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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
Bus Priority at Traffic Signals—
Evaluating Strategy Options

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Abstract

This article compares different strategy options for providing bus priority at traffic signals. The different strategies considered vary in the strength of the priority awarded and in the selection of the buses that are to receive priority. The strategies include so-called differential priority, where buses receive individual priority treatment according to some criterion such as lateness, and nondifferential priority, where all buses are treated in the same way.

The strategies are compared using a simulation model, SPLIT, that has been developed and validated by the authors. The article describes some of the modelling issues that are involved in simulating bus priority systems and how they have been treated within the SPLIT model.

Introduction

Bus transit priority at traffic signals has been used in many cities worldwide and is becoming increasingly accepted as a way in which bus operations can be improved, complementing other measures such as bus lanes and automated ticketing arrangements. One of the reasons why the use of bus priority at traffic signals is widespread is that it can be applied almost anywhere, as there is no need for additional road space for buses or for buses to be segregated from general traffic. Example applications of bus priority at traffic signals include London, Tokyo,
Melbourne, and Portland, Oregon. The state-of-the-art in bus priority applications in Europe was reviewed by Hounsell and Wall (2002).

This article describes research undertaken in a European Union funded project, PRISCILLA, investigating the performance of different bus priority strategies. These strategies differed from one another in terms of the strength of the priority actions taken and in the selection of which buses to give priority to. The form of priority where different buses are awarded different levels of priority, usually according to a bus lateness criterion, is known as differential priority.

The majority of reported bus priority applications tend to be implemented on a single bus corridor or on a small number of bus corridors. One of the objectives of this research was to widen the application to consider bus priority over a citywide bus network. The city used here was Southampton in the United Kingdom.

The research was based on the bus priority facilities available within the SCOOT traffic signal control system, as developed by the Transportation Research Laboratory (TRL) in the United Kingdom (Bretherton et al. 1996). Updated details of these facilities are reported at the website: http://www.scoot-utc.com/SCOOTFacilities/busprior.htm. The basic priority actions that can be taken under this control system are to give an approaching bus extra green time to get through the junction or to recall the required signal phase sooner than would be done otherwise. Since these priority actions are fundamental to the majority of bus priority control systems, the results presented here will be of general interest and application.

Assessment of different bus priority strategies was undertaken using a simulation model, Selective Priority to Late buses Implemented at Traffic signals (SPLIT), that has been designed and developed by the authors since 1996 (McLeod 1998). This article includes details of some features of this model, including the modelling of buses, passengers, nonpriority traffic, and how they interact with each other.

The network used was based on the City of Southampton in the United Kingdom. The article describes the network topology, bus services modelled, routes taken, and numbers of traffic signals encountered. Results and conclusions from the simulation runs of the different bus priority strategies are described.

**The Bus Priority System**

The research presented here was based upon the bus priority facilities available within the SCOOT traffic signal control system (Bretherton et al. 1996). This
section provides a brief description of these facilities and gives details of the priority strategies considered.

**Priority Levels**

Different levels of priority can be awarded to different buses, typically according to the lateness of the individual bus. Each priority level is defined by parameters that specify the traffic degree of saturation conditions under which the bus is allowed to receive either:

1. a signal *extension*, where the bus is detected on a green signal aspect, which is maintained until the bus passes by, or
2. a signal *recall*, where the bus is detected on a red signal aspect, whose length is reduced so that the desired green signal aspect comes around quicker.

These degree of saturation parameters can be used to constrain the bus priority actions, where desired, to ensure that delays to nonpriority traffic streams are acceptable. Clearly, the definition of “acceptable” here is a question of policy and will depend on a number of political factors.

Four different priority levels were considered in this research (Table 1).

**Table 1. Priority Levels**

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Priority Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No priority</td>
</tr>
<tr>
<td>1</td>
<td>Signal extensions only (no recalls)</td>
</tr>
<tr>
<td>2</td>
<td>Extensions and recalls (constrained: degree of saturation of nonpriority traffic stream not allowed to exceed 95% as a result of any bus priority action)</td>
</tr>
<tr>
<td>3</td>
<td>Extensions and recalls (unconstrained)</td>
</tr>
</tbody>
</table>
Priority Strategies
A number of different priority strategies were considered, varying both in the level of priority awarded and in the buses that receive the priority. The priority strategies are described below.

Priority strategy P0—No Priority.

None of the buses in the network are given priority. This is the base case against which the other priority strategies are compared.

Priority Strategy P1—Extensions Only.

All buses in the network are awarded traffic signal extensions, where required, but traffic signal recalls are not awarded to any bus. This is a moderate form of priority that, from previous experience, has little or no negative effect on nonpriority traffic.

Priority Strategy P2—Priority to Late Buses Only.

Buses that are late receive the highest priority level, while buses that are on time or early do not receive any priority.

Priority Strategy P3—Hybrid of P1 and P2.

In this strategy buses that are late receive full priority while other buses are eligible for a traffic signal extension only. This may be justifiable because extensions provide substantial delay savings to the small proportion of buses (~10%) for which an extension is appropriate.

Priority Strategy P4—Full Priority.

The highest level of priority is awarded to all buses. This is the most extreme, strongest priority strategy possible and the most likely to have a negative effect on nonpriority traffic.

Central or Local Control
Traffic signal extensions can be controlled by the central SCOOT computer or by the local traffic signal controller. The main advantage of local control is that a faster response to buses can be achieved than through central control, which incurs delays due to transmission lags between the local traffic signal controller and the central SCOOT computer. A fast response is particularly important for the awarding of a traffic signal extension, as it has a direct influence on the “window of
opportunity" for gaining an extension. The effect of a transmission lag of $x$ seconds is equivalent, in effect, to detecting the bus $x$ seconds closer to the stopline. In practice, central control is often preferred, however, as it is easier to set up and maintain.

**Restricting Recalls**

Previous experience of bus priority applications in London (Hounsell et al. 1996) found that traffic signal recalls can sometimes have a damaging effect on nonpriority traffic. This is particularly true when the nonpriority traffic flow is high, as can happen when the priority bus turns into a busy main road from a side road. One of the reasons for this negative effect is the resulting loss of good traffic signal coordination on the main road. Bearing this in mind, it seems sensible to restrict traffic signal recalls to junctions where the total volume of nonpriority traffic, summed over all of the nonpriority traffic arms, is below some specified limit. For the purposes of this research, a limit of 1,500 vehicles/hour was specified and simulation runs were made to investigate the effects.

**Simulation Network Details**

The bus priority system was modelled using a simulation model, SPLIT, developed by the authors since 1996. Details of the model and its validation are provided by McLeod (1998). The following sections provide information about some of the modelling aspects of the research, including modelling of the buses, passengers, other traffic, and their interactions.

**Bus Network**

The bus network used was based on the City of Southampton, United Kingdom. Southampton has a population of around 215,000 but with a travel to work area population of approximately 500,000. It is a regional center with the port as the main industry. Southampton is constrained by the sea to the south and two rivers that dissect the City. As with most cities throughout the world, the City council’s policies limit the use of private transport within the highly developed area and promote the use of public transport.

The modelled network consisted of six bus services operating on overlapping routes. These bus services run between the city center to the south and Southampton Airport and the University of Southampton at the northern end of the City. Details of these bus services are shown in Table 2.
Table 2. Bus Services in Southampton SPLIT Network

<table>
<thead>
<tr>
<th>Route No.</th>
<th>No. of Bus Stops</th>
<th>Bus Frequency (bus/hr)</th>
<th>Route Length (km)</th>
<th>Average No. of Users (passenger/bus)</th>
<th>No. of Traffic Signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>30</td>
<td>3</td>
<td>7.7</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>31</td>
<td>3</td>
<td>8.1</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>13</td>
<td>29</td>
<td>3</td>
<td>8.1</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td>2</td>
<td>8.8</td>
<td>36</td>
<td>14</td>
</tr>
<tr>
<td>102</td>
<td>21</td>
<td>2</td>
<td>8.8</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>103</td>
<td>10</td>
<td>2</td>
<td>4.6</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

Key: No. of users = total number of boarding passengers

Bus Punctuality

Bus punctuality, or lateness, was an important consideration, as it affected which buses received priority under the differential bus priority strategies (P2 and P3). Bus lateness was calculated for each bus whenever the bus departed from a bus stop and was defined to be the difference between the actual departure time and the scheduled departure time. Bus entry times onto the network were varied in the simulation runs to give a range of different starting conditions for buses, in terms of their lateness at the start of the route. An example frequency distribution of bus lateness near the start of one of the routes being modelled is shown in Figure 1. This frequency distribution was based on a sample of five day’s data collection.
**Figure 1. Frequency Distribution of Lateness**

*Route 11 Swaythling on departure*

Average Lateness = -1.5 minutes (i.e., early)
Standard deviation = 1.5 minutes

**Bus Passengers**

Passenger arrivals at bus stops in the Southampton network were obtained from on-street surveys and were used to validate the simulation model. For high frequency bus services (10-minute frequency or more), it was found that passengers tended to arrive at random. For lower frequency services, there was a tendency for passengers to time their arrival time according to the scheduled arrival time of the bus. This tendency was most marked at the lowest frequency service considered here (30-minute frequency).

**Traffic Congestion**

Bus travel times along a route vary from day to day according to a number of factors, including traffic congestion. Clearly traffic congestion will have a significant effect on bus punctuality and on any bus priority control strategy that tries to maintain buses running to schedule. Although, vehicles are not explicitly modelled within SPLIT, the effects of varying levels of traffic congestion were approximated by varying the amount of junction delay incurred at traffic signals by buses. Typical junction delays were obtained through collection of data from the traffic signal control system, SCOOT, operating in Southampton.
Results and Evaluation

The different bus priority strategies were compared through a series of simulation runs. The strategies were compared in terms of their effects on:

- bus travel cost saving (euro/hour); this was totalled over the whole bus network modelled (15 buses/hour) and reflects the effect on bus journey times through the network;
- passenger waiting cost saving (euro/hour); this was totalled over all waiting passengers (~340 passengers per hour) and reflects the regularity of the bus service and how long passengers have to wait at bus stops;
- disbenefit to nonpriority traffic (euro/hour); this was totalled over all of the nonpriority traffic flows modelled; these varied from link to link with an average nonpriority traffic flow of 1,000 vehicles/hour approximately; this measure took into account any negative impact of the priority system on nonpriority traffic;
- overall cost saving (euro/hour); that is, the aggregate of the above cost savings less the disbenefit to nonpriority traffic.

Costs for the whole network, in terms of euro/hour, were chosen as performance measures to allow a direct comparison between the different aspects of performance, namely the effects on bus journey times, passengers waiting times and delay to nonpriority traffic. Costs per bus, per passenger or per vehicle are not shown here but can be readily derived by dividing by the appropriate numbers of buses, passengers, and vehicles as stated above.

Results from the different priority strategies are compared in Figure 2.
**Figure 2. Effect of Priority Strategy**

![Bar Chart](image)

**Comparison Strategies**

**Effect on Bus Travel Time**

As one might expect, bus travel time savings increase as the priority strength is increased and as more buses receive priority.

The largest saving is seen for strategy P4, where the highest level of priority was given to all buses.

**Effect on Passenger Waiting Times**

The largest passenger waiting time saving is found for the differential priority strategy (P2), where only late buses receive priority.

A smaller waiting time saving was found for strategy P3, where late buses received full priority and other buses were eligible to receive a traffic signal extension.

Where all buses were treated identically (i.e., nondifferential priority), the effects on passenger waiting time were negligible or worse.

In the case of strategy P4, where all buses received the highest level of priority, a negative effect on passenger waiting time was found. The reason for this was that some buses in the model were ahead of schedule and were still given
priority under this scenario. In practice, it is likely that there would be some form of bus fleet control, separate from the bus priority system, to avoid buses running ahead of schedule. This result would not generally be expected.

Effect on Delay to Nonpriority Traffic

There is a negative effect on nonpriority traffic that tends to increase the more priority is given to buses. It should be explained, however, that this effect is built into the SPLIT simulation model based on measurements taken in field trials in London (Hounsell et al. 1996). Explicit modelling of traffic and their interaction with the bus priority actions taken at traffic signals is not undertaken in SPLIT.

Overall Effect

Two differential priority strategies, P2 and P3, gave the best overall results, as they had positive effects on both bus travel time and passenger waiting time and only a relatively small negative effect on nonpriority traffic.

The full priority strategy, P3, did not perform so well overall here, as bus travel time benefits were cancelled out by negative effects on passenger waiting time and disbenefits to nonpriority traffic.

**Central or Local Extensions**

The results of implementing traffic signal extensions either locally or centrally are compared in Figure 3. The priority strategy used here was to award extensions only (strategy P1). It can be seen that the overall benefit, taking both buses and

**Figure 3. Comparison of Central and Local Traffic Signal Extensions**

![Figure 3. Comparison of Central and Local Traffic Signal Extensions](chart.png)
general traffic into account, increased from around 15 euros/hour to 25 euros/hour, as a result of moving from central control to local control.

**Restricting Recalls**

The effect of restricting traffic signal recalls to those junctions where the total nonpriority traffic flow was less than 1,500 vehicles/hour is shown in Figure 4 for two different priority strategies: differential priority strategy (P2) and full priority strategy (P3). With this restriction in place, the number of recalls awarded was reduced by about 20 percent. It can be seen from Figure 4 that restricting traffic signal recalls has:

- reduced the benefits to buses,
- increased benefits to nonpriority traffic,
- for the differential priority strategy, these results have cancelled each other, and
- for the full priority strategy, there has been a small net overall benefit here, although, this result is specific to the relative bus and nonpriority traffic flows used in this simulation run, as described earlier.

*Figure 4. Restricting Number of Traffic Signal Recalls*
Conclusions
A number of different bus priority strategies have been compared. These have had different impacts on bus journey time, bus passenger waiting time and on delay to nonpriority traffic. These impacts are summarized in Table 3.

Table 3. Impacts of Priority Strategies

<table>
<thead>
<tr>
<th>Priority to Late Buses</th>
<th>Priority to Other Buses</th>
<th>Bus Passenger Travel Time</th>
<th>Bus Passenger Waiting Time</th>
<th>Nonpriority Traffic</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>extensions only</td>
<td>extensions only</td>
<td>✓</td>
<td>✓</td>
<td>0</td>
<td>✓/✓</td>
</tr>
<tr>
<td>full priority</td>
<td>none</td>
<td>✓</td>
<td>✓</td>
<td>0</td>
<td>✓/✓</td>
</tr>
<tr>
<td>full priority</td>
<td>extensions only</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓/✓</td>
</tr>
<tr>
<td>full priority</td>
<td>full priority</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓/✓</td>
</tr>
</tbody>
</table>

Key:
- 0 - no impact
- ✗ - small negative impact
- ✗* - medium negative impact
- ✓ - small positive impact
- ✓* - medium positive impact
- ✓/✓ - large positive impact

The differential priority strategies (i.e., those that target priority for late buses) give the best results, as they provide a good balance between travel time savings and passenger waiting time savings. In addition, since the number of buses that receive full priority is restricted, there is less chance of the bus priority actions having a damaging effect on nonpriority traffic.

Full priority to all buses is not generally recommended due to the possible negative impact on nonpriority traffic and since this does not usually improve the regularity of the bus service. Full priority to all buses might be advantageous where the nonpriority traffic flow is relatively insignificant in volume. This might be the case where buses travel along a major road and the side road traffic flow is low.

Care must be taken to ensure that the bus priority system does not have a serious negative effect on other traffic. This is most likely to happen as a result of awarding too many traffic signal recalls, particularly when it involves shortening the length of the main road stage. There is a strong case for restricting the number of recalls awarded to buses where the nonpriority traffic flow is high.
It is desirable to implement traffic signal extensions locally, at the traffic signal controller, rather than via the central control computer, as the opportunities for buses gaining traffic signal extensions are increased. This is due to the avoidance of the transmission lag associated with the communication between the traffic signal controller and the central computer operating the bus priority system. Anticipated benefits to bus passengers were confirmed by the simulation runs. Provision of local traffic signal extensions requires special conditioning of traffic signal controllers. This additional work could act as a barrier to implementation of local extensions and the preference of using central extensions in SCOOT.
References


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Contract Areas and Service Quality Issues in Public Transit Provision: Some Thoughts on the European and Australian Context

David A. Hensher, The University of Sydney

Abstract

The introduction of contract regimes for the provision of bus services, such as competitive tendering and performance-based contracts, is usually premised on a prior assumption that the size of the physical contract area is given and that any policies related to interactions between contract areas, such as integrated ticketing and fares, are agreed to. This article examines the evolving arguments that encourage a review of contract area sizes before reconstructing and the positions supporting the benefits of service quality-related issues such as an integrated fares policy. Given that a growing number of analysts (especially in Europe and Australia) are promoting the appeal of increasing physical contract area size to facilitate, among other reasons, an integrated fare regime, it is timely to explore the pros and cons for such reform to ensure that they are not counterproductive to the desired outcomes of a reform process. The arguments presented here caution the support for too small a number of large contract areas on grounds of internal efficiency losses and limited gains in network economics (but support amalgamating very small contract areas). Existing
empirical evidence, limited as it is, tends to support contract areas (and depots) currently serviced by fleet sizes in the range 30 to 100 regardless of urban development profile. Alternative ways of delivering cross-regional and broad-based network benefits are proposed.

Introduction
Reform of the bus sector in many countries has focussed on alternative service delivery regimes such as competitive tendering and performance-based quality contracts (see, for example, Hensher and Stanley [2003] and Preston and van de Velde [2002] for details). Two issues that arise when detailing specific reform strategies are the geographical definition of the service area (or even whether it is a single route as in London) and the flow-through implications of service quality initiatives such as integrated fares. The latter relates to the ability of a passenger to travel between public transport modes and operators on a single fare as well as potentially offering time savings.

In developing an implementation plan for performance-based contracts (such as the one developed by Hensher and Houghton [2003]), a number of commentators have raised the question of how many contracts should best be provided within a particular geographical setting. Should we take the existing contracts (and areas) or rationalize the contracts to a smaller number? Arguments proposed for fewer contract areas are mainly related to administrative coherence and passenger benefits from network integration. A concern with fewer contracts (depending on the meaning of “fewer”) is the potential loss of internal efficiency and the high risk of monopoly power and/or market dominance, with resultant pressures on government to increase subsidies beyond what currently exist and/or are in any sense optimal.

This article examines the arguments for and against a range of reform initiatives associated with the determination of the geographical size of contract areas, as well as revenue allocation and patronage benefit issues linked to integrated fares associated with cross-contract service delivery. Although the article focuses on Australia (Sydney in particular), and to a lesser extent Europe, to illustrate some of the evidence, the arguments presented are of relevance universally and are especially useful for the United States, which appears to lag behind the reform programs of Europe and Australia.
Contract Area Size and Number

The problem is that individual firms in the transportation industries provide service only over limited portions of a network, but some customers' demands extend over the entire network. The necessity of providing service from any origin to any destination requires cooperation among firms who are also expected to compete in the new environment of regulatory reform. These industries have been regulated in the past precisely to deal with the 'interconnect' and 'competitive access' issues. But the [competition policy] laws generally presume that firms should compete [in a potential if no actual sense], not cooperate. (Tye 1987: xviii)

Is there such a thing as an optimal contract area size in a geographical sense? What criteria might one apply to decide on this? Presumably the answer relates to demand-side considerations, such as network connectivity impacts (economies of scope through networks, integrated fares, etc.), and the supply-side, in terms of cost and service delivery efficiencies. It is not dissimilar to the arguments on the optimal number of firms in an industry.a

There are two issues (at least) to address: (1) what likely changes in network service delivery are desired and can be achieved by amalgamating contract areas that cannot be achieved by alternative strategies, such as establishing network alliances (even incentive-based ones9) within the existing contract area regime; and (2) will such amalgamations lose the internal (to an operator) efficiencies that currently exist and which promote sufficient observations for benchmarking performance? How many contract areas are appropriate? Preston and van de Velde (2002) comment that the U-shaped subsidy profile detected over time in competitive tendering is, in part, due to the winner's curse10 but more importantly in the current context, in part, due to excessive concentration or collusion. The upping of prices in rebids is becoming common (as observed in Europe in particular) as the number of bidders drops (as a result of fewer operators in the market). Contract area size is a feature of the literature on spatial monopoly where each contract area may be in the hands of a few operators who are able to collude activities across contract areas under their control. By amalgamating contract areas this is tantamount to the same implications for efficiency (albeit legally) as collusion.

The trade-offs between network/demand economies and internal efficiency will depend on a number of structural and historically contingent characteristics in-
cluding such different aspects as urban development and operator culture (Carlquist 2002). This was certainly true in the Sydney context in the early 1990s when the NSW 1990 Passenger Transport Act was introduced. It defined a suite of 78 contract areas based primarily on incumbency (tantamount to grandfather rights). Since then the number of operators has been reduced, while the contract areas have remained in tact. New global operators have moved into Sydney (e.g., National Express from the United Kingdom, Connex and Transdev from France) looking for opportunities to expand in the Australian market. Where geographically adjacent operators have been willing to sell, in part due to pressures to sell from the large global operators, but also because of the perceived uncertainty of the new reform agenda (under discussion in 2003 but without a direction to date), there is evidence of larger service areas under one operator (strictly the same contract areas as before but now bringing a capability of cross-contract operations).

The State Transit Authority of New South Wales (STA), the government-owned operator, is the largest operator with 26 contracts and runs the public bus network which covers almost half of Sydney (1.6–1.8 million population, nearly 800 square kilometres, and 1,750 buses operating out of 11 depots) centered on the Sydney CBD (See Figure 1). It has many adjacent contract areas so that its services are not delivered on a contract area basis per se, operating as one very large provider. The STA has designed a route network of services that takes passengers to key centers across a region, not just within the contract area. This network economy is achieved, however, at a relatively high internal inefficiency cost of $4.86 per bus kilometer11 (in contrast to the best practice cost of $2.60/bus kilometer for private operators who currently have 53 contracts among 30 operators). The important question herein is the extent to which the cross-contract area service provision has contributed to these higher unit costs or whether it is the product of government ownership and specific restrictions of service delivery. Part can be attributed to externalities such as traffic congestion. Based on the STA’s operations outside of the Sydney Metropolitan Area (in Newcastle, a regional Center 120kms from Sydney with a population of about 500,000), we could reduce the $4.86 to $3.54 (Daniels 2002). However internal inefficiency must account for much of the remaining increment above $2.60.
Figure 1. The Sydney Metropolitan Area and the STA Contract Area
The literature on industrial organization from which ideas central to tendering evolved such as principal-agent relationships, transactions costs, and economies of scale and scope, puts forward compelling arguments that many of the gains in service delivery to the market can be effected through preservation of smaller effective management units working within a range of alliance structures, where each alliance is established to best accommodate the interests of the market (i.e., customers) and the interests of the supplying stakeholders (see Hay and Vickers [1987] and Williamson [1987]). To assume that one large organization with a single large contract area (or even a few under an oligopoly) is the best way forward in servicing the market is questionable. It assumes that the transactions costs between operators and customers are excessive and the transactions costs within an organization are nonexistent or minimal. Indeed the literature on the economic theory of regulation (or “capture” theory) describes how regulatory agencies may end up more or less in the pocket of those whom they purport to regulate. The response in some industries has been the dismantling of such regulatory frameworks through economic deregulation (e.g., airlines, telecommunications), with a replaced regulatory regime focused on monitoring.

There is an analogous literature arguing for local specialization and alliances instead of the formation of large, single-entity businesses. Indeed, it does not take long before we see many of the very large entities essentially operating as a set of separate entities with occasional cross-subsidy to facilitate short-run (at least) viability across the entire set of organizations under the one control. This breeds inefficiency (like governments bailing out their own public monopolies) and upward pressures on subsidy support from government. As Preston and van de Velde (2002) state "...governments caving in to operators suffering from the winner's curse or generally finding life tough was a real threat to competitive tendering in some countries and situations."

Fundamentally, the reduction in the number of contract areas runs the risk of further promoting dominance and a further move away from the ideals of competition policy. It is a dangerous move if it erodes the competitive base of the bus market in the sense that it reduces the ability to promote and maintain a process of effective or potential competition so as to achieve a more efficient allocation of resources. In large measure, we have to put to the test the case that such amalgamations deliver additional benefits that more than outweigh the additional costs.
However alliances do not just happen. The market may well send signals to encourage such alliances but there is no guarantee that the signals will be registered and acted upon. To ensure market signal activation, appropriate information and incentives need to be put in place. Government, through its regulatory agency, can make a major contribution to this process. In the presence of imperfect information, signaling and incentive systems are at the center stage. To date in most international settings where regulatory reform is active, there is little evidence of alliances (although see Norway in the next paragraph), which is disappointing, but this may well be explained by the strategic intent of the new (global) players and the lack of incentives in the past. The evolution of alliances will require much more incentive-driven initiatives by the regulator especially where there is a loss of internal efficiency due to the scale of operations. There is no denying that this happens, but what is important is the size of an operator beyond which such internal efficiencies come into play. In Sydney, for example, where most recent purchases involve operators controlling more than 100 buses, these are worrying signals (see evidence below).

There is an interesting history of cooperation and merger in Bergen, Norway (Carlquist 2002). Although a merger attempt between the two major operators failed in the early 1990s, it led to substantial route and fare cooperation. In 1998 a new merger attempt succeeded. Furthermore, all bus companies in the region already cooperated in an alliance regarding electronic ticketing fare coordination and purchasing. It was, therefore, easy for the regional public transport authority to impose a requirement for integrated fares in the performance contract, initiated in 2000. The operators were obliged to have a common ticketing system and fare tariff, but there is no limit to the upper fare level. There is no evidence to support (or falsify) the existence of new patronage attraction or increased benefits to existing passengers, although Carlquist (2002) suggests that the latter is more likely than the former. In either case, it would be difficult to hypothesise that a “successful” integration was due to regulatory intervention, as a successful alliance between the operators already existed.

Whether by amalgamation of ownership or alliance formation, these are both merger phenomenon. For example, combining three contract areas into one area is a (horizontal) merger and should be assessed along the same lines as the merger of two organizations. If there are economies of scale (for the exact same service type), then there are efficiency gains. The realization of these gains, however, could be offset by welfare losses due to reduced competition, be it a actual or yardstick, in
the case of either competitive tendering or performance-based contracts (the latter during the contract period in competing for incentive payments, the former at the time of bidding). DeBorger and Kerstens (2000) review the evidence and conclude overall that there are no economies of scale but mild economies of scope associated with demand complementarities where the evidence suggests spatial demand exists beyond contract/operator areas. The latter is an empirical issue. It is investigated below for Sydney where there is very little intercontract area use of public transport but opportunities for cross-regional services capable of being delivered efficiently by a single operator. Indeed, as organizations increase in size, they lose the relative precision required to establish the value of specific activities; in contrast, through alliances there is much more precision and transparency. A synthesis of some key themes is given in Table 1.

Table 1. Synthesis of Key Issues in Determining Optimal Size Operator/Contract Area

<table>
<thead>
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<th>Theme</th>
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| Density of route network and network economies | • As it increases, there is operational dependency on availability of fixed facilities (central depot, local terminal...)  
 • Very high fixed costs of depots which require sharing of these costs  
 • Presence of such high costs involves a trade between sharing costs over many more activities/services, risks of diseconomies of scale and elimination of potential competition (either leading to entry under deregulation or competitive tendering or competition for incentive payments under PBC) |
| Route Structure | • The balance between degrees of hubbing ranging from hub-dominated to more uniform distribution in urban area moves to latter as a continuous spatial diffusion of urban activities takes place |
| Demand complements | • Attributes of individual services as demand complements means that a change in frequency (say) of one service affects the demand for another |
| Internal efficiency | • Delivering services under benchmarked best practice in respect of cost efficiency, cost effectiveness, and service effectiveness |
The Theoretical Argument

The relevant literature on the optimum number of firms in a market focuses on the cost and performance structure of each firm both in respect of the supply of services and the welfare benefits to passengers of a specific supply regime. Evidence of scale and scope (especially network economies) is an important basis for commenting on the appropriate number of operators (and hence contracts).

Transaction cost economics (TCE) provides an appealing framework within which to develop the arguments for the roles of the market and governance. A transaction occurs when one stage of activity finishes and another begins. With a well-working interface these transfers occur smoothly. Establishing a smooth transfer is what network economies (including integrated fares) are all about. Their achievement is possible through a number of strategies such as alliance contracts and merger (see the Bergen experience cited above). TCE supplants the usual preoccupation with technology and distribution costs, with an examination of the comparative costs of planning, adapting, and monitoring task completion under alternative governance structures. It is as much about transactions within a single entity (e.g., one bus operator, a regulator) as it is between entities. It pays special attention to information signaling and processing (and its asymmetry throughout the system), bounded rationality (i.e., the ability to process a limited amount of information), hazard, opportunism, and asset specificity.

Transaction cost economics maintains that it is impossible to concentrate all of the relevant bargaining action at the ex ante contracting stage (which is what competitive tendering essentially does). Instead, bargaining is pervasive in which case the institutions of private ordering and the study of contracting in its entirety take on critical economic significance. Performance-based contracts (PBCs) align with this view (see Hensher and Stanley 2003) since the market operates actively throughout the contract period (under signals delivered through incentive payments). The behavioral attributes of human agents, whereby conditions of bounded rationality and opportunism are joined, and the complex attributes of transaction with special reference to the condition of asset specificity, are responsible for this condition (Williamson 1987: 178). Alignment of incentives is central to efficient contracts and property rights. The latter emphasises that ownership matters, with rights of ownership of an asset defined as the rights to use the asset, the right to appropriate returns from the asset, and the right to change the form and/or substance of an asset.
Transaction cost economics acknowledges merit in both monopoly and efficient risk-bearing approaches to contract. It insists, however, that efficiency purposes are sometimes served by restraints on trade. (Williamson 1987:188). This statement by a pioneer of transactional economics, X-efficiency, and contracting theory, is crucial to the discussion because it puts forth the argument that examination of the underlying attributes of transactions discloses that restraints on trade can help to safeguard the integrity of transactions when firm-specific investments are at hazard.

Evidence on Cost Savings from Scale of Operations

One useful analysis to establish the potential gains for larger operations (which also means larger contract areas and hence less operators) is to look at the evidence on performance outcomes when tendering for different size bids. A caveat: The great majority of the empirical evidence focuses on operational cost savings and little about the true costs of conducting tendering and monitoring etc. The competitive tendering of a large public sector provider delivers an immediate cost saving but it is a once-only gain.\textsuperscript{15} This gain is greater when the pretended unit is large (as in most government-owned bus operations, such as occurred in London in the 1980s and 1990s) and it is being tendered out as a set of smaller contracts. Subsequent retendering of the smaller contracts, however, leads to very little cost savings if any. Indeed, the often-quoted cost savings up to 20 percent (net of administrative costs of tendering) do not shed light on the crucial question as to what proportion of these savings can be attributed to competitive tendering per se.\textsuperscript{16} The switch to a smaller operator with lower fixed costs and overheads in itself, could achieve these savings regardless of the mechanism used to select the operator.

The main message is that savings increase as system size increases, which implies that if we move to larger contracts by operator merger (or buyouts by large players), we can expect increases in the costs of doing business. While this might not be disputed, the rebuttal is likely to come in terms of network economies on the demand side. This is where we draw on transaction cost economics to assist, since even in the presence of economies of network integrity there are alternative ways of delivering optimal network performance without creating a small number of large and relatively inefficient contract areas.
**Summary of the Main Argument**

In determining the appropriate size of contract areas, it is important to recognize both internal efficiency and external benefit arguments. Internal efficiency arguments recognize the importance of the performance of the service delivery entity regardless of whether the objective is commercial or social obligation. Efficiency encompasses cost efficiency, cost effectiveness, and service effectiveness. External benefits focus primarily on accessibility and, in particular, the integrity of the network and associated network economies.

In considering the appropriate size of the service delivery unit (SDU), the costs of transaction are very important. These costs are not limited to the interfirm environment (which would include integrated fares and servicing of an interconnected network) but include the costs outlaid within a firm. An issue of relevance in achieving the efficiency and network benefits is the revealing of information through appropriate signals (either from the market or by the regulator) to ensure that the best information is acted upon to deliver services to the market at cost efficient and effective levels that, within a subsidy-dependent environment, delivers best value for money (in an efficiency and equity sense) for the scarce subsidy dollar.

Looking at the internal efficiency of an SDU, the evidence from the published literature supports the view that there are no scale economies (over 100 buses) but mild network economies. The latter translates in particular into an argument for having fewer (or even one) SDU operating a network-based cross-regional service, since the argued benefits to passengers are greater than if the cross-regional services were provided by more than one operator. The assumption implicit in this evidence is that passengers would have to transfer between modes (or bus operators) to complete their journey. These network economies are relatively weak where cross-regional services are shown to be deliverable by smaller operators who move through other contract areas or where, through contract area alliances for specific routes, they can pick up and drop off passengers anywhere along the route.

A good example in Sydney of the former is the private operator, Forest Coaches, who has a service from St Ives/Chatswood (20 kms north of the city in a very wealthy area) to the city; a good example of the latter is the 35 km orbital service about 5 kms out from the CBD in Perth (Western Australia) operated through an alliance of three operators. This last example is equivalent to what Adelaide (South
Australia) would refer to as a route-specific contract across contract areas (see Appendix 2). Creating a monopoly supplier to deliver the mild network economies is false economy since it will almost definitely lead to major losses in internal efficiency. Rather, given the evidence from the Transport Data Centre (TDC) of the NSW government that the majority of travel in Sydney occurs locally (mainly within one contract area but also between two adjacent contract areas), typically over 80 percent of all trips (often within a single contract area using a bus service locally or to access a rail interchange), the risk of delivering highly expensive local services to the majority of users just to satisfy a claim on network economies for a small amount of patronage service delivery is poor economics. Indeed, encouraging longer trips by any form of transport seems inconsistent with a desire to curtail travel and promote more local activity.

An important message from the institutional economics literature is that we should focus on efficiency and not market power (the concern with reducing the number of contract areas); and we should not aggregate operators or contract areas just to gain network benefits in situations where most of these benefits are within an existing contract area in the main. Through recognition of market opportunities (using appropriate signalling methods to reveal and share information and hence reduce information asymmetry) created by partnerships between all operators and government (via the regulator), and the formation of operator alliances to serve specialised cross-regional market niches, the major transaction costs (e.g., information asymmetry) appear to be more than offset by the huge gains in internal efficiency associated with operators with contracts in the 30 to 100 fleet-size range. Importantly, an individual operator may have more than one contract (as many do), but there are sensible arguments to support the maintenance of each contract as a separate business center. Large operations, such as many Asian-based bus businesses (e.g., in Hong Kong), might benefit by reviewing their structures and may reduce the growing levels of subsidy support that, in part, funds inefficiencies.

**Integrated Fares: Regulatory Control and/or Genuine Benefit to Passengers?**

*Do people need to use more than one mode of public transport/operator to use public transport as an alternative to the car? Maybe the transfers associated with multi-modal movement are a major barrier regardless of what fare arrangements are in place?*
Integrated fares are seen as a way of attracting more public transport patronage because they enable one to purchase a multimodal and/or multioperator ticket at one point in time from one source. Although there is initial appeal in this fare strategy, the justification must be based on an agreed set of objectives. The most important must be a benefit to passengers (and associated flow through to operators and the community at large). It is assumed that one of the reasons why public transport is not used as much as it might be is the poor integration of services across the network. One feature of poor integration is the need to purchase a separate ticket from each operator, which is assumed to be more expensive than the purchase of a single multimodal/operator fare because of the fixed-cost component in each ticket. The presumption is that there would be a single-fixed component in an integrated fare (although this needs to be demonstrated).

Overriding the actual fare level is the issue of network integrity and what this actually means for passenger growth and benefit. What is the evidence that passengers actually want to travel by a number of public transport modes across a network if the modes were better integrated? What is the evidence that integrated fares is the solution (or even a significant contributor)? The counterfactuals would have to show that improved integration, on whatever criteria are adopted, would indeed show movements between modes and operators that are currently not able to be undertaken. The opportunity for such travel does exist in most cities (at least to some extent) in terms of services available, but is it what people want? Such a system leads to transfers and with greater dominance of a few operators there is a real risk on hubbing whereby transfers become a negative feature. The evidence in Appendix 1 from around the world initially looks compelling, but it must be interpreted very carefully. What exactly are we seeing—some sort of discount disguised through integrated fares and/or genuine contributions to improving mobility across the network?

To illustrate this matter, Table 2 shows the year 2000 evidence on public transport use in Sydney involving more than one public mode. The use of multiple public modes in 2000 is 17.4 percent. This table distinguishes the number of times in a trip that a specific mode is used. Of particular interest is the use of more than one bus for a one-way trip. Out of a total of 1.29 million daily passenger trips that involve at least one public mode in a trip chain, 2.861 percent of all trips (i.e., 36,982 trips) involve two or more buses. It might be argued that switching between buses highlights a downside of services that is better delivered through single-vehicle cross-regional services. The greater amount of the multiple-bus trips
are on government buses (31,508 or 85.2%) operating close to the CBD, which may say something positive about the ability to travel beyond contract areas by bus although it says something negative in respect of the requirement to have to transfer.\textsuperscript{20}

| Table 2. Average Day Linked Trips Involving at Least One Public Transport Mode, HTS2000 |
|---|---|---|---|---|---|---|---|
| Ferry | Private Bus | Train | 0 | 1 | 2 | 3 | 4 | Total |
| 0 | 0 | 0 | 338,364 | 28,065 | 1,396 | 346 | 368,171 |
| 0 | 0 | 1 | 446,502 | 73,852 | 3,229 | | 522,583 |
| 0 | 0 | 2 | 34,313 | 2,868 | 197 | 235 | 37,432 |
| 0 | 0 | 3 | 2,739 | 571 | 214 | | 3,524 |
| 0 | 0 | 4 | 428 | | | | 428 |
| 0 | 1 | 0 | 267,790 | 2,372 | | | 270,162 |
| 0 | 1 | 1 | 45,883 | 2,605 | | | 48,488 |
| 0 | 1 | 2 | 1,926 | 365 | | | 2,291 |
| 0 | 2 | 0 | 6,688 | | | | 6,688 |
| 0 | 2 | 1 | 2,471 | 132 | | | 2,603 |
| 0 | 3 | 0 | 1,397 | | | | 1,397 |
| 1 | 0 | 0 | 15,281 | 5,166 | 1,070 | | 21,517 |
| 1 | 0 | 1 | 2,574 | 1,044 | | | 3,618 |
| 1 | 0 | 2 | 1,252 | | | | 1,252 |
| 1 | 1 | 0 | 634 | 234 | | | 868 |
| 1 | 1 | 1 | 375 | | | | 375 |
| 2 | 0 | 0 | 1,055 | 159 | | | 1,214 |

Note: Data includes trips that may have used other (non-T) modes. The other modes are ignored; therefore one public bus may mean one public bus only or one public bus plus car.
Interconnectivity involving more than one bus operator in Sydney is negligible (even if one argues this is due to relatively poor existing interconnectivity) and is unlikely to be of concern to most of the traveling population. While it might be argued that the nature of the existing network of services denies this opportunity (and certainly the counterfactuals are not available), if such network connectivity were to be provided and would increase patronage, the issue of relevance here is whether cross-regional and long-haul metropolitan services can be achieved under existing area contracts by appropriate alliances which preserve the efficiencies of each operator (including transaction cost advantages).

The recent growth in cross-regional services in Sydney by private operators without transfers demonstrates one useful counter-factual in which a passenger can travel on a single-mode/single-operator service without transfers over long distances within the Sydney Metropolitan area (to/from the CBD which is not owned by a single contract and an open-access service zone). Examples include the Westbus M2 and Hills services (in the north-west), Harris Park Citybus (from Parramatta in the west), and Forest Coaches St. Ives/Chatswood-City service (in the north), all of which serve the outer suburbs and deliver passengers into the CBD (see Figure 1).21 Similar examples exist for the STA except that many of the STA services are across contract areas belonging to the STA enabling pick up and drop off across the contract areas (although one might argue that strictly this is violating the terms of a contract). The need for integrated fares in these examples (where public transport is showing evidence of serious competition with the car) is not relevant.22

Integrated fares are a form of regulatory intervention if imposed on all operators from above since all must conform to the grand plan. As Hibbs (2000) has indicated, constructs of integration (of which integrated fares are an example) lead to a weakening of both effectiveness and efficiency. It denies individual operators or groups of operators the full ability to be responsive to market opportunities in ways that are consistent with delivering the appropriate services to customers. Again, Hibbs and others argue that other than the regard for safety and issues of scale and power, public passenger transport is a market-based, customer-driver activity and especially with regard to its relationship with the private car, from where most of its competition comes. Integrated fares dictated across the board may well be inequitable as well as an inefficient way of securing optimum social benefit.23 Market-based fares policies designed to benefit users are needed, and the best test of this is the levels of patronage resulting from the policy. If a specific
arrangement or alliance between operators in a particular public transport chain sees merit in integrated fares, then this should be supported, but not as a carte blanche, no-choice policy. The “one-size-fits-all” philosophy is very dangerous and counterproductive.

**What Is the Broader Evidence on Patronage Benefits?**

The matter of integrated fares and impacts on patronage is not well studied. There are virtually no published papers on the topic that make the link clear and unambiguous. That is, unless one can separate out all the other changes that are happening at the same time (e.g., fare discounting), it is not possible to make any sensible statements on the specific contribution of integrated/intermodal/interoperator fares.

In reviewing the literature we have found a number of comments that state that intermodal fares are often inappropriate where one has mainly mode-specific travel. That is, most circumstances where the topic is mentioned, talk about limited modal switching (i.e., rail to bus) and focus on single-mode discounted fares and other deals (including the growing interest in multipurpose fare media that enable one to use a smartcard on buses, shopping, cinemas). The examples never refer to smartcards for traveling on buses and trains, which is interesting by its absence.

The studies in Appendix 1 are based on a literature review by Booz Allan Hamilton (BAH) in 2002. Most are questionable. For example, one of the better studies by London Transport (Fairhurst 1993) found that the introduction of Travelcards boosted passenger miles in the first year by 3.83 percent—is based on very aggregated time series data. We question what other control variables were included. The paper by Foote and Darwin (2001) for Chicago concludes that a 36 percent increase in ridership over a year when AFC was introduced is attributed to many factors but most is attributed to fare policies within a single mode (which is more reflective of where the market is). The overall growth impact (i.e., new trips) of all sources of fare changes is maximally 30 percent of 3.6 percent or 1.08 percent. Clearly much less than 10 percent suggested by the BAH review.

The Dutch rail-taxi combination introduced in 2000 is another example of integration of two modes. One cannot infer anything about patronage growth because the new taxi services provided were rather different from those of the ordinary taxis. The train-taxi’s have a lower quality of service. With more passengers per taxi, one may have to wait at the railway station. Another example is the
introduction of the standardized nationwide bus/tram/metro ticket in the Netherlands in the 1970s, enabling passengers to use the same ticket irrespective of the mode or the company providing the services. No monitoring was undertaken on the effects of its introduction at that time. Such changes tend not only to encourage integration but also produce a different price structure.

Conclusions
The arguments and evidence presented in this article suggest that the perceived gains from the reduction in the number of contract areas are likely to be illusory. If the gains in network economies are not sufficiently large to outweigh any likely loss of internal efficiency, there is a case for amalgamating contract areas to ensure that local services are not hampered by cross-contract area constraints on service delivery. Given the major focus on local service provision, opportunities to deliver appropriate cross-regional and cross-network services can be revealed and promoted by partnerships between bus operators and the regulator.

A mechanism by which the appropriate market signals are captured and made available to all relevant parties (i.e., the release of information) is required. Integrated fares as one instrument to promote network public transport activity, while having some merit, are unlikely to be a major influence on the take-up rate of cross-regional network services since they are best supplied as a single modal service through an alliance or agreement for a single operator to deliver cross-contract route-specific services where transfers are minimised if not eliminated. Then and only then might we have a chance of taking some traffic from the car market.
Appendix 1. Impact of Fares and Ticketing Integration on Patronage International Case Studies

Source: Booz Allan Hamilton Review 2002

London

As part of a number of initiatives to increase public transport use, multimodal Travelcards were introduced for bus and underground services during early 1983. Rail was later included in the scheme with the merging of Travelcard and Capitalcard during 1989. Fairhurst (1993) sought to separately isolate patronage impacts from changes in fares and fares integration. The first year impact from fares integration was significant with passenger miles increasing around 18 percent on buses, 28 percent on underground services, and 24 percent overall.

Paris

In mid 1975, the “Orange Card” was introduced in the Paris region. The card is a nontransferable, monthly (or yearly) season ticket that can be used on different transport modes including bus, the metro, suburban train, and various operator networks (i.e., RER, SNCF, APTR). The Orange Card has had a significant effect on patronage although the impacts on bus and metro services have been disproportionate.

New York

A major change in ticketing occurred in New York during 1997 with the introduction of the “MetroCard.” A stored value card, the MetroCard can be used on the bus and the subway and is accepted by all operators. The MetroCard had a significant effect on patronage, particularly buses. Between July 1996 and July 1997, average weekday bus ridership increased 16.9 percent and average weekend bus ridership increased 20.2 percent. The effects on the subway were less marked, with weekday subway ridership increasing by 2.6 percent. Overall ridership levels were at their highest since 1971 (Walker 1997).

Zurich

Prior to the introduction of integrated ticketing, Zurich was characterized by an exceptionally high level of public transport use. Schedules were coordinated on a voluntary basis with each operator having its own fares.

After the formation of the Zürcher Verkehrsverbund (ZVV), a comprehensive integrated fare and ticketing system was introduced. This involved the full coordi-
nation of services and the development of a single fare system based on zonal fares. The combination of these two factors increased overall patronage by an average 12 percent in the first two years of operation, with significant increases of 53 percent and 30 percent for feeder buses and heavy rail respectively (Laube 1995).

**Surrey**

Surrey County Council has made significant investments in several public transport schemes including the Travelwide ticket in Woking. User surveys were conducted to evaluate the performance of such schemes. Surveys revealed that the Travelwide ticket had little effect on patronage in terms of take-up by existing users (i.e., less than 2% of bus users had used the Travelwide ticket). The Travelwide ticket had limited success in generating new bus journeys. Overall, the study concluded that the multiple journey Travelwide ticket had a negligible effect on patronage (unknown author).

**Los Angeles**

Interoperator transfers accounted for less than 0.5 percent of total regional rides prior to the growth of fares and service integration. As service and fares integration grew, the number of passengers making multioperator trips increased. By 1994 the number of multioperator trips had increased 2 percent (i.e., 11 million boardings per year) (Carter and Pollen 1994).

**Chicago**

A Chicago study estimated that ridership would increase between 2 to 5 percent as a result of the introduction of automated fare collection systems (Dinning 1996).

**West Midlands**

One of the first major examples of integrated ticketing in Britain was the West Midlands Travelcard scheme introduced in 1972. As result of the scheme it was estimated that 7 percent more trips were being made by 1981 (White and Brocklebank 1994).

**Singapore**

During 1991 to 1992, the “Farecard” system in Singapore increased passenger numbers by 2.5 percent. Given the increases in fare levels, this outcome was not anticipated (Baggaley and Fong Choon Khin 1994).
Appendix 2. Contract Area Size: The Adelaide View

Source: Tom Wilson, Passenger Transport Board, Adelaide

Our limited experience in Adelaide was that there seemed to be little interest from tenderers in contracts with less than 30 buses (e.g., the Outer NE Transit Link Contract for 25 buses). Of course, there are many arguments about bus depot size, but a large contract can easily have a number of depots.

As someone who largely designed the shape/size/boundaries of our Adelaide contracts, I would suggest that the most important issues are:

- Closely examining the structure of the existing route network to see how it fits together, and locate the natural breaks and boundaries
- Examining geographic boundaries
- Examining passenger travel patterns as well as having a knowledge of nonpublic transport (but potential) travel patterns
- As the main all-day public transport passenger flows in Australian suburbs are primarily to the City and to major regional/district centers, these centers (and major interchange points) should form the focus points of contract areas. They can either be in the center of them, so the contract area surrounds and focuses on them, or on the boundaries of two or more contract areas, so that each adjacent contract area can focus on those centers. The trade areas of these centers is an important element in contract area design
- Allowing cross-boundary services to continue, and ensuring that new cross boundary services can be implemented by writing their possibility into the contracts. Cross boundary services should generally be allocated to the contract area within which most of the route falls
- Alternatively, very long cross boundary routes could be treated as separate “route” contracts, providing a significant number of buses is involved
- Small route groups that do not comply with all of the above should be amalgamated with the larger area contracts to allow flexibility in network planning. They could be retained if necessary where they serve an isolated area (e.g., a suburban area on one of Sydney’s many peninsulas could have its own contract without impacting on flexibility)
Endnotes

1 Readers unfamiliar with the details of competitive tendering will find a useful summary in Hensher and Brewer (2001: 27–34.)

2 Integrated fares is not the same as integrated ticketing. The latter refers to the technological platform within which operators provide electronic tickets.

3 See Note 1.

4 See Note 2.

5 Although not the focus of this article, an important issue is the mechanism for distributing the fare revenue to the transport suppliers, complicated in some jurisdictions by the absence of a “flag fall” component of a bus fare for each leg of a trip (i.e., a fixed overhead charge per trip regardless of distance traveled).

6 Australasia includes Australia and New Zealand.

7 An important distinction is made between contract/operator areas that are a single route in contrast to a geographical area. The distinction appears primarily a matter of shared resources such as depots and coordinated timetabling. A review of the literature failed to find a single paper addressing this issue.

8 Although the firm size literature includes direct competition between firms, it also recognises situations in which firms operate as spatial monopolies as is the situation with bus operators who do not compete in the market (even though they compete with the car).

9 The question not addressed in the literature on bus provision is the extent to which innovative opportunities are greater under regimes which lessen the power of the regulator in delivery of services. It may be the case that the empirical evidence, as limited as it is, is misleading because of the failure of incentive structures to deliver the gains which are inherent in a less constrained market. We need to understand the circumstances under which incentives can evolve and be effective. One problem with the bus industry may be that the lack of experience in managing change and/or the reticence in being innovative given a history of suppression of innovation is hampering the speed of taking up opportunities waiting for action. Generational inheritance, for example, which often lacks an understanding of the need to sustain wealth and survival leads to a reduction in entrepreneurial activity and hence a decline in any potential innovation.
The winner's curse exists when the winning operator discovers after winning that it has overpaid given the real value of the tender.

All costs are in $AUD, with $AUD1.0 approximately equal to $U.S. 0.59.

The internal efficiency of an organization depends on the degree of competition it faces in so far as competition affects managerial incentives and opportunities. One way that competition sharpens incentives, and hence internal efficiency, is by permitting the relative performance of agents to be compared. Benchmarking runs the real risk of being lost with a very few operators.

In Oslo there is currently discussion about the contract size for the future bus tenders. The authority has clearly stated that operators should be given financial incentives for passenger growth and service quality, and performance contract principles should be applied. The problem here is that there are two principal-agent relationships. Firstly, there will be a contract between the city and the municipal company (Oslo Sporveier) that serves as the public transport executive (PTE). This will be a network-wide net contract that will not be tendered. Previously, this relation was subject to a performance-based subsidy, but this has been discontinued. Secondly, there will be tendered subcontracts for various packages. These are the contracts for which performance-based principles will be applied. (Both net and gross contracts are currently in use for these operations, but tendering has not yet commenced.) To ensure a sufficient number of competitors, it is expected that the PTE will want to restrict the size of contract areas. In practice this will mean that the tender packages will consist of a small number of routes. The Oslo network is complex and routes crisscross all over the city. Consequently, it may be difficult to implement net-cost contracts, at least without a sophisticated revenue allocation system. The alternative is a gross-cost system with quality incentives, but that is something different from the Hordaland type model, which requires a net-cost contract.

Although not specifically related to number of operators, the issue of who owns what is very important in determining economic efficiency in service delivery. Operating franchises, such as those in Adelaide that separate investment from operating decisions, are 'bound to result in resource misallocation, manifested by overcapitalization and the production of dispensable and underutilized services' (Berechman 1993:294). Apart from the diverse goals of the owner of the assets (i.e., public sector) who promote social welfare outcomes in contrast to the commercial outcomes of the operator, the government and operator disproportion-
ately share the overall risk since the bulk of the risk associated with capital investment (notably the fleet) is assumed by government. With the risk of overcapitalization greater than under single ownership (and a single commercial objective), the loss of economic efficiency is very real, exacerbated if the operator engages in higher risk projects than it would otherwise do so if it carried the full risk. This risk can, in part, be circumvented by monitoring but at a much higher level than would be required if the operator carried all the risk. It is doubtful that the government would be able to acquire all the necessary information on costs and demand without outlaying a lot of resources. Transactions costs are likely to raise questions about the value of this approach to service delivery. Under risk-sharing the notion that bidders are expected to bear the entire risk stemming from investment and operational decisions, with the face value of their bids serving as a sound predictor of their expected performance, evaporates.

15 “If costs of having a private firm supply the services could be reduced by means of a negotiated contract, the considerable costs of organizing a competitive bidding would be averted. Indeed ... a competitive tendering scheme might in some cases be inferior to methods of contract renewal or negotiation” (Brechechman, 1993, 298–99)

16 Within the Sydney metropolitan area, private bus operators are some of the most cost efficient in the world. Consequently, competitive tendering is very unlikely to deliver financial benefit.

17 There is a case for economies of scale in moving from a very small operation such as 1 to 4 buses up to about 30 buses, but over the range 30 to 100 we see almost constant returns to scale with decreasing returns to scale over 100 buses (Brechechman 1993 and personal communication (July 11, 2002) with Kjell Jansson, Sweden). Fleet size is an appropriate indicator of scale, being highly correlated with other contenders such as population per square kilometer (a correlation of 0.886 for the STA contract areas). Other indicators such as area (in sq kms) has a simple correlation of −0.80 for STA areas.

18 The Sydney 2000 Olympics provided valuable evidence on this matter (Hensher and Brewer 2003). The depot set up to coordinate bus services accommodated more than 1,000 buses, substantially larger than the largest depot in Sydney under normal conditions (an STA depot with 250 buses). In hindsight, it was concluded that major internal efficiencies could have been obtained by having a series of smaller depots up to 150 buses.
19. We would argue that this is common in most large metropolitan areas.

20. Research by Alsnih and Hensher (2003) suggests that seniors and the elderly (i.e., individuals over 55 years old) are less inclined to use public transport where transfers are required.

21. Examples of cross-regional services in the text are very weak because they do not involve picking up and dropping off in more than one contract area. (The CBD of Sydney is not a contract area.) This ability does not exist among private operators in Sydney because of the existing contract requirements. It is suggested that the government operator (State Transit) has true cross-regional services such as Route 400 (Burwood to Bondi Junction), Route 370 (Coogee to Leichhardt), and Route L20 (City to Parramatta). Private operators have not to date developed strategic alliances to pick up and drop off in more than one operator’s area, denying themselves of alliance revenue.

22. Although the automated fare collection (AFC) system of the STA shows that one in five boardings is made by a TravelPass ticket of which 66 percent are a train+bus+ferry ticket and 32 percent are a bus-ferry ticket (with only 3% being bus only), it is unclear as to whether the ticket purchaser actually uses more than one mode or is simply taking advantage of the attractive discounts offered. For example, the average discount on TravelPasses is between 27 and 36 percent.

23. The inequity is likely to arise from cross-subsidy to the relatively wealthier travelers who tend to undertake the longer trips.

24. The introduction of integrated fares is often in conjunction with other measures, such as increased marketing budgets to push the new ticketing and promoting bus travel, better information systems, increased bus frequencies and discounts to fares. Increased discounting would be a feature of many integrated ticketing exercises and would have an impact on ridership.

25. One referee suggested, “The appendices definitely demonstrate increased ridership in cases of fare integration.” While not denying the absolute evidence, the text argues that the contribution of fare integration to the patronage increases is by no means clear and that other factors have played a role. We support a much more carefully constructed empirical study to establish the wider set of influence on patronage increases rather than credit it all to fares integration.
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Pupil Fatalities on Public Transit Buses:
A Comparison with School Buses

Lidia P. Kostyniuk
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Abstract

Fatality rates of school-age children on trips to/from school by transit buses (while passengers or pedestrians approaching or leaving the bus) were estimated from existing data and compared with school-bus-related fatality rates. Data from FARS 1996–1998 were used to identify deaths of school-age bus passengers and pedestrians in all crashes during times that children normally travel to/from school. Police crash reports were obtained for the pedestrian deaths and reviewed for bus involvement and identification of the trip as one to/from school. The average number of pupils killed on such trips on transit buses in the United States was 0.3 deaths per year, and possibly as high as 1.7 deaths per year. Using NPTS data to control for exposure, a fatality rate of four deaths per billion pupil trips (95% confidence interval of 1–11) was estimated. Within the precision achievable with available data, no recognizable difference between pupil fatality rates by transit buses and school buses was found.

Introduction

There are approximately 57 million children, age 5–18, in the United States (U.S. Census Bureau, 2001) and most of them are pupils in kindergarten through 12th grade (K-12). About 23.5 million of these children travel to and from school on
school buses,\textsuperscript{1} operated or contracted by schools or school districts [National Highway Traffic Safety Administration (NHTSA) 2001a]. In many states, there is no legal mandate to provide pupils with transportation services and because of other funding priorities and limited budgets, some schools and school districts look to public transit buses as an alternative to school buses. Indeed, many urban public transportation systems have special fares for students, and adjust their schedules and routes to meet the demand for trips to and from school. The number of children who travel to and from school on common carrier buses operated by public transit agencies is not known, but was reported in 1996 to be about two million (National Association of State Directors of Public Transportation Services 1996). Although the number of fatalities and injuries on public transit systems is very low (e.g., see NHTSA 2001b), most riders are adults, and communities considering public transit for pupil transportation have questions about the safety of children traveling on these buses. Periodically, a tragic death of a child on the way to or from school by public transit bus intensifies these questions (e.g., National Transportation Safety Board 1997).

Children traveling either by school bus or transit bus are exposed to risks of injury or death as passengers on the bus as well as pedestrians approaching or leaving the bus. There are, however, more measures to reduce these risks for children on school buses than for children on public transit buses. For example, many of the Federal Motor Carrier Safety Standards (FMCSS) that apply to buses have additional requirements for school buses, including outside mirrors that allow a seated driver to see along both sides of the bus, amber and red warning lights for use when loading and unloading passengers, emergency exits, and special fuel system requirements. In addition, four FMCSs are unique to school buses, including minimum structural strength for rollover protection, bus body joint strength, high-backed and well-padded passenger seats, and a pedestrian safety system consisting of a stop signal arm to protect pupils in the bus loading and unloading area (Code of Federal Regulations 49 CFR 571.3, 2002). Furthermore, traffic laws of all 50 states and the District of Columbia require motorists to stop when they encounter a school bus that is loading or unloading children (Hamada 1999). There are no similar traffic rules for public transit vehicles.

Although the extra safety precautions associated with school buses seem to indicate greater safety on the school bus system, a comparison of the rates of fatalities and injuries sustained by children on the way to and from school by both bus systems would provide a more definitive answer to the question about pupil
safety on public transit bus systems. A direct comparison of such rates, however, is challenging because the information available from national vehicle crash databases is not sufficient to perform the necessary statistical analysis, so indirect methods must be identified and used. Furthermore, some indirect methods may be suitable for estimating fatalities but not injuries, thus calling for separate approaches and analyses.

This article explores the differential effects on safety of children traveling to and from school (henceforth called school trips) by public transit buses and by school buses. The objectives are (1) to obtain on a nationwide basis, comparable estimates of fatality rates\(^2\) of pupils on school trips by these two modes using existing data sources, and (2) to identify the shortcomings and uncertainties that come from using these data. The measures selected for assessing safety of school trips are the numbers and rates of fatalities sustained by pupils as passengers on public transit buses and school buses, and as pedestrians when approaching or leaving either type of bus. Pedestrian fatalities include those with direct and indirect involvement of the bus, with direct involvement including cases in which the victim was struck by the bus that he or she was approaching or leaving, and indirect involvement including cases in which the child was struck by a vehicle other than the bus.

The rest of this article is organized as follows. Potential data sources for fatalities of children on school trips on public transit vehicles and school buses are assessed in the next section. Measures and data sources of exposure are examined in the third section. Methods used for estimating the numbers and rates of pupil fatalities on school trips are described in the fourth section. Results are presented in the fifth section. The overall findings are discussed in the last section.

**Data Sources**

The first step in this study was to identify data sources that record fatal crashes involving pupils on school trips. Ideally, such sources would identify the victim as a pupil, the trip as a school trip, and the vehicle as a school bus or public transit bus. Such information should be available for bus-related crashes involving other vehicles as well as pedestrians.

For fatal crashes, the Fatality Analysis Reporting System (FARS; NHTSA, 1999a) is the most complete database, covering all fatal motor vehicle traffic crashes nationwide and subject to thorough quality controls. FARS has detailed vehicle-body codes that allow clear differentiation of school buses and public transit buses.
FARS also has a special code to indicate that a school bus was involved in a crash. Crashes involving school buses with other vehicles or with pedestrians are coded as school-bus related. Pedestrian crashes in which a child was struck by another vehicle while approaching or leaving the school bus are also coded as school-bus related, if the lights on the school bus were flashing. Cases in which the victim was a passenger on a public transit bus or was struck by the bus can be easily identified in FARS, but there are no codes to identify a victim as a pupil on a school trip. There are also no elements for coding the indirect involvement of public transit buses in any pedestrian crash. It is feasible to identify victims as possible pupils by determining if the victim was of school age, and if the crash occurred at the time a child would be traveling to or from school, but there is no way of assessing whether a public transit bus was indirectly involved.

Other electronic data sources were examined to determine if they contained information about indirect involvement of public transit buses in pedestrian deaths or if victims could be identified as pupils on a school trip. Among the data systems examined were: the National Accident Sampling System (NASS) General Estimates System (NHTSA 1999b), NASS System Crashworthiness Data System (NHTSA 1998), NASS Pedestrian Crash Data Study (NHTSA 1997), Crash Out come Data Evaluation System (NHTSA 1996a, the National Transit Database (Federal Transit Administration 1999) and state crash data files (NHTSA 1999c). None of these data sources could provide information on the indirect involvement of public transit buses in pedestrian crashes. With the exception of Colorado’s state crash data, which has a provision for identifying a victim as a child on a school trip, none of the data sources could identify a victim as a pupil on a school trip.

Several nonelectronic data sources were also considered including annual national surveys of school bus loading and unloading accidents published by the Kansas State Department of Education (KSDOE 1996, 1997, 1998, 1999) and original hard-copy police crash reports (PCRs). The KSDOE reports contain much information about direct and indirect involvement of school buses, but provide little information about public transit bus crashes. The PCRs (from which electronic crash records are coded) include narratives, crash diagrams, witness statements, and other information about the crash. Thus, additional information about cases in FARS electronic data can be found in these PCRs and may provide enough information to determine if a child was on a school trip, and also to determine if a public transit bus was indirectly involved.
The most promising source for comparing fatalities on public transit buses to those on school buses appears to be a combination of FARS electronic data and PCR materials. Fatal crashes involving pupil passengers on school buses and pupil pedestrians, whether they were struck by the school bus or by another vehicle when approaching or leaving the school bus, can be obtained from FARS electronic data. Cases in which victims were school-age passengers of public transit buses or school-age pedestrians struck by public transit buses can also be identified directly from FARS electronic data. Indirect involvement of public transit buses in pupil fatalities may be determined through the review of hard-copy PCRs of cases identified by screening FARS data. Because indirect involvement of a bus in a crash occurs when a pedestrian, approaching or leaving the bus, is struck by another vehicle, the set of all vehicular crashes involving pedestrians of school age that occurred at the time that children regularly travel to and from school should also contain those cases in which public transit buses were indirectly involved.

**Exposure**

**Measures**

To calculate rates of crashes involving pupils on school trips, a suitable measure of exposure had to be selected. This was done by examining the types of risks pupils are exposed to on school trips by bus, the measures of these risks, the relative magnitude of these risks, and the availability of meaningful data.

Children on school trips by bus are exposed to the risk of two types of crashes: the risk of a crash while they are passengers on the bus and the risk of being struck by the bus or another vehicle when they are approaching or leaving the bus. Pupil-miles of travel is an appropriate exposure measure for the first type of crash. Crashes of the second kind can occur only at two points during each trip; that is, when the pupil gets on or off the vehicle. Thus, the number of pupil trips is an appropriate exposure measure for the second type of crash.

NHTSA (1999d) reports that in school-bus-related crashes, three times as many pedestrians as passengers are killed. Because the overall number of fatalities aboard public transit buses is small, the number of pupil fatalities on board transit buses is also small. Therefore, it is plausible to expect that the risk to children is greater when they are approaching and leaving a public transit bus than when they are passengers on that bus. Furthermore, estimating pupil-miles of travel would involve estimating distributions of the pupil-trip lengths and pupil bus occupancies over bus routes, and any proxy for pupil-miles would at best be a crude approxi-
mation. These challenges led to the selection of pupil trips as the single exposure measure for this study.

**Exposure Data**

School bus ridership by state is available from the National Association of State Directors of Pupil Transportation Services (Bobbitt Publications 2002). The challenge in this study was to find a source of comparable pupil ridership on public transit systems. Several sources were examined including the National Transit Database (Federal Transit Administration 1999), American Public Transportation Association (APTA), public transit systems, and the National Personal Travel Survey (NPTS; Research Triangle Institute and Federal Highway Administration 1997).

The National Transit Database does not have student ridership nor does it distinguish riders by age. APTA does not routinely collect student ridership information. While many public transit agencies collect student ridership data, several were contacted and indicated that their legal departments would not allow them to provide data for this study.

The NPTS is the national database of travel patterns and can be used to estimate trips by age group by purpose by modes, including the number of school trips by various modes. The latest available NPTS data at the time of this study were from 1995. There are several problems, however, with using NPTS data to estimate the number of pupil trips on public transit buses. One problem is that NPTS has codes for three types of buses: intercity bus, school bus, and bus. This distinguishes school buses from other buses, but does not distinguish public transit buses from other types of buses. Although the buses coded as “bus” in NPTS for school trips are most likely public transit buses, the possibility of other types of buses (e.g., private bus, shuttle service bus) cannot be ruled out.

Another problem may be how accurately actual school trips can be estimated from the NPTS data. The NPTS survey collects data from a national sample of households on all personal travel, of which school trips are a very small part. The actual number of school trips in the sample is relatively small, which suggests that the uncertainty associated with national estimates of these trips from NPTS is large.

Despite these shortcomings, NPTS was by far the best source of national modal information for school trips and using NPTS for pupil trips for both school buses and public transit buses provides comparable estimates. NPTS was, therefore,
selected to provide a national estimate of pupil transit bus ridership and school bus ridership for this study.

**Method for Estimating Pupil Fatalities and Rates**

Because the number of fatalities involving school buses and transit buses is small, one year of FARS data would not be sufficient for this analysis. Accordingly, three years of FARS data (1996–1998) were used. The following set of criteria was used to identify potential cases involving children on school trips by school bus and by public transit bus.

**Time Criteria**

- September through June, excluding Labor Day, Thanksgiving and the following Friday, Christmas, New Year’s Day, and the week between Christmas and New Year’s Day, and Memorial Day
- Monday through Friday
- Hours: 6:00–8:59 and 14:00–16:59
- Victim criteria
- Age 5–18 years
- Occupant of a bus or van or a pedestrian in a crash with any vehicle
- Vehicle criteria, if victim is not a pedestrian
- School bus or van, operated by a school, school district, or private contractor
- Transit bus or van, operated by public transit system

Applying these time criteria may exclude crashes on some school trips that occurred during regular school hours, late in the day, on weekends, or during summer school. Furthermore, because vacation periods and holidays vary between states and often within a state by school district, use of these time criteria may exclude some cases that occurred on a school day and retain others that did not. However, examination of the distributions of school-age fatalities in school-bus related crashes recorded in FARS by month, day, and hour (Kostyniuk and Joksch 2002) showed that these criteria captured most of the cases. Time periods identified by the time criteria are referred to as regular school-travel hours in the rest of this article.
**Pupil Passenger Fatalities**

School-age passenger fatalities were identified directly from the FARS electronic data files and are shown in Table 1. There were 84 crashes involving buses, of which 10 involved at least 1 school-age passenger fatality. There were 9 crashes involving school buses in which 12 children were killed. There were no school-age children killed as passengers on public transit buses during regular school-travel hours. However, 1 school-age passenger was killed on a bus coded in FARS as “other” bus.

**Table 1. Number of Crashes Involving Buses During Regular School-Travel Hours**

<table>
<thead>
<tr>
<th>Bus Type</th>
<th>No. of Crashes</th>
<th>No. of Crashes in which Child Passenger, age 5-18 was killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>School bus</td>
<td>75</td>
<td>9</td>
</tr>
<tr>
<td>Public transit bus</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Other bus</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Unknown bus</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>84</strong></td>
<td>10</td>
</tr>
</tbody>
</table>

Source: FARS, 1995-1998

**Pupil Pedestrian Fatalities Near Buses**

Analysis of FARS electronic data from 1996–1998 found 401 fatal crashes involving pedestrians age 5–18 that occurred during regular school-travel hours. The PCRs for all cases were requested from the states through NHTSA. Of the 401 cases, PCRs were available for 388. Review of these narratives found that in 14 of the 388 cases, the person killed in the crash was not a pedestrian age 5–18, but some other person involved in the crash. These cases were dropped from further consideration. The PCRs of the remaining 374 cases were carefully read to determine if the victim was on the way to or from school, and if any type of bus was involved in the crash. A summary of these results is contained in Table 2.

Further review of the 374 cases identified 73 cases in which buses were specifically mentioned (school buses in 58 cases; public transit buses or other buses—e.g., “city bus” or just “bus” in 15 cases). Of these 73 cases, 24 were dropped from
Table 2. Initial Sorting of the 401 Cases Involving Pedestrians Age 5-18 During Regular School-Travel Hours

<table>
<thead>
<tr>
<th>Category</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCRs not available</td>
<td>13</td>
</tr>
<tr>
<td>Fatal victim not age 5-18</td>
<td>14</td>
</tr>
<tr>
<td>Fatal victim age 5-18</td>
<td>374</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Was victim on school trip?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>127</td>
</tr>
<tr>
<td>Likely</td>
<td>86</td>
</tr>
<tr>
<td>Not likely</td>
<td>19</td>
</tr>
<tr>
<td>No</td>
<td>56</td>
</tr>
<tr>
<td>Not enough information</td>
<td>90</td>
</tr>
<tr>
<td>Total</td>
<td>374</td>
</tr>
</tbody>
</table>

Source: Based on review of PCRs.

Further consideration because they were not relevant to study (e.g., the crash occurred near a bus stop with no bus present; a bus happened to be in the vicinity but was not involved in the crash; a pedestrian was struck by a random vehicle in the traffic stream that happened to be a bus). The remaining 48 crashes were cases in which school-age pedestrians were killed while approaching or leaving a school bus or public transit bus. Table 3 shows the distribution of these cases by type of pedestrian-vehicle interaction.

Exposure

Table 4 shows the numbers of pupil-trips during regular school-travel hours based on NPTS. Pupils who drove themselves were excluded and the small number of trips by intercity bus is included in the “other/unknown” category. There were an estimated 4.6 billion pupil-trips by school bus and 0.3 billion pupil-trips by bus. The latter category is referred to as the nonschool bus category in the rest of this article and consists mostly, but not exclusively of trips by public transit buses.
Table 3. Number of School Bus and Public Transit Bus Crashes by Pedestrian-Vehicle Interaction

<table>
<thead>
<tr>
<th>Pedestrian-Vehicle Interaction</th>
<th>School Bus Crashes*</th>
<th>Public Transit Bus Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Was Victim on School Trip?</td>
</tr>
<tr>
<td>Victim leaving bus, struck by the bus</td>
<td>17</td>
<td>Yes - 17</td>
</tr>
<tr>
<td>Victim approaching bus, struck by the bus</td>
<td>2</td>
<td>Yes - 2</td>
</tr>
<tr>
<td>Victim leaving bus, struck by another vehicle</td>
<td>15</td>
<td>Yes - 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Victim approaching bus, struck by another vehicle</td>
<td>8</td>
<td>Yes - 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>Yes - 42</td>
</tr>
</tbody>
</table>

*Among the 42 school bus crashes are 12 that were not coded as school-bus related in the FARS data. In these cases, the school-bus flashing lights were not on. In most of these cases, the child was struck by another vehicle when running across the street to meet the approaching school bus; in two cases, the child got off the bus, and ran across the street as the bus was leaving. A summary of all these cases can be found in Kostyniuk and Joksch (2002).
Table 4. Number (in billions) of Trips between Home and School by Children, Age 5-18 During Regular School-Travel Hours from September through June

<table>
<thead>
<tr>
<th>Mode</th>
<th>To School 6:00-8:59 Hr</th>
<th>From School 14:00-16:59 Hr</th>
<th>Total To or From School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Privately owned vehicle</td>
<td>2.728 (44.1%)</td>
<td>1.528 (20.7%)</td>
<td>4.266 (38.1%)</td>
</tr>
<tr>
<td>School bus</td>
<td>2.299 (37.9%)</td>
<td>2.312 (46.4%)</td>
<td>4.611 (41.2%)</td>
</tr>
<tr>
<td>Walk</td>
<td>0.713 (11.5%)</td>
<td>0.725 (14.6%)</td>
<td>1.438 (12.8%)</td>
</tr>
<tr>
<td>Bus (trans schooled bus, public transit bus)</td>
<td>0.158 (2.5%)</td>
<td>0.139 (2.8%)</td>
<td>0.297 (2.7%)</td>
</tr>
<tr>
<td>Bicycle</td>
<td>0.077 (1.3%)</td>
<td>0.061 (1.3%)</td>
<td>0.142 (1.3%)</td>
</tr>
<tr>
<td>Other/Unknown</td>
<td>0.225 (3.6%)</td>
<td>0.214 (4.3%)</td>
<td>0.438 (3.9%)</td>
</tr>
<tr>
<td>Total</td>
<td>6.21 (100.0%)</td>
<td>4.98 (100.0%)</td>
<td>11.19 (100.0%)</td>
</tr>
</tbody>
</table>

Source: NPTS 1995.

Results

Passenger Fatalities

Passenger fatalities are shown in Table 5. Between 1996–1998, there were 12 pupil fatalities in nine crashes in which a pupil was killed while a passenger on a school bus during regular school-travel hours (four deaths annually). Assuming that the crashes are Poisson distributed, the 95 percent confidence range is from 2.1 to 7.0. Dividing these numbers by 4.6 billion pupil-trips per year by school bus gives a rate of 0.9 pupil passenger deaths per billion pupil trips, with a 95 percent confidence interval of 0.5 to 4.5.

There were no school-age passenger deaths on public transit buses during regular school-travel hours during 1996–1998. However, there was one crash and one school-age passenger death on board a bus coded in FARS as “other.” Assuming a Poisson distribution for crashes and school-age passenger deaths gives a 95 per-
cent confidence interval from 0.03 to 1.9 passenger deaths per year on nonschool buses. Dividing by 0.3 billion pupil-trips by nonschool bus per year, gives a rate of 1.1 pupil passenger deaths per billion pupil trips, with a 95 percent confidence interval from 0.1 to 6.2.

If only trips by public transit bus are considered, no school-age passenger fatalities were observed during regular school-travel hours. This gives a 95 percent confidence interval for the number of fatalities from 0 to 1.2. Because there was no exposure measure specifically for public transit buses, the number of pupil-trips per year by nonschool buses was used to estimate the rate. The resulting rate was 0 with a 95 percent confidence interval of 0 to 4 passenger fatalities per billion pupil school trips by public transit bus.

Table 5. Number and Rate of Pupil Passenger Fatalities on School Buses, Nonschool Buses, and Public Transit Buses During Regular School-Travel Hours

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Pupil Passengers Fatalities/Yr (95% confidence interval)</th>
<th>Rate of Pupil Passenger Fatalities/Billion Pupil-Trips (95% confidence interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>School bus</td>
<td>4 (2.1 - 7.0)</td>
<td>0.9 (0.5 - 4.5)</td>
</tr>
<tr>
<td>Nonschool bus</td>
<td>0.3 (0.0 - 1.9)</td>
<td>1.1 (0.1 - 6.2)</td>
</tr>
<tr>
<td>Public transit bus</td>
<td>0 (0.0 - 1.2)</td>
<td>0 (0.0 - 4.0)</td>
</tr>
</tbody>
</table>

Pedestrian Fatalities

School Buses. There were 42 pupil deaths near school buses between 1996–1998 (14 pupil deaths annually). The resulting fatality rate is 3.0 pupil fatalities per billion pupil-trips with a confidence interval of 2.2 to 4.1 (Table 6).
Table 6. Estimate of Number and Rates of Pupil Pedestrians Killed Near School Buses During Regular School-Travel Hours

| Pupil pedestrians killed in 3 years (95% confidence interval) | 42 (30.3 - 56.8) |
| Annual average of pupil pedestrians killed (95% confidence interval) | 14 (10.1 - 18.9) |
| Rate of pupil pedestrians killed per billion pupil trips (95% confidence range) | 3 (2.2 - 4.1) |

**Public Transit Buses.** In the pedestrian cases involving public transit buses or other buses in which school-age pedestrians were killed during regular school-travel hours, all buses were public transit buses. However, the estimate of numbers and rates of pupil fatalities depends on the level of uncertainty that is accepted in determining if the trip was indeed a school trip.

It was known with certainty in only one incident that the child was on the way to school. If cases classified as definitely or likely to be school trips are assumed to be school trips, the number of pupil fatalities near public transit buses increases to three. If the two cases for which it was not possible to determine if the victim was on a school trip are included, the number of pupil fatalities near public transit buses in the three-year period increases to five. Table 7 shows the three different estimates for fatalities and rates near public transit buses.

Table 7. Estimates of Number and Rate of Pupil Pedestrians Killed Near Public Transit Buses During Regular School-Travel Hours

<table>
<thead>
<tr>
<th>Child Was on School Trip</th>
<th>Definitely</th>
<th>Definitely or Likely</th>
<th>Definitely, Likely, or Possibly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupil pedestrians killed in 3 years (95% confidence interval)</td>
<td>1 (0.1 - 5.6)</td>
<td>3 (0.6 - 8.8)</td>
<td>5 (1.6 - 11.7)</td>
</tr>
<tr>
<td>Annual average of pupil pedestrians killed (95% confidence interval)</td>
<td>0.3 (0.02 - 1.9)</td>
<td>1 (0.2 - 2.9)</td>
<td>1.7 (0.5 - 3.9)</td>
</tr>
<tr>
<td>Rate of pupil pedestrians killed per billion pupil trips (95% confidence range)</td>
<td>1.1 (0.1 - 6.2)</td>
<td>3.3 (0.7 - 9.8)</td>
<td>5.6 (1.8 - 13.0)</td>
</tr>
</tbody>
</table>
Of the three estimates, the first is likely to be conservative and can serve as a lower bound. The second estimate is most plausible because it is based on the assumption that cases with trips judged as likely to a school trip are indeed so. The resulting estimate gives a pupil fatality rate near public transit buses that appears to be similar to the fatality rate near school buses. The third estimate includes cases that may only possibly be school trips and yields essentially a worst-case estimate that may serve as an upper bound.

Table 8 shows the full range of estimates for the total (passenger and pedestrian) pupil fatality rates for public transit buses. There are two sets of estimates. The first set uses the total number of deaths on or near all nonschool buses and the second uses only deaths on or near public transit buses. The estimates of the rate of pupil fatalities per billion school trips by nonschool buses range from 2.2 to 6.7, depending on the level of uncertainty accepted in the identification of school trips. If only known public transit bus cases are included in the estimation, this range is from 1.1 to 5.6.

<table>
<thead>
<tr>
<th>Pupil Fatalities per Billion Trips (95% confidence interval)</th>
<th>Non-school Buses</th>
<th>Public Transit Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservative Estimate</td>
<td>Most Likely Estimate</td>
<td>Worst Case Estimate</td>
</tr>
<tr>
<td>2.2</td>
<td>4.4</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Figure 1 shows the most likely estimates of rates of transit-bus-related pupil fatalities to the rate of school-bus-related fatalities and their 95th percent confidence intervals. These average rates do not appear to be different from each other. This is true whether the pupil fatality rate from school-bus-related cases is compared to the rate for public transit buses or to the rate for the broader category of nonschool buses, which includes not only the transit vehicles but also buses coded in FARS as "other." However, because the number of cases is very small, any differences would have to be very large to be recognizable.
Figure 1. Pupil Fatality Rates on School Trip by School Bus, Nonschool Bus, and Public Transit Bus
Findings
Fatality rates for grade K–12 pupils on public transit buses and school buses on school trips were estimated based on fatalities in FARS data files, review of police crash reports, and exposure information from NPTS data. The overall finding of this study is that, within the precision achievable with the available data and available effort, there is no recognizable difference between pupil fatality rates by school buses and by public transit buses. Both rates were about four fatalities per billion pupil trips.

While there was no recognizable difference in rates, the difference in absolute numbers was large because many more children are transported to and from school by school buses than by public transit buses. The nationwide average number of pupils in the killed going to or from school as bus passengers or pedestrians approaching or leaving the bus was found to be 0.3 deaths per year, and possibly as high as 1.7 deaths per year (depending on the uncertainty accepted in interpreting crash records) for public transit buses, and 18 for school buses. The very low number of pupil deaths by public transit bus greatly limits the statistical precision of attainable estimates. Precision could be increased by using data from longer time periods, perhaps as long as 20 years. However, policies and practices change over such long periods, introducing other sources of uncertainty.

In addition to this basic difficulty caused by small numbers, the process of estimating these rates was particularly challenging because of limitations in data availability. National and state motor vehicle crash databases do not contain all the information needed to identify pupil fatalities and even the original police crash reports do not always have this information. The lack of exposure data presents another problem. The NPTS was the most comprehensive source of national data on school trip modes available but because it groups public transit buses together with all other nonschool buses, it was not possible to estimate pupil trips or other exposure measures for public transit buses alone from these data.

Sufficiently detailed data would reduce the uncertainty in future estimates of pupil fatality rates on public transit buses. Key pieces of information needed are identification of a pupil on a school trip and the indirect involvement of public transit buses in pedestrian crashes (crashes in which the victim was struck by another vehicle while approaching or leaving the bus). National and state motor-vehicle crash data files identify crashes as school-bus related if a school bus was
directly or indirectly involved. A similar code for transit-related crashes should be invaluable for identifying the cases involving public transit buses.

More detailed exposure data is also critical for more precise estimates of pupil fatalities by public transit bus. The NPTS, although not fully compatible with the definitions of public transit buses, was the best nationwide estimate available for the present study, because the National Transit Data Base maintained by the FTA does not contain information on pupil ridership. Most large public transit systems have information on pupil ridership and could report it, although they are not required to do so.

Changing national crash databases or the national transit system reporting requirements is not a simple undertaking. An alternative approach could address the question of relative safety of pupil transportation by the two bus modes. A study could be designed to collect information about school trip crashes at the school district level. Such a study would involve developing an appropriate sample and then recruiting a number of school districts, with some using school buses, some using transit buses, and some using both types of buses. The school districts would report all crashes involving their pupils on school trips by school bus and by transit bus on special forms, which they would complete with the cooperation of the police agency investigating the crash. The advantage of this approach is that the exposure and crash information could be fully matched for the sample of pupils. This approach could also be used to collect injury information. Further, it need not be limited to the bus modes but could also be used to determine the safety of the school trip by all modes of travel.

The relative risk of children's travel to and from school by various modes is an important issue. Only by knowing the relative risks and safety records of each travel mode, can communities, parents, and school districts make informed choices that balance safety, community needs, and resources.
Endnotes

1 49 CFR 571.3 (Code of Federal Regulations 2002) defines a school bus as a bus that is sold, or introduced into interstate commerce, for purposes that include carrying students to and from school and related activities, but does not include a bus designed and sold for operation as a common carrier in urban transportation.

ANSI 16.1, Manual on Classification of Motor Vehicle Traffic Accidents defines a school bus as a vehicle used for the transportation of any school pupil at or below the 12th grade level to or from a public or private school or school-related activity. This vehicle is not a school bus while on trips which involve the transportation exclusively of other passengers or exclusively for other purposes. It is a school bus only if it is externally identifiable by the following characteristics: (1) its color is yellow, (2) the words “school bus” appear on the front and rear, (3) flashing red lights are located on the front and rear, and (4) lettering on both sides identified the school or school district served, or the company operating the bus.

2 The research on which this article is based did investigate the feasibility of estimating pupil injuries on the school trip by transit bus. Because of type and quality of data available, the methods for obtaining nationwide estimates of pupil injuries were very different from those used to obtain fatality estimates and are not reported in this article.

3 The vehicle category “van” was included in these criteria because there are separate codes in FARS for van-based school bus and van-based public transit bus. Van-based school buses are included in the school bus category, and public transit vans are included in the public transit bus category in this study.

4 The assumption of a Poisson distribution for passenger deaths is somewhat tenuous because multiple deaths in one crash may not be independent.

Acknowledgments

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article. The opinions and conclusions expressed or implied in this article are those of the author and not necessarily of the sponsoring agencies.

References


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Valuing Rider Quality in Swedish Special Transport Services—New Findings

Stig Knutsson, Department of Social Work, Stockholm University

Abstract

The Swedish Special Transport Services, with 0.42 million authorized pass-holders, is integrated into the Swedish public transport system. This article compares STS rider quality with present-day public transportation standards.

A Swedish rider quality index is used to examine a stated preference questionnaire sent to 2,200 randomly chosen riders in Stockholm, Göteborg, and one rural district. A logit model was used for the statistical analysis.

Waiting time at telephone switchboard was weighed for the entire population to 81 percent, information to 53 percent, and driver assistance to 21 percent regarding trip frequency. One minute Waiting time at telephone switchboard corresponded to 17.5 minutes travel time in the vehicle. Several rider categories are discussed.

The results of this analysis help to bring into focus decisive quality development aspects of the regular public transportation system from a city perspective. This is important, especially in encouraging the elderly, who experience different kinds of functional disabilities, to use the regular public transportation system more often than they do at the present time. A public transportation standard must be offered that is adequate and that corresponds in quality to what both employed and elderly disabled riders want and need in accordance with their capabilities. Questions
Concerning timetable, information, and driver assistance are brought forward as important attraction components.

Introduction

The main Special Transport Services (STS) travel mode in Sweden is “färdjänst.” The färdjänst mode is comprised of 400,200 STS pass-holders. In 2001 the STS provided 13,556,100 one-way trips (SIKA 2002). In 2000, Stockholm County alone had 20.8 percent of all the riders in Sweden and 25.6 percent of all one-way trips in the country (SIKA 2002). Taxicabs and minivans are used for the trips and authority-organized vehicle pooling is the basic passenger quality standard. The most typical STS pass-holder in Sweden is a woman with pension benefits (National Board of Health and Welfare 1998); the most frequent user is, in contrast, an employed man around 40 years old.

A political policy shift, supported by the Swedish Special Transport Service Act 1997 (SFS 1997:736), has taken place within STS from the social policy area to the transport domicile. As a consequence, since 1998 STS has been seen as an integrated part of the public transport system in Sweden. The quality standard of this mode must be compared with the standard of the present public transport as opposed to the common interpretation of the Swedish legislation (SFS 1997:734, SFS 1997:736). The STS reformation is the result of a strongly expressed demand for Swedish transportation policy effectiveness in terms of government cost reduction (SFS 1997:736). Actual use of STS has also been dramatically reduced during the last decade. For example, in 1994 there were 441,300 STS pass-holders and the service provided 17,456,100 one-way trips (SIKA 2002).

Performance evaluation methods are useful elements in the transportation development process at least as far back as Paaswell (1977). We have frequently seen economical measurements of transport productivity from the producer perspective (Gillingwater et al. 1995; Thatcher et al. 1991). In Sweden, while it has also been common to measure STS productivity from the producer perspective in terms of quantity ahead of quality (Knutsson 1999), some attention has been given to rider quality aspects and attributes. In the United Kingdom, Sutton (1990) uses a multinominal logit model to estimate travel demand for STS. McKnight et al. (1986) provides a rider quality index for the United States. Mc Kee (1993) offers an outline of a rider quality model that focuses on rail vehicles accessible to disabled passengers. In a Swedish context, there is only one published report known (Knutsson 1998) to model STS travel demand in terms of rider quality attributes.
This article reports on part of the 2000 follow-up study in the County of Stockholm, County of Östergötland, and the Municipality of Göteborg. It is based on results and knowledge from the reported 1998 Swedish study (Knutsson 1998).

**Methods**

A rider quality index of Swedish STS (Knutsson 1998, 2000) is used as a platform for the planned Stated Preference (SP) experiments. The Index of Rider Quality (IRQ) outlines the most important aspects of rider quality in a Swedish context based on customer utility and well-being in terms of the right to make choices, to act independently, and to maintain dignity and self-esteem.

For many years the SP technique, which normally deals with the demand of the average passenger, has been a common tool used in transportation research (Jones 1989; Pearmain et al. 1991; Widlert 1992). The SP should be designed with instinctive feeling toward the target rider group. But are the planned SP experiments a good, realistic, and beneficial strategy in this particular case? Based on the results of a customer postal questionnaire, the answer has to be yes.

The 2,200 receivers of the survey questionnaire, all with at least one STS trip in 1999, were randomly picked from the STS pass-holder population in the County of Stockholm, County of Östergötland, and the Municipality of Göteborg. The response frequency was 69 percent.

Chosen key attributes were based on the fact that STS quality standards have to be compared with passenger comfort in conventional public transport. The second reason for the choice was the desire to continue to expand the method approach from 1998 and to capture the most important attributes that depict no time-related attributes. For the STS pass-holders, those attributes are closely linked to the ability to actually control the timetable of the trip. A crucial point is the authority-organized vehicle pooling and its effects on the rider's space of action.

The parameters used in this study included:

**Information access (vehicle-pooling)**

- Driver assistance
- Frequency of service
- In-vehicle time
- Waiting time at telephone switchboard
### Index of Rider Quality (IRQ) of STS

*Source*: Knutsson 1998

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Measurement</th>
</tr>
</thead>
</table>
| **Information** | Information access  
Understandable information  
Faultless and complete information  
Unambiguous information |
| **Dignity** | Being taken seriously as a traveller  
Confidence with respect to what to do and where to go  
Personal privacy  
Reliability of service  
Day and night time safety  
Medical emergency capability  
Suitability and motivation of driver  
Courtesy and friendliness  
Familiarity with personal needs |
| **Comfort** | Service on weekdays  
Service on weekends  
Punctuality of departure  
Punctuality of arrival  
Freedom from crowding  
Booking  
Follow-up to complaints  
Few travel restrictions  
Prebooking of return  
Smoothness of ride  
Vehicle inside design  
Number of steps  
Space and seating  
Lift or ramp  
Distance to vehicle  
Driver assistance  
Ease of complaining  
Possibility to choose departure time |
| **Travel Time** | Reasonable in-vehicle time  
Waiting time away from home  
Switchboard waiting time  
Total trip time  
Delays on vehicle  
Prebooking time  
Punctuality of pick-up time |
| **Fare** | Worth its price compared to public transport fare |
The set of variables and their levels are detailed in Table 1. In relation to the IRQ index attributes, the IRQ attribute 31 opportunity to choose departure time is transformed to frequency of service in this study. Also, the IRQ attribute 32 reasonable in-vehicle time is shortened to in-vehicle time. In addition, in-vehicle time in comparison with normal public transport minus 20 minutes in level A, represents an improvement and level B plus 10 minutes stands for a deterioration.

The results of this study are dependent on the SP design. Therefore, the selected levels of the attributes are very important.

Table 1. Variables and Levels Used in the Calculations

<table>
<thead>
<tr>
<th>No</th>
<th>Group of Attribute</th>
<th>Variable</th>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
<th>Level D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Information</td>
<td>Information access (vehicle-pooling)</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Comfort</td>
<td>Driver assistance</td>
<td>All help you need</td>
<td>As today</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Comfort</td>
<td>Frequency of service</td>
<td>Every 30 min.</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Travel time</td>
<td>In-vehicle time</td>
<td>Minus 20 min.</td>
<td>+ 10 min.</td>
<td>Equal</td>
<td>-10 min.</td>
</tr>
<tr>
<td>34</td>
<td>Travel time</td>
<td>Waiting time at telephoneswitchboard</td>
<td>0 minutes</td>
<td>5 minutes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rider attitudes toward authority-organized vehicle pooling, the basic STS performing standard today, is discussed later in this article. This rider quality aspect is not an independent attribute in the IRQ index. Instead, vehicle pooling has become an integrated part of the STS production form. Vehicle pooling consists of a large number of IRQ attributes (see Table 2).
Table 2. IRQ Variables Constituting the Authority-Organized Vehicle Pooling

<table>
<thead>
<tr>
<th>No</th>
<th>Group of Attribute</th>
<th>Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Information</td>
<td>Information access (vehicle-pooling)</td>
</tr>
<tr>
<td>6</td>
<td>Dignity</td>
<td>Confidence with respect to what to do and where to go</td>
</tr>
<tr>
<td>14</td>
<td>Comfort</td>
<td>Service on weekdays</td>
</tr>
<tr>
<td>15</td>
<td>Comfort</td>
<td>Service at weekends</td>
</tr>
<tr>
<td>16</td>
<td>Comfort</td>
<td>Punctuality, departure</td>
</tr>
<tr>
<td>17</td>
<td>Comfort</td>
<td>Punctuality, arrival</td>
</tr>
<tr>
<td>18</td>
<td>Comfort</td>
<td>Freedom from crowding</td>
</tr>
<tr>
<td>19</td>
<td>Comfort</td>
<td>Booking</td>
</tr>
<tr>
<td>26</td>
<td>Comfort</td>
<td>Space and seating</td>
</tr>
<tr>
<td>32</td>
<td>Travel time</td>
<td>Reasonable in-vehicle time</td>
</tr>
<tr>
<td>35</td>
<td>Travel time</td>
<td>Total trip time</td>
</tr>
</tbody>
</table>

To explore the differences between how employment, age, income, and other socioeconomic variables influence the calculation results, the population was segmented using the following criteria:

- Employment status
- Household income
- Age
- Gender
- Type of municipality
- Trip purpose
- Type of obstacle
- Degree of STS use
- Use of public transport
- Degree of vehicle-pooling

The chosen segmentation of the population in the study is a combination of standard segments and more specific ones. Starting with the total population results, this article discusses the following segments: age groups, employment categories, gender groups, travel purpose, number of one-way trips, mobility obstacles (e.g., wheelchair respective not wheelchair user respective), and user opinions of authority-organized vehicle pooling.
For the statistical analysis, a logit model (Algers et al. 1987) was employed. The utility function was formulated as follows:

\[ u_1 = p_{10} + p_{11}FB + p_{12}VV + p_{13}HT + p_{14}RT + p_{15}P + p_{16}FBET \]  \hspace{1cm} (1)

where:

\[ p_{10} - p_{16} \] are parameters to be estimated.

To run the estimations, the ALOGIT program (Hague Consulting Group 1992) was chosen. Based on the segmentation presented above, 29 estimations were made.

**Results**

The results presented in Table 3 constitute the main findings and relationships between the variables using the full database.

**Table 3. Main Results of Estimated Rider Quality Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-24.4</td>
<td>-9.9</td>
<td>-16.6</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-29.2</td>
<td>-15.2</td>
<td>-20.9</td>
</tr>
<tr>
<td>Information access</td>
<td>-19.9</td>
<td>-11.3</td>
<td>-11.5</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>-7.9</td>
<td>-5.3</td>
<td>-5.5</td>
</tr>
</tbody>
</table>

**Main Results**

The maximum, minimum, median, and mean values shown in Table 3 are collected from the 29 different ALOGIT estimations. Estimates are expressed in minutes and the values are all in weight comparison to one minute in-vehicle time.
Total Population
The nonsegmented calculation and value results for the total population are shown in Table 4.

Table 4. Estimation of STS Attributes for the Total Population

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>T-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-0.6431</td>
<td>(-16.1)</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-0.7884</td>
<td>(-19.3)</td>
</tr>
<tr>
<td>Information access</td>
<td>-0.4182</td>
<td>(-10.5)</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>-0.1666</td>
<td>(-4.2)</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>-0.0367</td>
<td>(-18.2)</td>
</tr>
</tbody>
</table>

Observations: 3763
Final log(L): -1977.8240
D.O.F: 5
Rho²(0): 0.2417
Rho³(c): 0.2117

As shown in the table, the overall average calculation pattern is established. Note the strong t-values compared with the weaker t-value for driver assistance, which is weaker in comparison with all other selected variables in the study. On the whole, however, the chosen variables seem to be relevant to the needs of the STS pass-holder, mirrored by the random sample.

Table 5. Time Valuation of STS Attributes for Total Population (in minutes)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-17.5</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-21.5</td>
</tr>
<tr>
<td>Information access</td>
<td>-11.4</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>-4.5</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
</tr>
</tbody>
</table>
The average value path and its interrelated correlations are depicted in Table 5. 
Frequency of service is in the unchallenged lead. According to the total population in this study, switchboard waiting time is weighted to 81 percent, information access to 53 percent, and driver assistance to 21 percent of the weight of frequency of service. Typically in-vehicle time is far easier to tolerate when you actually are sitting in the car, compared to waiting time at telephone switchboard or frequency of service. These variables depict vital aspects on, or strong tools for, rider trip control or, in other words, our own feeling of space of action opportunities. The main problem is the lack of planning opportunities in the rider's daily life. Timetable issues are as important for this group of riders as for everybody else.

**Age Groups**

Waiting time at telephone switchboard was reported as the most important variable for the senior rider groups (Table 6). Waiting can be difficult even if you have free time. In this case, riders are totally bound to the call situation and their opportunities to choose between other transport modes are small compared to non-STS pass-holders. Naturally, this is because to be a STS pass-holder normally defines a crucial mobility or economical obstacle linked to your use of buses or terminals in the public transport or regular taxi systems. For the younger rider groups, with employment or a similar day pattern, regular, survivable, repetitious weekday trips can easily be ordered in advance. In addition, to organize daily life activities inside the framework of constantly prebooked trips, is seen as a limitation to planning opportunities—a limitation on space of action in life.

**Table 6. Time Valuation of STS Attributes for Age Groups**

<table>
<thead>
<tr>
<th>Variable</th>
<th>18–64 Minutes</th>
<th>65–84 Minutes</th>
<th>&gt;65 Minutes</th>
<th>&lt;=64 Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-15.2</td>
<td>-17.6</td>
<td>-18.5</td>
<td>-15.9</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-21.6</td>
<td>-20.0</td>
<td>-20.8</td>
<td>-22.5</td>
</tr>
<tr>
<td>Information access</td>
<td>-10.2</td>
<td>-11.2</td>
<td>-11.3</td>
<td>-11.6</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>*</td>
<td>-4.7</td>
<td>-5.6</td>
<td>*</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level*
Not surprisingly, frequency of service is valued highest in the younger group and driver assistance in the oldest rider group. But the frequency of service value only occupies rank seven in the total list; that is, six other segments put more weight on frequency of service. For driver assistance, there is a distinct valuation difference between the limit group 65–84 and the unlimited group >65.

**Employment Categories**

In the employed STS pass-holder group, lower values connected with waiting time at telephone switchboard, frequency of service, and information access were observed compared to the population as a whole (Table 7). Information access is not an important point here in relation to the other variables, probably because of a frequent use of the STS system.

**Table 7. Time Valuation of STS Attributes for Employed/Student Respective Not Employed/Student (in minutes)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Employed/Student Minutes</th>
<th>Not Employed/Student Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-14.4</td>
<td>-18.1</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-16.0</td>
<td>-22.4</td>
</tr>
<tr>
<td>Information access</td>
<td>-6.0</td>
<td>-12.3</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>*</td>
<td>-4.9</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level

On the other hand, all of the variables in the nonemployed rider group have increased weights, with the same starting point for comparison. As discussed in the age group section above, these facts can be seen in the light of differences in the demands of daily life. An employed person has more nonnegotiable, time-fixed tasks and meetings to confront.

**Gender Groups**

As shown in Table 8, the ranking order is the same between the sexes. Note the high weight for frequency of service and its relation in minutes to in-vehicle time reported by male STS pass-holders. In comparison with the total population re-
sults, men are consistently making a higher attribute valuation. In other words, men are more demanding about the STS service standards identified in this study.

The female value for waiting time at telephone switchboard is only 75 percent of the male value. In this study, typical STS pass-holders are women. As stated earlier, the usual STS pass-holder is a woman with pension benefits; the most frequent STS user is, in contrast, an employed younger man.

**Table 8. Time Valuation of STS Attributes for Gender Groups**
*(in minutes)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men Minutes</th>
<th>Women Minutes</th>
<th>Difference Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-21.2</td>
<td>-15.9</td>
<td>-5.3</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-23.5</td>
<td>-20.2</td>
<td>-3.3</td>
</tr>
<tr>
<td>Information access</td>
<td>-12.9</td>
<td>-10.8</td>
<td>-2.1</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>-7.4</td>
<td>-3.0</td>
<td>-4.4</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Travel Purpose**

This study looked at three types of travel purposes: work trips, visiting trips, and hospital trips (Table 9).

**Table 9. Time Valuation of STS Attributes for Travel Purpose**
*(in minutes)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Work Trip Minutes</th>
<th>Visiting Trip Minutes</th>
<th>Hospital Trip Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-14.6</td>
<td>-14.6</td>
<td>-20.4</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-20.1</td>
<td>-18.6</td>
<td>-24.2</td>
</tr>
<tr>
<td>Information access</td>
<td>-10</td>
<td>-9.9</td>
<td>-12.6</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>*</td>
<td>*</td>
<td>-6.1</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level
Waiting time at telephone switchboard to order work trips can, by planning activities in advance, be reduced in respect to frequency and therefore is not as highly valued as we would expect. In the work-trip case, the value of information access about vehicle pooling is slightly lower than for the total population. Riders ordering visiting trips are typically more patient regarding punctuality of departure or arrival precision.

On the other hand, hospital trips demand a quick response from the telephone switchboard: Users needing hospital treatment typically require a rapid one-way ride. This trip category is clearly on top in all values when comparing the values of total population.

In frequency of service, the valuation differences between the different travel types are what we can expect. For hospital trips, the valuation of frequency of service is the second highest value in the study. Only wheelchair riders place a higher value on frequency of service.

The values in Table 9 indicate that if the authorities need to cut STS costs, they should not do it in waiting time at telephone switchboard or frequency of service qualities. Costs should be cut by extending the in-vehicle time, that is, when the user is finally riding in the vehicle. Total trip time, the total time span from ordering a ride to the actual arrival at the agreed destination, is another quality aspect not to be forgotten, but not calculated in this study.

**Number of One-Way Trips**

Note the value levels of the seldom/never rider fraction in Table 10. The value for waiting time at telephone switchboard is 17 percent higher, frequency of service

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Daily/Weekly Minutes</th>
<th>Every Month Minutes</th>
<th>Seldom/Never Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-15.3</td>
<td>-14.8</td>
<td>-20.5</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-22.1</td>
<td>-21.3</td>
<td>-20.4</td>
</tr>
<tr>
<td>Information access</td>
<td>-10.8</td>
<td>-9.2</td>
<td>-12.5</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>-4.9</td>
<td>-6.1</td>
<td>*</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level
5 percent lower, and information access 10 percent higher than in the total population calculation. These values imply that STS pass-holders who travel rather seldom need to have a relatively higher transportation quality than the more frequent and experienced STS users.

**Mobility Obstacles: Wheelchair User Respective Not Wheelchair User**

STS technical performance differs between wheelchair riders and other STS pass-holders in reference to vehicle demands (Table 11). Usually, wheelchair users need minivan transport as opposed to basic taxicabs.

**Table 11. Time Valuation of STS Attributes for Mobility Obstacles: Wheelchair User Respective Not Wheelchair User (in minutes)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Wheelchair Minutes</th>
<th>Not Wheelchair Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-18.5</td>
<td>-17.6</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-29.2</td>
<td>-20.6</td>
</tr>
<tr>
<td>Information access</td>
<td>-13.6</td>
<td>-11.3</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>*</td>
<td>-5.0</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level

Compared to the total population figures, Table 12 shows that the deviations expressed in percent are obvious. All statistically significant variables are increased in the wheelchair user group, especially the levels of frequency of service respective and information access. Wheelchair users must plan ahead, down to the smallest details.

Here again, this situation brings up the discussion of personal alternative costs in all respects.
Table 12. Comparison between Wheelchair User Respective Not Wheelchair User and Total Population Values (in percent)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Wheelchair</th>
<th>Not Wheelchair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>106</td>
<td>101</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>136</td>
<td>96</td>
</tr>
<tr>
<td>Information access</td>
<td>119</td>
<td>99</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>*</td>
<td>111</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level

User Opinions of Authority-Organized Vehicle Pooling

As stated in the introduction, vehicle pooling is the basic quality standard of today's STS performance. Vehicle pooling consists of a large number of IQR attributes. Sharing passenger seats in an STS vehicle is, in many ways, like sharing passenger seats in the regular public transport buses. In the STS case, though, negative qualities are added (e.g., rider uncertainty about route orientation and timetable issues). Imbedded in the authority-organized vehicle-pooling situation is an indefinite loss of space of action, daily life overview, and opportunities for planning ahead. These losses need to be seen from a very long-term, never-ending, and repetitious perspective as opposed to one or two occasions weekly.

Table 13. Time Valuation of STS Attributes for Positive, Respective, Negative Opinion of Authority-Organized Vehicle Pooling (in minutes)

<table>
<thead>
<tr>
<th>Variable</th>
<th>A Minutes</th>
<th>B Minutes</th>
<th>C Minutes</th>
<th>D Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-18.2</td>
<td>-17.2</td>
<td>-13.2</td>
<td>-9.9</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-20.8</td>
<td>-19.0</td>
<td>-15.2</td>
<td>-23.2</td>
</tr>
<tr>
<td>Information access</td>
<td>-8.5</td>
<td>-9.3</td>
<td>-11.4</td>
<td>-15.5</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>*</td>
<td>-3.7</td>
<td>-7.9</td>
<td>*</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Not significant at 95 percent level
Table 13 shows the great value span in the variable values for the indeed negative users. The indeed negative riders to vehicle pooling have the most striking deviations in valuation compared to the total population. That is, waiting time at telephone switchboard is valued at 57 percent—lowest of all segments—frequency of service to 108 percent, and information access to 136 percent of the total population weights.

The rather negative STS pass-holders value frequency of service lowest of all segments and driver assistance highest of all 15 statistically significant segments in the study.

Positive riders, in contrast, are on the whole rather close to the total population values. The valuation of information access is, not surprisingly, lower in the positive segments in comparison with the total population pattern. In relation to information access, the other variable values in these groups are strongly increasing. They are placed in the quality forefront.

Another observation to take into account concerns driver assistance. The rather positive riders value this variable to less than half, or 3.7 minutes, compared with the rather negative STS pass-holders value of 7.9 minutes. The total population value for this variable is 4.5 minutes.

These facts point out the importance of not viewing the collective of STS pass-holders as a homogeneous group of transport consumers who react in the same manner to STS mode design and performance changes.
Discussion

An important political policy shift has taken place in the STS from the social policy area to the transport domicile. This trend is supported by the Swedish Special Transport Service Act 1997 (SFS 1997:736). Since 1998, STS has been seen as an integrated part of the public transport system in Sweden. The explicit authority intention was, and still is, to reduce government spending and make the STS transport system more cost effective from the organizers’ perspective. The transportation authority also aimed to stimulate an overflow of passengers from the expensive STS transport system to the cheaper regular public transport bus system.

Several STS issues are of vital interest from a regional planning perspective. The STS service has experienced a reduction in performance. In 2001, the STS served 400,200 pass-holders, or 4.5 percent of the Swedish population. In 1994, 441,300 pass-holders were accommodated. The total number of STS trips has been reduced from 17.5 million one-way trips in 1994 to 13.6 million in 2001. Government costs in 2001 were roughly 2 billion Swedish kronor, or $ U.S. 215 million.

The authority-organized vehicle-pooling technique is successful from the organizers’ perspective because the vehicles are filled by picking up passengers in the district or during the trip in the direction of the destination.

Based on this information, a Swedish methodology for calculating rider quality in STS was developed. The methodology uses utility modelling presented in a Swedish context for the first time in 1998 (Knutsson 1998, 2000). The model used is based on the basic logit formulation and estimated with the ALOGIT program.

Estimated rider quality variables are shown in Table 3.

Table 14 shows the valuation of the rather or indeed negative to authority-organized vehicle-pooling STS pass-holders. To extend the in-vehicle time, in contrast maybe to the not here valued total trip time, is the least expensive change. The subject for quality standard comparison is the timetable in the regular public bus system in contrast to taxis. Another area to address involves prolonging the wait time at telephone switchboard. One way to present these suggestions is through strengthened user information access.
Table 14. Comparison between Rather Respective Indeed Negative Opinion of Authority-Organized Vehicle Pooling (in minutes)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rather Minutes</th>
<th>Indeed Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time at telephone switchboard</td>
<td>-13.2</td>
<td>-9.9</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>-15.2</td>
<td>-23.2</td>
</tr>
<tr>
<td>Information access</td>
<td>-11.4</td>
<td>-15.5</td>
</tr>
<tr>
<td>Driver assistance</td>
<td>-7.9</td>
<td>*</td>
</tr>
<tr>
<td>In-vehicle time</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

From the passenger perspective, however, these proposals are a further cut into the space of action and daily life planning opportunities.

For wheelchair users, one of the most vulnerable rider groups, frequency of service ranks as the top quality priority. To thin out frequency of service beyond the public transport bus standard in the region to fill up the vehicles, is an expensive alternative.

In seeking the best alternatives, the organizers want to maintain good relations, confidence, and goodwill with STS pass-holders and at the same time, diminish customer complaints. Their aim is comfortable travel for all.

The rider quality index (IRQ) and the Swedish results can contribute constructively toward a focused, decisive quality development within the regular public transportation system from a city perspective. If we are to succeed in this endeavor, a public transportation standard must be offered that, at the very least, corresponds to the demands and needs of both employed and elderly disabled riders.

Acknowledgment

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Journeys to Crime: Assessing the Effects of a Light Rail Line on Crime in the Neighborhoods

Robin Liggett, Anastasia Loukaitou-Sideris, and Hiroyuki Iseki
UCLA Department of Urban Planning

Abstract

The implementation of new transit lines is sometimes dogged by concerns that such lines may increase crime rates in station neighborhoods. Affluent communities have often complained that transit lines transport crime to the suburbs. This study focuses on the Green Line transit system in Los Angeles and examines its effects on crime in the adjacent areas. The Green Line light rail system passes through some high-crime, inner-city neighborhoods and terminates at its western end in affluent suburban communities. The study examines neighborhood level and municipality-wide crime trends for five years before and five years after the inception of the line. A piecewise regression model is developed to evaluate the impact of the opening of the line in the station neighborhoods. Geographic Information System (GIS) analysis is also utilized to identify spatial shifts in crime hot spots for the municipalities abutting the Green Line. The study finds little evidence that the transit line has had significant impacts on crime trends or crime dislocation in the station neighborhoods, nor has the line transported crime from the inner city to the suburbs.
Introduction
Does a transit line bring crime to the neighborhoods adjacent to its transit stops? Does a mass transit system that passes through crime-ridden inner-city areas help transport crime to the suburbs? Is such a line expanding the range of action of potential criminals by facilitating their "journeys to crime"? Such concerns have early on dogged the planning and implementation of light rail lines in Los Angeles because of their alignment through areas vulnerable to crime.

Criminologists have called transit stations "crime attractors" and "fear generators" (Felson et al. 1990; Brantingham and Brantingham 1995) because they can generate crime and disorder by producing crowds. Urban railway stations have been described as behavior settings that gather flows of people on their way to work, shopping, or recreation. Some people are easy targets; being tired, preoccupied, carrying packages or other stealable objects (Myhre and Rosso 1996). But in addition to crime occurring at the station, some have argued that mass transit systems have the potential of "exporting" crime from one area to the other. According to Canadian criminologists Paul and Patricia Brantingham:

...transit shapes the crime pattern of the city by moving large proportions of high-risk populations around the city along a limited number of paths and depositing them at a limited number of destination nodes; awareness spaces and target search points become tightly clustered. Transit shapes the types of crime that are likely to be committed, by shaping the opportunity and the getaway potential of high-risk populations. (1991:93).

Some have also reported on the dual nature of the relationship between transit crime and the environment of adjacent neighborhoods, noting that the socio-physical characteristics of the immediate station area affect the danger at a transit station. At the same time, the presence of a station affects the danger in the immediate neighborhood (Block and Block 2000). In an earlier work, the Green Line transit system in Los Angeles was used to examine the first part of the "transit crime-environment" equation. The effects of socio-demographic and physical characteristics of station neighborhoods on crime incidence at the station were analyzed (Loukaitou-Sideris et al. 2002). This study showed that station crime was strongly related to ridership. Less serious crime (e.g., vandalism) was higher in stations located in dense neighborhoods with higher proportions of youth. Such crime tended to occur more in unkempt neighborhoods with deteriorating building stocks. Certain design characteristics of the station were related to platform
crime against people. At the same time some socio-demographic indicators of the neighborhood (income, household size, concentration of youth) were also related to station crime. Finally, certain land uses in the transit neighborhood (notably the presence of liquor stores) were strongly correlated with station crime.

The present study focuses on the examination of the effects of the Green Line on its adjacent areas. Particular interest is placed on investigating possible crime influences of this inner-city line on its outlying suburban areas. More specifically, the study will respond to the following questions:

1. Have the neighborhoods adjacent to Green Line stations experienced more crime after the introduction of the line?
2. Has the introduction of the line contributed to a shift or a dislocation of crime within the municipality?
3. Is there a concentration of hot spots of crime in areas adjacent to the station? Are these hot spots correlated with particular land uses?
4. Has the introduction of this line that passes through high-crime, inner-city areas brought more crime to the outlying affluent suburban communities located at its western segment?

This article begins by outlining the theoretical background of the study by summarizing criminological theories that seek to explain a perpetrator’s journey to crime and move through city spaces. This is followed by a literature review of empirical studies that have investigated the crime effect of transit systems on neighborhoods. Finally, the findings of our empirical research are presented and responses are provided to the aforementioned questions.

**Urban Structure, Mobility, and Crime**

A study of crime that involves an investigation of possible transit influences on surrounding areas requires examination of the concept of “journey to crime,” the trip that an offender takes to access potential crimes (Plano 1993). Criminal justice theory has sought to trace the relationship between a criminal’s mobility and the incidence of crime. As early as the 1930s, ecological theorists described movements through space as related to opportunity structures; arguing that criminals tend to move and act in city zones where more opportunities for crime are evident (Lind 1930; White 1932). Decades later Boggs (1966) similarly suggested that environmental opportunities, which vary throughout an urban area, determine
crime rates. In a well-known article of the 1970s, Capone and Nichols argued that “criminal mobility is related to urban structure and the analysis of movement behavior will yield insight into offender decision-making and spatial preferences and contribute significantly to our understanding of the urban system as a crime opportunity structure” (1976: 200).

In the last decades, criminologists have become increasingly interested in the spatial distribution of crime, as well as the journeys of criminals to commit crimes. Picturing criminals as rational decision-makers, they have noted, “... from a criminological perspective, if a person is searching for a target to rob, and several potential targets exist, all things being equal, the closest target will be chosen. All things are never equal, but it is argued that on the whole, there is a strong spatial bias that results in more short trips than long trips within any particular category of time” (Brantingham and Brantingham 1984:237). Theoretical work on the geometry of crime has assumed that the range of criminal activity for offenders is determined by a “constricted awareness space” that is based on their familiarity with particular places (home, work, school, mall, park, etc.), and from areas adjacent to the paths that lead them to these sites (Brantingham and Brantingham 1991).

Empirical studies have shown that criminals can often travel beyond their immediate neighborhood to commit property crimes (robbery, burglary, car theft) (Capone and Nichols 1976; Pyle 1976). Capone and Nichols (1976) distinguished between “open space occurrences” and crime occurrences at “fixed premises,” arguing that the former tend to be more spontaneous and not involving long travel, while the latter tend to require advance planning and often longer journeys to crime. However, differentiation exists between fixed premises, with liquor stores, supermarkets, and cash checking establishments requiring longer trips, while residences, grocery stores, and gas stations exhibiting shorter average journeys to crime. Capone and Nichols concluded: “Urban structure and criminal mobility are inextricably linked, for criminal movement behavior is the product of an essentially rational structure of decision-making process that involves evaluation of an objective urban opportunity structure, the differential attractiveness of particular elements of that structure, and the universal constraint of distance (1976:211).

While there is a consensus that criminals may be willing to travel a certain distance to reach potential targets, some criminologists have also promoted the “distance decay theory.” This argues that criminal travel patterns are characterized by a distance-decay function—the further the distance of a place from a criminal’s place of residence (or point of origin) it is less likely that this criminal will travel to that
place to commit a property crime. This is attributed to the fact that potential offenders do not have a good reconnaissance of distant areas (Plano 1993). Pyle (1976) studying crimes committed in 27 public housing estates in Cleveland found that for crimes against persons, the average distance between the offender’s origin and destination was just under 2 miles. For property crimes, the average travel distance was 2.3 miles (Pyle 1976). Similarly, examining the distribution of robbery incidents in Miami, Capone and Nichols (1976) found that the frequency of robbery trips declined with increasing distance from the residential location of offenders. While findings from these studies seem to support the distance-decay function, this theory has been recently denounced by Van Koppen and Keijser (1997). According to them, studies showing a distance of decay of journeys to crime rely on correlations in aggregate data that cannot be good predictors of correlations in individual criminal behavior.

Regardless of whether the journey to crime is influenced by a consideration of distance, it is well known that other factors also intervene to enhance or decrease the appeal of a potential site as a target. These include the type of existing land uses, level of police and natural surveillance, environmental factors (visibility, lighting, urban form condition, etc.), area accessibility, and perceived opportunities for escape.

**Literature Review**

The criminological theories outlined in the previous section seem to give support to the notion that transit lines can expand a criminal’s range of action. For one, rapid transit systems can compress the amount of time necessary for a criminal to reach his or her destination, and can familiarize him or her with an increased number of outlying areas. Second, the imposition of a major transportation artery, such as a transit line or a freeway, in an area increases the area’s accessibility. In describing the “geometry of crime” Paul and Patricia Brantingham (1981) have argued that a concentration of criminal activities occur close to major transportation arteries and highways. Such contentions have supported the notion that transit lines might bring increased crime to the areas they serve, and have often fueled a neighborhood’s reaction against the “intrusion” of a railway line, especially in more wealthy, suburban areas (Poister 1996). A study of resident and business perceptions prior to the initiation of construction activities for a MARTA station in Atlanta found that crime (after construction) was the second most major concern of residents, after traffic congestion (Ross and Stein 1985).
While theory and public perception seem to agree that new transit lines have the potential to bring more crime to the surrounding neighborhoods, empirical research on the subject is quite mixed. Very few studies have analyzed the effect of railway stations on surrounding areas. In examining the environs of Chicago railway stations, Block and Davis (1996) found that the bulk of robberies were not concentrated immediately at the station, but about 1 to 1½ blocks away. Block and Block (2000) found the same pattern in Bronx, where 50 percent of all street robberies had occurred within about 700 feet of a transit station. The researchers argued that the high level of guardianship at the stations negated the great number and good choice of potential targets. Instead crime was displaced in the near vicinity.

Little empirical research has investigated the issue of transit-related crime in outlying residential or commercial areas by perpetrators who have used the transit system. The findings of such studies are contradictory. In a study that analyzed police crime reports for transit-related crime in an unnamed city, Shellow et al. (1974) found that criminal predators tended to work in territories familiar to them and were not likely to use public transit as a means for extending their territory or as a means for escape. Examining crime patterns of the neighborhoods around three Baltimore stations for three years before and three years after the metro line's opening Plano (1993) found that reported crime was on an upward and erratic trend after the opening of the stations. However, lack of accurate crime locations prevented him from attributing the crime increases to the stations' openings, or from identifying any distance trends or clustering patterns of the crime occurrences. An analysis of burglary trends before and after the opening of two MARTA stations in suburban Atlanta found no evidence to suggest that burglaries have increased after the opening of the stations (Poister 1996). In a study of crime patterns before and after the opening of the Blue Line in Los Angeles Loukaitou-Sideris and Banerjee (2000) found that in most station areas the introduction of the light rail line has reduced crime incidence in the immediate station neighborhood. The study also found that the station area was relatively safer than its larger surrounding communities, a fact attributed to the high deployment and visibility of transit police.

The review of the literature reveals that the empirical research about the effect of transit on the crime rates of adjacent neighborhoods is quite inconclusive. The few studies on the topic have produced mixed or contradictory results.
The Context

The Los Angeles Green Line is used as a case study in this research to explore the impact of a transit line on crime in its adjacent neighborhoods. The researchers test the validity of the assumption that a transit line can transport crime from high-crime, inner-city areas to low-crime, suburban neighborhoods.

The Green Line is a light rail line that runs a total of 19.6 miles from Norwalk (to the east) to El Segundo (to the west) in Los Angeles County (see map in Figure 1). The line has 14 stations and had a daily average ridership of 23,000 passengers in 2000. For the most part (16.3 miles), the line operates in the middle of the I-105 Freeway. As it nears El Segundo the line leaves its alignment in the freeway median and continues for another 3.3 miles to its western terminus in Redondo Beach. Four suburban stations are located along this segment, all on elevated structures.

The Green Line corridor passes through communities that are quite different. The 14 station-neighborhoods vary significantly in terms of their land uses and sociodemographic characteristics. The suburban neighborhoods at the western end of the line are more affluent than the inner-city neighborhoods in the middle. Neighborhoods at the eastern end can be characterized as middle class. In terms of racial characteristics, the western neighborhoods are primarily white, the inner-city neighborhoods are primarily Latino and African American, while the eastern neighborhoods are more diverse ethnically. Some stations are within primarily residential areas (although the ratio of single and multifamily housing varies). Some stations are surrounded by industrial facilities, some by primarily commercial uses, while others have a mixture of uses in their vicinity.

Crime rates in the jurisdictions5 along the Green Line corridor also vary significantly (AEGIS 1991) (see Table 1). At its middle section the line has stations in high-crime, inner-city areas (e.g., Vermont, Harbor, Avalon, Wilmington, and Long Beach Blvd. stations). At its eastern edge the Green Line crosses communities with generally low to average crime rates (cities of Downey and Norwalk). At its western edge the Green Line runs through (or comes very close to) the low-crime suburban beach communities of El Segundo, Manhattan Beach, and Redondo Beach. The fact that the line passes through both high-crime, inner-city areas and low-crime, suburban areas makes it a good case to test the validity of the perception that rapid transit brings crime to the suburbs.
Figure 1. Map of Metro Green Line with Political Jurisdictions
Table 1. Jurisdiction Crimes Rates*

<table>
<thead>
<tr>
<th>City/LAPD Service Area</th>
<th>Stations</th>
<th>Type 1 Crime as % of County Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downey</td>
<td>2</td>
<td>72.1%</td>
</tr>
<tr>
<td>LAPD/Southeast</td>
<td>4, 5, 6, 7</td>
<td>165.2%</td>
</tr>
<tr>
<td>Hawthorne</td>
<td>8, 9</td>
<td>116.4%</td>
</tr>
<tr>
<td>LAPD/Pacific</td>
<td>10</td>
<td>148.3%</td>
</tr>
<tr>
<td>El Segundo</td>
<td>11, 12</td>
<td>87.5%</td>
</tr>
<tr>
<td>Manhattan Beach</td>
<td>13</td>
<td>78.0%</td>
</tr>
<tr>
<td>Redondo Beach</td>
<td>14</td>
<td>81.2%</td>
</tr>
</tbody>
</table>

*Green Line Security Analysis, April 1991

Research Design

Crime data was collected for six cities adjacent to the Green Line and surrounding 12 of the 14 stations (data could not be obtained for areas adjacent to the Lynwood station #3 and the Norwalk station #1). Crime data by type and location for 1990 through 1999 was obtained from the cities of Downey, Los Angeles (LAPD service areas in the vicinity of the station), Hawthorne, El Segundo, Manhattan Beach and Redondo Beach. Data was geocoded and aggregated to the station neighborhood level (1/2 mile radius around each station) to generate a quarterly time series database for the 10-year period. To identify long-term trends, the crime series data sets were first adjusted for quarterly (seasonal) variation and then smoothed using three-month moving averages (Smith 1991; Poister 1996). Similarly crime trend data was created for the larger municipalities/LAPD service areas abutting the Green Line over the 10-year period. This allowed us to study crime trend changes by quarter during the 10-year period both at the station neighborhood level and larger municipality level. To control for other factors influencing crime rates, station neighborhood trends were also compared to county crime trends during the same period. Additionally, the geocoded crime data was used for GIS analysis, which attempted to identify spatial shifts in crime hot spots for the municipalities abutting the Green Line.

The study of the Green Line entails a methodological problem, since, for the most part, the line runs in the middle of the I-105 Freeway, which could also theoretically increase the accessibility of likely offenders to outlying suburban areas. To separate the crime effects of each station on the adjacent neighborhoods, the level of crime in the areas around the Green Line stations was examined during three
different time intervals: (1) January 1991 to September 1993 (prior to the opening of the I-105 Freeway); (2) from October 1993 to August 1995 (when the Green Line started operation); and (3) from September 1995 to December 1999.

Additional data collected for our earlier study (Loukaitou-Sideris et al. 2002) provided information on socio-economic characteristics of the population in the station neighborhood as well as the primary land uses in the neighborhoods. We also had data from the Los Angeles Metropolitan Transit Authority (MTA) on boardings and alightings (ridership) by station (Table 2).

**Table 2. Station Neighborhood Characteristics**

<table>
<thead>
<tr>
<th>Station</th>
<th>Ridership</th>
<th>Neighborhood Characteristics (1/2 mile radius)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Primary Land Use</td>
</tr>
<tr>
<td>2</td>
<td>2066</td>
<td>Residential</td>
</tr>
<tr>
<td>4</td>
<td>8383</td>
<td>Multi-family Residential, Retail</td>
</tr>
<tr>
<td>5</td>
<td>1696</td>
<td>Residential</td>
</tr>
<tr>
<td>8</td>
<td>1325</td>
<td>Residential, Retail</td>
</tr>
<tr>
<td>7</td>
<td>2373</td>
<td>Residential, Retail</td>
</tr>
<tr>
<td>8</td>
<td>2392</td>
<td>Residential, Industrial</td>
</tr>
<tr>
<td>9</td>
<td>2285</td>
<td>Residential, Retail</td>
</tr>
<tr>
<td>10</td>
<td>2748</td>
<td>Vacant, Parking, Industrial, Office</td>
</tr>
<tr>
<td>11</td>
<td>1358</td>
<td>Industrial, Office, Vacant, Parking</td>
</tr>
<tr>
<td>12</td>
<td>1034</td>
<td>Industrial, Office, Parking</td>
</tr>
<tr>
<td>13</td>
<td>891</td>
<td>Office, Retail, Industrial</td>
</tr>
<tr>
<td>14</td>
<td>1064</td>
<td>Office, Retail, Industrial</td>
</tr>
</tbody>
</table>

**Crime Trend Analysis**

Nonauto related serious crime (Type 1) against persons began decreasing in Los Angeles County from a peak of about 145,000 crimes per quarter at the end of 1991 to a low of under 80,000 crimes per quarter by the end of 1999 (Figure 2). Type 1 crime related to autos also declined over the same time period. Starting at the end of 1991, the number of crimes decreased from a peak of about 35,000 in 1991 to a low of about 12,000 in 1999.

Most areas surrounding the Green Line stations experienced similar declining trends in Type 1 crime. Figure 3, for example, shows decreasing numbers of Type 1 nonauto crime in the station neighborhoods in the LAPD/Central jurisdiction. The present analysis focused on whether crime trends in the station neighbor-
Figure 2. Los Angeles County Crime Trend (1990-2000)
hoods (operationalized as ½-mile radius surrounding the station) differed significantly from trends in the larger jurisdictions along the Green Line and/or the county as a whole. Was there an increase in crime after the freeway or Green Line opened? Or, in the case of a decrease in station neighborhood crime, was the decrease less than what would be expected based on larger area trends?

To evaluate the impact of both the opening of the I-105 Freeway and the opening of the Green Line (shown by reference lines on the trend graphs) on crime in the station neighborhoods, the following piecewise regression model was developed for each station:*

\[
\text{Total crimes} = b_0 + b_1 \times \text{Time} + b_2 \times \text{FWOPEN} + b_3 \times \text{GOPEN} + b_4 \times \text{IPOSTFW} + b_5 \times \text{IPOSTGL} + b_6 \times \text{CONTROL}
\]

where:

- \( \text{Total crimes} \) equals number of Type 1 No Auto, Type 1 Auto, or Type 2 crimes in the station neighborhood seasonally adjusted and smoothed
- \( \text{Time} \) represents quarter (2\(^{nd}\) quarter 1990 is time 0)
- \( \text{FWOPEN} \) is the dummy variable for opening of Century Freeway:
  - 0, before 4\(^{th}\) quarter 1993 (\( \text{Time} < 14 \))
  - 1, 4\(^{th}\) quarter 1993 and after (\( \text{Time} \geq 14 \))
- \( \text{GOPEN} \) is the dummy variable for opening of Green Line:
  - 0, before 3\(^{rd}\) quarter 1995 (\( \text{Time} < 21 \))
  - 1, 3\(^{rd}\) quarter 1995 and after (\( \text{Time} \geq 21 \))
- \( \text{IPOSTFW} \) equals \( (\text{Time}-14) \times \text{FWOPEN} \) (Measures change in slope after freeway opens)
- \( \text{IPOSTGL} \) equals \( (\text{Time}-21) \times \text{GOPEN} \) (Measures change in slope after Green Line opens)
- \( \text{CONTROL} \) is the total crime at local city/jurisdiction level or at LA County level used to control for other factors influencing crime rate trends.
Figure 3. Type 1 Non-Auto Crime Trends at Inner City Station Neighborhoods
Tables 3 and 4 show results of fitting the piece-wise regression model to crime-time series data for each of the station neighborhoods. In the Table 3 models, crime trends at the local jurisdiction/city level are used for control while Los Angeles County crime trends are used as control in Table 4. Significant changes in slope and intercept post-freeway and post-Green Line are indicated with a “+” or “-” in the corresponding table cell, and positive changes (increases in crime) following the opening of the Green Line are further highlighted with shading.

### Table 3. Regression Model Results

<table>
<thead>
<tr>
<th>Station</th>
<th>Type 1 Crime</th>
<th></th>
<th>Type 2 Crime</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non Auto Related</td>
<td>Auto Related</td>
<td>Non Auto Related</td>
<td>Auto Related</td>
</tr>
<tr>
<td></td>
<td>Post Fwy</td>
<td>Post GL</td>
<td>Post Fwy</td>
<td>Post GL</td>
</tr>
<tr>
<td>2-Lakewood (Downey)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4-Wilmington</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>5-Avalon</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>6-Harbor</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>7-Vermont</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>8-Crenshaw</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>9-Hawthorne</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>10-Aviation</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>11-Mariposa</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>12-El Segundo</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>13-Daughlas (MB)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>14-Marine (Redondo)</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

#### b) Change in Intercept Controlling for Local Jurisdiction Crime Trend

<table>
<thead>
<tr>
<th>Station</th>
<th>Type 1 Crime</th>
<th></th>
<th>Type 2 Crime</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non Auto Related</td>
<td>Auto Related</td>
<td>Non Auto Related</td>
<td>Auto Related</td>
</tr>
<tr>
<td></td>
<td>Post Fwy</td>
<td>Post GL</td>
<td>Post Fwy</td>
<td>Post GL</td>
</tr>
<tr>
<td>2-Lakewood (Downey)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4-Wilmington</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5-Avalon</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6-Harbor</td>
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<tr>
<td>7-Vermont</td>
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<tr>
<td>8-Crenshaw</td>
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<tr>
<td>9-Hawthorne</td>
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</tr>
<tr>
<td>10-Aviation</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>11-Mariposa</td>
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<tr>
<td>12-El Segundo</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>13-Daughlas (MB)</td>
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<td>-</td>
</tr>
<tr>
<td>14-Marine (Redondo)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Significant negative change (p<.25) in slope or intercept during freeway (Fwy) or Green Line (GL) opening
- Significant positive change (p<.25) in slope or intercept during freeway (Fwy) or Green Line (GL) opening

No significant model.
Table 4. Regression Model Results

### a. Change in Slope Controlling for County Crime Trend

<table>
<thead>
<tr>
<th>Station</th>
<th>Type 1 Crime</th>
<th>Non Auto Related</th>
<th>Auto Related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Post Fwy</td>
<td>Post GL</td>
</tr>
<tr>
<td>2-Lakewood (Downey)</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>4-Wilmington</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5-Avalon</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>8-Harbor</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7-Vermont</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>8-Crenshaw</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9-Hawthorne</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10-Aviation</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11-Marina</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>12-El Segundo</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>13-Douglas (MB)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>14-Marina (Redondo)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

- Significant negative change (p < 0.05) in slope or intercept following Freeway (Fwy) or Green Line (GL) opening.
- Significant positive change (p < 0.05) in slope or intercept following Freeway (Fwy) opening.
- Significant positive change (p < 0.05) in slope or intercept following Green Line (GL) opening.
- Variable not included in model.

### b. Change in Intercept Controlling for County Crime Trend

<table>
<thead>
<tr>
<th>Station</th>
<th>Type 1 Crime</th>
<th>Non Auto Related</th>
<th>Auto Related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Post Fwy</td>
<td>Post GL</td>
</tr>
<tr>
<td>2-Lakewood (Downey)</td>
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<td>+</td>
<td>-</td>
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<tr>
<td>4-Wilmington</td>
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<td>8-Harbor</td>
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<tr>
<td>14-Marina (Redondo)</td>
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<td>+</td>
</tr>
</tbody>
</table>

- Significant negative change (p < 0.05) in slope or intercept following Freeway (Fwy) or Green Line (GL) opening.
- Significant positive change (p < 0.05) in slope or intercept following Freeway (Fwy) opening.
- Significant positive change (p < 0.05) in slope or intercept following Green Line (GL) opening.
- Variable not included in model.
Inner-city Stations

After the opening of the Green Line, crime in the inner-city stations followed the declining trends witnessed throughout Los Angeles County (Figure 3). However, for four inner-city stations (#6, #7, #8, and #10) the decrease in nonauto related Type 1 crime was less than what would be expected based on the larger area trends (Table 3). These four stations were in jurisdictions with significantly higher crime rates than the county as a whole (Table 1). They tended, however, to have lower numbers of crimes than other stations in similar areas (see bar charts in Figure 4 which compare average crime levels in station neighborhoods³). For example, the neighborhoods around stations #6 and #7 had lower numbers of crimes than stations #4 and #5.

The four inner-city stations that witnessed a significant increase in slope in nonauto-related Type 1 crime had different land uses. Stations #6 and #7 were primarily in residential neighborhoods with similar population density and demographic characteristics. The neighborhood around station #8 in the City of Hawthorne had a low population density and primarily industrial land uses. Families that lived in this station neighborhood were mostly middle-income homeowners. Station #10, which is close to the Los Angeles airport, was surrounded by vacant lots and parking lots with some industrial and office buildings.

Two inner-city station neighborhoods (#6 and #8) also witnessed a significant increase in slope for the post Green Line Type 2 crime trend. In particular, the neighborhood of Harbor Station (#6) saw an absolute increase in Type 2 crime following the station opening.

The Eastern Suburbs

Crime data for the suburban City of Downey was only available from late 1993 so it was difficult to compare pre- and post- I-105 Freeway crime trends. Nonauto-related Type 1 crime peaked for the City as a whole shortly after the Green Line opened and has been declining since then (Figure 5). In contrast, nonauto-related crime in the neighborhood of station #2 has remained relatively stable at about 25 crimes per quarter, while Type 2 crime has increased, indicating that the introduction of the Green Line may have had some negative influence on station neighborhood crime rates (Table 3).
Figure 4. Average Quarterly Crime Rate in Station Neighborhoods
Figure 5. Crime Trends at Eastern Suburb Station Neighborhoods
The Western Suburbs

We gave particular emphasis in documenting and analyzing shifts in crime trends at the western end of the line to test the assumption that an inner-city line brings crime to the suburbs. Significantly, we did not observe any increase in crime trends in the suburban stations at the west end of the line. In fact, in station #14 in Redondo Beach, we witnessed a statistically significant decrease in crime in the station neighborhood after the line's opening (Table 3, Figure 6). Comparing station neighborhood crime to the countywide crime trends, we again did not see significant changes in the western suburban stations, with the only exception of an increase in auto-related crime in station #13 (Table 4).

More specifically, the City of El Segundo, which is at the western end of the I-105 Freeway, has relatively low levels of crime. Type 1 crime, which increased in the period after the freeway opened, has been decreasing since the opening of the Green Line (about a 50% decrease). Auto-related Type 1 crime has also been cut in half. The two station neighborhoods in El Segundo (#11 and #12) had few crimes; however, auto-related crime has been increasing in recent years. The regression model for station #11 shows a significant post-Green Line increase in slope for auto-related Type 1 crime after controlling for local trends (i.e., trends in the City of El Segundo). However, when numbers of crimes are small (in this case auto-related Type 1 crime hovers between 5 and 10 crimes per quarter), a difference of just a few crimes can make it look as if there is a significant change in trend.

Station #13 is located at the boundary of El Segundo and Manhattan Beach in an area of relatively new (since early 1990s) upscale retail and commercial development. While Type 1 crime has been decreasing in the adjacent municipalities since 1993, we see a different picture in the area immediately surrounding station #13, where such crime has been on an upward trend since the early 1990s. However, there has been no significant change in this trend (i.e., increase in slope) with the opening of the Green Line (Figure 6). Rather, the increase in crime is most likely attributable to new developments since the early 1990s, such as office buildings, restaurants, movie theaters, and specialty stores that have attracted many visitors to the area. Station #14, which is on the boundary of Redondo Beach and southern Hawthorne, is the western terminus of the Green Line. As with station #13, there was an increasing trend in Type 1 crimes in the ½-mile around this station although this has decreased since the opening of the Green Line (the regression models show a significant negative change in slope) (Figure 6). There was more Type 2 crime in the area around station #14 (about three times the level as at
Figure 6. Type 1 Non-Auto Crime Trends at Western Suburb Station Neighborhoods
station #13). While there was considerable fluctuation in the Type 2 crime trend it seemed to be gradually increasing. Particular land uses around station #14, such as a continuation high school and a large discount retail shopping area, may be contributing to crime here.

**Hot Spot Analysis**

Crime specialists often argue that a localized decrease in crime may be elusive, as crime may be dislocated to neighboring sites in response to certain changes (e.g., more policing, new land uses, etc.). Therefore, in this part of the study, GIS and spatial analysis techniques were employed to examine changes in the spatial distribution of crimes in the communities served by the Green Line. Geocoded crime data was converted into crime-density grid maps (using ArcView Spatial Analyst) to identify and map hot spots of crime (concentrations of incidents). Analysis of these maps was followed by observational studies of the areas identified as hot spots of crime.

Maps showing average crime density (hot spots of crime) for the periods before and after the opening of the Green Line can be seen in Figures 7 and 8. The maps in Figure 9 show the differences in crime concentrations between the two time periods. The upper map in Figure 9 shows hot spots of crime increase, where the lower map indicates areas where crime has decreased.

Figures 7 and 8 show high concentrations of both Type 1 and Type 2 crimes in the LA Central area before and after the introduction of the Green Line, although a significant decrease in crime density can be noticed (Figure 9). Our fieldwork showed that the few crime-density increases or shifts in density in the LA Central area took place in public housing developments.

Crime in Hawthorne was primarily concentrated along the commercial corridor of Hawthorne Boulevard (Figure 10), which runs south from station #9, as well as in the southeast corner of the City, an area quite far from the Green Line. Both these areas have seen a decrease in crime density since the opening of the Green Line. Only one new hot spot has emerged in the neighborhood just south of the Green Line between stations #8 and #9 (Figure 9), in a residential area with single-family, detached dwelling units of varying condition (many with bars on the windows and doors as shown in the photo in Figure 11).
Figure 7. Type 1 Crime Hot Spots Before and After the Green Line Opening
Figure 8. Type 2 Crime Hot Spots Before and After the Green Line Opening
Figure 9. Type 1 Crime Density Change Before and After the Green Line Opening
There were no hot spots of serious (Type 1) crime and only a few hot spots of Type 2 crime in the western suburbs. There has been a slightly higher concentration of Type 1 crime near station #12 in El Segundo since the Green Line opening but this is likely due to the increased development in the area. Overall, the before and after pictures do not show any significant changes in the concentration of crime.
Conclusions
At the end of the study, we find no evidence that this transit line has opened up new and outlying territories for exploitation by potential criminals. Overall, most station neighborhoods have either experienced no change or have witnessed a reduction in crime after the introduction of the Green Line. Transit has certainly not brought more crime to the affluent suburban areas, which have continued to enjoy relatively higher levels of safety and prosperity than the County average. Some crime increase was witnessed in the inner city, where limited spillover effects of crime from more high crime to less crime-ridden areas were observed. However, major shifts and dislocation of crime have not occurred within the municipalities that surround the Green Line. We were also unable to notice a relationship between hot spots of crime and proximity to a transit station. Rather the existence of hot spots could be better explained by the presence of certain land uses (e.g., concentration of retail along a busy commercial street, existence of a high school, or a public housing development).

This study is limited by the fact that it only examined one light rail line. Also the findings cannot prove or disprove the distance-decay theory, as we were not aware of the points of origin of the different criminals who committed crimes in station neighborhoods. However, it seems clear that criminals have not used the Green Line to access potential targets miles away. The journey to crime has not become easier because of the Green Line.

Acknowledgments
This study has been supported by grants from the John Randolph and Dora Haynes Foundation and the California Department of Transportation (through the University of California Transportation Center).

Endnotes

1 Rhodes and Conly (1981) found that criminals tend to be primarily attracted to commercial and transitional areas, followed by industrial areas. Residential areas are considered less attractive. Multiple-family housing tends to attract more crime than single-family housing.

2 Comparisons of high- and low-crime neighborhoods have shown that area accessibility is associated with high crime (Eck and Weisburd 1995).
3 The Green Line crosses 13 political jurisdictions: Norwalk, Downey, Paramount, South Gate, Lynwood, City of Los Angeles, Inglewood, Hawthorne, El Segundo, Manhattan Beach, Redondo Beach, Lawndale, and unincorporated areas of Los Angeles County.

4 For classification purposes the Federal Bureau of Investigation has classified crime into two major categories: Type 1 crime (criminal homicide, forcible rape, robbery, aggravated assault, larceny theft, burglary, grand auto theft, and arson), and Type 2 crime (crime of less serious nature against people and their property, such as petty theft, disorderly conduct, vagrancy, non-aggravated assaults, drug violation, etc.). For purposes of this study, we further divided Type 1 crime into non-auto-related crimes versus auto-related crimes. Crime classifications were not consistent across the various jurisdictions from which crime data was collected making it difficult to compare crime statistics across jurisdictions.

5 Crimes used in this study do not include crimes at the stations or the station parking lots, which were reported in Loukaitou-Sideris et al. (2002). We are looking rather at changes in crime levels in the neighborhoods surrounding the stations and shifts in crime locations in the larger jurisdictions around the Green Line.

6 Historically, crime trends have followed economic/employment trends (Koch Crime Institute 1998). The study reported in this article coincided with a period of economic growth and a declining crime trend nationwide.

7 Variables associated with the opening of the I-105 Freeway were not considered in the models for stations #2, #13, and #14. Sufficient data was not available to develop a prefreeway trend for station #2. Stations #13 and #14 are not located in the vicinity of the I-105.

8 Type 2 crime trend data was not available at the county level.

9 Crime data could not be collected for the full ¼-mile radius surrounding some of the stations due to differences in political jurisdictions. Crime data collected for each station neighborhood was weighted to account for area differences for comparison purposes in the bar charts.

10 Since this station as well as station #14 are not particularly close to the I-105 Freeway and are located within a few of blocks of the older 405 Freeway, the...
regression models used for both stations do not include dummy variables for the I-105 Freeway.

Crime-density maps are based on data for seven quarters before and seven quarters after the opening of the Green Line.
References


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