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Our troubled planet can no longer afford the luxury of pursuits confined to an ivory tower. Scholarship has to prove its worth, not on its own terms, but by service to the nation and the world.

—Oscar Handlin
Reforming Innercity Bus Transportation in a Developing Country:
A Passenger-Driven Model

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Abstract

The transportation system in Dhaka City, Bangladesh, requires significant improvements. The shortage of motorized vehicles and the excessive number of nonmotorized vehicles on the city’s streets have been the cause of unbearable traffic congestion, leading to negative externalities such as productivity loss, increase in stress levels, and adverse health effects from pollution. In a city inhabited by more than 12 million people, predominantly representing the middle- and lower-middle class, a well-organized low-cost bus transportation system is yet to emerge to resolve the city’s transportation problems. This study explores ways of improving bus transportation services in Dhaka. Eight factors were identified to address satisfaction levels of regular bus users whose opinions and concerns are deemed vital in making bus services in the city better organized, need based, and service oriented. Using factor analysis and multiple regression, five of the eight selected factors were found to have significant effects on passenger satisfaction. These include comfort levels, staff behavior, number of buses changed to reach destination, supervision, and waiting facilities. Policy implications are discussed in view of the findings.
Introduction
The transportation needs of major cities will present significant challenges for policy makers as the unpredictable shifts in population dynamics in response to need for employment, housing, and sustenance continues. For example, bustling cities in India, China, Mexico, and Thailand today are struggling to keep pace with the demand for more and better transportation as the number of people in these cities begins to swell with economic growth and development. With a rise in demand for transportation comes congestion and other problems. Delays, uncertainty, and stress levels are also beginning to take their toll on both individuals and society (Morris et al. 2005). Improving public transportation is seen by many as critical (Ison and Wall 2002). The UK has already begun to look 10 years ahead to shape its transportation policy (Department of Environment, Transport and the Regions 2000). In South Korea also, the Seoul Metropolitan Government has “completely reorganized bus services, installed (rapid transit) corridors, improved coordination of metro and bus services, and fully integrated the fare structure and ticketing systems between routes, as well as modes” (Pucher et al. 2005).

The transportation system in Dhaka City, Bangladesh, catering to more than 12 million people, faces numerous and significant challenges. The complex and heterogeneous traffic pool, largely dominated by nonmotorized vehicles (especially rickshaws), poorly maintained motorized vehicles, and the lack of enforcement of traffic rules, creates serious and often unbearable congestion and heavy pollution in the city’s streets. These factors also contribute enormously to the travel-related suffering of city dwellers, a situation that by many accounts is deteriorating rapidly.

Unfortunately, research on Dhaka City’s transportation problems is seriously lacking. According to Mannan and Karim (2001), the number of vehicles per 100,000 people in the city is only 2,630; of these, 2,195 are nonmotorized. More significantly, rickshaws (a traditional, human-powered vehicle) and other nonmotorized vehicles account for 50 percent of the traffic flows. About 60 percent of the people travel on foot while almost half of the remaining people use nonmotorized vehicles. Moreover, roughly 40 percent of passenger trips and 5 percent of the freight movements are by rickshaws, estimated to be about 150,000 in number (Mannan and Karim 2001) and registered with Dhaka City Corporation. If we consider the number of unregistered rickshaws, the total estimate is much higher and may well be above 450,000. Rickshaws are used for lack of better alternatives. Unfortunately, these slow-moving vehicles are among the main causes of severe
traffic congestion, particularly in the city’s intersections, contributing to loss of work hours, exposure to health hazards from vehicular emissions, uncertainty of being on time, being subjected to adverse weather conditions, and many other inconveniences.

An inadequate road network is yet another impediment to the smooth flow of traffic in Dhaka City. Ideally, the road transportation network should cover about 25 percent of a city’s surface area (Banglapedia). There are approximately 436 kilometers of four-lane roads and 1,408 kilometers of two-lane roads covering about 8 percent of Dhaka City’s surface area. Most of these roads are poorly maintained. Almost two thirds of the available roads do not have engineered surfaces, and although more than a quarter of the roads have surface dressing, these show signs of extensive deterioration (Mannan and Karim 2001). Also, while more than half the city’s travelers are pedestrians, a meager 220 kilometers of sidewalks exist (Banglapedia). Many sidewalks are occupied by street vendors that constrict space available to pedestrians who then spill over onto the streets to narrow traffic lanes and further aggravate the congestion.

Other problems in the city’s traffic system include lack of clear traffic regulations and their poor enforcement and environment pollution from old and ill-maintained motorized vehicles that emanate toxic suspended particulate matters (SPM), carbon monoxide (CO), sulphur dioxide (SO₂), and airborne lead (Asian Development Bank 2001).

Bringing about long-term improvements in the city’s worsening traffic system requires a change in the status quo and large investments in the transportation and road-communication sector. The World Bank is currently financing the government of Bangladesh to implement the Dhaka Urban Transport Project, a public transport system in Dhaka City estimated to cost Tk.10,000 million (World Bank 1999). According to the World Bank, Dhaka’s transport problems are multifaceted and massive, and require a program phased in over several years.

The overall grim picture of the city’s transportation problems and constraints suggests the need to bring about significant improvements. Although suggestions have been made for exploration of underground and air space in various forums (subways and monorails), and these alternatives certainly have some attractive features for relieving congestion, it is difficult to envision their immediate implementation in view of their technical and financial feasibilities.
What is imminent, however, is to improve the ground transportation system in the city, which today is comprised of rickshaws, buses, minibuses, premium (air-conditioned) buses, taxis, CNG auto rickshaws, and some commuter train facilities. Rickshaws, powered by raw muscle, are slow, lack capacity, and cause congestion. Considering the size of the taxis and auto rickshaws vis-à-vis their passenger-carrying capacity, their expansion also does not appear to be a suitable solution to the congestion problem. Commuter trains block traffic frequently at crossings and exacerbate the congestion. Under the circumstances and because of the dominance of a low-income population in the city, we advocate quick and significant capacity increases in the city’s bus transportation network. While developed cities like London and Seoul have already begun to increase their investments in this mode, this option has not been satisfactorily explored or addressed for Dhaka City. A World Bank press release on the Dhaka Urban Transportation Project stated that Dhaka was perhaps the only city of its size without a well-organized bus system or mass transportation system (World Bank 1999).

The estimated number of registered buses and minibuses plying in the metropolis as of January 2003 was 4,500 (Ghani 2003), which is quite insufficient for this densely populated city. Significantly, this population is expected to double by 2025 (Ali 2004). Furthermore, a large majority of these buses are unfit both environmentally and mechanically, adversely affecting the city’s ecological environment and being highly susceptible to accidents. Shortages of terminals and bus stops, the absence of separate lanes for buses, and the extreme lack of discipline in how and where buses stop on the thoroughfares create additional problems for traffic movement. Andaleeb (2003) depicts this as a failure of city management that contributes to the daily chaos.

An efficient and effective urban transportation system can promote urban development and renewal while providing adequate access and mobility. In fact, cities of developing countries are often the major engines for economic growth and improvements in city transportation can make them much more efficient and productive (Button 1993). The present deficiencies and inadequacies of the transportation sector in Bangladesh may be seen as one of the major impediments to the socioeconomic development of the country. In fact, Dhaka City has a major role to play in regional and subregional development (Karim 1998), which can be facilitated by an effective and efficient transportation system. Unfortunately, the poor transportation conditions in this bustling city curtail productivity and ultimately hinder international trade and economic development indirectly. For
example, the links between the production centers and export shipment points are often decoupled by the horrible tangle of traffic. This reduces turnaround time, delays schedules, introduces related inefficiencies, dissatisfies overseas customers, and reduces competitiveness.

To induce more people to use the city’s bus transportation system, it is important to obtain insights from actual users of the system about the changes they would like to see to better meet their needs. These insights must then be factored into a coherent strategy to provide real value to passengers. In this regard, Jen and Hu (2003) examine the perceived value model for Taiwan in which they contend that if benefits relative to costs of using bus service exceed the benefits and costs of alternative transportation modes, it will increase reuse intentions for buses. By identifying the key dimensions that offer value and influence customer satisfaction, alternative bus service strategies can be devised so that more people opt in favor of this service. In turn, this would alleviate the present congestion and related problems faced by the city and its population.

The two major research objectives of this study are to:

- Identify the key factors in the context of bus transportation in Dhaka City that explain customer/passenger satisfaction.
- Assess the relative importance of these dimensions to prioritize service provision and enhance passenger satisfaction.

**Literature Review**

Macario (2001) suggests that for any urban mobility system to provide appropriate and effective solutions to its clients, it must focus on the interaction between different agents of the system acting within and across different levels of planning and control (i.e., authorities, operators, suppliers of equipments, citizens, etc.). Macario also cites Ciuffini (1995) to emphasize the need for an adequate balance between the following dimensions:

- Transport dimension should obtain adequate balance between modes and means of transport, so that those who give up the use of private transportation have available good quality alternatives without any social, geographical or sectoral discrimination.
- Environmental dimension should establish a configuration of the urban
mobility system that results in a total sum of pollution below the endurance level.

- Economic dimension should offer good “value for money,” induce adaptive behavior from the users, and be able to create new financial resources to support investment.

- Social dimension should ensure that citizens are provided with an adequate mobility system to their needs and that no exclusion through price or any other criteria is imposed on the basis of economic or financial goals.

Macario also suggests that there is no perfect transportation system, and therefore the second best solution lies in establishing trade-offs between the various dimensions according to the socioeconomic and cultural reality of each specific environment (urban area). These trade-offs are conditioned by practical options that result from the interaction between the local, regional, and national levels of interventions. Clearly, an effective transportation system is a function of the strategic objectives designed to address stakeholders’ interests.

Customer satisfaction with transportation services can be placed in the framework of stakeholder (passenger) interests. From this perspective, customer satisfaction with bus transportation can be used to find reasonable solutions to problems. There is, in fact, no comprehensive study on customer satisfaction with bus (or transportation) services in Bangladesh. Passengers’ opinions regarding the quality of bus services can be vital in making this sector popular, attractive, and of greater value relative to other modes so as to induce more people to use it regularly.

In the absence of any comprehensive local research, we relied partially on studies conducted in other countries to identify the key attributes regarding urban bus transportation needs. However, the conditions existing in these countries relative to Bangladesh may raise questions of comparability. Acknowledging the differences, our findings are discussed below.

UK’s Midlands operator Trent Buses conducted a thorough research with a view to improving services (Disney 1998) and identified customers’ top requirements as: reliability/frequency of services, friendliness of services, clean bus interiors, comfort, value for money, clean bus exteriors, easy access, reasonable fares, and easy to understand and remember timetables. The top four items stood out in importance, and value for money was revealed as an embodiment of these attributes. Thus, if bus operators failed to deliver on the four items, they were not producing value for money. Low fare was not perceived as a critical requirement
by a majority of the customers. Despite scoring high on reliability, Trent Buses fell short of expectations in the other three top values and was seen as weak in value for money. In the study, bus driver attitude and behavior were seen as problematic. Although only 10 percent of the drivers were responsible for this problem, what was far more damaging was the perception. Vehicle cleaning standards were also severely criticized.

In another study, analysis of complaints received by the Rail Users Consultative Committee (RUCC) in the UK revealed that staff attitude, reliability, punctuality, and cleanliness of the trains are sources of a majority of the complaints by passengers (Disney 1998). In India, transportation systems have also been criticized for their low quality of services reflected in the growing number of standing passengers, lack of punctuality, irregularity, and substandard amenities (Mishra and Nandagopal 1993).

Edvardsson (1998) examined written customer complaints to Goteborg Regional Public Transport AB in Sweden (GLAB), performed personal interviews with customers who had previously complained, and found staff attitude to be the dominant issue in the written complaints. In the personal interviews, however, punctuality emerged as the major problem. This indicates that customers accept lack of punctuality as an unfortunate but unavoidable effect of road congestion but it reduces their tolerance in other areas, particularly on how they are treated by front-line staff and on vehicle comfort levels embodied in heating and ventilation.

Based on the attributes identified in the above studies, in depth interviews with local passengers, as well as the authors’ personal experiences with bus services, several hypotheses were initially developed for the Dhaka City research. This study is believed to be the first of its kind in Bangladesh that takes a broad and systematic customer-based approach to establishing the determinants of satisfaction with bus transportation services.

Hypotheses
Comfort is an important consideration for passengers using public transportation, which can be delivered by ensuring that the interior facilities (lights, fans, air-conditioners) function properly. Passengers also like to sit comfortably in good seats with enough legroom. In the event a passenger has to travel standing, he or she
would like to have sufficient ceiling height to avoid crouching that can contribute to serious discomfort. It is posited therefore that:

**H1: The more comfortable the inside of the buses, the more satisfied the passengers will be.**

Another factor deemed important in providing customer satisfaction was the quality of the ride. Often, in the in depth interviews, it was indicated that bus drivers blow the horn too often, drive too fast, overtake other vehicles dangerously, or brake hard frequently without any consideration to passengers’ ability to maintain balance. In other words, passengers felt that the quality of the bus ride often poses serious hazards. We posit, therefore, that:

**H2: The better the quality of the ride, the more satisfied the passengers will be.**

Various categories of people use the city’s bus transportation system. Many of them have little education and come from the lower income segment of society. Their social and economic context shapes their behaviors as passengers in ways that other societies may not fully comprehend. For example, issues regarding personal hygiene need to be addressed as some passengers may be traders who use the bus to go to the market with goods to trade; others may be grimy day laborers returning from work. In addition, passenger behaviors, such as pushing and shoving, in crammed buses often lead to altercations. These behaviors vary widely and may be perceived by others as inappropriate. We group these behaviors under whether passengers are disciplined, well-behaved, and clean, to posit that:

**H3: The more passengers perceive the behaviors of copassengers as inappropriate, the less satisfied they will be with bus services.**

Personal security has deteriorated alarmingly in Dhaka City in the past decade. Newspapers daily report stories of mugging, stealing, extortion, or even death as routine episodes. Cases of people losing their wallets to pickpockets are not uncommon, especially on public buses. These acts often instill a sense of insecurity among passengers that can attenuate their satisfaction with public transportation. We posit that:

**H4: The greater the feelings of insecurity associated with the use of bus services, the lower the level of customer satisfaction with these services.**

Passengers indicated during the in depth interviews that bus driver behaviors are often inappropriate. Overloading and crowding is a well-documented practice
given the dearth of buses. Adding to this problem is the fact that buses stop almost anywhere to pick up or drop off passengers often in sheer haste. Rude and argumentative service personnel also mar the service experience. When such practices exist, we posit that:

H5: The greater the perception of improper behavior of the service personnel, the lower the satisfaction of the passengers.

There is also the perennial problem of capacity in the transportation sector, especially for bus services. It is reasonable to assume that people would prefer buses to rickshaws and baby taxis as a quick and more affordable alternative mode of transportation. Unfortunately, this preference often succumbs to the lack of availability of sufficient numbers of buses as reflected in the long waiting lines and the frantic dash to clamber aboard a bus upon its arrival at most stops. If a sufficient number of buses are made available for city commuters, enabling them to reach their destination comfortably and on time, it will allow more people to use buses for their daily traveling needs. This factor reflects the supply-side problem or inadequacy of the number of buses and lack of seating capacity to serve the needs of the public. We therefore posit that:

H6: The greater the perceived inadequacy of the capacity of bus services to serve passenger needs, the less satisfied the passengers.

Dhaka City commuters are not provided with good bus stand facilities. Very few permanent bus stands offer appropriate physical structures and facilities for people to board or disembark from the buses. Passengers often stand in queues by the roadside or on the road. Moreover, there is no shelter from the scorching sun or heavy rains. For a long wait at the bus stands, there is no alternative but to remain standing. In the evenings, not many stops are well lit and this can be a cause of consternation. Thus, it is proposed that:

H7: The better the waiting facilities at the bus stands, the more satisfied the passengers.

Bus routes are also seen by passengers as disorganized and not well coordinated. Many passengers have to change buses several times to reach their chosen destinations. Since, for the large majority, getting to the destinations quickly and efficiently is important, we posit that:

H8: The more frequently passengers have to change buses to get to their destinations, the less satisfied they will be with bus services.
Many buses that ply the city have minimal inspection requirements and are quite dilapidated. They continue to operate on city streets for lack of systematic monitoring and supervision of their physical and mechanical conditions. With extensively damaged exteriors, nonfunctioning lights, broken windows, dented and bent bumpers, etc., they epitomize how many buses are able to avoid official inspection and maintenance while endangering public safety. This tangible, visible evidence of poor supervision by the authorities evokes feelings of uneasiness and may even attenuate confidence in bus services. For example, passengers may feel that the dilapidated conditions make the buses susceptible to accidents. They may even infer that flaws may exist in the buses’ mechanical systems (engines, brakes, or clutches) for which passengers should have every reason to be apprehensive. It is important, therefore, that the government authorities responsible for supervising the physical and mechanical conditions of the buses, as well as the bus fares, do so regularly. Visible and vigorous supervision can raise the confidence of the passengers to use more public transportation. Hence we propose that:

**H9: The greater the perceived government supervision of buses, the higher the level of passenger satisfaction.**

**Research Method**

**Secondary Research**

Secondary research was first conducted to find studies on customer satisfaction with urban bus transportation services. Of the published studies that were found, most of them were from developed countries. These findings are likely to be different from the context of developing countries. However, the lack of indigenous literature led to our derivation of preliminary insights from the models found in developed countries.

**Questionnaire Design and Pretesting**

The questionnaire was based on secondary research, as well as in depth interviews and extensive brainstorming. The factors most apt to explain passenger satisfaction are reflected in the hypotheses. The survey questions measured each attribute of a factor on 7-point Likert scales with “strongly agree” reflecting the highest favorable response and “strongly disagree” indicating the least favorable response to each statement. Demographic questions were also included in the questionnaire and were mostly dichotomous and multichotomous in nature. The questionnaire was originally developed in English and translated and retranslated.
several times to obtain an appropriate local language (Bangla) version. The questionnaire was pretested on several randomly selected respondents. Minor adjustments were made to ensure conciseness, objectivity, and clarity. A panel of experts concurred on the content validity of the English and Bangla versions, confirming they were comparable.

**Sampling and Data Collection**

Dhaka City bus commuters were the target population because they were homogeneous in their use of buses but heterogeneous in other aspects (income, profession, etc.). Their opinions were mainly sought because they would be best able to evaluate existing levels of services and levels of satisfaction with such services. Probability sampling using a multistage cluster-sampling method was used to select a representative sample of commuters. The city was divided into several areas based on the location of the major bus stands/stops (e.g., Saidabad, Motijheel, Malibagh Crossing, Farm Gate, Gabtali, etc.). The entire area covered by each bus station was considered a cluster. From each cluster, a number of residential streets were randomly selected after an enumeration of the streets were completed. Systematic sampling was then used to select households. Respondents from each household were selected based on their usage of bus services. According to research protocol, respondents were asked not to identify themselves so that they could freely respond to the questions. They were also given the option to withdraw from the study or skip questions they did not want to answer.

Due to time and resource constraints, data were collected from 250 respondents via face to face interviews. In the event the respondents were educated, they were asked to self-administer the questionnaire; otherwise the interviewer filled the questionnaire based on the respondent’s verbal responses.

**Analysis**

Frequency distributions were obtained to check for data entry errors and to obtain descriptive statistics. Data were then factor analyzed using principal components analysis with varimax rotation. Factor analysis is a data reduction technique that allows grouping of variables under a common theme or dimension (see Figure 1). A rotated structure of seven factors was expected based on the nine hypotheses since two of the hypotheses used single-item measures that were not included in the factor analysis. The seven factors were adequacy of buses, comfort, copassenger behavior, quality of the ride, insecurity perceptions, bus stand facilities,
Comfort
1. Seats are comfortable.
2. Ceilings are at a comfortable height.
3. Facilities inside buses are in good condition.
4. There is enough foot space.
5. Buses are well maintained.

Quality of the ride
1. Drivers blow the horn too much.
2. Drivers drive too fast.
3. Buses overtake other vehicles dangerously.
5. Buses often breakdown on the road.

Copassenger behavior
1. Passengers are disciplined.
2. Passengers are well behaved.
3. Passengers maintain cleanliness.

Insecurity
1. You are afraid of being robbed/mugged at the bus stand.
2. You are afraid of being pick-pocked on the bus.

Bus Operator/Conductor Behavior (single-item measure)
1. Staff behave properly with you.

Adequacy
1. There is sufficient number of buses in the city.
2. Seats are generally available on the buses.
3. There are sufficient seats in the buses.

Bus stand facilities
1. There is enough lighting at the bus stands.
2. There is enough shelter at the bus stands against rain, sun, storm, etc.
3. There is enough seating arrangement at the bus stands.

Change buses (single-item measure)
1. You have to change buses many times to reach your destination.

Government supervision
1. Government supervision in checking bus fare is good.
2. Buses are randomly checked to ensure mechanical fitness and safety.

Figure 1. Measures of Variables in the Model Using 7-point Likert Scales (anchored at strongly agree [7] and strongly disagree [1])
Reforming Innercity Bus Transportation in a Developing Country

and government supervision. The two single-item measures were about having to change several buses to get to the desired destination and behavior of the staff.

The initial factor structure did not support our selected dimensions. One factor, the adequacy of the buses, did not load as expected: the items were distributed over more than one factor. After systematic removal of these items, the final rotated solution with 21 items was retained. Six factors resulted from the final rotated solution; each was easy to interpret and explained 58 percent of the cumulative variation as shown in Table 1.

The six factors were comfort, quality of ride, copassenger behavior, insecurity, bus stand facilities, and perceived government supervision. Each factor was assessed for reliability using Cronbach’s $\alpha$. The reliability coefficients of most of the factors, along with the measures of satisfaction, exceeded the value of 0.7 recommended by Nunnally (1978), except for bus stand facilities and supervision, which had coefficients of 0.57 and 0.43, respectively. While these two values are on the low side, they were retained because of the preliminary and exploratory nature of this research. To assess the validity of the measures, the multiple items measuring each construct were further factor analyzed. In each case, the items always loaded on one factor only, lending support to their convergent validity. To these six factors were added the two additional single-item measures—behavior of the staff and need to change buses—that led to using eight variables in the final analyses. Thus, from the nine hypotheses proposed, we tested eight: inadequacy of bus capacity (H6) was dropped from the analysis as its measurement properties did not bear out as originally expected. This is not to imply that inadequacy of capacity as an issue is unimportant; perhaps it is reflected in the other constructs (comfort, need to change buses, etc.).

Descriptive statistics reflecting the mean scores, standard deviations, and reliability scores are provided in Table 2. The results clearly indicate how users perceive bus services. Overall satisfaction (the dependent variable), measured on a 7-point scale, rated a mean score of 2.95 ($s = 1.49$). Comfort, comprising seven items, had a mean of 2.74 ($s = 1.22$); supervision had a mean of 2.65 ($s = 1.60$); bus stand facilities had a mean of 1.80 ($s = .98$); ride quality measured in a negative sense had a mean of 4.96 ($s = 1.39$); copassenger behavior had a mean of 3.91 ($s = 1.45$); and insecurity had a mean of 5.39 ($s = 1.60$). Two single-item measures, staff behavior and need to change buses had mean scores of 3.38 ($s = 1.86$) and 3.93 ($s = 2.30$), respectively. Clearly, none of the variables purported to explain satisfaction with bus services are viewed favorably. The mean scores suggest the need for large-scale
Table 1. Factor Analysis Results

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<tr>
<th>Rotated Component Matrix</th>
<th>Component</th>
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<tr>
<td></td>
<td>Comfort</td>
</tr>
<tr>
<td>There is enough foot space</td>
<td>.812</td>
</tr>
<tr>
<td>Seats are comfortable</td>
<td>.746</td>
</tr>
<tr>
<td>Ceilings are at a comfortable height</td>
<td>.644</td>
</tr>
<tr>
<td>Seats are generally available</td>
<td>.643</td>
</tr>
<tr>
<td>Facilities inside buses (window, seat, light, etc.) are in good condition</td>
<td>.626</td>
</tr>
<tr>
<td>There are sufficient seats in the buses</td>
<td>.430</td>
</tr>
<tr>
<td>Buses are well maintained</td>
<td>.430</td>
</tr>
<tr>
<td>Drivers drive too fast</td>
<td>.044</td>
</tr>
<tr>
<td>Buses overtake other vehicles dangerously</td>
<td>-.101</td>
</tr>
<tr>
<td>Bus drivers frequently brake hard</td>
<td>-.047</td>
</tr>
<tr>
<td>Buses often break down on the road</td>
<td>-.139</td>
</tr>
<tr>
<td>Passengers are well behaved</td>
<td>.105</td>
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<td></td>
<td></td>
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<tr>
<td>-----------------------------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Passengers are disciplined</td>
<td>.193</td>
</tr>
<tr>
<td>Passengers maintain cleanliness</td>
<td>.103</td>
</tr>
<tr>
<td>Bus stands have enough shelter against heat, rain, storms, etc.</td>
<td>.039</td>
</tr>
<tr>
<td>There is enough seating arrangement at the bus stands</td>
<td>.080</td>
</tr>
<tr>
<td>There is enough lighting at the bus stands</td>
<td>.271</td>
</tr>
<tr>
<td>You are afraid of being robbed/mugged at the bus stands</td>
<td>.040</td>
</tr>
<tr>
<td>You are afraid of having your pockets picked or belongings lost</td>
<td>-.035</td>
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<tr>
<td>Government supervision in checking bus fare is good</td>
<td>.137</td>
</tr>
<tr>
<td>Buses are randomly checked to ensure mechanical fitness and safety</td>
<td>.058</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
improvements in each of these dimensions to bring about a satisfying and value-driven bus service system in Dhaka City.

The final factors derived from factor analysis, along with the two single-item measures, were used as independent variables in a multiple regression model to test the hypotheses and determine their ability to explain and predict passenger satisfaction.

### Results and Recommendations

This study suggests that several variables have major implications for delivering satisfaction to bus passengers and for shaping travel behaviors that can lead to a more systematic and efficient traffic system in a city that is beleaguered by its population pressures and unimaginable traffic tangle. The final regression model had an overall $F_{6, 38}$ value of 22.54 ($p < .001$) with an $R^2$ of .349 and adjusted $R^2$ of .327. Considering that no prior scales and measures were available for this particular research, the results explaining 34.9 percent of the variation in the dependent variable were very encouraging.

Four of the factors—comfort, need to change buses, behaviors of the staff, and government supervision—were found to be significant at the 1 percent significance level ($\alpha$). A fifth factor, quality of bus stand facilities, was found to be marginally significant with the probability of making a Type I error 10 percent of the time. The three remaining factors—quality of the ride (driving practices),

### Table 2. Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction</td>
<td>2.95</td>
<td>1.49</td>
<td>248</td>
</tr>
<tr>
<td>Change several buses to reach destination</td>
<td>3.95</td>
<td>2.30</td>
<td>248</td>
</tr>
<tr>
<td>Staff behavior</td>
<td>3.38</td>
<td>1.86</td>
<td>248</td>
</tr>
<tr>
<td>Comfort</td>
<td>2.74</td>
<td>1.22</td>
<td>248</td>
</tr>
<tr>
<td>Ride quality</td>
<td>4.96</td>
<td>1.39</td>
<td>248</td>
</tr>
<tr>
<td>Copassengers</td>
<td>3.91</td>
<td>1.45</td>
<td>248</td>
</tr>
<tr>
<td>Bus stand facilities</td>
<td>1.80</td>
<td>.98</td>
<td>248</td>
</tr>
<tr>
<td>Insecurity perceptions</td>
<td>5.39</td>
<td>1.60</td>
<td>248</td>
</tr>
<tr>
<td>Supervision</td>
<td>2.65</td>
<td>1.60</td>
<td>248</td>
</tr>
</tbody>
</table>
copassenger behavior, and feelings of insecurity—were not found to be significant in predicting passenger satisfaction.

Table 3 summarizes the regression results of the final model. The standardized beta ($\beta$) values indicate that the factor “comfort” had the greatest impact on passenger satisfaction. Apparently, the comfort level provided by the city’s buses is a major element that leaves much to be desired, attenuating perceived value and satisfaction.

With the exception of some premier buses that ply a limited number of key city routes, owners/operators of a large proportion of the buses, including government-owned Bangladesh Road Transport Corporation (BRTC) buses, do not pay adequate attention to passenger comfort. Internal facilities, such as lights and fans, are frequently out of order or in need of repair. Many of these buses do not have fans and lights at all. Other amenities, such as lighting during night travel and better airflow and ventilation, must also be constantly monitored to ensure a desirable passenger experience. Basic passenger requirements, like comfortable seats and open windows for airflow, also do not measure up to standards. Many public buses are minibuses, which do not provide adequate legroom or even adequate ceiling height for standing. Passenger discomfort increases during rush-hour traffic when riders have to travel standing all the way in extremely crowded conditions. The results suggest that if comfort can be increased, passenger satisfaction can also be increased significantly, leading perhaps to greater proclivity to use public buses. Comfort is a huge passenger priority and basic standards for comfort must be established and monitored to ensure that the city buses adhere to them.

Staff behavior had the second most impact. Staff managing the embarkation and disembarkation of passengers and collecting fares often lack civility as indicated during the in depth interviews. However, it is important to add that the type and nature of the passengers sometimes necessitate such behaviors, especially when they try to avoid paying for the service. While rude behavior of the staff is not displayed with every passenger, it appears to affect those who use bus services. Many people would like the staff to improve their behavior with all passengers if customer satisfaction is to be improved.

To minimize adverse behavior, a complaint system may be installed to track offenders and take effective action against them. This means installing a mechanism through which the particular bus and the particular employee can be identified via color coding and name tags with visible identification properties. Consideration may also be given to training and certifying transportation workers
### Table 3. Regression Model

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t-value</th>
<th>Sig.</th>
<th>Tolerance</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>.631</td>
<td>.484</td>
<td>1.303</td>
<td>.194</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change several buses</td>
<td>-.108</td>
<td>-.167</td>
<td>-2.879</td>
<td>.004</td>
<td>.814</td>
<td>1.228</td>
</tr>
<tr>
<td>Staff behavior</td>
<td>.176</td>
<td>.220</td>
<td>3.655</td>
<td>.000</td>
<td>.752</td>
<td>1.329</td>
</tr>
<tr>
<td>Comfort</td>
<td>.327</td>
<td>.268</td>
<td>4.358</td>
<td>.000</td>
<td>.720</td>
<td>1.389</td>
</tr>
<tr>
<td>Ride quality</td>
<td>.062</td>
<td>.057</td>
<td>.997</td>
<td>.320</td>
<td>.821</td>
<td>1.219</td>
</tr>
<tr>
<td>Copassengers</td>
<td>.031</td>
<td>.030</td>
<td>.519</td>
<td>.604</td>
<td>.815</td>
<td>1.227</td>
</tr>
<tr>
<td>Bus stand facilities</td>
<td>.145</td>
<td>.095</td>
<td>1.641</td>
<td>.102</td>
<td>.810</td>
<td>1.235</td>
</tr>
<tr>
<td>Insecurity</td>
<td>.034</td>
<td>.037</td>
<td>.652</td>
<td>.515</td>
<td>.858</td>
<td>1.165</td>
</tr>
<tr>
<td>Supervision</td>
<td>.144</td>
<td>.155</td>
<td>2.732</td>
<td>.007</td>
<td>.851</td>
<td>1.175</td>
</tr>
</tbody>
</table>

$R^2 = .349$, $F_{6,38} = 22.54; p < .001$

Dependent variable: satisfaction
Reforming Innercity Bus Transportation in a Developing Country

placed in the service of the general public. Such training and certification are actually needed across the board in all service sectors and may even be introduced in school curriculums to sensitize young citizens to the needs of society.

If capacity restrictions (i.e., the number of passengers on a bus) can be imposed via better supervision (after many more buses are introduced in the city system), and if ticket prices can be collected before people board buses, perhaps the staff would behave less rudely. By changing the processes, customers would not have to interact as much with the staff or endure their bad behavior, thereby improving their satisfaction with bus services.

Passengers also indicated that changing buses several times to reach their destinations heightens their dissatisfaction. As the city’s population continues to grow, ways must be found to provide more direct services to different customer segments via proper routing, scheduling, color coding of buses, and adjusting capacities for different routes (minibuses, regular buses, maxibuses, etc.), depending on the demand.

Perceived government supervision of the buses emerged as the next dimension influencing passenger satisfaction. Many of the public buses are very old and susceptible to mechanical failures. These buses, including the government-owned BRTC buses, are also unfit for road use because of their battered appearances and the dark black smoke they emit. Their exteriors are often severely damaged, and vital accessories like back lights, side lights, indicator lights, and wipers are either missing, broken, or nonfunctioning. Such confidence-diminishing features are easily visible to the passengers. If similar problems exist in the internal/mechanical components of the buses like the engine, carburetors, radiators, clutches, spark plugs, master cylinders and so on, they pose threats to passenger safety. As a result, people may have serious reservations about traveling on these buses. In fact, a stalled bus in the middle of the road is a common sight in Dhaka City, adding to passenger inconvenience and the already chaotic conditions on the streets. This finding calls for better supervision of innercity buses.

When supervision is visible and vigorous, it is likely to instill greater confidence in the passengers that there will not be any price gouging and that the mechanical fitness of the buses would be ensured so that they would reach their destinations safely and on time. Clearly, the need for visible and vigorous enforcement of price and mechanical fitness are important elements for bus passenger satisfaction.
Finally, inadequate facilities at bus stands were identified by our model as another source of dissatisfaction among passengers. These facilities are quite deplorable, exposing commuters to crime, discomfort, uncertainty as to whether the buses would stop, and many other physical and psychological costs that substantially exceed the benefits of bus travel. Many bus stands do not offer protection from the sun, rain, dust, pollution, and other elements that have significant implications for health or safety. Often, passengers are seen waiting on sidewalks for buses while blocking the paths of pedestrians. These passengers have no place to sit. Sometimes the bus stands are situated near dumpsters, creating an unhealthy and suffocating situation for passengers. Unless these situations are remedied, expecting people to use a more efficient mode—adopted widely in developed and many developing countries—will not materialize. The consequences are dire: the city’s streets will continue to clog up, and this situation will be exacerbated in the future as the city’s population continues to grow. The opportunity costs of the traffic tangle are incalculable.

Discussion

Evidence from travel behavior models suggests that several factors can effectively predict travel demand and mode choice. Among these, fare, frequency of service, waiting time, and travel time have been easy to quantify and integrate into choice models (Ben-Akiva and Morikawa 1990; Koppelman and Wen 1998). Yet additional factors such as service, value, comfort, and psychological and social costs can also influence travel behavior and have not been adequately explored, nor have their relationships to travel satisfaction adequately been investigated. The literature on customer satisfaction and repurchase intentions also demonstrates the role of service quality and perceived value as critical in influencing satisfaction and choice (Teas and Aggarwal 1997; Cronin et al. 2000).

Insights from these studies suggest that people’s choice of a transportation mode (city bus service in this instance) would be influenced by the value received from one mode relative to the value received from alternative modes. The proliferation of rickshaws in the city, in this regard, is a crushing indictment of the quality of bus transportation service available to the public. Not only are bus services poor, but also access to them in terms of capacity is deplorable, making the use of rickshaws almost a necessity. If Dhaka City’s population is to be made mobile more effectively, both these issues need to be addressed.
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The multipronged strategies that ought to be implemented to bring about changes in transport capacity and usage behavior in Dhaka City must be integrated. For example, increasing the number of buses is absolutely essential, and can be attained via privatization and provision of tax benefits and loans to private parties on easier terms. Supervision can be increased by hiring the city’s unemployed but educated youth, who can also be empowered to impose fines on bus operators that do not abide by established standards. A part of the fines collected could be used to remunerate these incentive-driven youth to bring order to the transportation system. Comfort levels must be defined and standards established to ensure appropriate services. Realistically, it may not be possible to offer the standards that exist in the developed countries initially, but they must be gradually upgraded as bus travel begins to play a much bigger role in transporting more people. Bus stand facilities must also be markedly improved. Effective designs could be solicited from schools of architecture via design contests. These designs could then be given to corporate bodies to build according to specifications. Corporate involvement and investment could be induced by allowing companies to market their products in these facilities, rent out the space, or by giving them tax breaks.

Broader measures are also needed to better utilize the limited road capacity to service the transportation needs of the teeming population. It is important, for example, to impose high taxes on existing private motor vehicles to introduce a “large disincentive” for inefficient and frivolous use of precious road space. In particular, tax rates should be increased exponentially for those who own multiple cars but have few users. Private car users must also be charged a congestion fee for driving in key areas of the city (as has been done in central London where the cost is about eight pounds for each trip to the area).

In addition, an “irresponsibility tax” must be levied on those who have built edifices on Dhaka City’s streets without making any allowance for parking and expansion of road capacity. Businesses may also be required to pay a surcharge to help build multistoried parking lots in the more congested areas to free up road space. The government should participate in congestion removal by allocating funds to buy nonmotorized vehicles and offering loans to their owners to support other gainful pursuits.

If the city dwellers want better transportation services, they must collectively bear the costs of congestion removal and introduction of rapid mass transit systems such as buses. By paying more to improve the traffic situation, the enhanced efficiencies from time saved may more than compensate for the higher costs they are
being asked to incur. If this surcharge can be collected in a special account, the work of improving traffic flows, introducing better transportation modes, increasing road capacity, and rehabilitating the displaced workers from the nonmotorized sector can begin almost immediately.

Greater use of bus services can also be promoted through social learning as more social elites use this service, inducing others to emulate them. For example, requiring new and junior-level government officials to use public buses by helping them purchase monthly bus passes at subsidized rates could be a start. Gradually, more senior officials may also be required to do so as they are weaned from their private cars, because in addition to relieving congestion, improper use of their cars can also be reduced. The weaning process may be accelerated by requiring officials to pay for their own gasoline at the beginning and then having them pay for the car in installments. Of course, commensurately, their pay packages must be increased to give them the choice of how they want to use the additional pay. Radical as the idea may be, even public officials of high rank (including cabinet ministers) may be required to use a bus at least periodically to demonstrate their commitment to bringing about positive change. As a consequence, people working in the private sector may also begin to use buses. For this to work, however, the system must offer a service level that is improved quite dramatically from its present state.

This article proposes an outline of what needs to be done to improve Dhaka City’s bus services. Key elements are delineated that need to be judiciously addressed. Since this study is the first of its kind based on the passenger’s perspective, additional research would be useful in refining the measures and corroborating the model. When such studies confirm, support, and strengthen the findings of this research and offer additional strategic guidance, the state of the public bus transportation systems, not only in Dhaka City but also in other major metropolitan cities that resemble the trying conditions of this megacity, could be significantly improved.

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Making Regional Railroads More Attractive—Research Studies in Germany and Patronage Characteristics

Dietmar Bosserhoff,
Hessian Office for Roads and Transportation, Germany

Abstract

This article summarizes current research on regional rail passenger service in Germany. The aim of the research was to help rail operators, municipalities along the rail lines, and transportation planners identify the most effective strategies for improving rail service and patronage. The article outlines study contents and purpose and then summarizes the most important study findings. It also presents action and research recommendations. In addition, current rail developments in Germany and methods for increasing patronage and reducing costs with special focus on the separation of infrastructure and operations are described. Finally, patronage data for different rail segments are compared to help determine whether improvement measures should be applied and what impacts they could have on patronage.

Introduction

In 1994, competition was introduced into railway operation in Germany. The former national railway (Deutsche Bundesbahn) was separated into the Deutsche Bahn (DB) network company (DB Netz), which operates the tracks; DB Station&Service, which operates the stations; and three other DB companies,
which operate the trains on the DB Netz network (long-distance trains, regional trains, and freight trains). DB Regio is the company that operates regional trains. Among the main aims of the strategy were to enable private railway companies to use the national railway network, to create a better railway service by competition, and to reduce costs for railway service. Complementary former federal subsidies to the national railway company for operating deficit-producing regional lines were diverted to the regional authorities. The regional authorities were allowed to decide for themselves what to do with the money (e.g., improve railway service, maintain service, replace railway lines by bus service, or even reopen railway lines). Federal funding (collected from gasoline taxes) is possible to facilitate infrastructure measures (e.g., building new stops, track improvement, building new lines, or introducing new vehicles). The result of these changes was better train service with less operating costs on many regional and rural passenger lines.

This article summarizes the results of 12 recently completed research studies on regional passenger rail operations in Germany. The first part of the article outlines the main focus and results of each research study examined. The research is divided into three sections: studies financed by the German Ministry of Transport, studies financed by the German Ministry of Research, and important third-party research. The second part summarizes the most important findings of all the studies, proposes needed actions, and describes areas for additional research. The last part compares the results of passenger demand surveys of different types of regional rail segments. The article is based on a lecture on behalf of the German Ministry of Transport at the Railway Transportation in the Region conference (Bosserhoff 2004a) and two publications about regional rail transit (Bosserhoff 2003; 2005).

**Research Funded by the Federal Ministry of Transport**

**Study 1: Standardized Evaluation of Public Transportation System Investments and Calculation of Subsequent Costs (Intraplan and University of Stuttgart 2000)**

In Germany, federal funding for public transportation system investments is granted only if a standardized procedure of evaluation of the investment shows that the overall benefits of the project exceed its costs. The principal purposes of Study 1 were to update the existing procedure of the evaluation, to extend the appraisal procedure developed for rail segments in urban centers to regional rail segments, and to adapt the passenger demand model accordingly. Ten example railway segments from throughout Germany served as a basis for the adjustment.
On two segments, urban rail vehicles operate over streets in the city center and on existing general rail infrastructure outside the city (tram-train system). This concept was first introduced by the German city of Karlsruhe (Figures 1 and 2). The studies considered in this article underscore the fact that tram-train service induces a high patronage increase because of fast connections from the region into the city center without having to transfer between systems.

![Figure 1. Light Rail Vehicle and Intercity Express Train on Heavy Rail Infrastructure](source: Karlsruher Verkehrsverbund 2005)

The main results regarding regional rail were:

- Patronage increases are generally the result of several different variables. It is difficult to isolate the impacts of single variables.
- No specific mathematical relationship could be developed between the particular improvements and increased patronage based on the segments investigated in the study.
Nevertheless, to obtain “comparable evaluation results” for different investment projects, a pragmatic formula based on the difference in travel time between car and rail, number of transfers necessary, number of trains per day, and comfort (vehicles, stops) was developed for estimating the increased patronage. This formula was calibrated using data from the segments investigated.

**Study 2: Impact of Improvement Measures on Regional Rail Patronage (Bosserhoff et al. 2003)**

The principal goal of Study 2 was to examine in detail the impact of improvement measures on regional rail patronage to determine whether a mathematical formula can be derived for the estimation of these impacts and to provide business recommendations for helping local authorities or rail service operators determine when an improvement is sensible and therefore justified. Additionally, the study identified the costs of regional rail passenger and freight transportation improvement measures.

The study considered 20 railway segments from throughout Germany, two of which had tram-train linkages. This study had the largest sample size of all those mentioned in this article. All types of improvement measures (integration of
Making Regional Railroads More Attractive

transportation and land-use planning, railway service, railway infrastructure, customer comfort, security, fares, and marketing) were considered. The study determined the extent of improvement measures for each segment investigated and the extent of missing measures. As a result it was possible to identify the connection between improvement measures and patronage impact for each segment. Figure 3 presents an example of a regional railway near Frankfurt.

The study’s most important results were (Bosserhoff 2003):

- Much time is needed to make patronage data from different segments comparable because there is no uniform data collection procedure.
- A mathematical formula could not be derived between improvement measures and their patronage impact because, among other reasons, the local conditions (e.g., the amount of transit service operated) and the level of improvement measure implementation are crucial.
- Patronage increases are generally the result of several different improvement measures; implementing sets of improvement measures cause the largest patronage increase.
- A long-term view of an improvement measure’s patronage impact is necessary.
- In the long-term patronage increases are almost always at least proportional to the increase in service (e.g., train-km).
- The highest values for the measure “persons boarding per train-kilometer” are achieved with tram-train linkages.

The study developed a pragmatic procedure that allows users to estimate the patronage impact of improving a segment by comparing the proposed improvement to results found on the segments considered in the study. A checklist was prepared to help evaluate a potential improvement measure (measure selection, patronage effect, costs, etc.). The criteria used are the competitive situation with respect to automobiles (WCO), potential land-use development, comfort/security, marketing/information, and investment/costs.

Study 3: Integration of Regional Railway Lines into the Regional Public Transportation System with Special Consideration of Effective Operation (Planungsbüro für Verkehr and KMPG Consulting 2003)

Study 3 examined the integration of regional rail networks into the regional transit system and developed a manual with practical examples for improving regional
Figure 3. Connection between Improvement Measures and Patronage (Passengers Boarding and Alighting per Day: Monday–Friday).

- **1990**: Municipalities along the line decide to take over the railway line from the state-owned DB railway company.
- **1995**: Increase of train-km because of reactivation of 8 km at the rural end of the line.
- **1997**: Shift from car because of reactivation and optimal feeder bus.
- **1999**: New timetable with more trips per day (33 instead of 13), some direct trains to the main station in Frankfurt. Beginning of weekend service (1/1994). Reduced fare because of new tickets including public transit inside the city of Frankfurt (Verkehrsverbund) since 9/1993.
- **2001**: Introduction of one ticket for public transit valid almost all over the state of Hessen (RMV Verkehrsverbund).
- **2002**: Nearly all trains as direct trains to Bad Homburg with immediate connection to S-Bahn for Frankfurt. One more direct train to Frankfurt.
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railway service. The possibilities and limits of increasing the attractiveness of regional rail segments and the regional-specific as well as the transferable basic conditions and success factors were identified.

The study examined six railway segments in Germany. Its main findings were:

- Impacts on different segments were not always comparable because different data were available.
- Patronage increases often exceeded the increase in demand projected before implementation of the improvement measures.
- Local municipalities must be committed to the regional rail system for it to be successful.
- Bus lines must be integrated into the concepts and should not compete with the rail lines.

The study identified success factors for improving the attractiveness of regional rail transportation on basis of the evaluations and prepared an action catalog with the topics organization, conception, infrastructure, economy, and other. The result is a manual for local decision makers, planners, and interested citizens (Johannsmeier and Markgraf 2003).

Study 4: Development of Land Use Based on Railway Lines (Planungsgemeinschaft Theine et al. 2003)

The principal purpose of Study 4 was to examine whether current public transportation land-use planning techniques (designed to promote development along one of the regional rail corridors) are sufficient and what additional strategies (incentives, promotions) are necessary to improve coordination. The study also determined positive and negative factors in the linking of land-use and public transportation planning, measured the patronage effects of improvements at railway stations, and evaluated the developed strategies and measures in terms of their implementation practicability.

The study examined six examples and the strategies were tested using railway stations on a segment near Bremen. The results were:

- Settlement development patterns must be coordinated with station orientation.
- Short station access times are particularly effective for high patronage.
• A new planning and implementation instrument called the “station-oriented outline plan” is recommended in addition to the general zoning plan.
• The study identified and described components for this outline plan including station functions, location appreciation, and neighborhood/city linkages.

**Study 5: Model Project of Area Planning: Regional Railway Lines (SCI Verkehr 2004)**

This project consisted of a two-phase research study on land-use and regional railway planning. The first phase outlines possible solutions for maintaining the operation and increasing the efficiency of passenger and freight transportation on secondary rail segments. It also identifies success factors and obstacles for increasing rail transportation. Finally, it provides a list of action recommendations needed for sustainable transportation development. In contrast to the other studies, the goal of phase two was to implement and test, working with regional participants, the land use-planning conceptual measures identified in the first phase in two different rural regions.

The main results of this study are action recommendations in the areas of sustainability and stabilization of passenger and freight transportation on regional rail segments. The study identified the following factors for success:

• The larger the amount of floor space oriented to the rail line and/or of trade areas with track connections the better.
• Bus transportation must be integrated into the concepts and competition with rail avoided.
• Local governments must be committed to regional rail service and provide financial support.
• It is difficult to finance rail infrastructure without regular passenger rail service.

Specific recommendations were given for optimizing rail transportation for both example regions and suggestions were made for implementing these recommendations. However, these met differing success. While service improvements succeeded in increasing passenger patronage and freight transportation on one segment, passenger service was discontinued on parts of the other segment in 2004.
Study 6: Strategies for Developing the Market Potential of Railways (Universities of Karlsruhe, Kassel and Stuttgart 2004)

The goal of Study 6 was to describe strategies for developing the market potential of railways and conditions for their success. The study considered a regional railway in a tourist region and a diesel regional railway extended on tramway tracks to the city center.

The study results regarding passenger transportation were:

- In Germany, the strongest market potential for rail service is for region-connecting (interregional) rail passenger transportation (i.e., travel distance of 50-150 km) and for intraregional rail service.
- Regional rail in rural areas and tram-train linkages have an important supplementary function for interregional transportation.
- The rail share for these market segments can be increased by implementing appropriate improvement measures.

The research also describes success factors for the two regional rail market segments as well as concepts and recommendations for political action and for actions by service operators.

Research Funded by the Federal Ministry of Research

Study 7: Optimizing Regional Rail System Operations and Infrastructure in the Transition from Urban Centers to the Region (Fachhochschule Gelsenkirchen 2003)

Study 7 analyzed regional rail improvement measures accomplished since 1994 and examined them for additional potential and mutual combinability. The study also identified further possibilities for increasing patronage and reducing costs in regional rail operations and made action recommendations. Three example segments were closely examined, one from each of the three types of regional rail operation: “general railway standard” (operated by the federally owned DB Netz network company), “branch line standard” (operated by private railway companies), and “urban rail service” (electric tram-train service).

The research study points out that a very broad spectrum of measures has been completed throughout Germany to improve regional rail segments. These measures can be grouped into four main categories: track, vehicle, organization, and
rail service, as well as land–use development/planning. The majority of these measures can be combined. The study identifies possibilities for optimization and cost reduction in each of the four categories. Substantial cost reduction potential exists in the track category. Performing construction and maintenance work to branch-line standards can save slightly more than 50 percent of the costs compared with the same work performed under the general railway standards. In the organization and rail service category, the study recommends promotion of competition, with all railway infrastructure and rail service separated completely from the publicly owned infrastructure (segments with long-distance transportation should be controlled by the federal government, while segments with predominantly regional service should be controlled by the state or region). Transportation services should be awarded via competition. The study also identifies obstacles for the optimization (e.g., no real separation of infrastructure and rail service by the DB railway company) and suboptimal funding methods.

Study 8: Bahn.Ville—Railway-Based Land-Use Development and Modal Interchange (ISB Hochschule Aachen et al. 2005)

Study 8 is a joint French-German project that examined the interaction between land use and transportation as well as the coordination processes and organizational aspects. The study considered a series of case study examples from German and French regions.

The project used the case studies to examine the ideas, strategies, and potential for integrated land-use and transportation planning to reduce sprawl-type urbanization. The objective was to determine the pros and cons of the example strategies, as well as their benefits in relation to the impacts and the coordination processes. On the one hand, the study describes how railroad lines generate development patterns (forms, density, variety); on the other hand, it describes the laws that control development to implement more purposefully and more successfully public transportation policies (equipment, vehicles, organization). In Germany six best practice examples were analyzed, two of which included a tram-train service.

The following variables were considered:

- Rail service: Upgrading the regional rail service.
- City: Increases in development along the rail line and around stations.
- Station: Revaluation of railway stations as transportation and community centers.
The main results of the study were the assessment of the pros and cons of different basic approaches used in the planning process, an estimation of the qualitative and quantitative developments, and a manual with recommendations for local decision makers, planners, and rail operators. The manual describes meaningful strategies for improving the integration of land-use and transportation planning and their implementation. The research study found that focusing settlement development at railroad lines is possible but has limits because of increasing land prices along railroad lines.

**Study 9: Regional Importance of Railway Lines—Development and Test of an Evaluation Method in the State of Thuringia (Fachhochschule Erfurt 2003)**

Study 9 developed a decision-assistance tool to help answer questions about the elimination of regional rail service, for temporarily suspending service, and/or to protect the rail infrastructure. The starting point of the study was that often regional rail service was simply replaced by bus service and the railway line shut down without considering the regional effects of these actions because there was no procedure with objective decision criteria in existence to evaluate this decision. The study included a literature search on arguments for and against rail segment service suspension, collection of available data on the regional effects of railway structures, and developing a methodology to estimate the regional impacts of railroad lines. The applicability of the method was tested by examining 20 example segments in the state of Thuringia. The main findings were:

- Substitution of regional rail service by bus led almost without exception to worse public transportation service.
- The following factors were determined to be relevant and they were quantified for the evaluation procedure: development function, regional economy, safety, travel time, network effect, environmental effect, tourism, and connecting function.
- The evaluation procedure developed in the study supplies plausible results for the importance of regional segments. However, the ranking of segments using this procedure was partially surprising. Some of the segments where regional rail service has been cancelled have higher values than other segments where there is not even any discussion of eliminating regional rail service.
- The evaluation procedure developed represents a meaningful addition to the standardized evaluation process (Intraplan and University of Stuttgart...
2000) used for investments in public transportation systems because while the regional rail segments are subject to the service elimination, to date there have been no objective decision criteria for evaluating these decisions.

The study recommended that the regional rail infrastructure be recognized as a public responsibility. Only then would its long-term economic use become relevant to the evaluation; otherwise only short-term economics (e.g., direct revenues and costs) enter into the decision over cancellation of regional rail services.

**Important Third-Party Research**

**Study 10: Areas of Application for Regional Railway Lines (Zöllner 2002)**

Study 10 developed a procedure for objectively evaluating reactivation of, or improvement measures on, regional railroad lines, which requires only simple input data. In contrast to the other research studies mentioned in this article, this study derived a mathematical formula to estimate the patronage impacts of improvement measures on the basis of 14 example segments. However, this formula is not generally accepted.

The study also examined the cost and revenue situation for regional rail and bus transportation under two alternative scenarios: operating regional rail service or replacing rail service with bus transportation. The patronage demand model showed that the examined railroad lines that were converted from rail to bus operation experienced an average patronage decrease of about 45 percent. This loss could be reduced to a decrease of 9 percent by doubling the bus frequency (i.e., buses that operate twice as frequently as trains formerly did). Based on these results, it is possible to identify a rail bonus of 35 to 45 percent in relation to bus transportation. Rail transportation exhibits advantages in particular with respect to patronage, travel time, road safety, and its effect on regional structure. In terms of cost, bus transportation—even with twice as high a service frequency—is less expensive; rail transportation is only cost effective if track and station costs are not included (e.g., regarded as part of the overall government economic responsibilities).
Study 11: Procedure for Estimating the Effects of Improvement Measures in Public Transit and Rank Listing of the Measures Investigated (University of Kassel et al. 2001; Arndt et al. 2002)

Study 11 developed a procedure for comparing improvement measures for railway service in the central part of Hessen including the Frankfurt region. It examined the connection between individual measures, their associated costs, and their respective effects on passenger demand.

The study developed a procedure that helped rank improvement measures in terms of efficiency (i.e., comparison between additional revenues from passenger increases and associated additional costs) using examples from the region. It used this procedure to examine groups of improvement measures and place them in a rank listing, which can serve as a guideline for investment decisions. The study found that the most favorable projects were new and upgraded S-Bahn (regional rail rapid transit) segments and the building of new railway stations. In the middle category were the modernization of stations as well as new park-and-ride facilities and reactivation and/or improvement of regional railroad lines.

Study 12: Estimation of the Patronage Potential of Regional Railway Lines Based on Several Examples (Schuler 2001)

Study 12 determined how rural area rail segments operated by DB Regio (successor of the former federally owned passenger company operating regional railways) can be operated more economically and whether these segments could obtain similar patronage increases by implementing best practices of other rail operators. In this study, 35 segments of the DB regional network owned by the federal infrastructure company (DB Netz) were compared with structurally similar best practice segments of five private railway companies and one regionally operating subsidiary of the DB with integrated infrastructure and operations. Using these data, the patronage potential of the regional lines was derived on the basis of population, employment, overnight accommodations, and number of students.

The study result was that DB Regio segments show a lower demand, although in 81 percent of these segments similar conditions are present as with the best practice segments, and therefore patronage increases from 22 percent to 700 percent compared to the starting level are possible if DB Regio adopts these best practices. The most important factors for these increases are service frequency and number of the stops. The segments operated by private companies were substantially better with respect to these factors than those operated by DB Regio.
Summary Evaluation of the Research Projects

Examined Railway Segments

Extensive research and many case studies have examined the topic of making regional rail service more attractive. The segments considered in the studies outlined above were from throughout Germany. Figure 4 illustrates regional rail studies financed by the German federal government. While many regional rail
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segments were considered in the studies, only four examples for linking urban rail segments and railroad lines (tram-train) were analyzed because there were insufficient time series data to measure the patronage changes, although particularly high passenger increases were observed on these systems.

Main Findings

Methodology. Decision makers should consider all the referenced research studies relevant for a particular question, especially those that are based on the largest sample size and a careful data analysis, before deciding which specific improvement measures to implement. To evaluate high cost improvement measures, detailed cost benefit studies are also necessary, especially if federal funds are needed.

Local Commitment. A central finding of the research studies considered in this article is that local commitment is crucial for the success of regional rail lines. The municipalities in the region must consider the railway segment as theirs and strongly support continued operation and improved service. A local rail service provider is optimal for obtaining good rail service; private rail operators have proved this for many routes formerly served by the national railway company DB. However, it appears not crucial whether the local proximity is provided by a private rail operator or a DB regional subsidiary. For example, patronage per kilometer on a DB subsidiary once threatened with closing (Figure 5) rose almost 880 percent between 1992 and 2002 (Allianz pro Schiene 2005). The four existing DB regional subsidiaries reported passenger increases of 15 percent in their two first years (Göbel 2004).

Cost Reduction Through Competition. Competition should be used more consistently to reduce the cost of regional rail service. One study shows that competition provides a possible cost savings of approximately 18 percent with small and 38 percent with large services (Private Sector Participation Consult 2004). However, there is still substantial need for improving the basic conditions for competition in Germany, given that the private operator market share for regional rail service amounts to only 9 percent and the DB Regio’s dominance with more lucrative products is even larger.

Infrastructure Finance. The general railway rules need to be examined for cost-reduction possibilities. On regional lines, rail service should be operated based on branch-line standards. Also, private operators should be able to receive federal
funds for infrastructure. It is favorable when the federal railway infrastructure operator (DB Netz) is not responsible for the improvements because branch-line standards are more economical, high cost increases in the planning and building phase occur less often, and the construction time is reduced. Similarly, construction work at stops is more economical and completed more quickly when the federal railway station operator (DB Station & Service) is not responsible: the costs are on average about 40 percent lower with private operators (Agentur Bahnstadt 2004). The most favorable model (particularly for regional rail line infrastructure) is where the DB-owned infrastructure is leased to private companies that are responsible for both maintenance and service. There are examples, however, where DB Netz has rejected leasing of track segments that are experiencing increasing number of trains (Naumann 2004).

Eliminating Regional Rail Services. The replacement of regional rail service with bus service led nearly without exception to the degradation of public transportation service. The regional economic impacts of railroad lines were not considered in the decision over the cancellation of regional rail service or reactivation of rail routes.
Patronage Effects. The patronage increases after making improvements are often larger than predicted. With only one exception it was not possible to derive a mathematical formula for estimating the patronage change due to improvements. To determine the total effect of an improvement measure, a long-term view is necessary. Two important measures for increasing patronage are increasing service frequency and linking urban rail and regional railway segments (tram-train). Rail-oriented land-use planning has special meaning. The bundling of the settlement development along the rail is possible, however it has limits because of increasing land prices. Increasing service almost always boosts patronage at least proportionally to the increase of the service miles. For all the DB Regio served segments, service miles grew by 23 percent between 1993 and 2003, while the number of the person kilometers grew by 30 percent (DB Regio 2004). Many of the private operator-served segments registered substantially higher increases. In Rhineland-Palatinate (Figure 6) the number of train-kilometers grew by 50 percent between 1994 and 2004 on all segments (DB Regio and private operators), while the number of person-kilometers rose around 90 percent (Ministerium Rheinland-Pfalz 2004).
Identification of Efficient Measures for More Attractive Regional Rail Traffic

To identify the most efficient measures for increasing patronage on a rail line, it is necessary to evaluate fully the current service level and quantities as well as deficiencies. The potential demand depends substantially on the type and extent of the train service. Therefore, a detailed analysis of the surrounding field conditions has to be completed, especially to judge the current competitive situation between rail and private car traffic as the main competitor. The analysis should include:

- Investigation of the major traffic flows and an estimate of passengers who could be attracted to rail
- Examination of the current and the desired competition situation to private car traffic including comparison of travel times and decision-relevant costs
- Evaluation of the current comfort situation for passengers (trains and stations)

Deficiencies in these areas have to be eliminated to the maximum extent feasible to reach a high degree of attractiveness and big patronage increases. The quality of train service should be as equivalent as possible to or better than car traffic. This requires:

- Competitive travel times to destinations with high passenger flows
- Sufficient train capacity
- High reliability of train service
- High schedule availability (long period of operation during the day, dense timetable, regular clock-face schedule)
- High spatial availability (stations close to high concentration of settlements and destinations with high traffic flows)
- Safe and comfortable railway stations (e.g., protected waiting shelters, transparent design, close to housing areas)
- Direct and safe access routes, which can be used by persons with mobility problems (e.g., persons with physical handicaps, persons with buggies)
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- Comfortable trains, matching to platform levels that enable fast boarding and alighting without problems
- Parking facilities for cars and bikes close to the stations
- Good public transit connections with short transfer times

Furthermore, it is important to pay attention to image factors, which can highly influence patronage. Examples of image factors include well-maintained appearance of the trains and stations and attractive surroundings of the stations.

Action and Additional Research Recommendations

Action Recommendations

The following list outlines specific urgently needed actions:

- Uniform regulations should be provided for preparing patronage projections and collecting patronage data. One goal must be making data collected from different segments comparable.

- Regular passenger patronage surveys should be made on regional rail segments to compare with results on other segments, to determine causes for deviations, and to develop improvement measures if necessary. A good example is the annual survey program in the state of Baden-Württemberg (Landtag Baden-Württemberg 2004), which includes the number of passengers per segment-kilometer and the required subsidy per person-kilometer, the number of passengers compared to population potential, and the difference of travel time between rail and private car. These data are used to compare rail segments in terms of transportation and economics.

- A detailed estimate of potential passenger demand should be prepared. This estimate should include all types of trips including leisure and shopping.

- Regional service should be planned from the customer's point of view. To attract choice customers, it is important to offer rail service that competes with the automobile by providing short travel times and high frequency service.

- The federal government must improve the ability for competition in the rail transport market.

- A balance must be created between too much (and too little) detailing of requests for bids and business concepts.
• The “infrastructure” and “service” sections of the DB railway company must be truly separated into independent companies to avoid discrimination against private rail companies.

• Transportation policy must support development and promotion of regional rail service.

• Regulations for railroad infrastructure, construction, and service must be standardized with the goal of “cost reduction.”

• Solutions must be found for the financing of railway infrastructure (e.g., segment reorganization, providing federal funds for private company operated segments, requiring acceptable prices for the purchase of segments from the federal railway company, and new models for the regional rail infrastructure).

• Funding regulations and incentives for architects and engineers should be changed to provide incentives for economical solutions.

• The integration of transportation and land-use planning should be improved and railroads should be more strongly considered as a location factor in future planning. A rail-orientated settlement plan and providing financial incentives for rail-oriented settlement patterns are important; however, it is also necessary to provide a good railway service (Bosserhoff 2004b).

• The regional rail infrastructure should be recognized as a public responsibility.

• The long-term economical value of railroad lines should be considered in the decision over the cancellation of regional rail service. The appraisal procedure mentioned in this article can be used for this purpose (Fachhochschule Erfurt 2003).

Recommendations for Additional Research

Additional research is particularly needed on the following subjects:

• The impact of linking urban rail and general railway segments (tram-train) and the possibilities for cost reduction (e.g., rail service without overhead lines). The largest patronage impacts were obtained for tram-train service.

• The impact of measures for increasing the passenger demand not yet suf-
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- Fare measures that effect trips by people who do not normally use the regional rail system.
- The question of a common financing scheme for regional rail and other regional public transportation service.
- More economical possibilities for the financing of regional rail infrastructure.
- Suitable ways to separate the infrastructure from rail service.

In the state of Hessen, a study was recently completed on the future of regional rail service to maintain rail service in the middle to long term (ETC Consultants 2005). Alternative possibilities for infrastructure ownership, operation, and maintenance were examined. The study compares these possibilities using a concrete example and considering the different expectations of the public transit operator, the state, DB Netz with respect to regional rail financing, high infrastructure availability, improved infrastructure quality, regionalization of the decision-making process, economy, cost transparency, faster project realization, and implementation. One solution for maintaining regional rail service is to transfer the operation of regional infrastructure to a regional operator without simultaneous transfer of the property. Three models were examined all of which consider an integration of tracks and stations. The regional network model represents the strategy currently being pursued by the DB with its regional subsidiaries integrating infrastructure and service. In the cooperative model a close co-operation takes place between the regional rail service provider and the DB Netz in a joint enterprise. The lease model is characterized by having a private company lease the segments from DB Netz and provide both service and infrastructure.

Results of Patronage Data Studies

Regional Segments

Figure 7 illustrates the development of the parameter “daily persons boarding and alighting per segment-kilometer (work days)” for different segments after the implementation of improvement measures. Broken curves were used, when no values were available for intermediate years.

Figure 7 shows fairly substantial passenger increases in all but two cases. The two exceptions can be explained by problems with new tilting vehicles used on these segments. The number of passengers boarding and alighting continues to increase
Figure 7. Increase of Daily Patronage per Segment-Kilometer Over Time
Figure 8. Passengers Boarding and Alighting per Train-Kilometer (Daily)
Figure 9. Passengers Boarding and Alighting per Inhabitant (Daily)
on the majority of segments after improvement into the range of between 50 and 150 persons boarding per kilometer; higher values are observed for a few segments in the catchment areas of larger cities.

Figures 8, 9, and 10 show different parameters of patronage per day (Monday–Friday): passengers boarding and alighting per train-kilometer (Figure 8) and per inhabitant (Figure 9). In these figures the segments are distinguished by type (black, located in agglomeration areas; grey, located in rural areas; white, tram-train service). The values displayed correspond to the most current published patronage data (see Figure 7).

Figures 8 and 9 show that high patronage is achieved where urban rail segments are linked to general railroad lines. Each criterion can be meaningful (e.g., economically the measure “persons boarding per train kilometer” is the most important, while when considering potential demand the measure “persons boarding per inhabitant” is most important).

Figure 10 illustrates the increase in patronage (passengers boarding and alighting) per segment-kilometer after improvements for selected regional segments in rural areas and Figure 11 for selected regional segments in agglomeration areas. Comparing Figures 10 and 11 shows the absolute increase in patronage per segment-kilometer generally results in higher values for segments in agglomeration areas. The average value before improvement is approximately 40 passengers per segment-kilometer for rural areas, and approximately 80 for agglomeration areas (neglecting the segment Mettmann-Kaarst which operates with an S-Bahn standard and is therefore a special case). The average values after improvement are 85 passengers per segment-kilometer for rural areas and 200 for agglomeration areas. This is equal to increases on average of 240 percent and 260 percent, respectively. With only four exceptions the patronage increase was at least two thirds for all segments considered.
Figure 10. Increase of Daily Patronage per Segment-Kilometer Before and After Improvement of Regional Railway Segments in Rural Areas

Figure 11. Increase of Daily Patronage per Segment-Kilometer Before and After Improvement of Regional Railway Segments in Agglomeration Areas

**Linkage between Urban and Regional Railroad Lines**

Figure 12 shows the increase of patronage per segment-kilometer for segments in the area of Karlsruhe (Karlsruher Verkehrsverbund 2005) after linking urban rail and general railway segments (tram-train service). The average value of the passenger demand before the linkage was approximately 130 passengers per segment-kilometer. The absolute increase in segments using the tram-train linkage is substantially larger than the patronage increases for the regional segments. The increase on segments with the linkage averaged 410, highest for all segment types.
The middle proportional increase of 290 percent is even higher than the increase for regional segments in agglomeration areas.

Figure 12. Increase of Daily Patronage per Segment-kilometer Before and After the Beginning of Tram-Train Service

Source: Menzel 2006.

Figure 13. Kassel Vehicle for Tram-Train Service on Diesel Sections
Figure 14. Kassel Vehicle for Tram-Train Service on Electric Sections

It is expected that tram-train service will become much more widespread as hybrid vehicles that can be used on tracks with catenary and tracks for diesel use have been developed (Alstom 2005; van der Bijl and Kühn 2006). This technology allows direct connections from the region into the city center, avoiding the high cost for electrification of sections outside the cities. The first hybrid vehicle for regular gauge (Figures 13 and 14) has been in service since 2005 in the city of Kassel (Menzel 2006).

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Design and Evaluation of Passenger Ferry Routes

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Abstract

This article introduces a planning framework for improving and best utilizing existing water and ferry resources. It presents an analysis framework and formulation for designing and evaluating passenger ferry routes. The motivation for this work emanates from problems encountered by the ferry service in Hong Kong, including the continuous loss in ferry patronage. This loss is believed to be caused by the ferry’s relatively poor level of service and intense competition from more attractive alternatives. The article reports on an evaluation and design methodology for the entire passenger ferry network, consisting of a framework with operational objective functions that takes into account passengers, operator, and community interests. This framework considers both the evaluation of existing ferry routes and the design of new ones. The methodology presented combines the philosophy of mathematical programming approaches and decision-making techniques, allowing the user to select an efficient solution from a number of alternatives. The evaluation procedure established provides practical and measurable criteria for evaluating the “goodness” of each route and for comparison between sets of routes at the network level.

Introduction

The motivation for this study arose from problems encountered by the ferry service in Hong Kong (HK), where the role of ferry service has been shrinking as evidenced by the loss in both market share and actual patronage against a background of
strong overall growth in travel demand during the last 20 years. Traditionally, ferry services excel where they provide direct service between two terminal points or where the provision of land-based transport would require major infrastructure investments in terms of time and cost. With the continuous expansion of road and rail networks in HK in the last 30 years, the former advantages of the ferry have, to a large extent, disappeared for the island’s inner harbor routes (IH) and, more recently, for some of the outlying island routes (OI), long considered a stronghold for ferry operations.

Many of the problems facing the ferry industry are driven by forces that will continue to prevail in the future as land-based transport networks and the economy further develop. Because of the low infrastructure cost required for ferry services in comparison with other public transit modes, and the fact that a ferry trip is often part of a trip chain, it is worthwhile to develop ways to improve the ferry network design by making it both more attractive and more efficient. Thus, the ferry routes do not have to be viewed as point-to-point systems because in many respects these routes can act similarly to bus and rail routes. This study, while using the HK ferry network as an example, provides measurable criteria and tools for evaluating the quality of each route and for comparing the sets of routes at the network level.

This article begins with a literature review of transit route design methods. The second section outlines the framework of the entire study and its methodology. The third segment, which is the core of the research, establishes and interprets the framework, notation, and objective functions of the ferry network design problem by using a detailed example. The case study of HK, utilizing a multiobjective approach, is discussed briefly in the fourth section. Finally, the last part provides concluding remarks.

**Literature Review**

This section presents a review of papers that propose methods for optimizing the configuration of transit routes systems. Fundamentally, a passenger ferry routing system has the same characteristics as any other transit system in terms of objectives, constraints, and integration consideration. Baaj and Mahmassani (1991, 1992, 1995) develop transit network design methods based on artificial intelligence (AI). The methods are based on a typical formulation of the network...
design problem as a programming problem with minimal frequency, load factor, and fleet size constrains.

Ramirez and Seneviratne (1996) propose two methods for route network design under multiple objectives using GIS. Both methods involve ascribing an impedance factor to each possible route and then choosing those that have the minimum impedance. Pattnaik et al. (1998) present a methodology for determining route configuration and associated frequencies using a genetic algorithm. In genetic algorithms, solutions are chosen from a large set of possibilities in an iterative process, where the chances of a solution surviving through the iterations are higher if it yields a high value to a given fitness function.

Soehodo and Koshi (1999) formulate a programming problem for designing transit routes and frequencies. Similarly to other models, the problem is solved by first creating all feasible routes and then choosing an optimal subset. In addition to some traditional components, such as minimal frequency and fleet size constraints, the problem has some unique elements, such as the inclusion of private car user costs, transit passenger crowding costs, and transfer costs to the minimized objective function. Bielli et al. (2002) describe another method for designing a bus network using a genetic algorithm. As in other genetic algorithms, each population of solutions goes through reproduction, crossover, and mutation manipulations whose output is a new generation of solutions. In the proposed model, each iteration involves demand assignment on each network of the current set of solutions and a calculation of performance indicators based on the assignment results.

Wan and Lo (2002) develop a network design model with an explicit consideration of intermodal and interroute transfers. The model has two separate phases. First, the points that are to be connected with a direct service are determined in a heuristic algorithm. Next, an actual bus route system is built in a mixed integer linear programming problem. Yan and Chen (2002) present a method for designing routes and timetables that aims to optimize the correlation between bus service supply and passenger demand. The method is based on the construction of two timespace networks: a fleet flow network and a passenger flow network.

Tom and Mohan (2003) continue the development of genetic methods for route network design. In the current model, frequency is the variable, and thus it differs from earlier models in terms of the adopted coding scheme. While fixed string length coding and variable string length coding were used in previous models, the simultaneous route and frequency coding model is proposed here.
The literature review provided in this section is intended to shed light on what methodologies and quantitative methods were recently used to overcome the planning issues of transit network design. In the following section a different concept with the idea to bridge between theory and practice is presented.

**Overview of the Study**
The overall description of the entire ferry study methodology (Ceder 2001) appears in Figure 1. This overview is arranged by the main input and outcome elements for each of the twelve elements listed in the figure.

**Data Collection Stage**
This element is related to the data collection stage of existing ferry routes and candidate routes. The outcome is derived by tabulating the ferry route characteristics. These characteristics include: average travel time (peak, off-peak), distance, average passenger loads (peak, off-peak), vessel’s speed and capacity, competition measures of bus and rail in terms of fares, travel time, and frequency. In addition, this element summarizes information on passengers’ satisfaction and complaints.

**Current Vessel Types and Piers**
Apart from site visits, all major operators in HK have been consulted on a wide range of issues: vessel type, fleet size, staffing level, vessel performance, and berthing operation.

**Legal Issues of Ferry Operation**
This element, which is only indirectly related to the main body of the study, addresses legal issues of ferry operation and suggests amendments.

**Design of Survey and Data Collection Processes**
The purpose of this element is twofold: (1) to prepare adequate data and information input for the forecast and evaluation analyses, and (2) to establish proper databases to be updated continuously for future use.

**Theory and Methods of Designing New and Improved Ferry Routes**
This element emphasizes the construction of objective functions and measures from the user (passenger), operator, and government perspectives. The objective functions and measures evaluate the “goodness” of the ferry route and compare it to other sets of routes.
## Design and Evaluation of Passenger Ferry Routes

### Figure 1. Overview of the Major Elements of the Entire Study

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<th>OUTCOME</th>
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<td>The Outcomes of All the Above Mentioned Components</td>
<td>Establishing the Study Recommendations</td>
<td>List of Recommendations</td>
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**Construction of Forecasting Methodology for Ferry Patronage**

This element, which analyzes ferry patronage for 2000 and 2006, is based on three parts: (1) identification of main attributes and their weights in affecting potential ferry patronage, (2) demand prediction using a calibrated growth factor from past ferry demand figures for any projected changes on the established ferry routes, and (3) transit modal split between specific origin-destination (O-D) pairs on any new ferry routes and/or changes in fares and/or journey times in the transit competitors.

**Development of the Financial Model and Its Modules**

This model considers (1) capital cost of vessels, octopus fare equipment, and pier development for new routes; (2) operating costs of staffing, maintenance, and administration; and (3) revenue from farebox, concessions, advertisements, and freight.

**Results from Survey and Forecasting Analyses**

The survey results include the elasticities of fare, travel time, waiting time, walking time, and comfort items for changes in the ferry demand. Survey results come from both commuters and noncommuters. Results from noncommuters are important for gaining information on tourism flows and weekend patronage. In addition, the survey results reveal a certain picture with respect to arrivals and departures from ferry piers (walk or transit). The forecasting results produce O-D matrices for daily, peak, and off-peak ferry patronage for 2000 and 2006, and for the existing and candidate routes.

**Evaluation of Existing and Candidate Ferry Routes**

Financial results point out the nonviable routes and then group them under essential (captive users) and nonessential (noncaptive users) routes. For essential unviable routes, the financial results contain break-even fares, break-even demand, packaging potential, and possible changes in the operating characteristics. Some of these results appear in this work.

**Practical and Simplified Excel Tools**

The main tools for future HK Transport Department (TD) use are: (1) model split database file for demand forecasting, (2) financial model with the study data and results, and (3) quality of routes model with the study data and results. All the Excel tools can be updated easily.
**Recommendations for Existing and Candidate Routes**

This element summarizes the results from the ninth element—evaluation of existing and candidate ferry routes using financial and quality approaches—and partially appears in this work. It provides recommendations for existing and candidate routes, and suggests the best-suited set of routes to serve HK between 2000 and 2006. It proposes that some existing routes should be dropped, and some candidate new routes be added.

**Study Recommendations**

The last element in Figure 1 establishes recommendations primarily regarding the outlying islands, inner harbor, and vehicular ferry routes. In addition, other recommendations are specified to cover issues of government support, vessels, fares, and regulations.

**Optimal Design and Evaluation of Routes**

The overall ferry route design approach is similar to that which appeared in Ceder (2003), but with different framework and objective functions. The following presents the formulation of the approach and an example used as an explanatory tool.

**Formulation**

The formulation in this research considers a connected network composed of a directed graph $G = \{N,A\}$ with a finite number of nodes $|N|$ connected by $|A|$ arcs. In this section, transit stands for ferries and vehicles—for ferry vessels. The following notations are used:

- **Route** is the progressive path initiated at a given transit terminal and terminated at a certain node while traversing given arcs in sequence
- **Transfer path** is the progressive path that uses more than one route
- $R = \{r\}$ equals the set of transit routes
- $TP = \{tr\}$ denotes the set of all transfer paths
- $S = \{sp\}$ is the set of all shortest paths
- $N_r$, $r$ equals the set of nodes located on route $r$
\( N_{tr} \) represents the set of nodes located on transfer path \( tr \)

\( N_{sp} \) is the set of nodes located on the shortest path \( sp \)

\( d_{ij}^r \) equals passenger demand between \( i \) and \( j \), \( i, j \in N \), riding on route \( r \)

\( d_{ij}^{tp} \) is passenger demand between \( i \) and \( j \) along the transfer path \( tr \)

\( d_{ij}^{sp} \) denotes passenger demand between \( i \) and \( j \) along their shortest path

\( F_r \) is vehicle frequency associated with the route \( r \)

\( F_{\text{min}} \) is the minimum frequency (inverse of policy headway) required

\( t_{ij}^r \) is travel time between \( i \) and \( j \) on route \( r \)

\( t_{ij}^{tp} \) equals travel time between \( i \) and \( j \) on transfer path \( tr \)

\( t_{ij}^{sp} \) represents travel time between \( i \) and \( j \) on the shortest path

\( t_r \) is the overall travel time on route \( r \) between its start and end

\( L_r \) denotes maximum passenger load on route \( r \)

\( W_r \) equals passenger waiting time on route \( r \)

\( d_o \) represents desired occupancy on each vehicle (load standard)

\( a_{tp}^r \) equals 1, transfer \( tp \) contains route \( r \)

0, otherwise

The transit route design problem is based on two main objective functions, \( \min Z_1 \) and \( \min Z_2 \), across the different sets of transit routes:

\[
Z_1 = \alpha_1 \sum_{i,j \in N} Wt(i, j) + \alpha_2 \sum_r Esh_r + \sum_{i,j \in N} [\alpha_3 Ph(i, j) - \alpha_4 Dph(i, j)]
\] (1)
\[ Z_2 = NF \]  \hspace{1cm} (2)

where:

\( Ph(i,j) \) is passenger-hours between nodes \( i \) and \( j \), \( i, j \in N \). It is defined as passengers’ riding time in a transit vehicle on an hourly basis. It measures how much time is spent by passengers in vehicles between the two nodes.

\( Dph(i,j) \) is the difference in passenger-hours between \( Ph(i,j) \) and the total passenger-hours from \( i \) to \( j \) when only using the shortest path, \( i, j \in N \).

\( Wt(i,j) \) equals the waiting time between nodes \( i \) and \( j \), \( i, j \in N \). It is defined as the amount of time passengers spend at the transit stops between the two nodes.

\( Esh_r \) denotes empty space-hours on route. It is defined as the unused seats in a transit vehicle on an hourly basis. Empty space-hours measures the unused capacity on vehicles.

\( NF \) is the fleet size; that is, the number of transit vehicles needed to provide all trips along a chosen set of routes.

\( \alpha_k \) equals monetary weights, \( k=1, 2, 3, 4 \) (see next section).

**Objective Functions.** The objective functions take into account three perspectives: the passengers, the operator, and the community. A good transit route is defined as an attractive one from all the three perspectives.

The first straightforward objective is to minimize the total waiting time of the passengers. This is strictly from the perspective of the transit user. The formulation of this objective takes the following form:

\[
\min \alpha_1 \sum_{i, j \in N} Wt \ (i, j) \hspace{1cm} (3)
\]

where:

\( \alpha_1 \) is the monetary value of one hour waiting time.
The second objective is to minimize the total unused seat capacity as to allow for a more viable transit service. This is strictly from the perspective of the operator who wants to see more usage of the available transit seats. The following is the formulation of this objective:

$$\min \alpha_2 \sum_{r} E_{sh}$$

where:

$$\alpha_2$$ is the equivalent of one hour average monetary revenue divided by the average number of hourly boarding passengers. The objective is to minimize the total monetary value of the unused seat capacity.

The third objective is to minimize the total loss if all transit passengers switched to the shortest path. This objective attempts to take into account the comparison between the transit route and its best competitor, which is usually the private car, or in certain cases the aircraft or railway. This objective represents the perspectives of the government and the transit passengers, and takes the following form:

$$\min \Delta = \sum_{i,j \in N} [\alpha_3 Ph(i, j) - \alpha_4 Dph(i, j)]$$

where:

$$\alpha_3$$ is the equivalent of a one-hour difference in average cost between riding the shortest (and more expensive) path and the transit route.

$$\alpha_4$$ equals the monetary value of one hour in-vehicle time.

The value of $\Delta$ is the total monetary loss (or saving, if it is negative) if all the transit passengers are switched to the shortest path.

where:

$$\alpha_3 Ph$$ is the total monetary loss, with respect to cost only, if all the transit passengers are switched to the shortest path.
\(\alpha_s Dph\) equals total monetary value of the time saved if all the transit passengers are switched to the shortest path.

The fourth objective is to minimize the number of vehicles to carry on the determined frequencies (timetables). This is strictly the operator perspective that wants to perform all the transit trips using the minimum number of vehicles. This objective takes the form:

\[
\min NF
\]

Objectives (3), (4), and (5) are all in passenger-hour cost, therefore for simplicity, could be summed up to \(\min Z_1\) as shown in equation (1). Objective (6) stands alone to some extent and is termed \(\min Z_2\) as in Equation (2).

Calculation of \(Z_1\) and \(Z_2\) Elements. In the previous section the objective functions of the transit network design problem are established. The next step is to apply them to the HK ferry network and to assess the quality of existing and candidate routes. The general framework of the quality of ferry routes evaluation is shown in Figure 2 in flowchart format. The framework covers the following eight steps for a design year and for a given ferry route or a set of routes:

1. Use a forecasting method to calculate the average O-D demand for peak, off-peak, and daily.
2. Use given minimum frequencies and desired occupancies for peak and off-peak period to calculate peak and off-peak frequencies.
3. Calculate \(Wt\) for peak, off-peak, and daily periods.
4. Calculate \(Esh\) for peak, off-peak, and daily periods.
5. Use the travel time information of the ferry, best transit competitors, and ferry and bus for certain O-D to calculate \(Ph\) and \(Dph\) for peak, off-peak, and daily periods.
6. Use the information of ferry travel times to determine the required fleet size, especially for peak period and off-peak period, for estimating the number of crew required.
7. Evaluate the cost of \(\alpha_1 Wt, \alpha_2 Es, \Delta, Z_1, Z_2\) based on the cost estimates of \(\alpha_i\), \(i = 1, 2, 3, 4\).
8. Use the components of \(Z_1\) and \(Z_2\) to compare different alternative ferry routes, if any, or individual routes. Use these measures for establishing recommendations.
The input for the quality of routes evaluation is derived from

- a given ferry route or set of routes;
- O-D demand for peak, off-peak, and daily;
- travel times for peak and off-peak for each direction;
Design and Evaluation of Passenger Ferry Routes

- round-trip times for peak and off-peak;
- average vessel capacity;
- desired occupancy (% of seat capacity) for peak and off-peak;
- minimum frequency for peak and off-peak; and
- minimum relevant (same segment as the ferry or the ferry and bus for certain O-D pairs) travel time of best (shortest time) transit competitor.

In the next section the route quality evaluation method is interpreted using a detailed example.

**Example**

The objective function $Z_1$ is based on the so-called load profile. It is a histogram describing the number of passengers on board the transit vehicle vs. the transit route length (in distance or time units). Figure 3 provides an example of calculations. Figure 3c shows a load profile between North Point (NP) and Kowloon Point (KP) in HK.

The first element in $Z_1$ in Equation (1) is the total wait-time hours both at the transit stops and during transfers. This element represents the passenger perspective; its calculation is based on the maximum load point method for deriving the transit vehicles frequency (Ceder 1984) during the time covered by the passenger demand matrix:

$$ F_r = \max \left[ \frac{L_r}{d_o}, F_{\text{min}} \right] $$  \hspace{1cm} (7)

If $F_r = F_{\text{min}}$, the load profile will have no effect on the frequency determination.

The expected wait time for passengers on route $r$ is half of the transit vehicle headway where passengers arrived randomly to the transit stop and the headway is distributed in a deterministic manner (Marguier and Ceder 1984):

$$ w_r = \frac{1}{2F_r} $$  \hspace{1cm} (8)

hence,

$$ \sum_{i, j \in N} Wt(i, j) = \sum_{r \in R} \frac{1}{2F_r} \left( \sum_{i, j \in N} d_{ij}^{r} + \sum_{i \in N, t_p} d_{ij}^{tp} a_{r t_p}^{tp} \right) $$  \hspace{1cm} (9)
In the example shown in Figure 3, one obtains:

$$\sum_{i,j \in N} W_{t}(i,j) = \frac{1}{2 \cdot 24366/800} (24366) = 400 \text{ passenger-hours}$$

where:

- $d_{o}$ equals 800 (in this example a vessel with maximum 1,000 seats and desired peak occupancy of 80% is used)
The second element of $Z_1$ in Equation (1) describes the total empty-space hours or empty-seat hours (when $d_o$ equals the number of seats on the transit vehicle). This element represents an unproductive measure for the operator (e.g., unused seat capacity). Its formulation is

$$\sum_r Esh_r = \sum_{r \in R} \left[ \max \left( L_r, F_{\min} \cdot d_o \right) \right] t_r - \sum_{i, j \in N} Ph(i, j)$$  \hspace{1cm} (10)

In Figure 3

$Esh_r = (30 \cdot 1000 - 24366) \cdot 30/60 = 2817$ passenger-hours.

The first part of the third element of $Z_1$ in Equation (1) is total passenger-hour in the routing system

$$\sum_{i, j \in N} Ph(i, j) = \sum_{r \in R} \sum_{i, j \in N_r} d_{ij}^r t_{ij}^r + \sum_{tr \in TP} \sum_{ij \in N_{tp}} d_{ij}^{tp} t_{ij}^{tp}$$  \hspace{1cm} (11)

where, for the example in Figure 3d:

$$\sum_{i, j \in N} Ph = (30 \cdot 24366)/60 = 12183$$ passenger-hours

The second part of the third element in Equation (1) is the total passenger-hour difference between on $r$ and on the shortest path $sp$

$$\sum_{i, j \in N} \sum_{sp \in S} \sum_{i, j \in N_{sp}} d_{ij}^{sp} t_{ij}^{sp}$$  \hspace{1cm} (12)

where for the Figure 3d example:

$$\sum_{i, j \in N} Dph(i, j) = 24366 \cdot (30 - 20)/60 = 4061$$ passenger-hours.

**Estimation of $Z_2$**

The second objective function, $Z_2$, is an estimate for the fleet size required to carry the entire matrix of the passengers’ demand. The fleet size required for a given ferry route is primarily based on the timetable (frequencies). The minimum num-
ber of vessels required is derived from the Round Trip Time (RTT) for a given route. That is, a particular ferry departing, say, at 7:00 am at KP can carry out the next trip from KP only after it came back to KP. If RTT = 40 minutes, then this ferry can be responsible for a departure at KP from 7:40 am and on. All the departures made from KP after 7:00 and before 7:40 must be made by other ferries. If one looks at all the time windows of RTT and determines the number of independent departures, a list of these numbers (of departures) can be established. The maximum value in this list is, as can be understood, the minimum number of vessels required. This idea is demonstrated in Equation 12 with a small example for RTT = 30 minutes and a given timetable from which min NF = 4 vessels. Note that RTT is comprised of 10 elements as shown in Figure 4. In addition, the example problem shown in Figure 3 is also used for the minimum number of vessels. The combined data of this example problem with RTT = 75 minutes result in 38 vessels for the peak hour.

\[
\text{Min } N = \text{ Max number of departures in a time window}
\]

\[
\text{RTT across the peak (usually) period (operator perspective)}
\]

\[
\text{RTT} = \text{travel time} + \text{berthing time} + \text{alighting time} + \text{layover time} + \text{boarding time}
\]

Example: RTT= 30 min., Timetable:

\[
\begin{align*}
\text{Min } N &= 4 \\
7:00 & \quad 2 \\
7:15 & \quad 2 \\
7:30 & \quad 3 \\
7:45 & \quad 2 \\
8:00 & \quad 3 \\
8:10 & \quad 3 \\
8:20 & \quad 3 \\
8:25 & \quad 3 \\
8:40 & \\
8:50 & \\
9:00 & \\
\end{align*}
\]

Figure 4. Minimum Fleet Size Calculation
**Multiobjective**

The four main objectives in Equations 3, 4, 5, and 6 present a multiobjective picture for each route and can be evaluated separately. However, since the first three objectives are all in monetary units for passenger-hours, it is possible to combine them into one function: $Z_1$ as is indicated in Equation 1, and to examine $Z_1$ against the number of vessels required (and/or their capital cost) formulized as $Z_2$ in Equation 2.

The multiobjective perspective allows the decision-maker to select a solution based on the relative measures of the objective functions. This multiobjective stage is the last step in the quality of routes evaluation process. Its exact formulation and possibilities appear in Ceder (2003).

**Hong Kong Case Study**

The quality of the routes evaluation procedure establishes practical and measurable criteria for evaluating the “goodness” of each route and makes comparisons between the routes. This evaluation procedure ranks the various routes (or various sets of routes) and helps to prepare recommendations on adequate frequencies and possible improvements in vessel type and pier. In the HK study it was found that for $\Delta > 0$ (see Equation 5, for $\Delta$ explanation) a switch of passengers from ferry to its best transit competitor will result in monetary loss to passengers (also a loss from a governmental standpoint). Thus, there is good reason to further check and maintain the ferry route. If $\Delta < 0$, then by switching (theoretically) ferry passengers to the best transit mode, the passengers will gain, and the overall situation will benefit from closing the ferry route. Figure 5 illustrates one result in HK concerning the existing and candidate viable routes for 2006; such recommendations should commensurate with other nonquantitative factors.
Figure 5. Map of Existing and Candidate Outlying Islands Routes
Concluding Remarks
The main purpose of this research is to introduce practical planning and evaluation methods to assess existing and candidate ferry routes by taking into account the interests of passengers, operators, and the community. The ferry routes do not necessarily have to be point-to-point systems and in many respects these routes can act similarly to bus and rail ones. The first part of this study constructs a planning framework on how to improve and make the best use of existing water and ferry resources. The second part provides a procedure that incorporates optimization and enumeration processes to derive the minimal $Z_1$ objective function. This procedure, while searching for min $Z_1$, also creates various $Z_2$ solutions—each associated with a different $Z_1$ solution. The multiobjective framework developed was successfully utilized in a case study of the large Hong Kong ferry network. This multiobjective perspective allows the decision-maker to select a solution based on the relative measures of the objective functions.

References


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Allocation and Use of Section 5310 Funds in Urban and Rural America

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Abstract

Public transportation is a critical part of a community’s infrastructure for people with disabilities. Section 5310 of the Transportation Equity Act is a Federal program of capital assistance to address the mobility needs of the elderly and persons with disabilities. We identified 4,835 Section 5310 recipients in 49 states and the District of Columbia, and randomly selected 750 for a mail survey. The majority were organizations serving senior citizens or individuals with developmental disabilities. Only one was a tribal entity. Overall, Sec. 5310 vehicles made up 32 percent of the respondents’ fleets and 75 percent were lift equipped. More Sec. 5310 resources went to those organizations serving a mix of urbanized and rural areas than went to organizations serving rural-only areas. Ten percent of the respondents reported being faith-based organizations; more of these were in urban than rural areas. Almost half of the respondents participated in some form of cooperative system but less than 5 percent participated in a consolidated system. This study provides a baseline against which to measure changes following the implementation of the Transportation Act of 2005.
Introduction
Approximately 47 million Americans over 15 years of age report having a disability (U.S. Census 2000). Applying transportation classifications of urbanized and non-urbanized populations, approximately 31 million (67%) live in urbanized areas of 50,000 or more inhabitants and 16 million (33%) live in nonurbanized (i.e., rural) areas. For disabled individuals, the lack of transportation is consistently reported as one of their major challenges (Arcury et al. 2005; Arnold et al. 1997; Jackson et al. 1992; Johnson and Shaw 2001; Kidder 1989; National Council on Disability 2005; Nosek et al. 1992; Tonsing-Gonzales 1989).

The lack of transportation is experienced differently by urban and rural residents (Rucker 1994). For example, the Community Transportation Association of America (CTAA 2001) reports that rural public transit operates in only about half of rural counties nationwide. Similarly, the CTAA (1995) reports that a carless urban household can expect to receive about 933 public transportation trips per year compared to 25 trips per year for rural carless households. Despite the benefits of more transportation options, people with disabilities living in urban areas also experience significant problems with transportation (Johnson and Shaw 2001; National Council on Disability 2005). This is likely due to problems in using and dissatisfaction with existing urban transportation services (e.g., Denson 2000), as opposed to problems created by the absence of services.

Section 5310 of the Federal Transit Act (49 USC 5310) authorizes a program of transit capital assistance to address mobility needs of the elderly and persons with disabilities. Established in 1979, this program helps local organizations acquire vehicles to provide transportation services for these individuals when other public transportation is unavailable or insufficient. While this program is designed primarily to fund the purchase of vehicles, Federal law allows funds to be used for “purchase of service arrangements,” such as voucher programs (e.g., Bernier and Seekins 1999).

Sec. 5310 transportation funds are allocated to states, which in turn distribute them to eligible local applicants (e.g., Federal Transit Administration 1998). Typically, local programs provide a 20 percent match and all operational costs. These funds are often used by local nonprofit organizations to provide transportation for their clientele to and from service programs. For example, a community nonprofit corporation serving adults with intellectual or developmental disabilities might use a vehicle acquired through a Sec. 5310 program to transport clients from a group home they operate to a sheltered workshop at which the clients work.
Similarly, a local senior center may use a lift-equipped vehicle acquired through a Sec.5310 program to transport elderly community residents from their homes to the center for activities.

This “agency-driven” model provides some transportation in both urbanized and rural areas but it does not directly address the general mobility needs of all elders and persons with disabilities in a community. Further, while there is recent evidence of increasing coordination, critics have long suggested that vehicles operated under this model may be underused and nonclients may be excluded from riding in the vehicles, even if their destinations overlap (e.g., Sundeen et al. 2005; U.S. Department of Transportation 1980).

Several reports discuss transportation issues for elderly individuals and people with disabilities (Government Accountability Office 2004) but surprisingly little quantitative research has been published about transportation for people with disabilities (e.g., Rucker 1994). Burkhardt et al. (2004) identified three levels of cooperative systems, including coordinated systems, brokerages, and consolidated systems. Kidder (1989) showed that a cooperative model in which local human service agencies consolidated operations could greatly expand transportation within a community. Unfortunately, little is known about the extent to which such cooperative models have been implemented or their effectiveness. Moreover, Federal regulation has not required recipients of Sec. 5310 funds to cooperate with each other (Burkhardt et al. 2004; Government Accountability Office 2003). Rural disability service providers, advocates, and transportation planners need data on the actual distribution and use of Sec. 5310 funds in urbanized and rural areas (e.g., APRIL 2001) so they can effectively organize resources to maximize the availability and use of transportation. Further, there is a need to establish a baseline of such information against which the effects of new regulations and provisions of future transit acts may be evaluated.

The goal of this study was to assess the distribution and use of Sec. 5310 funds at the local level, specifically focusing on comparisons between urban and rural areas. We hypothesized that Sec. 5310 funds are inequitably distributed between programs located in urbanized and rural areas. We also hypothesized that fewer than 25 percent of Sec. 5310 recipients would report participating in any type of cooperative system and that less than 60 percent of vehicles purchased with Sec. 5310 funds would be accessible to persons with mobility impairments.

Further, we expected to find that those who do participate in cooperative systems would report greater efficiency and effectiveness as measured by the number
of riders and trips provided. Given the limited information about the Sec. 5310 program, we also sought to describe the characteristics of these transportation providers and how they used these resources.

Method

Sample Population
Respondents to the survey were staff of local service programs receiving Sec. 5310 assistance from their state. We contacted state Sec. 5310 coordinators by phone and email to secure lists of local recipients of Sec. 5310 assistance. We followed CTAA’s definition of the active network of Sec. 5310 recipients as any organization operating a vehicle acquired with Sec. 5310 assistance that is still within its anticipated useful life (e.g., CTAA 2006). Forty-seven states and the District of Columbia provided comprehensive lists of local recipients. Texas and Florida administered their programs through regional offices and those regional offices provided 32 lists of local recipients. North Carolina transferred all of its Sec. 5310 funds into the operation of its Sec. 5311 rural transit program, so it was excluded from this study. Overall, we identified 4,835 recipients of Sec. 5310 assistance in the 49 states and the District of Columbia. Our original data analysis plan suggested that the most demanding analysis would involve F-tests to explore differences across five regional groups. A power analysis (Fetterman 1998) suggested that a sample size of 375 would be needed for an expected small-to-medium effect size of .18 with an Alpha of .05 and power of .8. Anticipating a 60 percent return rate using Dillman’s (2000) survey procedures, we selected a pool of 625 respondents to achieve the needed sample of 375. To increase likely responses and limit follow-up, we increased that initial sample to 750 respondents selected at random from the list of 4,835.

Survey Instrument and Procedures
We took several steps to develop the survey instrument. First, we reviewed several states’ Sec. 5310 transportation policies and procedures. Next, we reviewed current literature on transportation programs to identify relevant issues. We developed a list of hypotheses about the Sec. 5310 program (e.g., funds would be disproportionately allocated to urban areas on a per capita basis, larger programs would be more likely to have accessible vehicles, rural respondents would be less likely to report participating in a cooperative system, etc.) and developed a “hypothetical report” of findings. This hypothetical report clarified the issues we
wanted to address. We drafted a survey to reflect the hypotheses and the hypothetical report. We then compared the content of the survey instrument to the hypothetical report to ensure that our questions addressed those issues. We asked several community transportation experts to review and comment on the survey draft. Researchers then conducted a read-aloud procedure with a potential survey respondent and edited survey items the respondent found confusing. Experts again reviewed the final draft and we incorporated their suggested changes.

The completed questionnaire contained 24 items, including:

- Seven questions about the characteristics of the organization and its service area,
- Four questions addressing the status of transportation services in the respondent’s community,
- Two questions about Sec. 5310 resources received,
- Three questions about the characteristics of the organization’s vehicle fleet,
- Two questions about the amount of transportation services provided,
- Five questions about various aspects of local coordination, and
- One open-ended question to allow for comments.

For consistency, we asked respondents to provide their answers using data from FFY 2002, the last official reporting period.

Local coordination is a particularly complex issue. The term coordination has been used to reflect a range of practices (e.g., Burkhardt et al. 2004). In an attempt to clarify the concept, we organized three major strategies under the concept of cooperative systems:

1. Coordinated systems in which independent agencies coordinate service areas and target groups, or pool purchases
2. Brokerages in which agencies coordinate schedules or “broker” rides across agency clientele
3. Consolidated systems in which several agencies pool all of their transit resources into a separate transportation agency that serves the entire community

We followed survey procedures specified by Dillman (2000). A postcard announcing the survey was sent to selected respondents. Two weeks later, we mailed a
cover letter, survey, and self-addressed return envelope to those respondents. After two weeks, we sent a reminder postcard encouraging completion and return of the survey. Two weeks later, we sent a second survey packet to all those who had not yet responded.

Data Analysis Methods
We used SPSS 11.5 to examine the data. Standard descriptive statistics were calculated to describe the demographics and general-use patterns of Sec. 5310 recipients. We conducted correlation analyses to examine relationships between variables and examined the data for differences across groups using ANOVA. As the central hypothesis states an expected direction in resource allocation, we used a one-tailed $t$-test of proportions to examine the direction of differences.

Results
A total of 305 ($n = 305$) local recipients of Sec. 5310 assistance from 49 states and the District of Columbia responded to our survey. Another 30 surveys were returned by the post office as undeliverable, yielding an effective response rate of 45 percent.

We created three geographic groups for analysis:

1. An urban-only services group ($n = 60$) composed of those operating solely in urbanized areas of 50,000 or more inhabitants
2. A rural-only services group ($n = 127$) composed of respondents operating solely in small towns and rural areas with fewer than 50,000 inhabitants
3. A mixed group serving both urbanized and rural areas ($n = 74$)

Table 1 shows the number and proportion of respondents serving four distinct geographic areas. Forty-nine percent of recipients operated exclusively in small towns or rural areas outside of urbanized areas.

Of the respondents, 204 (79%) reported being a private not-for-profit agency, 48 (19%) reported being a local government entity, 7 (3%) reported being a state agency, and only one reported being a tribal organization. No respondent reported being a private for-profit agency or a tribal government unit. Table 2 depicts the types of programs that recipients operated across urban and rural areas. Interestingly, respondents who were exclusively transit providers in urban areas accounted for only 6.7 percent ($n = 4$) of recipients of Sec. 5310 assistance,
Table 1. Geographic Areas Served by Respondents

<table>
<thead>
<tr>
<th>Geographic Areas Served</th>
<th>Number Reporting</th>
<th>Percent Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urbanized Area Over 200,000 People</td>
<td>37</td>
<td>14%</td>
</tr>
<tr>
<td>Urbanized Area of 50,000–200,000 People</td>
<td>23</td>
<td>9%</td>
</tr>
<tr>
<td>Small Towns or Rural Areas Outside of Urbanized Area</td>
<td>127</td>
<td>49%</td>
</tr>
<tr>
<td>Both Urbanized and Rural Areas</td>
<td>74</td>
<td>28%</td>
</tr>
</tbody>
</table>

Table 2. Program Type by Urban, Mixed, and Rural Service Groups

<table>
<thead>
<tr>
<th>Program Type</th>
<th>All</th>
<th>Percent</th>
<th>Urban</th>
<th>Percent</th>
<th>Mixed, Urban, Rural</th>
<th>Percent</th>
<th>Rural Only</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Services Agency</td>
<td>92</td>
<td>35.0%</td>
<td>21</td>
<td>35.0%</td>
<td>20</td>
<td>27.0%</td>
<td>50</td>
<td>39.4%</td>
</tr>
<tr>
<td>Developmental Disabilities Agency</td>
<td>65</td>
<td>24.7%</td>
<td>19</td>
<td>31.7%</td>
<td>15</td>
<td>20.3%</td>
<td>31</td>
<td>24.4%</td>
</tr>
<tr>
<td>Social or Community Service Provider</td>
<td>30</td>
<td>11.4%</td>
<td>10</td>
<td>16.7%</td>
<td>9</td>
<td>12.2%</td>
<td>10</td>
<td>7.9%</td>
</tr>
<tr>
<td>Exclusively Rural Transit Provider</td>
<td>24</td>
<td>9.1%</td>
<td>0</td>
<td>0.0%</td>
<td>4</td>
<td>5.4%</td>
<td>20</td>
<td>15.7%</td>
</tr>
<tr>
<td>Exclusively Urban Transit Provider</td>
<td>3</td>
<td>1.1%</td>
<td>3</td>
<td>5.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Other Disability Services Organization</td>
<td>14</td>
<td>5.3%</td>
<td>3</td>
<td>5.0%</td>
<td>5</td>
<td>6.8%</td>
<td>6</td>
<td>4.7%</td>
</tr>
<tr>
<td>Other</td>
<td>18</td>
<td>6.8%</td>
<td>3</td>
<td>5.0%</td>
<td>8</td>
<td>10.8%</td>
<td>7</td>
<td>5.5%</td>
</tr>
<tr>
<td>Exclusively Transit Agency Serving Urban and Rural Areas</td>
<td>17</td>
<td>6.5%</td>
<td>1</td>
<td>1.7%</td>
<td>13</td>
<td>17.6%</td>
<td>3</td>
<td>2.4%</td>
</tr>
<tr>
<td>Total</td>
<td>263</td>
<td>100.0%</td>
<td>60</td>
<td>100.0%</td>
<td>74</td>
<td>100.0%</td>
<td>127</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
while exclusive transit agencies accounted for 23 percent \((n = 17)\) and 18 percent \((n = 23)\) of mixed and rural-only recipients.

Since transportation is only one part of most Sec. 5310 providers’ program activities, we asked respondents to report both transportation and total program budgets. Respondents’ FFY 2002 transportation budgets averaged $505,987 with a median of $108,000. Respondents’ overall budgets averaged $4,853,238 with a median of $1,277,637. There were no statistically significant differences in agency budgets among the three geographic groups. The amount of Sec. 5310 funding received by the mixed group \((m = 45,228)\) was greater than the rural-only group \((m = 26,413; p = .018)\). The urban-only service group \((m = 42,710)\) approached statistical difference with the rural only group \((p = .083)\).

Table 3 presents the total number of vehicles reported by survey respondents, the number acquired with Sec. 5310 assistance, and the proportion of vehicles that are lift equipped. Overall, Sec. 5310 vehicles made up 32 percent of all fleet vehicles. Nearly half (47%) of all vehicles were lift equipped but 75 percent of vehicles acquired through Sec. 5310 were lift equipped. As the number of vehicles in a fleet increased, the number of vehicles purchased with Sec. 5310 assistance increased \((r = .58, p = .01)\), the number of Sec. 5310 vehicles equipped with a lift increased \((r = .79, p = .01)\), and the number of vehicles in the general fleet equipped with a lift increased \((r = .48, p = .01)\). There were also positive correlations between the total number of Sec. 5310 vehicles in a fleet and the number of Sec. 5310 vehicles

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Average</th>
<th>Median</th>
<th>Urban Only</th>
<th>Percent of Total</th>
<th>Mixed, Urban, Rural</th>
<th>Percent of Total</th>
<th>Rural Only</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Agency Vehicles</td>
<td>3,537</td>
<td>13.5</td>
<td>6</td>
<td>862</td>
<td>24%</td>
<td>1,258</td>
<td>36%</td>
<td>1,406</td>
<td>40%</td>
</tr>
<tr>
<td>5310 Vehicles</td>
<td>1,150 (32%)</td>
<td>4.4</td>
<td>3</td>
<td>206 (24%)</td>
<td>18%</td>
<td>467 (37%)</td>
<td>41%</td>
<td>473 (34%)</td>
<td>41%</td>
</tr>
<tr>
<td>Accessible Vehicles in General Fleet</td>
<td>1,656 (47%)</td>
<td>6.3</td>
<td>3</td>
<td>425 (49%)</td>
<td>26%</td>
<td>674 (54%)</td>
<td>41%</td>
<td>549 (39%)</td>
<td>33%</td>
</tr>
<tr>
<td>5310 Accessible Vehicles</td>
<td>867 (75%)</td>
<td>3.3</td>
<td>2</td>
<td>155 (75%)</td>
<td>18%</td>
<td>337 (72%)</td>
<td>39%</td>
<td>370 (78%)</td>
<td>43%</td>
</tr>
</tbody>
</table>
that were lift equipped ($r = .50$, $p = .01$), and the overall number of lift-equipped vehicles in the fleet ($r = .70$, $p = .01$).

Moreover, analysis showed significant differences on these measures across geographic groups. Specifically, the mixed group had more Sec. 5310 vehicles per provider ($m = 6.31$) than either the urban-only ($m = 3.43$; $p = .005$) or rural-only groups ($m = 3.72$; $p = .002$). The mixed group also reported a significantly greater proportion of their Sec. 5310 vehicles were lift equipped ($m = 4.55$) than either the urban-only ($m = 2.67$; $p = .008$) or rural-only ($m = 2.94$; $p = .006$) groups. Finally, the mixed group averaged more lift-equipped vehicles in its fleet ($m = 9.23$) than those in the rural-only group ($m = 4.36$; $p = .008$).

Survey respondents reported providing 5,897,058 one-way passenger trips in FFY 2002; an average of 25,978 (s.d. = 94,320) per agency but a median of 5,696 trips. The rural-only group reported providing an average of 3,000 one-way trips. The urban-only group provided an average of 3,586 trips. The mixed group averaged 44,021 trips. There were no statistically significant differences in the number of one-way trips provided between these groups.²

While there were no statistically significant differences in the total agency budgets among the three geographic groups, the mixed group received significantly more Sec. 5310 funding than the rural-only group. Further, organizations operating larger fleets were more likely to acquire accessible vehicles, as were agencies that operated more Sec. 5310 vehicles.

Table 4 presents the number of counties served, the average number of riders per county, the average number of mobility-impaired riders per county across the three geographic groups, and the number of other transportation providers in these counties. The number of other transit providers is important when considering the potential for developing cooperative transit arrangements. A one-way ANOVA showed that there were significant differences between the three geographic groups in the number of counties served $F(2, 258) = 3.80$, $p = .02$, and the number of other public or private transit providers $F(2, 258) = 5.22$, $p = .006$. Tukey’s post-hoc analyses showed that urban-only providers ($M = 1.10$, SD = .75) serve significantly fewer counties than those providers who serve mixed areas ($M = 1.70$, SD = 1.34; mean difference = -.60, $p = .018$). Further, rural-only providers ($M = 3.35$, SD = 4.85) estimated significantly fewer other public or private transit providers than providers who serve mixed areas ($M = 12.93$, SD = 37.02; mean difference = -9.58, $p = .005$). There were no statistically significant differences among
the number of riders per county or the number of mobility-impaired riders served per county.

**Table 4. Average Number of Counties Served, Riders per County, and Other Providers with Whom to Cooperate Across the Three Geographic Groups**

<table>
<thead>
<tr>
<th></th>
<th>All Respondents</th>
<th>Urban Only</th>
<th>Mixed Urban and Rural</th>
<th>Rural Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Counties Served</td>
<td>1.5</td>
<td>1.1</td>
<td>1.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Average Riders Served Annually</td>
<td>34,630</td>
<td>110,419</td>
<td>8,353</td>
<td>14,557</td>
</tr>
<tr>
<td>Average Number of Riders with Mobility Impairments</td>
<td>972</td>
<td>451</td>
<td>1,639</td>
<td>843</td>
</tr>
<tr>
<td>Average Number of Other Transportation Providers</td>
<td>7.4</td>
<td>9.2</td>
<td>12.9</td>
<td>3.35</td>
</tr>
</tbody>
</table>

Twenty-six (10%) respondents reported being a faith-based organization. Of these faith-based organizations, significantly more are located in the urban-only services group (n = 12; 20%) than in the rural-only (n = 6 or 5%) or mixed groups (n = 7 or 10% mean difference = .15, p = .003).

Table 5 shows the number of respondents reporting participating or not participating in cooperative systems across the geographic groups. Forty-six percent of respondents participated in some form of cooperative transportation system but only 14 percent participated in a brokerage system and only 5 percent participated in a consolidated system. There were no statistically significant differences in the likelihood of participating in a cooperative system across geographic groups. Nine faith-based providers (35%) reported participating in some form of cooperative system.

Of those not participating in any form of cooperative system, 16 (12%) reported that there was no need and 28 (20%) reported that there were no other providers with which to cooperate. Twenty-four (86%) of the 28 who reported that there were no other providers with which to cooperate were in the rural-only services group. Since several rural providers reported that there were no other providers...
with which to cooperate, we also conducted this analysis after removing those respondents. Still, no statistically significant differences emerged. It must be noted, however, that reports that there are no other providers in an area may not be highly reliable.

Table 5. Cooperative Systems by Rural, Mixed, and Urban Provider Groups

<table>
<thead>
<tr>
<th>Cooperative Systems</th>
<th>All Respondents Number and Percent</th>
<th>Urban Services Group</th>
<th>Mixed, Urban, Rural Group</th>
<th>Rural Services Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does Not Participate</td>
<td>138 (54%)</td>
<td>37 (64%)</td>
<td>33 (45%)</td>
<td>67 (55%)</td>
</tr>
<tr>
<td>Participated in a Coordinated System</td>
<td>68 (27%)</td>
<td>11 (19%)</td>
<td>21 (29 %)</td>
<td>35 (29%)</td>
</tr>
<tr>
<td>Participates in a Brokerage</td>
<td>36 (14%)</td>
<td>7 (12%)</td>
<td>15 (21%)</td>
<td>14 (12%)</td>
</tr>
<tr>
<td>Participates in a Consolidated System</td>
<td>12 (5%)</td>
<td>3 (5%)</td>
<td>4 (5%)</td>
<td>5 (4%)</td>
</tr>
</tbody>
</table>

Those agencies participating in some form of cooperative system had larger agency budgets \( t(104.9) = -1.945, \ p = .054 \), had larger transportation budgets \( t(121.5) = -2.813, \ p = .006 \), and received more Sec. 5310 funds \( t(151.3) = -2.965, \ p = .004 \). In addition, those agencies participating in some type of a cooperative system provided more one-way trips \( t(103.9) = -2.025, \ p = .045 \). There were no statistical differences in the number of one-way trips per vehicle provided by those who participated in or did not participate in cooperative systems, however.

Table 6 presents the effort to organize and willingness to take part in a cooperative system by respondents who did not yet participate in a cooperative system. While it appears that respondents not participating in a cooperative system have made some attempts to organize such systems, very few of those attempts appeared to involve much effort. Most respondents were ambivalent about participating in a cooperative system but nearly 34 percent were willing or very willing to do so. There were no statistical differences in willingness to cooperate across the geographic groups.
Table 6. Effort to Develop and Willingness to Participate in a Cooperative System by Those Not Yet Cooperating

<table>
<thead>
<tr>
<th>Effort to Develop</th>
<th>Overall</th>
<th>Urban</th>
<th>Mixed, Urban, Rural</th>
<th>Rural Only</th>
<th>Willingness to Participate</th>
<th>Overall</th>
<th>Urban</th>
<th>Mixed, Urban, Rural</th>
<th>Rural Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Effort</td>
<td>54 (41.5%)</td>
<td>16 (50.0%)</td>
<td>11 (36.7%)</td>
<td>27 (39.7%)</td>
<td>Very Unwilling</td>
<td>13 (10.7%)</td>
<td>6 (18.2%)</td>
<td>2 (7.1%)</td>
<td>5 (8.3%)</td>
</tr>
<tr>
<td>Little</td>
<td>21 (16.2%)</td>
<td>8 (25.0%)</td>
<td>2 (6.7%)</td>
<td>11 (16.2%)</td>
<td>Somewhat Willing</td>
<td>10 (8.2%)</td>
<td>2 (6.1%)</td>
<td>3 (10.7%)</td>
<td>5 (8.3%)</td>
</tr>
<tr>
<td>Some</td>
<td>43 (33.1%)</td>
<td>8 (25.0%)</td>
<td>10 (33.3%)</td>
<td>25 (36.8%)</td>
<td>Neither Willing nor Unwilling</td>
<td>58 (47.5%)</td>
<td>15 (45.5%)</td>
<td>13 (46.4%)</td>
<td>29 (48.3%)</td>
</tr>
<tr>
<td>More</td>
<td>10 (7.7%)</td>
<td>0 (0.0%)</td>
<td>5 (16.7%)</td>
<td>5 (7.4%)</td>
<td>Willing</td>
<td>27 (22.1%)</td>
<td>8 (24.2%)</td>
<td>8 (28.6%)</td>
<td>11 (18.3%)</td>
</tr>
<tr>
<td>A Great Deal</td>
<td>2 (1.5%)</td>
<td>0 (0.0%)</td>
<td>2 (6.7%)</td>
<td>0 (0.0%)</td>
<td>Very Willing</td>
<td>14 (11.5%)</td>
<td>2 (6.1%)</td>
<td>2 (7.1%)</td>
<td>10 (16.7%)</td>
</tr>
<tr>
<td>Total</td>
<td>130 (100%)</td>
<td>32 (100%)</td>
<td>30 (100%)</td>
<td>68 (100%)</td>
<td>Total</td>
<td>122 (100%)</td>
<td>33 (100%)</td>
<td>28 (100%)</td>
<td>60 (100%)</td>
</tr>
</tbody>
</table>
Table 7 depicts the barriers that respondents reported in trying to form a cooperative system. (Respondents were able to mark more than one barrier.) The most frequent barrier mentioned was organizational policy that required an agency to serve only its clients. This was followed by concerns over liability. Surprisingly, eight respondents reported prohibitive state policies as a barrier to cooperation.

### Table 7. Barriers to Cooperation Reported by Those Not Yet Cooperating

<table>
<thead>
<tr>
<th>Reported Barriers to Cooperation</th>
<th>All</th>
<th>Percent</th>
<th>Urban</th>
<th>Percent</th>
<th>Mixed, Urban, Rural</th>
<th>Percent</th>
<th>Rural Only</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Need</td>
<td>16</td>
<td>8.6%</td>
<td>5</td>
<td>9.1%</td>
<td>3</td>
<td>6.8%</td>
<td>8</td>
<td>9.5%</td>
</tr>
<tr>
<td>No Other Local Providers</td>
<td>28</td>
<td>15.1%</td>
<td>4</td>
<td>7.3%</td>
<td>5</td>
<td>11.4%</td>
<td>19</td>
<td>22.6%</td>
</tr>
<tr>
<td>Insurance and Liability</td>
<td>30</td>
<td>16.2%</td>
<td>12</td>
<td>21.8%</td>
<td>8</td>
<td>18.2%</td>
<td>9</td>
<td>10.7%</td>
</tr>
<tr>
<td>Other Unwilling to Cooperate</td>
<td>17</td>
<td>9.2%</td>
<td>4</td>
<td>7.3%</td>
<td>5</td>
<td>11.4%</td>
<td>8</td>
<td>9.5%</td>
</tr>
<tr>
<td>Organizational Policy Precludes</td>
<td>49</td>
<td>26.5%</td>
<td>17</td>
<td>30.9%</td>
<td>14</td>
<td>31.8%</td>
<td>17</td>
<td>20.2%</td>
</tr>
<tr>
<td>Prohibitive State Regulations</td>
<td>8</td>
<td>4.3%</td>
<td>3</td>
<td>5.5%</td>
<td>2</td>
<td>4.5%</td>
<td>3</td>
<td>3.6%</td>
</tr>
<tr>
<td>Other Reasons</td>
<td>37</td>
<td>20.0%</td>
<td>10</td>
<td>18.2%</td>
<td>7</td>
<td>15.9%</td>
<td>20</td>
<td>23.8%</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>100.0%</td>
<td>55</td>
<td>100.0%</td>
<td>44</td>
<td>100.0%</td>
<td>84</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 8 shows the average rating of the quality of public transportation for all citizens in a service area, for people with disabilities and for elderly individuals. Quality was rated on a 5-point scale where 0 was very poor and 4 was excellent. While there were no significant differences between or across groups, ratings fell at or below the mid-point. While there was a considerable amount of importance placed on providing accessible transportation in the areas served (79% rated it a 4 on the 5-point scale), at least 33 percent indicated that each of the services was inadequate.
Table 8. Average Ratings of the Quality of Public Transportation Across Geographic Groups

<table>
<thead>
<tr>
<th></th>
<th>All Respondents</th>
<th>Elderly</th>
<th>People with Disabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Respondents</td>
<td>1.9</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Urban Only</td>
<td>2.0</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Mixed, Urban, Rural</td>
<td>1.9</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Rural Only</td>
<td>1.8</td>
<td>2.2</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Sixteen respondents (6%) reported using an average of $701,354 (median of $30,000) for third-party contracts with other providers for purchase of services. Six respondents (2%) reported using an average of $7,248 to provide user-side subsidies in the form of voucher or taxi coupon models.

Discussion

This study examined the allocation and use of Sec. 5310 transportation resources nationally. We identified 4,835 local recipients of these resources in 49 states and the District of Columbia. The majority of respondents were local, not-for profit organizations that serve either senior citizens or individuals with developmental disabilities. This may mean that individuals with disabilities due to mobility impairments, chronic diseases, or psychiatric impairments are less likely to have access to this level of public transportation.

Some caution should be applied in interpreting these findings. First, our response rate was 45 percent and there may be response bias in the data. For example, some evidence suggest that larger programs and those which have received vehicles more recently responded in higher numbers than smaller organizations or ones that have not received Sec. 5310 support for some time. Second, our sample fell somewhat short of our goal of 350 responses. This means that our analysis may not have detected smaller differences between groups where they may exist. As such, some differences may exist between groups where we found none.

Rural advocates consistently report that the lack of transportation in rural areas is one of the major obstacles to community participation, especially for people with disabilities. We hypothesized that urban areas would receive more Sec. 5310 resources. In fact, respondents in the mixed group received more Sec. 5310...
resources than the rural-only group, but not more than the urban-only group. At the same time, rural-only respondents were significantly more likely to report fewer other public or private transportation providers serving their areas. Since the Sec. 5310 program was designed to provide transportation when other public transportation is unavailable, insufficient, or inappropriate, it is somewhat surprising that more of these resources do not go to rural areas. It may be that, even with the greater number of options available in urban areas, urban public transit is still insufficient or inappropriate. Perhaps, despite having fewer options, the services available in rural areas are more likely to be judged to be sufficient. It may also be that the mixed group is using its Sec. 5310 resources to fill the transportation gaps in the rural areas they serve. Alternatively, it may be that the mixed and urban-only recipients are more aware of this source of funds, have more experienced proposal writers, or are beneficiaries of policies that limit access to Sec. 5310 resources to those who have already received them.

We hypothesized that less than 60 percent of vehicles purchased with Sec. 5310 resources would be accessible to persons with mobility impairments. While only 47 percent of the general fleet was wheelchair accessible, we found that 75 percent of Sec. 5310 vehicles were lift equipped. This is quite encouraging, given that agencies are not required to purchase accessible vehicles with Sec. 5310 resources but have the flexibility to balance the types of vehicles in their fleets to meet needs. Further, the vehicles reported in this study included all those still in service regardless of age. This level of accessibility is a high benchmark. It suggests that the dream of some advocates for a totally accessible fleet could be within reach.

Our data show that the recipients report providing an average of 25,978 (s.d. = 94,320) one-way trips per year and a median of 5,696. Such data, if collected regularly, may contribute to establishing performance benchmarks that planners and administrators could use. Similar measures could be assessed on rides per vehicles and other factors.

We hypothesized that fewer than 25 percent of Sec. 5310 recipients would report participating in a cooperative system of any kind. In fact, we found that 47 percent reported participating in some form of a cooperative system but only 18 percent participated in the more sophisticated brokerage or consolidated forms of cooperative systems. Transportation providers face many challenges in trying to organize cooperative systems, including concerns about loss of service for their clients, loss of control over services and finances, increased demand on their vehicles, and the lack of any incentive to make the effort (e.g., Zeilinger 2003). One obstacle is
the simple cost of the administrative effort required to plan and organize such a system. A policy option that may assist some communities to develop brokerage or consolidated systems would involve providing target funding for local planning and transition projects.

We expected to find that those who reported participating in a cooperative system would achieve greater efficiency and effectiveness than those who did not. Our data show that providers operate their vehicles at about the same capacity, however, regardless of the organizational arrangement. This may be a function of vehicle financing. That is, providers are not likely to add more vehicles to their fleets if their current vehicles are underused. Alternatively, any gains in effectiveness as measured by one-way rides per vehicle may come only when local agencies created consolidated services. Unfortunately, the number of respondents participating in consolidated systems was too low to conduct a meaningful analysis of that particular arrangement.

On the other hand, cooperative systems may achieve greater effectiveness (i.e., more total riders in an area) rather than greater efficiency (i.e., rides per vehicle). That is, while both cooperators and noncooperators may use their available vehicles to a similar capacity, cooperators may reach a larger proportion of the “eligible” riders in a given area. This view receives support from the finding that providers who reported participating in a cooperative system have more vehicles, a larger budget, serve more riders, and provide more one-way trips than those who do not cooperate. Further geographic analysis is needed that compares the number of riders served in an area to those eligible to determine whether this represents service to a larger proportion of the eligible population. Alternatively, cooperators may provide rides of greater distance or a higher level of service (e.g., extended hours, door-to-door versus curb-to-curb, etc.). We did not collect data on these dimensions.

While more than 60 percent of respondents who did not participate in any cooperative system reported little or no effort to create a cooperative system in their community, 33 percent reported that they were willing or very willing to participate in one. This is encouraging in light of the new Federal emphasis on promoting coordination. Overall, the most frequently reported barriers to cooperation included organizational policies and concern over liability. Still, some respondents indicated they believed that their state agency’s regulations prohibited cooperation. These issues need further attention. One question, for example, is whether
an organization with policies hindering coordination should be deemed eligible for Sec. 5310 assistance.

For rural respondents, the most frequently reported barrier to forming a cooperative system is the absence of other transportation providers in the area with whom to cooperate. This suggests that special attention should be given to using Sec. 5310 resources where there are no other public options, especially to serve those with mobility impairments.

Interestingly, providers that were exclusively transit agencies serving mixed and rural-only areas substantially outnumbered their counterparts in urban areas. Smaller communities may be more likely than urban communities to rely on established transit providers to meet the needs of elderly residents and persons with disabilities. North Carolina presents the largest example of this approach. The state reported investing all of its Sec. 5310 resources in its rural transit program. This strategy achieves at least three objectives. First, it emphasizes the need for additional resources for the rural transit program, which has been significantly underfunded compared to the urban (5307) program. Second, it integrates transportation services for people with disabilities into the mainstream transit program, an important value to disability advocates. Third, it may assist the rural transit program in acquiring accessible vehicles for its fleet. This model deserves further study and consideration, especially considering that there are urban and rural areas without any public transportation.

In conclusion, public and specialized transportation is a vibrant and constantly evolving national commitment. Both consumer expectation and technology change over time. National policies and regulations are intended to maximize the use of scarce transportation resources in meeting these changing needs. This study provides a baseline against which to measure the effects of future changes in this important program’s policies and regulations.

Acknowledgments

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**Endnotes**

1 “Coordination” of Section 5310 funded activities has been a part of Federal Transit Administration programs since 1987, and has been required government wide since the signature of Executive Order 13330 in 2004. On-the-ground implementation of such collaborative arrangements has not been a central feature in states’ Section 5310 networks, however.

2 One agency was an outlier; reporting more than 1 million one-way trips. Even with this outlier removed, no statistical differences emerged. We did not assess distances of trips or the type of service provided (i.e., door-to-door, curb-to-curb, fixed route, extended hours, etc.).

**References**


Government Accountability Office. 2004. *Transportation-disadvantaged seniors: Efforts to enhance senior mobility could benefit from additional guidance*


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An Evaluation of Los Angeles’s Orange Line Busway

Richard Stanger, Consultant

Abstract

The new 14.2-mile Orange Line Busway opened in October 2005. Many aspects of the Orange Line’s design should be copied elsewhere: its attractive guideway and stations, state-of-the-art buses, proof-of-payment fare collection, and well-done environmental mitigations. On the other hand, a typical Orange Line bus trip catches about 11 red lights and waits up to nine minutes for them to change. Its end-to-end travel speed is 20 mph. The travel time is also compromised by a 25 mph speed restriction at all intersections and speed limits along other portions of the busway.

The lesson of the Orange Line to transit planners is that an at-grade busway will almost certainly not get signal preemption. This means it will not have the crossing gates that allow its buses to cross intersections at speed. Therefore, every other effort should be made to increase a busway’s travel speed through off-board fare collection, well-located platforms, minimal speed restrictions, and quick transferring to connecting services. A busway will be less expensive to build than a light rail alternative, but without signal preemption its travel speed will be significantly less.

A light rail alternative for the Orange Line would have had required crossing gates. Even if trains operated at the same lower speeds as buses within median rights-of-way, they would have been much faster (29 mph) and offered a more stable ride quality.
Introduction

This article reviews the operation of Los Angeles’s new Metro Orange Line busway. It is intended to help transit planners assess both the benefits and drawbacks of such a project. Local conditions will always determine the design specifics of a capital project, but often designs in one community build from designs—good or bad—for similar facilities elsewhere. The article also examines the supposition that the Orange Line operates like a light rail line.

Project Description

The Orange Line is a 4.2-mile busway on an old railroad right-of-way running east-west across Los Angeles’s San Fernando Valley. Its eastern end feeds the northern terminus of the Red (rapid transit) Line to downtown Los Angeles; its other end serves Warner Center, a locus of office towers to the west (see Figure 1). The project serves several colleges and civic centers along its routes, but the predominant adjacent land use is residential. In June 2006, the busway carried almost 21,000 daily trips.

Operationally, the Orange Line is an end-to-end trunk line using articulated, low-floor buses. Its scheduled run time is 42 minutes. Its headways are 5 minutes during the peaks, 10 minutes mid-day, and 20 minutes after 7:45 pm. The right-of-way has 33 street crossings, and bus speeds at these crossings are restricted to 25 mph by policy. After several early car-bus accidents, the crossing speed was further restrained to 10 mph, but this is expected to be temporary. Buses operate between crossings at maximum speeds of either 35 mph (within the median of a city street), 45 mph, or 55 mph depending on the line section.

The service was the result of a 20-year effort to clear and approve a light rail line. Perhaps for this reason the new service was described as “a train on rubber tires” during start-up ceremonies (Fanfare Greets Start of Orange Line Buses 2005, quote by MTA Chief Executive Director Roger Snoble). The articulated buses were “to mimic the metallic look and spacious feel of a passenger rail car” (Fanfare Greets Start of Orange Line Buses 2005, description of buses by staff writer Caitlin Liu). The line was named a color as are the Los Angeles County Metropolitan Transit Authority’s (MTA) subway and light rail lines and is shown on the MTA’s rail system maps.
Figure 1. Orange Line Alignment
History of Planning the Orange Line

Proposition A was approved by Los Angeles County voters in 1980. It provided a half-cent sales tax in part for a rail system to be built within 13 designated “Prop A” corridors. One of these broad corridors was east-west across the San Fernando Valley from North Hollywood to the Warner Center area. In 1984 it was designated one of six high-priority corridors for implementation. The preferred alignment within this corridor was Southern Pacific’s Burbank Branch, and the preferred mode was light rail.

Transit planners began developing a light rail line generally following the Burbank Branch right-of-way in 1985. Years of planning efforts followed. Community opposition to the rail project centered on the perception of lowered property values and system noise, although a general fear of change was also apparent. Major related reports were published in 1986, 1987, 1990, 1992, 1994, 1998, and 2000. The last report was the first to adopt a busway concept. The communities resisted the busway as well, but after 15 years of fighting, they realized some improvement was inevitable—and the MTA forcefully resisted further opposition. The decision to build the line was made in 2001, construction started in 2002, and the busway was inaugurated in October 2005.

Little discussion of bus operations is found in the environmental documents. Summary tables project end-to-end travel times between 8.8 minutes and 40.0 minutes. The goal of the project was very fast service. There is no indication in the environmental documents that bus cruising speeds would be limited to 35 mph and 45 mph for most of the busway. Nor is there any indication that bus crossing speeds would be restricted to 25 mph at all intersections. As to signal priority, there is only this disclaimer: “Precise signal timing and priority parameters would not be set until just prior to the commencement of BRT operations and would likely be adjusted throughout the life of the project.”

The Busway Design

In designing the busway, engineers had the advantage of being able to use an existing railroad right-of-way across an almost flat urban setting. The right-of-way is typically 100 feet wide, but varies from 70 to 200 feet. The bus roadway itself is 26 feet wide with one lane in each direction. At platforms, the roadway widens on one side to 23 feet, which allows a bus to pass another in case of breakdowns. There are also 50 pullouts along the busway primarily for maintenance vehicles to
park; these are typically 70-feet long and 10-feet deep. The alignment is capable of supporting maximum operating speeds of 55 mph.

The busway appears to be an asset to the communities along it route. It provides easy east-west access to important Valley destinations. It replaces an unused dirt right-of-way prone to trash dumping with a very attractively landscaped improvement offering some sound walls, pedestrian crosswalks, and the continuous bike-way. Unlike a light rail line (or the freight train traffic up to the late 1980s), there is no mandated horn noise associated with bus crossings at intersections.

**Busway Stations and Access**

The Orange Line has 12 stations within the railroad right-of-way portion of the line. Each has sidewalk-level platforms, canopied, long enough for two buses, and equipped with passenger information displays. Fare collection is by off-bus ticket vending machines and fare enforcement is proof of payment (on-board random checking with fines). Table 1 summarizes the platform location and access facilities of the stations.

<table>
<thead>
<tr>
<th>Station</th>
<th>Platform Location</th>
<th>Connecting N-S Bus Routes</th>
<th>Parking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warner Center</td>
<td>Sidewalk</td>
<td>8</td>
<td>No</td>
</tr>
<tr>
<td>DeSoto Avenue</td>
<td>Far Side</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Pierce College</td>
<td>Far Side</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>Tampa Avenue</td>
<td>Far Side</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>Reseda Avenue</td>
<td>Far Side</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Balboa Avenue</td>
<td>Westbound–Near Side</td>
<td>4</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Eastbound–Far Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodley Avenue</td>
<td>Far Side</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>Sepulveda Avenue</td>
<td>Not at Cross Street</td>
<td>1</td>
<td>1,179</td>
</tr>
<tr>
<td>Van Nuys Blvd.</td>
<td>Westbound–Near Side</td>
<td>7</td>
<td>824</td>
</tr>
<tr>
<td></td>
<td>Eastbound–Far Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodman/Oxnard</td>
<td>Westbound–Near Side</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Eastbound–Far Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valley College</td>
<td>Westbound–Near Side</td>
<td>3</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Eastbound–Far Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laurel Canyon</td>
<td>Far Side</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>North Hollywood</td>
<td>Near Side Terminal</td>
<td>1 convenient,²</td>
<td>K&amp;R</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 others, Red Line</td>
<td></td>
</tr>
</tbody>
</table>

1. Local bus route 164 parallels the Orange Line from Warner Center along Victory to the Sepulveda and Van Nuys Stations. Local bus route 156 parallels the line from Van Nuys to North Hollywood.
2. A major bus center is located east of the Red Line Station, but it starts 400 feet from the busway alighting platform west of Lankershim Boulevard.
The Traffic Signal Control System

The City of Los Angeles Department of Transportation (LADOT) now has 3,200 of its 4,300 intersections tied into its Automated Traffic Surveillance and Control (ATSAC) system. The ATSAC system improves the flow of traffic by coordinating the phasing and timing of green lights. LADOT developed an added feature, the Transit Priority System (TPS), to ATSAC to give buses on key bus routes up to 10 percent more signal cycle time if delayed. The Orange Line busway crossing signals are tied into the ATSAC/TPS system.

LADOT modeled a possible busway before it was officially adopted by the MTA. From this work, it was determined that signal priority was possible for the busway, but not full-signal preemption (any approaching bus causes crossing motorists to stop). LADOT calculated a total of one million daily north-south auto trips across the 33 Orange Line intersections; these trips needed as much green signal time as possible. Traffic engineers also recommended far-side platforms wherever possible because it would be more difficult to pretime the following traffic signal with a near-side station dwell of unknown duration. Crossing gates were considered, but were ruled out by LADOT because its traffic engineers felt that motorists did not require the same level of crossing protection from buses as they did from light rail trains. The need to lower crossing gates in advance of a bus’s arrival would also unnecessarily lengthen delays to the heavy north-south traffic. Although LADOT made its decisions for the Orange Line, the resulting busway operation is similar to that of the South Miami Busway and may reflect an emerging consensus among traffic engineers on how an at-grade busway should be operated.

As the MTA conducted prerevenue operations testing, LADOT engineers refined the timing of the signal priority system. It operates a little like a “green wave” assuming that buses travel at their posted speeds, have station dwell times of about 20 seconds, and cross intersections at 25 mph. But even then LADOT engineers estimate that a bus trip typically catches red lights at a third of the intersections (11 red lights), an average consistent with a dozen field trips made. The system is also designed to retain the scheduled headway. This means that if a bus is behind schedule, it is given more green time to help it catch up to the timetable, but the trailing buses are given no priority to preserve the timetable. If a lead bus is well behind schedule, all the following buses may be as well—but evenly spaced. The LADOT’s traffic monitoring center can follow the movement of each Orange Line bus by its on-board transponders and intersection cameras. The transponders
are also used to inform patrons when the next bus is due using automated station message boards.

**Project Costs**

The forecasted construction cost of the project is $290 million. It was funded through local Proposition C ($150.2 million), State of California ($145.0 million), and federal ($17.5 million) dollars.\(^3\) Table 2 shows the project’s costs by major cost categories.

**Table 2. Orange Line Project Forecasted Costs (millions)**

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Current Forecast(^1)</th>
<th>Percentage of Total</th>
<th>Cost per Unit(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideway</td>
<td>$136.2</td>
<td>34.8%</td>
<td>$10.1/bswy-mile</td>
</tr>
<tr>
<td>Systems and Equipment</td>
<td>$9.1</td>
<td>2.3%</td>
<td>$0.7/bswy-mile</td>
</tr>
<tr>
<td>Stations</td>
<td>$30.4</td>
<td>7.8%</td>
<td>$2.3/station</td>
</tr>
<tr>
<td>Vehicles and Buses</td>
<td>$16.7</td>
<td>4.3%</td>
<td>$1.1/mile</td>
</tr>
<tr>
<td>Special Conditions(^3)</td>
<td>$34.6</td>
<td>8.9%</td>
<td>$2.4/mile</td>
</tr>
<tr>
<td>Misc. Rights-of-Way</td>
<td>$13.4</td>
<td>3.4%</td>
<td>$1.0/bswy-mile</td>
</tr>
<tr>
<td>Yards and Shops</td>
<td>$1.2</td>
<td>0.3%</td>
<td>$1.2/project</td>
</tr>
<tr>
<td>Professional Services</td>
<td>$47.0</td>
<td>12.1%</td>
<td>$3.3/mile</td>
</tr>
<tr>
<td>Contingency</td>
<td>$2.1</td>
<td>0.5%</td>
<td>$0.2/mile</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$290.0</td>
<td>74.4%</td>
<td>$19.4/mile</td>
</tr>
<tr>
<td>RR, Drive-in, and Misc.</td>
<td>$100.0</td>
<td>25.6%</td>
<td>$7.4/bswy-mile</td>
</tr>
<tr>
<td>Rights-of-Way</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$390.0</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>$27.4/mile</strong></td>
</tr>
</tbody>
</table>

2. "Bswy-mile" = mileage of busway itself (13.5), "miles" = project miles (14.2).
3. Includes costs associated with environmental mitigation and compliance, master cooperative agreements, insurance programs, safety program, artwork, and systems integration testing.

In 1990 the LACTC purchased the entire 20-mile Burbank Branch and adjacent railroad properties for $122.1 million. Of the busway’s 14.2 miles, 13.5 miles were built on the right-of-way, which can be conservatively valued at $85 million. The Sepulveda Boulevard Station’s parking lot—an old drive-in theater—was purchased in 1991 for about $15 million. These costs do not show up in the official project budget, but have been included in Table 2.
The $27.4 million per mile for the Orange Line is substantially less than MTA’s cost per mile for its light rail lines. The Gold Line averaged about $65 million per mile, all costs included, and the Blue Line around $45 million, both in earlier dollars. The Exposition Line is projected to cost $70 million per mile by the time it starts operations in 2010. At $65 million per mile, an Orange (light rail) Line would have cost $925 million.

The City of Los Angeles contributed an additional $10.6 million for the bikeway. Portions of the bikeway already existed and others used existing city streets. The newly built segments totaled 8.2 miles, an average of $1.3 million per mile.

**Busway Operations**

The Orange Line operates as a trunk line feeder to the Red Line. Only new, articulated, low-floor buses painted specially for this service use the busway. Other buses do not merge into the busway at interim stations. However, the type of service one would associate with a busway (or light rail line) operating over its own right-of-way—high operating speeds and no delays—is compromised on the Orange Line in five ways.

**Signal Priority**

LADOT feels that blending the busway into its ATSAC/TPS system is the optimal solution. But it is disconcerting that buses catch an average of 11 red lights per trip. These delays are compounded because half the red light delays occur just before a subsequent far-side station dwell.

**Restrictions to Maximum Speed**

Maximum speeds are restricted along most portions of the busway to conform to neighborhood desires or to provide additional safety. Buses proceed at 35 mph from the North Hollywood Station along Chandler Boulevard to Woodman Avenue (2.6 miles), the most community-sensitive portion of the Line; 45 mph from Woodman Avenue to Sepulveda Boulevard (2.9 miles); 55 mph through the Sepulveda Basin (4.2 miles); then back to 45 mph from Reseda Boulevard to the end of the busway (3.8 miles).

**Slowing at Grade-Crossings**

All Orange Line buses initially slowed to 25 mph at all intersecting streets. The reason given for this is that bus-car accidents are more dangerous for bus passengers (than for light rail passengers) and more caution is therefore needed. After a series
of bus-car accidents in the first month of operation, the bus crossing speed was (temporarily) dropped to 10 mph. (In practice, bus drivers rarely cross an intersection below 15–20 mph, in part because the timetable and the ATSAC system timing were not changed.)

**North Hollywood Station Terminal Design**

The east end of the Orange Line ends just west of Lankershim Boulevard (see Figure 2). Across the street are the Red Line Station entrances and, further east, the Red Line’s bus center where six bus routes come together. Most Orange Line riders transfer to (or from) the Red Line and must walk at least 400 feet to the Red Line escalators and cross busy Lankershim Boulevard. An additional 50 feet more is required to get to and from the bus center. Three reasons are given by planners and engineers for this design:

1. A west-side pedestrian entrance to the Red Line mezzanine was planned, but its estimated $10 million cost was not affordable.
2. If the busway were to continue across Lankershim Boulevard, the Red Line station’s entrance plaza would have had to be reconfigured or even sacrificed.
3. Another intersection with Lankershim Boulevard would have been too disruptive for traffic in this busy area.

None of these points seem to outweigh the huge on-going passenger inconvenience caused by this poor interface.

**Bicycle Policy**

Because of the side sway of a bus, bicycles brought on-board must be anchored for passenger safety. The bus driver must leave his seat and supervise the loading; unloading is typically done by the bicycle’s owner. The results are station dwell times of 2 to 3 minutes for bicycle loading (compared with wheelchair loading times of less than a minute). The resulting scheduled delays, albeit only on occasional trips, makes this policy decision questionable.

**Alternative Busway Operating Scenarios**

Using engineering drawings of the busway, a run-time model was developed that allows the effects of different operating assumptions to be compared (Los Angeles County Metropolitan Transportation Authority 2002). The model calculates the accelerating, cruising, and braking times and distances for each line segment that
requires the bus to alter speed (e.g., intersections, stations, curves). It accumulates these times (plus station dwell) and distances over the length of the project. The model also incorporates “delay” time caused by red lights, etc. The result was calibrated against the Orange Line timetable by making adjustments to the “delay” times. Below are descriptions of the operating scenarios evaluated. They are summarized in Table 3.

- **Existing Service (Base Case).** 25 mph at cross streets, restricted maximum speeds, experienced delays from red lights, and 20-second average dwells.
- **Buses Slowing to 10 mph at Crossings.** Same as the base scenario except that buses slow to 10 mph at crossings, the temporary condition.
- **Signal Preemption.** No red lights are encountered, buses slow to 25 mph at street crossings. The difference between the base case time and this run’s time approximates the total delay for expected red light delays.
- **Speed at Crossings.** This means, for example, in the 35 mph maximum speed zone, buses cross an intersection at 35 mph.
- **55 mph Through Intersections.** This scenario treats the buses the same as light rail trains, and would probably require gated crossings at all intersections.

### Table 3. Assumptions for Alternative Busway Operating Scenarios

<table>
<thead>
<tr>
<th>Operating Scenario</th>
<th>25 mph at Crossings</th>
<th>Signal Priority</th>
<th>Restricted Max Speed</th>
<th>20-sec Dwell</th>
<th>Gated Crossings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base: Existing Service</td>
<td>yes</td>
<td>existing</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>10 mph Crossings</td>
<td>no</td>
<td>existing</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Signal Preemption</td>
<td>yes</td>
<td>complete</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Speed at Crossings</td>
<td>no</td>
<td>complete</td>
<td>yes</td>
<td>yes</td>
<td>1</td>
</tr>
<tr>
<td>55 mph Throughout</td>
<td>no</td>
<td>complete</td>
<td>55 mph</td>
<td>yes</td>
<td>all</td>
</tr>
</tbody>
</table>

Table 4 summarizes the resulting end-to-end travel times. The initial operating scenario is the base case, and its run time is 42 minutes as per the timetable. Giving Orange Line buses signal preemption—even though crossing speeds remain 25 mph—would save the most amount of time and raise the average travel speed the most. Allowing buses to cross intersections at the prevailing posted busway speeds further lowers travel time by 2.4 minutes. Finally, allowing buses to travel at a maximum speed of 55 mph throughout lowers travel time only 1.8 minutes.
more. Table 4 illustrates the importance of getting buses through red lights: up to 9 minutes could be saved if there were none.

Table 4. Busway Time Savings/Losses with Various Operating Assumptions

<table>
<thead>
<tr>
<th>Busway Operating</th>
<th>End-to-End Travel Time (minutes)</th>
<th>Average Travel Speed (mph)</th>
<th>Additional Time Savings (minutes)</th>
<th>Additional Time Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mph Crossings</td>
<td>46.6</td>
<td>18</td>
<td>- 4.6</td>
<td>- 11%</td>
</tr>
<tr>
<td>Base: Existing Service</td>
<td>42.1</td>
<td>20</td>
<td>0.0</td>
<td>0%</td>
</tr>
<tr>
<td>Signal Preemption</td>
<td>32.7</td>
<td>26</td>
<td>+ 9.4</td>
<td>+ 22%</td>
</tr>
<tr>
<td>Speed at Crossings</td>
<td>29.7</td>
<td>29</td>
<td>+ 3.0</td>
<td>+ 7%</td>
</tr>
<tr>
<td>55 mph Throughout</td>
<td>27.8</td>
<td>31</td>
<td>+ 1.9</td>
<td>+ 5%</td>
</tr>
</tbody>
</table>

Alternative Light Rail Scenarios
The Orange Line has been described as a rail line using rubber tires. Is it? To determine the travel times for the Orange Line were it in fact light rail, the same travel time model was used, but with the acceleration/deceleration profiles of the MTA’s light rail vehicles. As is standard design for light rail, all intersections have crossing gates that give light rail trains automatic signal preemption. Is it fair, then to compare the Orange Line without signal preemption with LRT with it? Yes, because each is being operated as it normally would in an urban setting. Table 5 summarizes the LRT operating scenarios.

Table 5. Assumptions for Alternative Light Rail Operating Scenarios

<table>
<thead>
<tr>
<th>Operating Scenario</th>
<th>25 mph at Crossings</th>
<th>Signal Priority</th>
<th>Restricted Max Speed</th>
<th>20-Sec Dwell</th>
<th>Gated Crossings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed at Crossing</td>
<td>no</td>
<td>complete</td>
<td>yes</td>
<td>yes</td>
<td>all</td>
</tr>
<tr>
<td>55 mph Throughout</td>
<td>no</td>
<td>complete</td>
<td>55 mph</td>
<td>yes</td>
<td>all</td>
</tr>
<tr>
<td>65 mph Throughout</td>
<td>no</td>
<td>complete</td>
<td>65 mph</td>
<td>yes</td>
<td>all</td>
</tr>
</tbody>
</table>

The resulting travel times are shown in Table 6. The base case for light rail results in an end-to-end travel time of 29 minutes. This time includes the 35 mph running along Chandler, 45 mph to Sepulveda, and 45 mph between White Oak and the
end of the railroad right-of-way. Allowing the light rail trains to travel at 55 mph throughout (except, of course, in Warner Center) lowers the total travel time by another 2.2 minutes.

**Table 6. Light Rail Time Travel Times with Various Operating Assumptions**

<table>
<thead>
<tr>
<th>Light Rail Operating Scenario</th>
<th>End-to-End Travel Time (minutes)</th>
<th>Average Travel Speed (mph)</th>
<th>Additional Time Savings (minutes)</th>
<th>Additional Time Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed at Crossing</td>
<td>29.0</td>
<td>29</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>55 mph Throughout</td>
<td>26.8</td>
<td>32</td>
<td>+ 2.2</td>
<td>+ 8%</td>
</tr>
<tr>
<td>65 mph Throughout</td>
<td>26.5</td>
<td>32</td>
<td>+ 0.3</td>
<td>+ 1%</td>
</tr>
</tbody>
</table>

The Orange (busway) Line’s operating performance cannot be compared favorably to an Orange (light rail) Line’s performance. A light rail line is much faster and more reliable because its crossing gates would allow it to avoid red lights. (Both wheelchairs and bicyclists could also board and alight within a normal 20-second station dwell.)

**Comparison with a Rapid Bus Route**

Local bus route 164 serves the Warner Center transit hub and from there to Van Nuys Boulevard it parallels the Orange Line alignment and serves four of its stations directly. It arrives at Van Nuys and Victory, one-half mile north of the busway station, and, were it to turn south, it could serve the Van Nuys Station within 34 minutes. Local bus route 156 serves the Van Nuys Station and then proceeds south and east to the North Hollywood Station. The end-to-end travel time of the combined two local routes is 57 minutes over a 15.4-mile length. The combined route would directly serve nine of the Orange Line’s 13 stations and be within one-half mile of the others.

If the combined route were to be converted into a rapid bus service, however, its end-to-end travel time would be much closer to the busway’s. To calculate its run time, the run-time model was calibrated for local bus routes 164 and 156. Then the number of bus stops was reduced from the existing 3.7 per mile to 1 per mile, the same spacing as the Orange Line. The same speed restrictions and signal delays encountered with the local buses were retained, although a rapid bus service
would receive some level of signal priority not calculated here. Orange Line articulated bus speed profiles were also substituted for regular local bus profiles.

The results are shown in Table 7. The end-to-end travel time drops to 44 minutes, almost that of the busway’s travel time. Capital costs associated with a rapid bus line would be an estimated $50 million including new buses, passenger information systems, upgraded stations/stops and support facilities.

### Table 7. Rapid Bus Time Travel Time

<table>
<thead>
<tr>
<th>Bus Scenario</th>
<th>End-to-End Travel Time (minutes)</th>
<th>Average Travel Speed (mph)</th>
<th>Additional Travel Time Savings (minutes)</th>
<th>Additional Travel Time Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Bus #164 &amp; 156</td>
<td>57</td>
<td>16</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rapid Bus Route</td>
<td>44.4</td>
<td>21</td>
<td>+12.6</td>
<td>+22%</td>
</tr>
</tbody>
</table>

The rapid bus alternative does have operational limitations. It is not on a protected, well-defined, transitway, which in and of itself is a great benefit to the San Fernando Valley. Over time, as San Fernando Valley traffic congestion builds, the rapid bus line may also become a slower service.

**Summary**

Table 8 presents the various travel times for all Orange Line options and their estimated costs. While the Orange Line does provide travel times substantially less than local bus services, it is not much better now than a rapid bus service. Light rail would have been the fastest and most reliable alternative, taking advantage of rail’s crossing gates and better rate of acceleration. Its capital cost, however, would have been the highest of all alternatives. Much of the cost for both the busway and the light rail alternatives entails assuring long-term schedule reliability, and this must be factored into any evaluation. The busway in turn should be more reliable than a rapid bus service operating on city streets.
Table 8. Summary of Orange Line Alternatives

<table>
<thead>
<tr>
<th>Operating Scenario</th>
<th>End-to-End Travel Time</th>
<th>Average Speed</th>
<th>Estimated Capital Cost</th>
<th>Long-term Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Bus Routes 164 and 156</td>
<td>57 minutes</td>
<td>16 mph</td>
<td>-</td>
<td>Low</td>
</tr>
<tr>
<td>Rapid Bus</td>
<td>44 minutes</td>
<td>20 mph</td>
<td>$50 million (estimate)</td>
<td>Fair</td>
</tr>
<tr>
<td>Busway</td>
<td>42 minutes</td>
<td>20 mph</td>
<td>$390 million</td>
<td>Good</td>
</tr>
<tr>
<td>Light Rail</td>
<td>29 minutes</td>
<td>29 mph</td>
<td>$925 million (estimate)</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

Conclusions

The Orange Line is a significant transit addition to the San Fernando Valley, providing direct access for communities along its route to important centers as well as to the Red Line. It is well designed as a roadway, well landscaped, and offers additional community benefits. It uses state-of-the-art, low-floor buses and takes advantage of the guideway and buses by using proof-of-payment fare collection. It is important to emphasize that planning of the Orange Line was a collaborative effort between the MTA and LADOT.

The operation of the Orange Line has been compromised, however, by a signal priority system that ended up less than what its planners and officials anticipated. It is here where other systems can learn important lessons.

- Traffic engineers appear to be very reluctant to give busway buses signal preemption with or without crossing gates. As a result, potential travel speeds on an at-grade busway are substantially compromised.
- A transit agency should be reluctant to build a busway without guarantees that signal preemption will be provided. But if it goes ahead with less than preemption, it should do a careful study of how to minimize delays: closing crossings, the fewest possible red lights, well-located platforms to minimize the double-stop penalty of far-side stops, quick and easy transferring at end-points, and fare collection and other policies that lessen delays. If signal preemption cannot be obtained during peak periods, it may well be acceptable off-peak and on weekends.
- When spending so much for a busway, crossing gates for buses are a good
investment to assure full signal preemption and higher operating speeds. This is the case even if bus speeds are restricted at crossings.

The analysis also shows it is not correct to equate the Orange Line Busway (or any similar at-grade busway) with a light rail line. Instead of an average end-to-end trip time of 42 minutes (20 mph), even a speed-restricted light rail line would have taken no more than 29 minutes (29 mph), a 31 percent drop in travel time. The ride quality of a light rail line would also be better.

This analysis does not conclude that the Orange Line should have been a light rail line. The Orange Line could not have been a light rail line because community opposition to that mode was clear and enduring. Nor does the analysis conclude that the Orange Line busway should not have been built; the San Fernando Valley is better served by a busway than a rapid bus route on ever-congested city streets. Given the availability of the Burbank Branch right-of-way, not using it as some form of transitway would have been unthinkable.

The MTA must continue to find ways to increase the Orange Line’s travel speeds, correct the very unfortunate North Hollywood Station transfer, and seek increased signal priority for its buses, up to and including crossing gates.

Endnotes

1 In June 2006 the MTA changed the Orange Line’s timetable. In the eastbound direction and throughout the day, up to 3 minutes were added to the earlier run times, often all 3 minutes between the last two stations. In the westbound direction run times decreased by up to 2 minutes, but never increased. For this analysis the original 42-minute schedule is used.

2 See Los Angeles County Metropolitan Transportation Authority 2004, Table RS-4a: Refinements to Locally Preferred Alternative.

3 See Los Angeles County Metropolitan Transportation Authority 2004.

4 Crossing gates are required by the California Public Utilities Commission for light rail trains above 35 mph in large part because a loaded light rail car weighs 110,000+ pounds and a collision with a railcar may well be fatal. Bus movements are controlled locally by traffic engineers. (A loaded 60-foot bus weighs 44,000 pounds.)
These figures total $313 million, the total funds anticipated for the project. The forecasted budget was $290 million in June 2006 with the project virtually complete.

On the advice of MTA staff, the model used the APTA guidelines for the acceleration and deceleration of articulated buses, which are compatible with Orange Line bus performance curves.

References


Los Angeles County Metropolitan Transportation Authority. 2002. San Fernando Valley east-west BRT project, bid-level drawings (June 14).

Los Angeles County Metropolitan Transportation Authority. 2004. Draft revised final environmental impact report Vol. 4, Chp. 8, p. RS-44 (October)


About the Author

Richard Stanger (stangerr@verizon.net) is a transportation consultant in Los Angeles. He received a masters in both urban engineering and city planning from the University of Pennsylvania. Between 1985 and 1990 he was director of Rail Development with the Los Angeles County Transportation Commission and between 1990 and 1998 was executive director of the Southern California Regional Rail Authority (Metrolink). Over the years he has published a number of articles on various aspects of urban transit.