city has established a new company that procures all transport and support services from the private sector (Torres 2007). In Dubai, the public transport authority has contracted out the maintenance of all recently acquired buses, being about 1,400 of the total fleet of 1,800 buses. In Ceres (Philippines), the largest private operator of intercity buses has established its own facility to build buses, manufacture spare parts, overhaul major bus components such as engines and transmissions, and make mid-life capital repair.

Table 2 presents a summary of changes in the form of operators and participation of the private sector.

Table 2. Summary of Changes in Form of Operators and Participation of Private Sector

Change in Form of Operator	Examples
Public sector bus operators have their corporate and ownership basis changed	China, Kazakhstan, Tbilisi (Georgia)
Private operators are given controlled access to the market	Rostov-on-Don (Russian Federation)
Individual minibus operators form associations or co-operatives to gain route contracts or to have access to facilities or finance	Samarkand and Bukhara (Uzbekistan), Tbilisi (Georgia), Dhaka (Senegal), East Jerusalem , Cebu (Philippines)
The private sector participates directly in infrastructure and rolling stock development and financing	Manila (Philippines), Fuzhou (China)
Private sector investors purchase vehicles and lease them to drivers	Accra (Ghana), Manila (Philippines), Tbilisi (Georgia), Palestine Samarkand and Bukhara (Uzbekistan)
Operating companies change their business model to gain efficiencies	Bangalore Metropolitan Transport Corporation (India), Indore (India), Dubai (UAE), Philippines

Changes in Transport Supply

Large-scale expansion of the conventional transport services to meet demand. In many Chinese cities, bus fleets and kilometers operated have more than doubled to meet population growth (Dotson and Finn 2007). In Dubai, as it became clear that a roads-oriented urban transport strategy was failing and congestion levels were unacceptable, bus services have been completely restructured and repositioned. An additional 1,300 new buses have been added to the fleet since 2002, and

this will increase further in 2009-2010 to provide “feeder” services to the two new Metro lines (Kaiser 2007).

Introduce high quality passenger transport modes. Bus Rapid Transit (BRT) has been implemented extensively in South America and Asia, and now systems are being implemented in the Middle East and Africa.

Large-scale paratransit services are established to replace large-bus services that have failed to expand to meet the increasing travel demand from population growth. *Collectivos* in Rio de Janeiro, Sao Paulo, Recife, and other Brazilian cities have emerged to provide services from the poor areas (*barrios*). In Rio de Janeiro, some of the routes have more than 700 vehicles operating on them (Goncalves 2005, Brasileiro 2007). In St. Petersburg (Russian Federation), minibuses (*marshrutka*) were permitted on fixed routes to complement the conventional services, as the financial conditions did not support bus fleet expansion. By 2002, these services carried 370 million trips annually (14.1% of the total public transport market), more than the trolleybuses and almost as many as the trams (Finn 2003, 2009). In Manila, about 50,000 minibuses (*jeepneys*) now provide an extensive network of services and are preferred by many users to larger buses and LRT due to their ability to support direct routing without forcing transfers for many or most origin to destination trips.

Large-scale paratransit services emerge to replace large-bus services as they go into decline. In cities of Kazakhstan, *marshrutka* replaced large-buses on routes where they ceased to operate or offered insufficient service. In general, they did not attack routes where buses continued to operate. (Finn 2005, 2008). In Ghana, Senegal, Tbilisi, and Santiago de Chile, paratransit that initially emerged to fill service gaps became the dominant form of transport and in some cases effectively “killed” the remaining large-bus service.

Shared taxis emerge to complement large-bus transportation or meet specific needs. In Amman, about 3,200 licensed shared taxis now operate on 70 fixed routes from the center to designated suburbs, on a fill-and-go principle. The shared taxis carry more passengers daily than the current underdeveloped large bus network. In Ghana, in the rural areas and villages, shared taxis (cars) provide an equivalent service to the minibuses and are the dominant form of public passenger transport (Finn 2008).

Large bus services are restored when the city or operator regains financial and/or organizational capacity. In Ghana, the government facilitated the emergence of

a new large bus company, leveraging private and public financing. Metro Mass Transit now has in excess of 500 large buses and operates services in the main cities and on intercity routes. It has regained 15-20 percent of the market share in Accra (Finn 2008). In Kaunas, the refinancing of the municipal bus company's fleet (referred to in Table 1) had the specific objective to restore large bus operations and reduce minibuses operations. The market share of the large bus sector increased from 50 to 90 percent (Bruggeman 2009). In Tbilisi, the municipality has funded the acquisition of more than 600 vehicles for the Tbilisi Bus Company (TBC), a mix of second-hand large buses and new mid-sized buses. TBC has restored service on all main routes and has improved from a 5 percent market share in 2001 to close to 50 percent, at the expense of minibuses (Finn 2008). In Cebu, all public transport is currently provided by jeepneys or taxis. BRT is planned, which will introduce urban large-bus operations.

Table 3 presents a summary of changes in transport supply.

Table 3. Summary of Changes in Transport Supply

Change in Transport Supply	Example
Large-scale expansion of the conventional transport services to meet demand	Chinese cities, Dubai (UAE)
Introduce high quality passenger transport modes	South America, Asia, Middle East, Africa
Large-scale paratransit services are established to replace large-bus services that have failed to expand to meet increasing travel demand from population growth	Rio de Janeiro, Sao Paolo, Recife (Brazil), St Petersburg (Russian Federation), Manila (Philippines)
Large-scale paratransit services emerge to replace large-bus services as they go into decline	Kazakhstan, Ghana, Senegal, Tbilisi (Georgia), and Santiago (Chile)
Shared taxis emerge to complement large-bus transportation or to meet specific needs	Amman (Jordan), Ghana
Large bus services are restored when city or operator regains financial and/or organizational capacity	Ghana, Kaunas (Lithuania), Tbilisi (Georgia), Cebu (Philippines)

Tables 1, 2, and 3 show that the changes can be wide-ranging and that individual countries experience more than one type of change.

Success Factors for Change

The cases presented in this paper indicate a very wide range of contexts and mechanisms. Each has been implemented with the objective either of strengthening the sector or of making a practical response to challenges within prevailing constraints. The changes considered in this paper primarily have had the objectives of reforming or strengthening public policy and/or the operator organizational framework. In this context, an outcome is deemed “successful” where improvements to urban bus service ridership, mode share, public transport quality, new investments, financial sustainability, or its profitability has resulted from changes in either framework or operator organisation level.

The principal stimuli for successful implantation of planned structural change are a leading political vision and/or policy, such as urban spatial development or economic regeneration; a need to respond to rapid growth in demand for passenger services due to population growth; a need to respond to serious challenges such as traffic congestion or air quality; a recognition that major infrastructural projects such as BRT cannot be implemented until the regulatory framework or operator structure/quality is improved; or a need to respond to serious degeneration of the available passenger transport services.

A number of contributing success factors emerge from the cases discussed here and elsewhere (Finn and Walters 2010) for building on the structural change to develop urban transport services in general in cases where they are currently underdeveloped, fragmented, or of low quality. These include:

- Presence of strong political leadership and support.
- Explicit, local urban transportation strategies and programs implemented within the context of national plans and strategies which have already been approved by the national government.
- Establishment of an effective regulatory framework defining responsibilities, roles, market access, and rights of initiative, with sufficient legal backing.
- Establishment of an empowered regulator with appropriate structure, technical capacity, continuity, and institutional memory.
- Development of the human and organizational capacity of the regulator.
- Establishing and maintaining real consultation and collaboration with the key stakeholders, especially the operators and impact communities.
- Organization of a controlled transport market with quality-based entry, supported by an effective enforcement capacity.
- Establishment of contractual or agreement-based relationships.

- Creation of effective mechanisms to align supply with demand and to stimulate investment/provision of increased resources where they are required.
- Development of the business and operational/technical capacity where the operator sector is already fairly well structured.
- Where the operator sector is fragmented, consolidation to facilitate economies of scale, increase professionalization, and access finance.
- Financial and other stimulus measures to encourage operators to upgrade and improve.

While many of these factors that successfully facilitate change might also apply to developed countries, the policy, institutional, regulatory, and fiscal frameworks in developing countries are already in place and are stable. In contrast, in developing countries and countries in transition, it is usually necessary to implement or enhance one or more of these frameworks before progress can be made to improve urban bus services. In extreme cases, it is necessary to establish a complete framework from scratch as well as build competency (in both framework and operational arenas) before the benefits can be realized from improving urban bus services more generally.

The successful implementation of these factors confronts the informal minibus, paratransit sector that has played a very important role in some, but not all, urban areas in developing and transition countries. Where they are already established, a number of factors determine their future development and, in some cases, their survival as significant transportation services. These include:

- The attitude of the authorities, in particular whether they accept the presence of this transportation mode (as in Ghana, Kazakhstan, Philippines, South Africa), whether they wish to contain it in a reduced or transformed role (as in St. Petersburg), or whether to systematically replace it (as in Kaunas, Tbilisi).
- Whether the services are seen as a permanent feature of urban transport provision or something transient. For example, in Ghana the services have been operating for at least a quarter century and are well understood by the population, and the routes are well known and, as a result, are now seen as a permanent feature; in the Philippines, jeepneys are accepted by both authorities and passengers as an integral feature of urban transport and culture.
- The willingness of the authorities to develop a formal regulatory framework within which the paratransit services can operate and develop, as part of their policy for the urban transport sector (as in South Africa, Philippines). This is in contrast to the developed world, where many policy-makers and

regulators consider these services to be primitive and “inappropriate” for their cities and regulate to prevent their emergence and have effective penalties in place should they emerge illegally.

- The ability of this sector to evolve from operational collectives of individuals into companies that can invest in vehicles, rationalize and optimize resources, and develop their business capacity. Despite high revenues in the sector, business evolution has not been observed, which will inevitably impact the potential longevity of operation.
- The ability and willingness of this sector to invest in continuous product improvement, especially in newer vehicles, professionalization of drivers, and better maintenance, so as to evolve from a low-cost, low-quality product to something citizens would use by choice.
- The determination to improve service quality and reliability and to integrate with other transport modes operating in the urban area. In South Africa, paratransit services and providers are being integrated into the BRT system. The restructuring of urban transport in St. Petersburg included the *marshrutka* as part of the planned supply. It occurs informally in Amman, where the shared taxis operate from bus terminals, and in Brazil when *colectivos* bring customers to Metro and large bus transfer points.

Conclusions

This paper has developed a framework for classification of changes in the urban passenger transport sector in developing countries and countries in transition with three elements: change in the role of the regulator/transport authority, change in the form of operators, and change in transport supply. Each element is illustrated with evidence, showing the way in which regulators and markets, the form of operators, and the supply of transport have changed in response to contextual change and highlighting the very many different ways in which sectors respond. It reveals that change, whether legislative or policy, does not lead to a unique response.

The practice presented in this paper shows commonality in the desire for change but distinct differences in policy and outcomes. This allows the factors that are evident in successful outcomes to be identified. It also establishes the importance of the minibus, paratransit, and informal sectors in the process of change in many countries and the issues that affect whether this sector is likely to be a permanent or transitory feature of the urban transport sector supply.

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Assessment of Surface Transportation Security Training Needs and Delivery Preferences

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Abstract

America's surface transportation system features long and inter-connected routes and open access to stations and vehicles, making the system vulnerable to terrorist attack. While a variety of security-related training products exist for the transportation sector, government and other reports have called for improvements in the transportation security training curriculum in terms of quality and consistency. At the same time, tight economic times have left few extra financial resources available for systems to deliver adequate training to employees. This study assessed the needs for additional security training through focus groups and interviews with representatives of major surface transportation stakeholders and agencies. Training content needs and the approaches that will most effectively implement training in the field are identified. The results are intended to inform those responsible for supporting, developing, or implementing security training about where gaps may exist and about which delivery mechanisms are preferred and most workable.

Introduction and Background

America's surface transportation system of roads, bridges, railroads, and subways and the buses, cars, and trains that travel on them feature long and inter-connected

routes and open access to stations and vehicles. These attributes make the system very vulnerable to terrorist attack. Public transit systems that carry hundreds of thousands of people daily in crowded buses and railcars are particularly attractive targets for terrorists whose goal is to affect the greatest amount of people in a confined space. Recent intelligence obtained after the death of Osama Bin Laden indicates that plans to sabotage surface transportation systems were in development. "Implementing Recommendations of the 9/11 Commission Act of 2007," also called the "9/11 Act" declares that a training program should be developed to "prepare public transportation employees, including frontline employees, for potential security threats and conditions" (Library of Congress). More recently and more broadly, a quadrennial review by the Department of Homeland Security (DHS) identified training for major incidents and coordinating preparedness and responses as major objectives (2010).

While a variety of security-related training products exist for the transportation sector, a 2010 report by the Government Accountability Office (GAO) found that the mass transit training curriculum can be improved in terms of quality and consistency. At the same time, tight economic times have left few extra financial resources available for systems to deliver adequate training to employees (Waugh 2004; Meyer 2008).

The 9/11 Act outlines the learning objectives or program elements for frontline employee training, including (1) threat determination, (2) suspicious activity reporting, (3) passenger communication, and (4) appropriate response actions. The Act also recommends live situational training exercises as important elements. In light of the identified concerns and challenges of securing our nation's transit system, this study set out to gain an understanding of the needed content areas and delivery mechanisms that can best accomplish training objectives for transit employees and managers.

Outside of the federal government, experts and stakeholders also have noted the need for more effective transportation security to deal with the terrorism threats the United States faces in the early 21st century (AASHTO 2002; Fries et al. 2008; Helmick and Compton 2004; Johnston 2004; Meyer 2008; Mitchell et al. 2004). Because potential threats are present in train and bus stations, ports, platforms and waiting areas, and on surface and maritime vehicles, all surface transportation workers need some training in the recognition and assessment of potential hazards and dangerous activities, as well as response and notification protocols in the event of an incident or evacuation.

There is little, if any, published literature that looks at security training needs for the transportation sector specifically. However, identification of training needs for any type of worker who could encounter dangerous chemical, biological, or radiological weapons or bombs was the subject of a 2002 conference sponsored by CDC and National Institutes of Occupational Safety and Health (NIOSH) and held at Johns Hopkins University. In a summary article, Mitchell et al. (2004) identify five key needs as training in the potential hazards involved: the individual worker's specific role in an emergency, incident command, activation of the emergency notification system, use of personal protective equipment (PPE), and safe evacuation of the workplace.

In the general training literature, there are numerous studies comparing the effectiveness of trainer attributes (Steiner et al. 1991) or of different training methods on skill retention and transfer of learning. Studies have shown that peer support in the training context resulted in greater improvement in skills (Martin 2010), and that supervisory support was not as influential (Van der Klink et al. 2001). An older study noted that traditional training methods may need to be adapted to work in a highly-unionized industrial setting (Young and Findlater 1972).

The promise of using computer-based learning formats is being explored, with the caveat that technology itself will not improve training outcomes without identification of the proper target audience and selection of the proper instructional strategies to meet objectives (Myers et al. 2008). Sitzman et al. (2009) add that in computer-based learning, prompting self-regulation (e.g., stop points with questions) resulted in stronger performance gains over time, especially for trainees who already have higher ability or higher self-efficacy. These results demonstrate prompting self-regulation improved performance over time, relative to the other conditions. Virtual teaming in training also was found to be effective in a study by Ahanchian and McCormick (2009), but also subject to the trainees' cultural predisposition to individualism (learning and doing things alone) vs. collectivism (learning and spending more time in groups). Gershon et al. (2010) found that a recently developed web-based simulation program was effective in training transit police officers in New York on how to recognize and respond to WMD attacks. However, Lammers et al. (2008) conclude that additional study is necessary to evaluate whether skills learned via simulation translate into real-world setting.

Call for a Needs Analysis

The Obama administration has identified “understanding transportation security training programs and gaps” as one of 20 priorities to improve security (President’s Office 2010). The Transportation Safety Administration (TSA) currently is preparing a matrix that lists available security training programs offered through and approved by federal agencies such as TSA, the Federal Emergency Management Agency (FEMA), and the U.S. Department of Transportation’s Federal Transit Administration (FTA).

It is not the objective of this paper to identify all existing programs, but rather to assess the needs for additional security training or identify gaps, and to learn from people in the transportation sector about the most effectively-implemented training in the field. The results are intended to inform those responsible for supporting, developing, or implementing security training on where gaps may exist and what delivery mechanisms are preferred and most workable.

Research Questions

The following research questions guided the analysis:

- What are the content needs and gaps in security training and education for surface transportation?
- What are the preferred approaches for effective training delivery to key audiences?

Methods

The study took place in four phases during 2009 and 2010 and resulted in obtaining input from 70 transportation and transit industry stakeholders representing 45 different transportation or security organizations through interviews and focus group methods. (See reports from each phase of research: Kozub et al. 2009a; Kozub et al. 2009b; Shaw 2010; Shaw and Lowrie 2010).

The data collection consisted of four parts: two regional stakeholder focus groups, one held in metropolitan New York with 24 participants and one in Houston with 12 participants and two sets of telephone interviews, one conducted with 19 transportation stakeholders in California and another conducted with 15 representatives from union, trade, and training organizations.

The focus group meetings lasted 4–5 hours, with participants broken into small groups of 5–8 people, each with a note-taker and facilitator from the research team. The three guiding questions for discussion were the following:

1. Who are the key audiences in need of security training?
2. What are the key content areas needed for security training?
3. What are the best and preferred delivery methods for training?

The interviews were conducted by phone with leaders and representatives of transportation organizations selected by consulted experts and also through a snowball sample from initial contacts. Interviewees were asked the same three questions as the focus groups, with prompts to guide discussion in the absence of the group prompts that would occur naturally in a focus group.

The surface transportation modes represented in the focus groups and interviews included city and regional public transit, intercity bus, rail, freight rail, ports, and highway, bridge, and tunnel agencies. Also, some city, county, and state public safety, homeland security, and emergency management personnel took part in the study (see Acknowledgments). Participant roles within the agencies and organizations were from either the training area, such as training managers, or the security/safety area, such as directors of security operations.

Findings

The findings from the data collection are summarized and synthesized into two main categories: training needs and delivery methods. The findings are broken down by various training audiences in both sections rather than by mode, because interviews revealed that employees within each of the transportation modes have very similar training needs. Findings that apply generally to all types of employees/audiences also are included.

Security Training Content Needs

General Training Content Needs

Participants recommended two key areas of content that are necessary for all types of employees and audiences, related to the broad areas of assessment and response. First is basic security awareness and risk assessment. In other words, there is a content gap related to training personnel to think analytically and assess what is suspicious and what is a true risk or emergency. Second, all employees of an agency or transportation network need to understand response protocols for

managing security incidents in those first minutes before law enforcement or first responders arrive. A common example would be the need to coordinate an evacuation of a city bus or a train platform. A key to effective response is communicating within the chain of command—knowing when to call and whom to call to report an incident or concern, and also communicating with riders or the general public. Many participants in the study commented that a “systems perspective” is helpful in response training—that is, an awareness of the network of organizations and modes that need to work together and have roles to play in both prevention and response.

Improved assessment and response could be accomplished by cross-training exercises and drills that involve multiple agencies, such as those carried out to train response agencies within the Incident Command System. Transportation personnel need to be involved in these multi-agency regional training exercises to the greatest extent possible, since this sector is just as vulnerable to terror and other human crime or attacks as other sectors.

By Audience

In addition to the general needs that apply across the transportation sector, study participants were asked about training content needs for six different audiences: frontline employees and their supervisors, transportation managers and professionals, transportation security and police officers, customers, contractors, and emergency responders. This section includes descriptions of each audience type and summarizes the training gaps pertaining to each group that were identified in the study.

Frontline Employees. Frontline employees are those who interact with customers or are directly responsible for providing and maintaining service. Examples are bus and rail operators, train engineers, conductors, mechanics, station agents, track workers, cleaners, customer service agents, and all of their respective, immediate supervisors. Any type of employee, from a road crew to an operator, could be called upon to respond in an emergency, but there is a common perception across all groups that frontline transit workers are under-trained in preventive and responsive practices.

For frontline employees, the topics identified as “general needs” above are critical ones. Even though there is some existing training on behavioral recognition and reporting, respondents felt that this should be expanded. Frontline employees need training on observational skills related to how to identify suspicious activi-

ties, surroundings, and packages. Training should focus on taking appropriate steps immediately, including how to communicate and report about those suspicions and incidents with awareness of the role of other emergency service providers.

In addition to these, the specific training needs identified for this audience related to:

- Evacuation and crowd control
- Emergency procedures for special populations (persons with disabilities, etc.)
- Protection of self and others
- Proper use of security equipment and technology for access control, alerts, and communication protocols

Because of their duties, some employees of different roles and modes may need specific training to better carry out their security-related responsibilities. The following are some examples:

- Station agents, conductors and bus operators who constantly interact with customers need more training on communicating with and managing those customers during an incident.
- First-line supervisors and managers need a higher level of training in overall incident management and the National Incident Management System to effectively carry out their responsibilities during an emergency.
- Vehicle, equipment, right-of-way, and facility maintenance and mechanical employees, including structural engineers, inspectors, and dedicated craft employees, need further training on sabotage and other attack tactics used against assets.
- Rail frontline employees need specific training for how to handle a crisis on an uncontrolled stretch of track or tunnel.
- Freight rail personnel need to know about the safety and security threats of carrying hazardous or dangerous cargo.
- School bus drivers in thousands of school districts across the country, carrying millions of children every day, get very little, if any, training about hazards and security.

There was clear concern that training for frontline personnel does not need to be too in-depth or technical. The training also needs to be maintained and kept current with case studies, statistics, and references that are timely and relevant.

Finally, one of the trade group representatives in our study observed that supervisors and station managers (middle management) need to be included with front-

line employees to break the “us vs. them” mentality and build a team approach. Focus group participants also felt that when frontline employees feel supported, it creates a positive climate of preparedness gives them confidence to act based on what they learn in training.

Professionals/Managers/Policy-Makers. Transportation professionals are mid- to high-level managers and executives in operations, planning, safety, security, maintenance, and other related fields. Our forum participants expressed a perception that the professional level does not have adequate training in security topics. Aside from the same basic security awareness training for frontline employees, this audience has special high-level training and education needs in the area of security risk assessment and management, vulnerability assessment, and planning for resiliency.

Regarding risk assessment and management, policy-makers need to understand likelihoods and consequences of various incidents in a transportation environment. They also need to understand how to apply risk assessment thinking and simulation results to decisions about cost-effective and proper mitigation and response solutions. Additional training in “security risk communication” also was identified—understanding how the public perceives risks, responds to risks, and how to properly communicate risks. In the area of vulnerability, professionals need training on how to recognize vulnerability within systems (i.e., places with easy access or more exposure to threats) and how to minimize vulnerability through both infrastructure design and hardening of current assets. This means ensuring that security considerations are included in all phases of planning, from initial investment through system operation and maintenance.

Study participants also felt that transit managers need to plan for redundancy and continuity of operations, such as resiliency planning, i.e., how to shift modes or routes to handle passengers in an emergency. Learning from past incidents is a good way to do this, but there is a gap in knowledge about previous incidents and applying lessons learned and best practices to improvements in resiliency.

One focus group thought that transportation professionals need to understand more clearly the difference between safety and security and the tension between them; a door could be secure from unwanted entry but may be less safe in terms of easy exit for fire safety. This group felt that safety issues are always paramount, while security issues are more likely to be pushed aside.

Another idea was to explore the issues and opportunities related to the creation and delivery of professional development courses for existing managers within the industry. A culture of professionalism might then evolve and drive the demand for these courses. Also, more certificate and degree programs for undergraduate and graduate level students will help to bring highly-trained professionals into the industry but who may expect continuing education opportunities.

Transportation Security and Police. Transportation security and police officers have the strongest direct connection with security awareness and response, since it is their specific job responsibility. Many are graduates of criminal justice degree programs and most undergo police academy training programs, but few have had specific counter-terrorism training related to transportation operations.

The primary needs of this group were classified into two areas. The first focuses on the need for a transportation-oriented police training program that would build a baseline level of commonality and credibility thereby reducing disparities between agency programs. This program should include:

- Overview of transportations systems and operations
- In-depth study of the security issues that impact transportation systems
- Explanation of security related vulnerabilities within transportation systems
- Review of hardening tactics employed by transportation security forces
- Explanation of legal issues regarding interacting with transportation customers

The second training need for transportation police is some form of continuing education. The current method of sharing information, best practices, and case histories is through industry association meetings. Police officers and security personnel require more structured educational programs to address both modal-specific and multimodal issues. As with the initial training program for new officers, the continuing education programs need to be offered to all modes and systems of all sizes to ensure industry-wide inclusion.

Customers. Customers of all modes also were seen as a viable group to receive security training at varying levels. Customers range from individuals using the services of intercity rail or bus to the companies and corporations that are served by the freight railroads.

Regarding individual customers, the needs focus on information sharing in multiple forms. These include prevention-based public awareness messages and

incident-based information about service disruptions, detours, and other time-sensitive issues. The California interviewees noted that in communicating with the public, transit organizations need to strike the right balance between awareness and anxiety, so they should develop approaches that foster awareness but do not alarm the passengers.

Additional training beyond a public message displayed on signs could include sharing information about how to distinguish what is dangerous from what is not. Text messages can inform passengers about recommended actions in the event of an emergency. In a few instances, agencies provide training for riders such as voluntary sessions to train customers to aid in evacuations and emergency preparedness and response.

Customers of the freight rail lines are primarily the companies that use the rail lines for shipping their goods. Training would cover their responsibilities for security measures within their facilities, including the railcars stationed on their property for loading, unloading, or storage. It was noted, for example, that the freight companies need to communicate with shippers, clients, and first responders along the route to ensure consistency in handling emergencies along the whole chain of shipping from beginning to end. Another “outside the box” method of increasing security is for freight railroad companies to use rail enthusiasts as resources to look for suspicious activity as they are watching or photographing trains.

Contractors. Contractors, particularly those who provide services on the vehicles, facilities, right-of-way, and service routes of the transportation agencies and companies, also are considered part of the requisite audience for security training programs. Contractors also include food service and gift establishments in rail stations. Given their physical presence within any given operation, training programs that exclude this audience in content or delivery would be insufficient, and the lack of training would contribute to potential security vulnerabilities.

The training content needs for this group will not be much different from that of the frontline employees in terms of emphasis on reporting suspicious and dangerous activities, but would vary in priority based on the contractor or vendor’s proximity and access to critical infrastructure and operations (for maintenance workers) and to public areas (for food and other commercial vendors).

Some of our interviewees suggested that contractors or vendors could be included in both awareness and response training drills, if possible. Training could be provided as a perk for those with transit contracts or offered in exchange for other

services. Short of actual training, another option is to instruct frontline employees and the transit police to use informal approaches to advise contractors on the practices of reporting suspicious behavior.

Emergency Responders. First responders play an essential role in assisting a transportation system in hardening its security measures. Whether local, county, or state police officers are patrolling areas that include transportation assets or operations, or fire and EMS personnel are responding to alarms, overall knowledge of specific operations, hazards, and vulnerabilities is critical to safe and effective response to incidents on or near transportation systems.

Study participants felt that emergency responders could be trained to know more about interfacing with transportation systems. In addition, middle- to high-ranking managers from both transportation systems and emergency services would benefit directly from an integrated approach to incident management training as it relates to the complicated transportation sector. The National Emergency Response and Rescue Training Center (NERRTC) of the Texas Engineering Extension Service (TEEX) is an example of a program that integrates all groups and sectors into intensive emergency preparedness and response training (see <http://teex.com/nerrtc/>). Many states have strong programs for training emergency responders, but there is little coordination between emergency responders and transit operators. Study participants noted that such programs need to be integrated into a program that also trains transit operators, transit administration/professionals, emergency responders, and police and fire services.

Table 1 summarizes the content needs identified for the different audience types.

Preferred Delivery Methods for Security Training

This section summarizes participants' preferences for delivery of training for different audiences (format, length, location), and also includes their suggestions for approaches to make delivery of training more feasible and convenient.

Instructor-Led Classroom Training

The small group classroom environment generally is seen as the most effective format for learning. It allows for multi-media presentation and gives the participants opportunity for interaction with their colleagues. One interviewee expressed it this way: "Experienced students will provide examples and scenarios, and there is synergy among the students." The classroom training format also allows the instructor to gauge the effectiveness of the training, adjust the approach if it is not working well, and maximize learning.

Table 1. Summary of Needs by Audience

Audience	Content Needs
Frontline	<ul style="list-style-type: none"> • Situational assessment of threats and incidents • Observational skills and reporting dangerous substances, suspicious packages, and situations • Appropriately reacting to all threats • Crew and passenger communication and coordination • Appropriate responses to defend or protect oneself and customers • Evacuation procedures for passengers and employees, including individuals with disabilities and the elderly • Proper use of security equipment or technology
Transportation Professionals	<ul style="list-style-type: none"> • Risk assessment and management • Applying risk and vulnerability concepts to transportation • Security risk-based decision making • Security risk communication • Redundancy and resiliency planning • Integrated incident management with field personnel
Transportation Security and Police Officers	<ul style="list-style-type: none"> • Study of security issues impacting transportation systems • Explanation of security related vulnerabilities within transportation systems • Review of hardening tactics employed by transportation police and security forces • Continuing education and reinforcement of “reality” of a terrorist incident
Customers	<ul style="list-style-type: none"> • Informational programs such as “If you see something, say something” • Knowledge of emergency procedures • Awareness of security measures relative to shipments and storage for users of freight rail
Contractors and Vendors	<ul style="list-style-type: none"> • Similar to frontline employee awareness training • Reporting suspicious activity
Emergency Responders	<ul style="list-style-type: none"> • Transportation system operations, hazards, and vulnerabilities • Integrated communications and response practices and procedures • Integrated incident management

Participants suggested that Subject Matter Experts (SMEs) should lead training to deliver knowledge and provide immediate feedback. When the leader is not an SME, the best format is a facilitated discussion, where the leader engages the expertise of those in the room to achieve the training goals. Respondents preferred courses that incorporate video and also include opportunities for the students to apply their skills in role-playing, with feedback from the instructor and peers, for better integration of the learning goals.

To be more practical and cost-effective for agencies, new classroom trainings should be designed so that they are flexible in time duration, for example, 10-minute modules that can be integrated into other meetings or trainings. The preferred length for training in a particular topic is 2–3 hours at a time.

Scenario-Based Training

For all subject areas and modes, study participants called for courses that are realistic and relevant. The effective use of scenario-based training exercises or drills, both tabletop and live or full-scale, was identified as a critical component to security training programs. For frontline employees, in particular, there was general agreement in favor of hands-on training and problem-solving for maximized integration of learning goals. When teams of employees must handle responses together across job functions, participants develop a sense of teamwork that is seen as a key element of effective on-scene management. Agencies can then evaluate those response actions and correct policies, procedures, or practices that are found to be counterproductive to effective response.

Live drills, however, are both expensive and time-intensive, involving elaborate staging, preparation, and debriefing. Because of the cost and difficulty of doing this for large groups, showing video of “live” scenarios is a viable alternative.

Online and Computer-Based Training

Reactions to computer-based training (CBT) were varied; some liked it for its flexibility, time savings, and consistency in content, while others felt it was not useful because it does not have the same verifiability of delivery that a classroom has, i.e., without an instructor present, there is no confidence that the desired learning goals have been accomplished. Self-paced learning can be set up to include stop points and pre- and post-tests, but many felt that CBT cannot replicate the human interaction of a classroom. Another downside is that if done individually, it can foster the problem of “silos”—the lack of understanding of other perspectives and roles. Other practical drawbacks to CBT include lack of access to enough computers to train thousands of employees within some systems or lack of familiarity with computers among employees.

Many suggested posting trainings online so they could be accessed easily from multiple or remote locations. Refreshers could be provided this way and could be particularly useful for managers. Union respondents saw the value in the self-paced format but also pointed out that it is successful only for highly-motivated employees with good work habits and educational skills.

Interactive Videos and Games

Interactive videos and games feature the ability to actively participate in a simulated scenario that takes place in a virtual environment. When the trainee makes the wrong decision, the game or program will loop back and allow for correction. Some participants commented about these formats, agreeing that they can work well if interesting and fun, i.e., not watching words on a screen and scrolling through them to get to the end. The trainers in the study noted that they appreciate games where there is a real consequence if a mistake is made.

There are also some of the same drawbacks as seen with CBT—not all work environments have computers and not all workers are skilled in using computers. This is particularly true in smaller or rural operations and among older or immigrant transit worker populations in urban areas for whom English is a second language. Also, if a scenario is generic and not tailored to local circumstances, it is not familiar and thus less “real” to the participants. For games to be meaningful, it is ideal if the local host has the ability to integrate local context and procedures into the game format.

Webinars

Internet-based webinars and teleconferences are gaining popularity. When transit organizations have financial constraints or are challenged to take staff out of their shifts to take training, webinars allow them to participate directly from their work sites. These formats still allow for the give-and-take and peer-to-peer learning found in a classroom setting, and there is still a desire for this to be balanced with some face-to-face training, which tends to ensure engagement.

Cross-Training

As mentioned in the content section above, a common theme that emerged from this study was the importance of having mid-level managers, frontline employees, and police personnel from the same agency together in training sessions. People with different roles and representing different modes need opportunities to learn from each other and to become comfortable with procedures and protocols.

Cross-training also means conducting some sessions, where appropriate, with an inter-agency audience. The goals for such training are that participants have a common approach, know one another and their organizations, and know how to support each other in the event of a crisis. Participants noted a need for sponsorship and coordination by a “surrogate,” e.g., DHS or universities.

Refresher Courses

Many participants noted that although employees are generally trained at the time of hiring, many operations have no formal refreshers. Courses should be offered in the form of annual refresher courses on important security topics, with updated information and new technologies incorporated. These refreshers on security topics could be offered in conjunction with other regular meetings or required tests or re-certifications. For example, in California, bus operators are required to have an annual Verification of Transit Training (VTT), which offers a universal opportunity for all operators to be trained on security issues. Industry association interviewees point out that annual meetings are good places to co-locate training to save time and reduce costs.

One method of ongoing education is the posting of safety messages in locations where people will read them. Bulletins can be distributed, or pocket guides can be carried by employees. Study participants also suggested that agencies should perform “spot checks.” For example, one agency uses the “red-card” system where a manager walks around randomly and gives out a red card to an employee with a scenario and asks what they would do. One interviewee observed: “Skills and knowledge have a shelf life—if not practiced within 90 days, they’ve probably forgotten a good amount.”

Summary and Recommendations

This section begins with a consolidation of the concerns that emerged across all of the groups regarding the major challenges faced in delivering transportation security training. Table 2 lists these challenges and corresponding suggestions for overcoming these challenges based on input from study participants. Then, the major findings collected from the needs analysis study are presented. These findings, with associated recommendations that flowed directly from the identification of needs, relate to the two main research questions concerning training topic or content needs and training delivery format.

Table 2. Training Delivery Challenges and Recommendations

Delivery Challenge	Recommendation
Expensive for transit agencies to pay operators for classroom training time (overtime or backfill pay required)	<ul style="list-style-type: none"> • Incorporate into regular meetings or other training • Offer shorter training and CBT, where possible • Apply for federal dollars to support training
High turnover of employees	<ul style="list-style-type: none"> • Incorporate security elements into new employee training • Introduce more refreshers • Add to other required certifications (e.g., CDL or VTT)
Lack of “mandate”	<ul style="list-style-type: none"> • Create certification or “professional development” culture
Lack of mobility for managers or scattered employees to attend training (cutbacks on travel)	<ul style="list-style-type: none"> • More online or remote delivery options, webinars, DVDs
Lack of computer skills	<ul style="list-style-type: none"> • Keep computerized training simple and use it in combination with face-to-face training
Complexity of coordination among transit agencies, local police, and other responders	<ul style="list-style-type: none"> • Establish interagency training sessions

Key Content Findings

- The primary training content needs are behavioral recognition and reporting (prevention) and security incident response.
- Frontline transit employees need more initial security training and periodic refreshers.
- There is a need to develop modal-specific standards and learning objectives for security oriented training and education.
- Courses need to provide a better understanding of the “big picture” and systems perspective for all audiences.
- Consistent information about security protocols should filter from management to employees.
- Frontline employees and police need a clear consensus definition of what is “suspicious” and skills to assess risks and situations.
- Upper-level management needs to maintain vigilance that a terrorist attack could occur and keep the agency in readiness mode.
- Different agencies sponsoring training and the organizations that provide it should improve consistency and coordination between course content.
- Analysis of reported information (e.g., suspicious activity reporting) needs to continually inform and revise training.

- Transit employees and emergency responders need integrated response training.
- Customers need to recognize and report unusual behavior.
- A baseline or benchmark standard of minimum training based on core objectives and competencies for each audience should be created and communicated by the federal government.

Key Delivery Findings

- Classroom training is preferred, but alternatives may train more employees more efficiently.
- Wherever possible, training should be scenario-based and focused on problem-solving.
- There is a need for refresher trainings to provide audiences with updated information and technologies.
- To increase convenience and reduce costs, training could be added either before or after existing trade association meetings or other required meetings.
- There is a need for cross-training formats to ensure that all levels of employees are responding in concert when there is an emergency.
- Interactive videos are gaining favor as effective training delivery systems.
- Interactive game formats can be flexible and cost-effective but need to be developed with feedback loops that ensure the information is learned.

Future Directions

Because there is no “one size fits all” product that will work to train all surface transportation employees, the emphasis in all modes was on a comprehensive or “campaign” approach to training packages. This would allow agency managers the opportunity to pick the best approach for their employees based upon responsibilities, availability, geographic and time constraints, and learning styles. For example, a course to teach awareness skills could include instructor-led modules, on-line elements, a computer-based interactive CD, videos, and printed materials to support training efforts in a way that meets the agency’s needs. Because of the continuing and worsening logistical difficulties to using work time to do training, approaches that minimize training time and maximize scenario-based problem-solving opportunities are highly recommended.

Finally, two recurrent and overarching questions arose in our groups and interviews—one concerning the mandate for more security training and the other concerning how to evaluate its effectiveness. A concern was voiced that if sufficient incentives are not available to promote security-related training and if it is purely

voluntary for surface transportation organizations to implement it, the nation will not meet the goal of providing the public with maximum safety. One union representative interviewee recommended that TSA mandate security courses and set certain security standards for transportation organizations. Yet, at the same time, the trade groups noted that they worry about unfunded mandates; if training is to be mandatory, a funding stream would be necessary. If it is recommended but not mandatory, support for agencies to deliver the training would foster greater and quicker spread of the training across the industry.

It is important for policy-makers to continually reevaluate whether security training is meeting its goals of broadly preparing employees of the transportation sector with skills to prevent and mitigate the impacts of hazards. This includes periodically assessing the training landscape in terms of the content that is provided, the quality of that content, and the effectiveness of delivery methods. For example, to detect whether training results in changed behaviors, it may be important to develop measures that present trainees with evaluation questions that consist of job-related scenarios, or even to measure direct changes in job performance at some period after training occurs (Ostroff 1991). A key issue for the future will be how to realistically implement adequate training according to these identified needs, given current fiscal constraints. More research and experimentation into effective ways to train with limited budget and time resources is worthy of attention.

If the federal government is to heed the call to keep our roads, railways, bridges, waterways, and tunnels safe, there will need to be support for training itself and also for research that can build the foundation for state-of-the-art training courses and innovative delivery mechanisms. Continued scientific inquiry into questions of effectiveness in meeting security goals is essential. Addressing the security training gaps identified in this study and providing delivery methods and formats that meet today's organizational contexts and practical realities will result in enhanced protection against the threats that face our nation's transportation systems.

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Bus Passenger Origin-Destination Estimation and Related Analyses Using Automated Data Collection Systems

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Abstract

This research explores the application of archived data from Automated Data Collection Systems (ADCS) to transport planning with a focus on bus passenger travel behavior, including Origin-Destination (OD) inference, using London as a case study. It demonstrates the feasibility and ease of applying trip-chaining to infer bus passenger OD from smart card transactions and Automatic Vehicle Location (AVL) data and is the first known attempt to validate the results by comparing them with manual passenger survey data. With the inferred OD matrices, the variations of weekday and weekend bus route OD patterns are examined for planning purposes. Moreover, based on the inferred OD matrices and the AVL data, alighting times for bus passengers also can be estimated. Bus journey stages, therefore, can easily be linked. By comparing the interchange time and the connecting bus route's headway, it provides a way to evaluate bus connections.

Background and Purpose

London has one of the largest bus networks in the world, with more than 6 million passengers transported on its 700 routes daily. A recent report states that “Bus usage is growing at its fastest rate since 1946. More than two billion passenger trips were made on London’s fleet of more than 8,000 buses in the year to March 2009. The number of operated kilometers has also risen to 478 million, the highest since 1957” (Mayor of London, 2009).

Every five to seven years, a Bus passenger Origin and Destination Survey (BODS) is conducted by Transport for London (TfL) for each bus route. This survey provides detailed information about passenger travel patterns, including the number of people boarding and alighting at each stop, the purpose of travel, the boarding and alighting locations for each journey, and how passengers get to the boarding stop and from the alighting stop to their final destination. Expansion factors are used to account for non-returned survey cards and non-surveyed bus trips. An automated database (BODS database) stores survey results, including boardings, alightings, and loads at each stop (or stop zone) for each route. BODS is one of the primary data systems used by the Bus Network Development Unit at TfL. A limitation of this type of survey is that it records passenger travel for only one day per route. Recognizing the substantial network growth and the dynamics of demand, supplementary data from other sources also are needed for network planning. Moreover, although surveyed passengers are asked for their ultimate origin and destination in addition to their travel on the route itself, this information is not generally transferred from the paper surveys into the BODS database and therefore is not readily available to network planners.

In addition to BODS survey data, London bus planners also get timely route-level passenger ridership data from Electronic Ticketing Machine (ETM) transactions, which are downloaded daily from each bus at the garage. One drawback of this data collection method is that this data source only records aggregate ridership for each bus trip, while detailed information such as boarding and alighting locations for each passenger cannot be obtained directly.

The Oyster smart card system was launched in London by TfL in December 2003 as a new ticketing medium (Transport for London). It is now accepted on the Underground, buses, the Docklands Light Rail (DLR), Tramlink, and National Rail stations. Though the full potential of this data source has not yet been realized by London bus network planners, Oyster data are readily available, provide large sample sizes, and potentially offer a full network perspective rather than strictly a

mode level view. Bagchi and White (2004) summarize the benefits of smart card data systems as follows: (1) much larger volumes of individual passenger trip data than from manual surveys; (2) the potential to link individual passenger trips to individual cards or travelers; (3) continuous trip data covering longer time periods than manual surveys, allowing for panel data analysis techniques; and (4) classification of different customer market segments using transit services.

In addition, using Oyster smart card data enables one to link trip segments and to determine OD flows across the network. This process can be repeated on a daily basis to assess variability in trips and get more accurate estimates of ridership for specific days of the week and times of the year. It provides an easier and more reliable way to get more detailed passenger behavior information than manual survey data, which potentially can help transit agencies improve efficiency and reduce cost.

Literature Review

Cui (2006) summarized OD estimation techniques using manually-collected data. Basically, the OD matrix can be obtained either from surveys or through techniques that combine various sources of data. The ever-increasing use of ADCS generates new transport data that can be used by service providers for a range of applications. Although most ADCS are designed to support specific agency functions, the resulting data can be applied to areas far beyond their design purposes. Recent research has examined the potential benefits of using ADCS for public transport planning, specifically using archived ADCS data to infer OD matrices to assess service performance for service planning. Because most Automatic Fare Collection (AFC) systems record the bus trip boarding location coarsely at the bus-route level, it is still difficult to obtain information about where individual passengers board a bus. Integration of the AFC system data, which includes characteristics of each fare card transaction, with the AVL system data, which includes vehicle locations, offers a solution through matching the vehicle location information with the passenger trip information to help transit planners infer individual passenger boarding locations (Cui 2006).

To infer the destinations for individual passenger trips, Zhao et al. (2007), Cui (2006), Trepanier et al. (2007), and Barry et al. (2008) all used trip-chaining methods with assumptions similar to those summarized by Zhao et al. (2007):

- There is no private transportation mode trip segment (car, motorcycle, bicycle, etc) between consecutive transit trip segments in a daily trip sequence.

- Passengers will not walk a long distance to board at a rail/bus station different from the one where they previously alighted.
- Passengers end their last trip of the day at the station where they began their first trip of the day.

Jang (2010) further examined the possibilities of using the ADCS archived data for public transport planning in Seoul, South Korea. One feature that distinguishes the Seoul ADCS from many other cities is that it records each trip's entry and exit times and locations, as well as the trip chains with interchanges. Based on this dataset, Jang analyzed interchange patterns and identified interchange points that needed improvement by examining the points where interchange demand exceeded 5,000 per day and/or the average interchange time exceeded 10 minutes.

Method Applied in London

The transit passenger OD estimation methodology used in this research builds upon the trip-chaining OD estimation method applied in Chicago by Cui (2006). Since different transit agencies may have different data sources with different characteristics, the next step is to describe the data sources used in the London application.

TfL ADCS Introduction

Oyster Smart Card Data

Oyster is the contactless smart card used for public transport for fare payment in London. It has a penetration rate of around 85 percent for all bus passengers in London. Oyster smart cards in London are owned by individuals and record every transaction the card holder makes while traveling on the public transportation system. For the Underground and Overground networks, generally both the time and rail station for entry and exit are recorded. However, for buses, only the time of passenger boarding and route number are recorded. Several types of analyses are possible with the smart card data, including ridership monitoring, revenue estimation, and service performance measurement. The key contribution of this research, however, is to develop a methodology to infer the origins and destinations for bus passengers in London using the Oyster data and to develop related applications for the London bus network.

iBus Data

iBus is a £117m AVL and radio system that aims to help London Bus Services Limited run more reliable and consistent bus service (Hardy 2009). The first installa-

tions took place in March 2007, with system-wide deployment completed in April 2009. iBus data contain information about the route and trip number as well as the direction for each bus trip, and most important, they provide a unique bus stop identifier and record the departure time from each stop.

Methodology Based on Oyster and iBus Data

The basic premise is that it should be possible to determine the boarding stop for every passenger who uses an Oyster card to board an iBus-equipped bus. For a given route and trip, the fare collection timestamp (including the date) from the Oyster card is used to search through the iBus dataset to determine the boarding stop and vehicle ID. The boarding location of the next trip taken by the passenger is then used to infer the alighting stop, where possible.

Origin Inference

Since the Oyster system records only the timestamp when an Oyster card user boards a specific bus, but no location information, while the iBus AVL system records the time when the bus doors open or close at each bus stop for each bus run, it is possible to determine the boarding stop by matching the Oyster transaction times with the corresponding iBus data. In this case, the origin inference procedure is implemented through a custom-built Java program.

Destination Inference

The destination inferences are based on the trip-chaining method and use the same assumptions proposed by Zhao et al. (2007), Cui (2006), Trepanier et al. (2007), and Barry et al. (2008), as described above. The destination inference is implemented in a custom-designed Java program that reads its inputs from an SQL database.

The procedures to implement this methodology are illustrated in Figure 1. The process begins by checking whether the bus fare transaction under examination is the only Oyster transaction for that card on that day. If it is, then the trip-chaining method cannot be applied and, thus, the trip destination cannot be inferred. Otherwise, it is determined whether this bus fare transaction is the last of the day for this card. If it is not, the trip-chaining method is applied by 1) determining whether the next fare transaction for this card is on bus or rail; 2) if the next transaction is also on bus, the algorithm moves onto the “next trip” rule with a bus lookup table sub-procedure; 3) if the next transaction is on rail, the algorithm moves onto the “next trip” rule with a rail lookup table sub-procedure. If the fare transaction currently under examination is the last of the day for that card, then the first transaction of the day is treated as the transaction immediately following this last trip

segment so that the “next trip” rule can be applied here to infer the destination of this last trip segment.

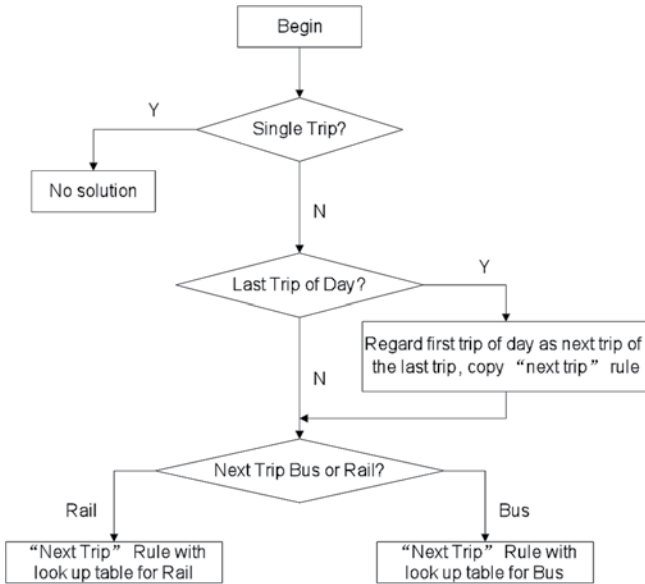


Figure 1. Process for destination inference

The lookup table mentioned here defines the stops on the bus route under examination that are closest to the boarding stop of the next transaction. While the two sub-procedures for bus and rail are similar, the London rail and bus networks are in two different GIS files, and the lookup tables are generated separately. The “next trip” rule is actually the same as assumption 2) listed in the literature review, meaning that travelers start their next trip segment at another station in close proximity (within walking distance, for example at most 1 km, or 12 minutes’ walking distance at a speed of 5 km/h) to the destination of their initial trip segment.

OD Inference Results

Five routes in the London bus network are selected to test the OD inference procedures, including two connecting suburban areas, two that terminate in Central London and one that runs through Central London. The results are shown in Table 1.

In general, the inference process has been shown to work fairly well. As shown in Table 1, origins can be inferred for more than 90 percent of all the bus passenger trips using Oyster cards on the five selected routes, and more than 57 percent of these bus passenger trips have both origins and destinations inferred. Such com-

prehensive information on a majority of bus passengers can provide very useful statistics on the use of service in complex transit networks.

Table 1. Origin and Destination Inference Results

Bus Routes	No. of Oyster Transactions	No. of Origins Inferred	% of Origins Inferred	No. of Destinations Inferred	% of Destinations Inferred
W4	8,585	8,212	95.7%	5,393	62.8%
70	12,074	11,381	94.3%	7,741	64.1%
185	2,4245	22,794	94.0%	13,947	57.5%
307	10,057	9,456	94.0%	6,968	69.3%
329	17,496	17,033	97.4%	13,737	78.5%

Validation

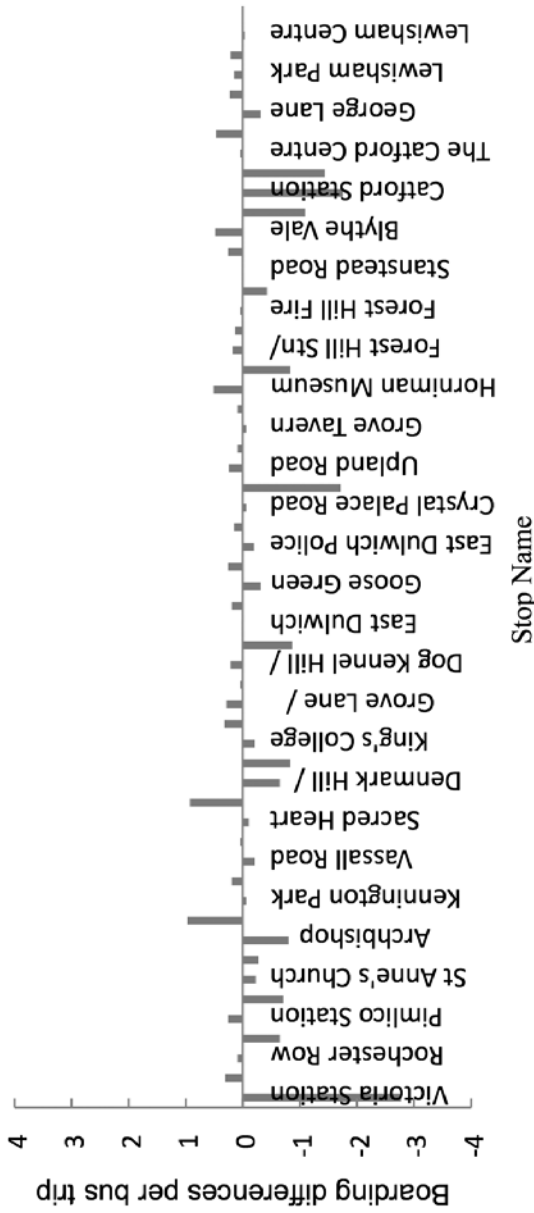
The next step was to validate the inferred origins and destinations for the selected bus routes in London. First, the origins inferred from Oyster transactions are compared with the BODS survey results for all the manually-surveyed bus trips. Then, the BODS surveyed destinations are compared with the results from the Oyster inference methodology for the same bus trips.

Comparison of Boardings for the BODS and Oyster Datasets

Since the origin inference rates are quite high and BODS does not survey every bus passenger (the sample rates for some bus trips are as low as 60 percent), the total number of boardings inferred from the Oyster transactions is close to that for the BODS survey. Table 2 summarizes the total number of boardings from BODS and Oyster datasets in terms of direction for the surveyed bus trips on Route 185. It shows that though Route 185 is one of the busiest bus routes running through Central London with a daily ridership of around 26,000, the number of boardings from BODS and Oyster for all the surveyed bus trips is quite consistent. Consequently, the number of boardings at each stop inferred from the Oyster transaction dataset should be close to that from the BODS database if the origin inference method works well. Figure 2 demonstrates the boarding location comparison results for this route.

Table 2. Number of Boardings from BODS and Oyster (Route 185)

Direction	No. of BODS Boardings	No. of Oyster Boardings	No. of Surveyed Bus Trips
Eastbound	7,304	7,911	66
Westbound	6,904	7,386	62



(a) Eastbound

Figure 2a. Boarding locations for Route 185



(b) (Westbound)

Figure 2b. Boarding locations for Route 185

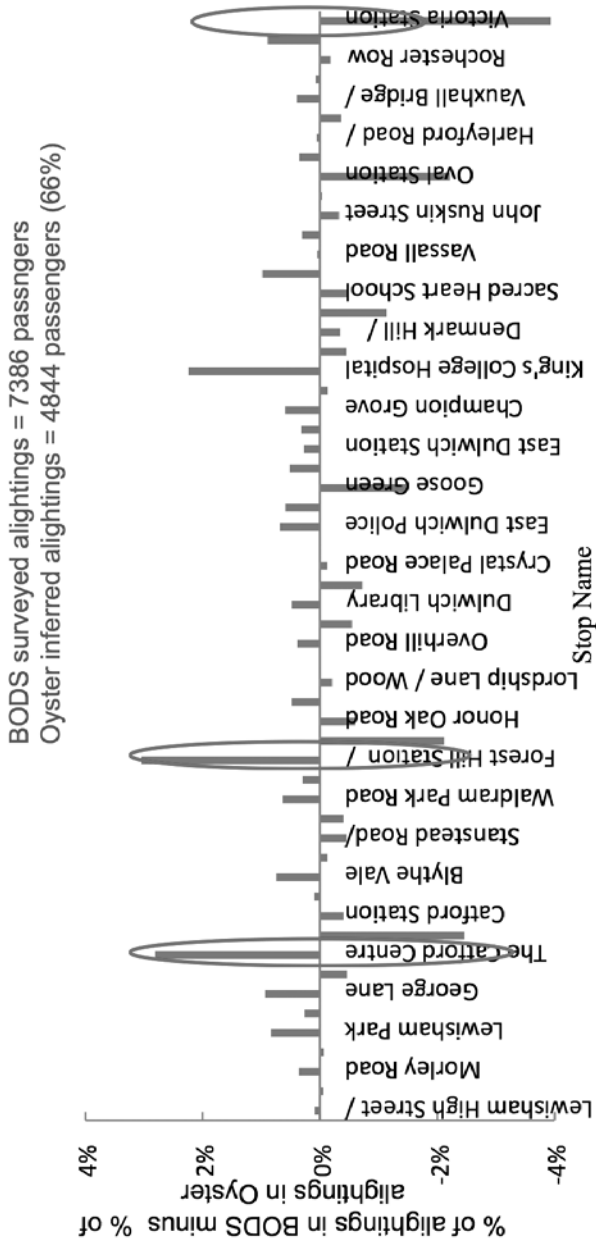
The total number of boardings for the surveyed trips from BODS is 607 fewer than that recorded in the Oyster dataset on Route 185 eastbound, and 482 passengers fewer westbound. These relatively large boarding differences between BODS and Oyster datasets are mainly due to the low BODS survey sample rates, as Route 185 is one of the busiest routes in London. Even so, the average difference per bus trip is small. As shown in Figure 2, most of the stops where the boarding differences are larger than one passenger per trip are close to shopping centers or stops with survey problems that are listed in the BODS summary report from TfL.

In general, the number of boardings at each stop from Oyster estimates is very close to that from the BODS survey. Some minor differences are caused by the low BODS sample rate. Overall, these and similar results from other routes studied show that the origin inference methodology works well and thus could be used to further infer bus passengers' destinations as well as to provide more comprehensive and reliable information for transit planners.

Comparison of Alighting Locations between BODS and Oyster Datasets

This section tests the destination inference methodology by comparing the percentages of alightings at each stop in the BODS dataset with the Oyster estimates. Since destinations could be inferred for only about 60 percent (see Table 1) of all the Oyster transactions on the studied bus routes, the number of inferred alightings at each stop from Oyster typically will be far less than the BODS survey result on any given bus trip. But it is expected that the percentages of inferred alightings from Oyster will be close to the percentages of alightings from the BODS dataset. Figure 3 demonstrates these results by comparing the alighting locations, again using Route 185 as an example.

As shown in the above figures, 7,386 alightings were recorded in the BODS survey, while destinations were inferred for 4,844 Oyster passengers (66% of BODS surveyed alightings) on Route 185 northbound. Southbound, destinations were inferred for 4,776 Oyster passengers (65% of BODS surveyed alightings). For both directions, the number of inferred Oyster alightings is far lower than the BODS survey results. However, the percentage of inferred alightings from Oyster at each stop is very close to the percentage of alightings from the BODS dataset, with the differences generally within two percent per bus trip. There is a relatively large difference (4%) between the BODS dataset and the Oyster estimates at the Catford Shopping Center bus stop southbound of Route 185. The BODS validation report provided by the BODS survey group in TfL mentioned some problems here, as several issued cards were not returned, which contributed to the difference. The other reason is



(a) Northbound

Figure 3a. Alighting location comparison for Route 185

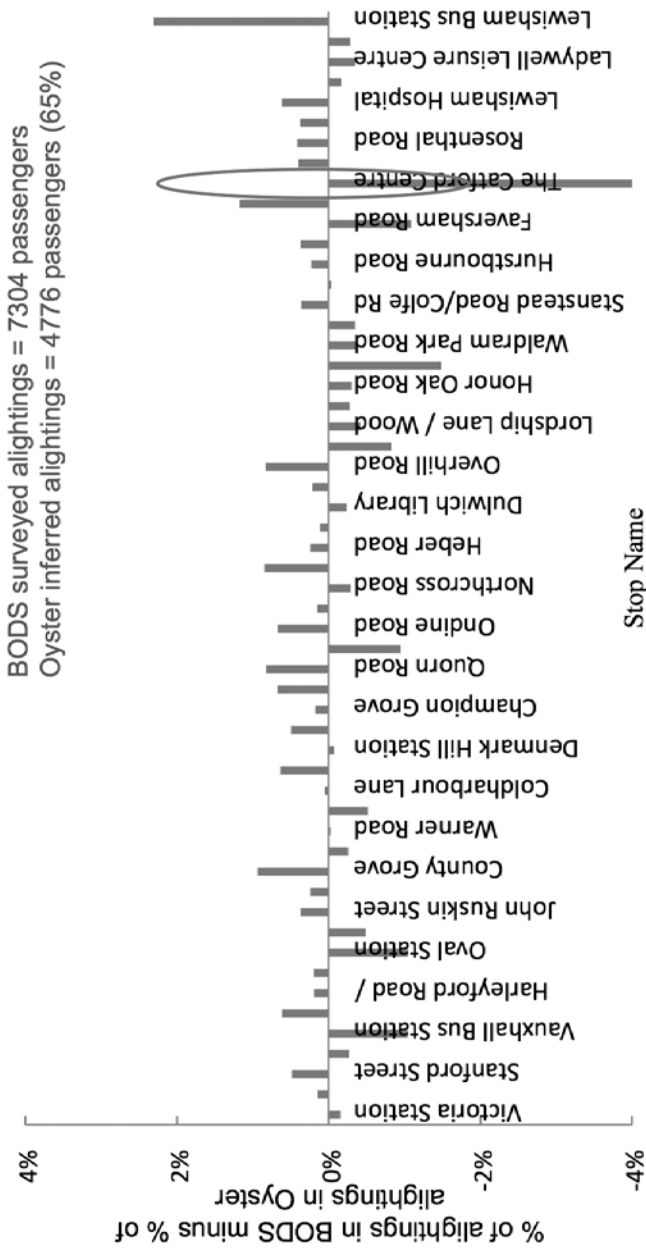


Figure 3b. Alighting location comparison for Route 185

that passengers might not necessarily get off the bus at the stop that is closest to their next boarding stop, especially when the stops are close to a shopping center, where people may walk further than usual. Another large difference appears at Victoria Station on Route 185 northbound, which is a major interchange hub and has connections with five other bus routes, as well as the Underground and National Rail. It is quite possible that the BODS survey did not reach all the passengers at this bus stop due to passenger crowding. However, for most of the other stops, if the percentage of alightings from the BODS dataset differs greatly from that from the Oyster estimates, these differences are generally offset by the differences at adjacent stops, as shown by the red circles in Figure 3. As mentioned above, passengers might get off the bus one or two stops away from their next boarding stop in order to walk and complete errands which our model cannot capture.

Application to Bus Network Planning

The validation has shown that the origin and destination inference process using the proposed methodology works well when compared with the BODS manual survey results. This section presents several applications using the results from the inference process. One of the most significant applications is using the automatic OD inference to better understand bus passenger travel patterns on a daily basis. Manual surveys are limited by narrow spatial and temporal coverage, while an automatic procedure can generate OD matrices for any bus route at any time at low marginal cost, as long as the ADCS and inference procedures have been developed and deployed.

Daily Load/Flow Profile Variation

Load/flow profiles are standard graphics showing passenger activity (boardings, alightings) and passenger load (or flow past a stop or segment in the case of multiple trips) along a route by direction. They allow planners to identify locations and values of the peak load, as well as underutilized route segments.

Route W4 during the AM Peak (7:00 to 9:30 AM) is chosen here as an example of how the daily load/flow profile varies over five successive weekdays. Figure 4 shows that there are large variations in the load/flow profile and specifically in the peak loads, even within the same week.

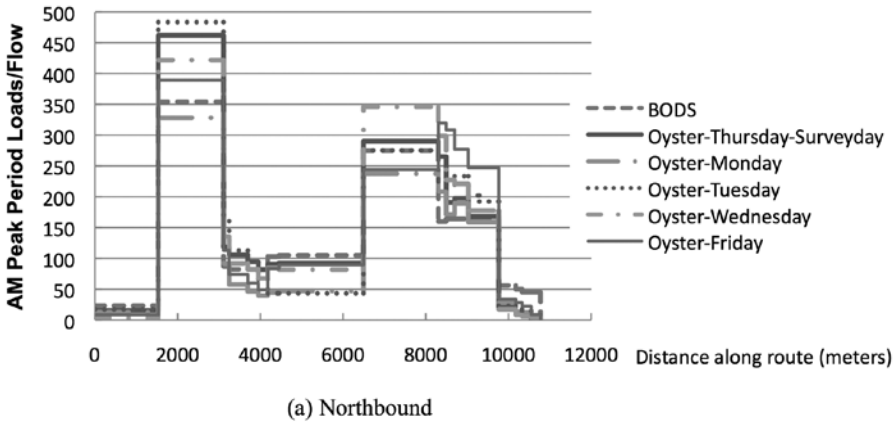


Figure 4a. Daily load/flow variation along Route W4 during AM peak

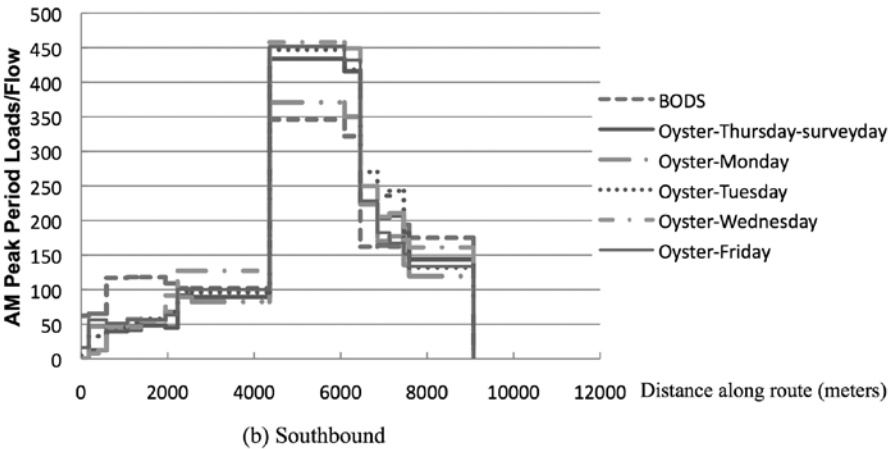


Figure 4b. Daily load/flow variation along Route W4 during AM peak

Since the OD information can be obtained for every day from the ADCS archived data, the load/flow profile differences for weekdays and weekends also can be studied. Figure 5 demonstrates the load/flow profile variations for a Friday and Saturday on Route 307. Generally, the load on Saturday is much lower than that on Friday, and the peak load point changes in the AM peak. On Friday, the peak load point is between Glyn Road (GR) and Crown Road (CR) while on Saturday, the peak load point is between Enfield Town Station (ETS), Trent Park Golf Course (TPGC)

and Oakwood Station (OS). It is quite likely that more passengers will visit the Golf Course on Saturday, which makes the load/flow around this bus stop higher than at other bus stops. In the PM peak (16 to 18:30), as shown by the circle in Figure 5(b), the peak load points are also around the Trent Park Golf Course bus stop and the Oakwood Station, but the loads/flows around these stops are even larger than on Friday. It is also likely that more people may transfer at Oakwood Station to other routes or the Underground on weekends for non-work trip purposes.

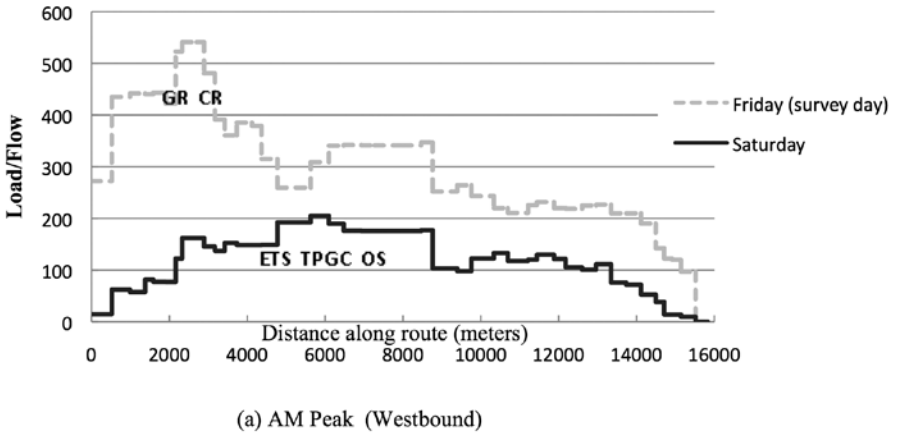


Figure 5a. Daily load/flow profiles for Route 307

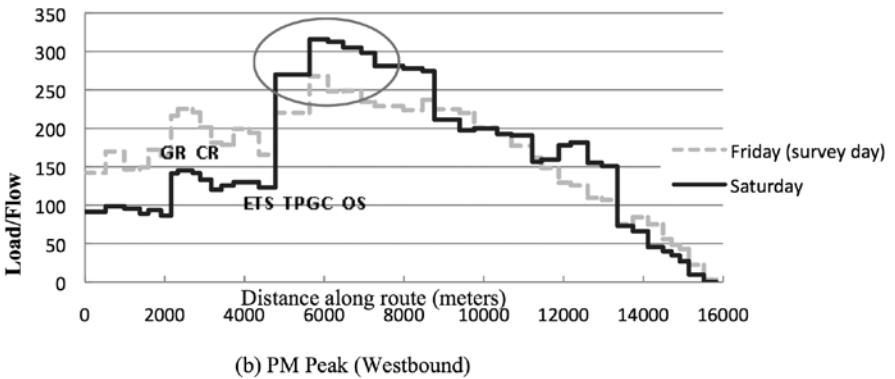


Figure 5b. Daily load/flow profiles for Route 307

Interchange Time Analysis

Interchanges affect the attractiveness of public transportation and making interchanges less burdensome is a critical consideration in public transport planning. Improving the level of service at interchange locations would enhance the overall quality of public transportation services. Both practitioners and researchers tend to pay most attention to the initial waiting experience and to in-vehicle travel for their obvious effects on ridership, but less work has been done on interchanges between segments of a linked journey (Guo and Wilson, 2010). However, reducing the out-of-vehicle times can help make public transit more attractive resulting in ridership increases. In this research, bus passenger alighting locations are inferred from the ADCS archived data. Also, since iBus AVL data provide information about the observed departure time for each bus trip at each stop, by matching the inferred alighting locations with the iBus AVL data, the alighting time for each individual passenger trip can be estimated. Hence, the interchange time can be calculated more accurately as the difference between the subsequent trip's boarding time and the previous trip's alighting time.

Taking Route 185 as an example, based on the Oyster transactions, Route 176 is found to be the most frequently used connecting route for passengers originating from Route 185, with 15 interchange stops for the parallel segments. The median interchange time for passengers from Route 185 to Route 176 is five minutes. The most frequently used connecting stop on Route 176 is the Forest Hill Station (a stop shared by these routes, so interchange times for transfers at this stop do not include walking time, and thus are actual waiting times), with seven minutes as the median interchange time for passengers originating from Route 185. Transit planners often use half the headway of the connecting bus route as the estimated waiting time, but there are no field data to support such theory. The analysis in this research supports this assumption that the actual waiting time is approximately half the headway of the connecting route, as shown in Figure 6. In this figure, the size of each dot indicates the number of interchange passengers and the color indicates the scheduled headway of the connecting route. By comparing the median interchange time with the headway of the connecting routes (the legend on the right side provides the route ID of the connecting routes), the passenger experience provided by those bus-to-bus connections can be evaluated further. For example, the dots in the blue circle under the red diagonal line suggest that these bus routes provide good (or at least better than random) connecting services while the dot in the blue circle above the red diagonal line suggest that those bus routes (Routes P13 and 356) provide poorer connecting services. Thus targeted improvements

could be made to coordinate the timetable. For this example on Route 185, the connecting services are fairly good as the median interchange times are approximately half the headway of the connecting routes.

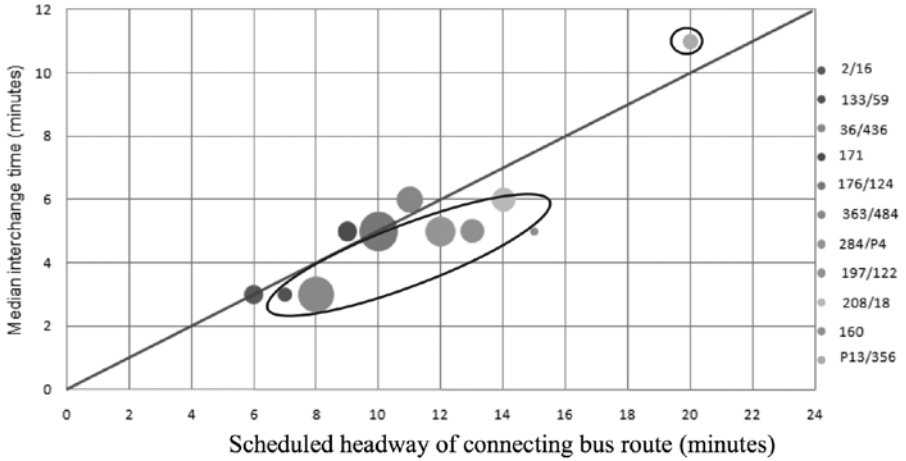


Figure 6. Relationship between connecting routes’ headway and interchange time (Route 185)

Conclusions

This research has examined the feasibility of using the ADCS archived data to analyze bus passengers’ travel behavior using data from TfL as an example. More reliable and comprehensive information enables public transport managers and planners to understand both their systems and customers more thoroughly, which may lead to significant changes in the effectiveness and efficiency of public transit services in the long term.

The first step in this process is to infer the origins for bus passengers by matching the smart card boarding transaction times with the AVL data. It then implements the trip-chaining methodology to infer each bus passenger’s alighting location. The origin and destination inference results were then compared with the BODS manual survey data, which is the first known attempt to validate the automatic inference results against large-scale survey results. Finally, this research demonstrates potential applications of the ADCS archived data to bus network planning, with a focus on daily ridership variations and interchange time analysis, and it extends

the measurement of mobility and service performance to weekend days, for which transit planners generally have very little information (Wang 2010).

Recommendations for Future Research

Some directly-related topics for further research are recommended below:

- Disaggregate analysis of both supply and demand. On the supply side, there is the potential to “optimize” equipment use by analyzing operational data and passenger-load information. By combining these operational performance data with better demand side data, using straightforward applications such as those described in this research, it should eventually be possible to improve our understanding of the behavior of public transport users. The analysis of individual user behavior will provide additional information to transit planners on the habits of users: departure times, preferred origins and destinations, preferred routes, etc.
- Linking system usage to home addresses, access behavior also can be better understood, for instance how individuals change their behavior with weather or with the impact of improved customer information systems.
- Using cluster analysis, different user patterns can be identified and clustered into similar groups. Currently, the automatically collected data do not contain information about travel purposes, but by identifying typical temporal patterns of boardings for smart cards of similar classes, it may be possible to partition card users into commuters, students and possibly seniors who travel less than others. If the smart card number is tracked over time, the survival model of transit users and retention of different ticket types can be analyzed, which would provide longitudinal information about the network use and better information for fare planning and revenue analysis.

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