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University of Auckland, New Zealand

Abstract

In the literature, there is a lack of clarity on attributes that classify a planned transfer as being a connection designed by policy makers and public transport network planners. This calls for a proper guideline to be developed to support policy makers and planners in designing “seamless” transfers. The present study has two main objectives. The first is to determine the attributes that define a connection as being planned transfer. The second is to understand the difference in transit users’ perceptions between planned and unplanned transfers and, thus, their decision to use routes with transfers. The proposed definition of planned transfer consists of five attributes: network integration, integrated timed-transfer, integrated physical connection of transfers, information integration, and fare and ticketing integration. A survey was conducted at two major public transport terminals in Auckland, New Zealand. Results support the attributes identified for the definition. Findings suggest that transit users’ willingness to use transfer routes increases when attributes of the connections are more closely aligned to being planned. The study provides a guide-
Introduction

Heightened awareness for the need to promote public transport (PT) as a viable alternative to cars has resulted in a global trend towards planned and integrated land use and transport development (Ibrahim 2003; Matas 2004; Ulengin et al. 2007). Many authorities are investing in new infrastructure to improve the quality of PT services (Vassallo et al. 2012). An example is the Auckland Transport Regional Public Transport Plan (Auckland Transport 2010), which is a statutory document created for the purpose of developing an integrated PT network to provide Aucklanders with a sustainable transport system in a safe, integrated, responsive, and affordable manner. One of the key components by which Auckland Transport (AT) plans to achieve full integration of the network is through facilitation of intermodal and intramodal transfers. Studies (Guo and Wilson 2004; Ceder et al. 2009) have shown that commuters are only willing to tolerate the inconvenience caused by transfers if the perceived benefits of selecting a route with transfers are greater than the direct route. A number of studies (Liu et al. 1997; Vande Walle and Steenberghen 2006; Bamberg et al. 2007; Beirao and Sarsfield-Cabral 2007; Guo and Wilson 2007; Iseki and Taylor 2009; Currie and Loader 2010; Guo and Wilson 2011; Sharaby and Shiftan 2012) have been conducted to identify the operational and psychological factors that dictate the inconvenience felt by transit users when undertaking routes with transfers. These studies have indicated the importance of including transfers in the planning stage of an integrated transport system. Yet, despite the awareness, in general, there is no tradition in service planning to treat transfers as a distinct topic (Guo and Wilson 2011).

In the literature, there remains a lack of clarity in attributes that define a connection as being a planned transfer. Which attributes of a transfer constitute the connection as being designed by policy makers? Clearly specifying the definition of a planned transfer will provide policy makers and PT network planners with a better guide in designing “seamless” transfers for an integrated multimodal PT network. The present study contributes to existing knowledge on policy and travel behavior by (1) identifying the attributes that define a transfer as being planned and (2) determining the difference in transit users’ perception of planned and unplanned transfers and, thus, their decision to use transfer routes. A guideline is developed to serve as a basis for planning new and improving existing connections to be planned transfers.
The paper is organized as follows: Section 2 is a literature review; Section 3 provides the proposed definition of planned transfers; Section 4 is a description of the survey design; Section 5 presents results; Section 6 is a discussion of the results; Section 7 is the guideline for policy makers and PT network planners; and Section 8 is the conclusion.

**Literature Review**

**Purpose of an Integrated Public Transport Network**

The aim of an integrated multimodal transport system is to provide transit users with a “wide spectrum” of destination choices and also with convenient, accessible, comfortable, safe, speedy, and affordable transport system while supporting future demand (Ibrahim 2003; Luk and Olszewski 2003; Ulengin et al. 2007). With an integrated transport system, transit users do not board a single line, but a whole system (Clever 1997). One of the key components in achieving an user-friendly integrated transport system is to develop “seamless” transfers (Luk and Olszewski 2003). Easy transfers provide transit users with access into the entire public transport network, thus making transfers a benefit rather than something to be avoided (Maxwell 2003). Hutchinson (2009) discusses that for urban journeys, commuters are willing to use transfer routes given integration among operators. Integration reduces the cost of transfers for users, which increases the attractiveness of PT (Hidalgo 2009).

**Location for Transfers**

The main purpose of transfer centers is to facilitate links among PT services. In Madrid, Spain, construction of transfer centers has been used as an important measure for development of multimodal integration to promote PT use (Vassallo et al. 2012). Some literature (Clever 1997; Vassallo et al. 2012) has illustrated the importance of strategic location of transfer centers to reduce the exchange time for travelers transferring from one transport mode to the next. A study by Currie and Willis (1998) suggested that physical integration of terminals is a key factor in facilitating transfers between terminals. The study noted that although some of the surveyed stations and bus stops were in close proximity to each other, transfers among these stations could not be classified as being “planned” since the stops were separate from the station area. Physical integration of terminals needs to be designed from a planning and management level (Currie and Willis 1998). Well-designed and appropriate location of transfer centers were shown to benefit the surrounding community by creating opportunity for development (Volinski and Page 2006). Involvement of the community during the design phase instigates
the transfer center to be perceived as a symbol of pride for the community. Security provisions at the center provide a safe environment for the surrounding area (Volinski and Page 2006).

**Trip Attributes Influencing Perception of Transfer Routes**

The trip attributes that have been identified to be most significant in the transit user decision making process to select routes with transfers are travel time, travel cost, transfer waiting and walking time, transfer information, fare ticketing system, security, and comfort at terminal (Atkins 1990; Callaghan and Vincent 2007; Iseki and Taylor 2009; Molin and Chorus 2009; Muller and Furth 2009; Sharaby and Shiftan 2012). Several studies have identified personal safety, travel time, and transfer time as the most sensitive indicators for transit user perception of transfer routes (Vande Walle and Steenberghen 2006; Zhou et al. 2007; Muller and Furth 2009; Eboli and Mazzulla 2012; Hadas and Ranjitkar 2012).

Personal safety at terminals has been revealed to be the most important factor in transit user decisions to use PT (Atkins 1990; Zhou et al. 2007; Kumar et al. 2011; Eboli and Mazzulla 2012). Travel time, for commuters, has been found to be more significant than transfer waiting and walking time (Vande Walle and Steenberghen 2006; Xumei et al. 2011). There is much support for transfer waiting time being valued more highly than transfer walking time (Vande Walle and Steenberghen 2006; Iseki and Taylor 2009). A well-integrated fare system has been shown to have a positive impact on ridership of PT by improving transit user intentions to use routes with transfers (Buehler 2011; Sharaby and Shiftan 2012). Other studies have shown that integrated information systems are required to increase the perceived ease of making a transfer (Bachok 2007; Grotenhuis et al. 2007; Molin and Chorus 2009). A high-quality information system is an essential factor in increasing ridership by retaining existing riders and attracting potential users (Eboli and Mazzulla 2012). Comfort at the transfer terminal has also been identified to be a determining factor in transit users’ perceived ease of making a transfer (Guo and Wilson 2011). Eboli and Mazzulla (2012) discusses that although comfort has been identified as an important factor in service satisfaction, it is less important in the transit user decision process than other service factors.

**Research Need**

Despite the well-understood importance of transfers in an integrated multimodal transport system, there is a lack of clarity in the attributes that define a planned transfer. Without a clear definition, policy makers and PT network planners will be unable to adequately design transfers for an integrated PT network. For example,
the objectives outlined in the Auckland Transport Regional Public Transport Plan (Auckland Transport 2010) aim to enable “seamless” transfers through network branding, an integrated network of services, high frequency services provided by the Quality Transit Network (QTN) and Rapid Transit Network (RTN), good access to quality service information, an integrated fare and ticketing system, and a well-designed PT infrastructure (Auckland Transport 2010). The document states the following:

Transport interchange facilities at RTN stations and major nodes on the QTN will facilitate passenger transfer by reducing transfer distance and time, providing a safe environment for waiting and passenger movement and giving access to transport information and trip planning help.

It is clear that although a certain amount of planning has been undertaken to facilitate transfers, complete comprehension of the level of planning required to produce “seamless” transfers is lacking. The outcome of this study is aimed to provide policy makers and PT network planners with a more in-depth understanding of the level of planning required to create a successful integrated multimodal PT network through facilitation of transfers and the affect this has on ridership of transfer routes.

**Definition of Planned and Unplanned Transfer**

A “planned” transfer is a connection that has been intentionally designed by policy makers and PT network planners in the planning stage of the multimodal PT network to improve service efficiency and convenience to transit users (Ceder 2007). An “unplanned” transfer is defined as a connection that has been created by transit users from available PT services without any additional guidance on how to make the connection. In this study, the following five attributes are proposed with justifications to define transfers in a PT network to be considered as being “planned.”

*Network Integration*

Routes are required to be connected from a network perspective to allow transit users to access a wider range of destinations. Planning connections, as such, will facilitate transfer to be perceived as a benefit rather than something to be avoided (Clever 1997). Proper integration of a multimodal transport system will reduce wasteful duplication of route services and, thus, improve the utilization of resources (Ibrahim 2003).
Integrated Timed-Transfer
The aim of integrated timed-transfers is to interconnect the multimodal PT network such that the transfer times are minimized (Clever 1997; Maxwell 1999). This is achieved by operators synchronizing their scheduled routes to develop a pulsed-hub network (Becker and Spielberg 1999). Since the performance of timed-transfer is dependent on schedule reliability, implementation improves the overall reliability of the transport system (Maxwell 2003). Routes and scheduling are required to be designed simultaneously (Becker and Spielberg 1999).

Integrated Physical Connection for Transfers
Terminals are required to be physically connected for the transfers among them to be considered as being “planned” (Currie and Willis 1998). Integration between terminals has been defined as sheltered walkways between terminals, security measures at connected walkways, and information provisions such as signage providing guidance between the connected terminals, a map of the local street area, and the locations of connected walkways (Currie and Willis 1998; Ibrahim 2003; Luk and Olszewski 2003).

Information Integration
Transfers are perceived as being barriers to using PT, and, therefore, suitable information is required to make connections easy and convenient (Grotenhuis et al. 2007). An integrated information system is essential to facilitate urban and interurban multimodal trip planning (Zografos et al. 2008). With many advanced PT information systems available, real-time information can be made accessible directly to the transit user en route (Zhang et al. 2011). Such an information system can assist transit users with pre-planning transfers and then providing guidance en route, thereby reducing the chances of missed connections and providing travel support (Grotenhuis et al. 2007; Zhang et al. 2011).

Fare and Ticketing Integration
A common global approach in the development of an integrated multimodal transport system has been fare and ticketing system integration (Luk and Olszewski 2003; Matas 2004; Garcia and Azan 2005; Hidalgo 2009). Fare system integration of a multimodal PT network has been shown to facilitate “seamless” transfers and thus encourage the use of transfer routes (Sharaby and Shiftan 2012). A simple user-friendly integration, such as smart cards, can improve the efficiency of boarding and egressing (Luk and Olszewski 2003; Blythe 2004).
Definition of Planned and Unplanned Transfer of Public Transport Service

A summary of the main characteristics of each planned transfer attribute is provided in Table 1. It should be noted that the table does not provide an exhaustive list but, rather, a direction to the level of planning required at an early stage by policy makers and PT planners.

**Table 1. Main Characteristics of Planned Transfer Attributes—Survey of Planned and Unplanned Public-Transport Transfers**

<table>
<thead>
<tr>
<th>Planned Transfer Attributes</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network integration</td>
<td>• Physical overlap of service lines</td>
</tr>
<tr>
<td></td>
<td>• Combination of high frequency routes and low frequency routes (feeder services)</td>
</tr>
<tr>
<td></td>
<td>• Network coverage</td>
</tr>
<tr>
<td></td>
<td>• Easy accessibility to PT network</td>
</tr>
<tr>
<td>Integrated timed-transfer</td>
<td>• Minimize transfer waiting time</td>
</tr>
<tr>
<td></td>
<td>• Synchronize scheduled routes</td>
</tr>
<tr>
<td>Integrated physical connection for transfers</td>
<td>• Sheltered walkways</td>
</tr>
<tr>
<td></td>
<td>• Security measures to protect transit users between separate stations/stops</td>
</tr>
<tr>
<td></td>
<td>• Information such as directional signage and maps to link stations/stops at separate locations</td>
</tr>
<tr>
<td>Information integration</td>
<td>• Journey planner to assist transit users in planning their transfers among all PT services</td>
</tr>
<tr>
<td></td>
<td>• Real-time information (arrival/departure/delay times) at stations/stops</td>
</tr>
<tr>
<td></td>
<td>• En-route guidance providing real-time information</td>
</tr>
<tr>
<td></td>
<td>• Maps and timetables for all PT services at stations/stops</td>
</tr>
<tr>
<td>Fare and ticketing integration</td>
<td>• Smart cards used for all services</td>
</tr>
<tr>
<td></td>
<td>• No additional cost for transfers</td>
</tr>
</tbody>
</table>

**User Preference Survey**

To confirm the proposed definition and determine transit user perceptions of planned and unplanned transfers, a user preference survey was undertaken in Auckland, New Zealand. This section provides a description of the survey locations selected and the questionnaire designed.

**Survey Locations**

The Northern Busway and Britomart were chosen as survey locations. Local feeder routes are connected to five designated stations along the Northern Expressway.
(Ceder et al. 2009). Transfers occur between local routes and the main line (Ceder et al. 2009). A majority of the buses entering and leaving the Auckland CBD begin and end their trip at Britomart. The hub provides a link between the main bus, train, and ferry services of the Auckland region (Auckland Transport 2012); this allows transit users with an opportunity to make transfers at Britomart. A comparison of the facilities available at both survey locations to assist transit users in making transfers was conducted. The comparison suggested that transfers at the Northern Busway can be classified as being “planned” more closely than transfers taking place at Britomart.

**Questionnaire and Implementation**

The questionnaire was composed of questions related to general socio-demographics, trip characteristics, and a hypothetical scenario. The bandwidth for the socio-demographic questions, age and income, was adopted from the NZ census questionnaire (Statistics New Zealand 2012). To participants who were currently using a transfer route, questions on details of the transfer connection and usage satisfaction were asked. To participants who were not using a transfer route, a multi-choice question was asked on improvements to trip attributes that would increase their willingness to do so.

All participants were asked a question on whether they would choose an alternative hypothetical transfer route when comparing the route to a hypothetical direct route with travel time of 40 minutes. The hypothetical transfer route scenarios had travel time savings of 10, 15, and 20 minutes with varying types of connection. This question was designed to determine transit user perceptions of planned and unplanned transfers.

The survey was conducted for 10 weekdays (5 days for each location) during commuter morning peak period (7–10 AM).

**Survey Results**

**Participant Socio-Demographic and Trip Characteristics**

A total of 131 transit users from the Northern Busway participated, of whom 55 percent were from the upper suburbs of North Shore and 45 percent were from the lower suburbs. From Britomart, a total of 125 transit users participated in the survey. Of the 125 participants, 50 percent were from the central suburbs, 14 percent were from the east, 13 percent were from the west, 11 percent were from the north, and the remaining 11 percent were from the southern suburbs. Table 2 provides a summary of the participants’ socio-demographic and trip characteristics. The
main differences between the two samples are (1) the proportion of frequent riders (80%) was greater in Northern Busway; (2) 55 percent of the participants from Northern Busway were in the age group of 24 to 44, and 50 percent from Britomart were less than 24; (3) a greater proportion of Northern Busway participants were in the high income ranges, and (4) the number of transit users making transfers was shown to be higher (36%) at Northern Busway.

### Table 2. Socio-Demographics and Trip Characteristics

<table>
<thead>
<tr>
<th>Socio-Demographic</th>
<th>Britomart (125)</th>
<th>Northern Busway (131)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>58 (46%)</td>
<td>82 (63%)</td>
</tr>
<tr>
<td>Male</td>
<td>67 (54%)</td>
<td>49 (37%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;24</td>
<td>62 (50%)</td>
<td>22 (17%)</td>
</tr>
<tr>
<td>24-44</td>
<td>45 (36%)</td>
<td>72 (55%)</td>
</tr>
<tr>
<td>45-64</td>
<td>17 (14%)</td>
<td>29 (22%)</td>
</tr>
<tr>
<td>&gt;65</td>
<td>0</td>
<td>8 (6%)</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;$30,000</td>
<td>58 (47%)</td>
<td>26 (20%)</td>
</tr>
<tr>
<td>$30,001–$70,000</td>
<td>63 (51%)</td>
<td>87 (66%)</td>
</tr>
<tr>
<td>$70,001–$100,000</td>
<td>3 (2%)</td>
<td>16 (12%)</td>
</tr>
<tr>
<td>&gt;$100,001</td>
<td>0</td>
<td>1 (0.8%)</td>
</tr>
<tr>
<td><strong>Trip Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent rider</td>
<td>84 (67%)</td>
<td>105 (80%)</td>
</tr>
<tr>
<td>Non-frequent rider</td>
<td>41 (33%)</td>
<td>26 (20%)</td>
</tr>
<tr>
<td>Transfer users</td>
<td>28 (23%)</td>
<td>47 (36%)</td>
</tr>
</tbody>
</table>

### Trip Attributes of Transfer Routes

As discussed previously, both Britomart and Northern Busway offer transit users provisions to facilitate ease of making transfers. Participants who currently used transfer routes were asked about their satisfaction. A 5-point Likert scale (very poor/very good) was used as the response measure. Rating scales such as the Likert Scale are designed to measure one specific perception of the statement presented to the respondent (May 2011). Rating scales have been commonly used in travel
behavior studies (Heath and Gifford 2002; Bamberg et al. 2007; Gatersleben and Uzzell 2007; Carrus et al. 2008).

Of the participants from Northern Busway, 61 percent rated their transfer route to be 4 (Good). Of the participants from Britomart, 54 percent rated their transfer route to be 3 (neutral), and none rated their routes to be greater than 3. The average transfer waiting time and walking time for users of the Northern Busway was found to be 12 minutes and 8 minutes, respectively.

Similarly, for Britomart, the average transfer waiting and walking time was found to be 6 minutes and 5 minutes, respectively. To determine transit users’ perceived ease of using the transfer routes, participants were asked which provisions are available to assist them in making the transfer. Figure 1 illustrates that a higher proportion of transit users from Northern Busway perceived more provisions to be available to them than users of Britomart.

![Figure 1. Proportion of transfer route users perceiving that facilities are offered by operator](image)

Participants who currently do not use transfer routes were asked about which improvements to trip attributes would increase their willingness to do so. Figure 2 shows the proportion of transit users willing to use transfer routes given improvements made to trip attributes.
Users of Britomart were willing to use transfer routes given more connected routes, more information on transfers, and the total transfer time being less than 20 minutes. Network integration was shown to have the most influence on willingness.

Northern Busway users’ willingness depended on better seating areas, sheltered walking areas, and an integrated ticketing system that offers no additional cost for transfers. Cost of transfer was shown to have a greater influence than the trip attributes related to comfort.

**Hypothetical Transfer Route Scenarios**

As discussed earlier, participants were given hypothetical transfer route scenarios to determine transit user willingness to use the routes given varying level of provisions for the connection and travel time savings. To determine the statistical difference in the responses for each scenario, the data were fit into generalized linear models (GLM) of the Poisson family. The statistical package, R, was used to fit the data. Poisson distribution was chosen, as the response measures are in counts (Graybill 1976). The p-value of the responses for each option was used to assess statistical differences between Option 1 (reference) and Options 2, 3, and 4.

Table 3 shows the proportion of transit users willing to use the transfer route present in each option and the respective p-value. For models of this form, model fit is not an issue. The predicted values from the model line up exactly with the observed data.
Table 3. Transit User Preference for Hypothetical Transfer Routes

<table>
<thead>
<tr>
<th>Savings (mins)</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Britomart</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>80% (reference)</td>
<td>55% (0.021)</td>
<td>17% (0.000)</td>
<td>7% (0.000)</td>
</tr>
<tr>
<td>15</td>
<td>73% (reference)</td>
<td>58% (0.115)</td>
<td>6% (0.000)</td>
<td>2% (0.000)</td>
</tr>
<tr>
<td>20</td>
<td>77% (reference)</td>
<td>43% (0.000)</td>
<td>43% (0.000)</td>
<td>7% (0.000)</td>
</tr>
<tr>
<td>Northern Busway</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>75% (reference)</td>
<td>63% (0.234)</td>
<td>12% (0.000)</td>
<td>11% (0.000)</td>
</tr>
<tr>
<td>15</td>
<td>79% (reference)</td>
<td>68% (0.278)</td>
<td>30% (0.000)</td>
<td>26% (0.000)</td>
</tr>
<tr>
<td>20</td>
<td>90% (reference)</td>
<td>85% (0.644)</td>
<td>34% (0.000)</td>
<td>30% (0.000)</td>
</tr>
</tbody>
</table>

Discussion of Survey Results

Findings from analysis of the survey data support the definition of planned transfers developed in the present study. A comparison of the perceived provisions offered at the two stations to facilitate transfers has shown that transit users perceived more provisions to be available to them when the connections are more closely aligned to being planned. Although the same provisions are provided at both stations, on average, more than 50 percent of the transit users who used transfer routes at Northern Busway (planned) perceived the facilities to be related to their connection and, on average, only 30 percent of transit users did from Britomart (unplanned).

For transit users who currently did not make transfers, their willingness to use transfer routes was influenced most by improvements to operational trip attributes. The intention of transit users from the Northern Busway was influenced most by improvements to the fare and ticketing system. An integrated ticketing system was one of the criteria that the connections of Northern Busway scored “partially achieved” for being planned. Analysis of responses for all hypothetical transfer route scenarios revealed strong statistical evidence (p-value < 0.001) of significant difference between the proportion of transit users willing to use the routes for Option 1 and the routes for Options 3 and 4. Such findings suggest the importance of an integrated physical connection of transfers to transit user perceptions of transfer routes. For the 10-minute travel-time-savings scenario, statistical evidence was shown to exist for the difference in the proportion of transit users from Britomart who were willing to use routes for Option 1 and Option 2.
Definition of Planned and Unplanned Transfer of Public Transport Service

This result demonstrates the importance of information integration to transit user perceptions of transfer routes.

It was noted that a higher proportion of transit users from the Northern Busway was willing to use the transfer routes for Options 3 and 4 in the 15-minute and 20-minute travel-time-savings scenarios. A possible reason for this is due to the journey times for participants from the Northern Busway ranging from 30 to 90 minutes. The journey times for the northern, southern, western, and eastern routes to Britomart ranged from 40 to 90 minutes and was 10 to 20 minutes for routes from the central suburbs to Britomart. As mentioned previously, 50 percent of the participants from Britomart were from the central suburbs; thus, the 15- and 20-minute travel-time-saving scenarios were not applicable to the majority.

Possible Guidelines for Planned Transfers

The objective of the guidelines is to assist decision makers and PT network planners in improving existing and developing new transfer routes to provide transit users with “seamless” transfers in a multimodal PT network. As discussed previously, the five main attributes of a planned transfer are network integration, integrated timed-transfer, integrated physical connection of transfers, information integration, and fare and ticketing integration. These five attributes can be grouped into two stages of planning: (1) initial and (2) operation. Network integration and integrated physical connection of transfers need to be achieved during the initial planning stage of the multimodal PT network, as the two attributes involve possible infrastructure construction. Integrated timed-transfer, information integration, and fare and ticketing integration can be achieved during the operation planning stage.

Guideline A: New Transfer Routes

In the development of new transfer routes, decision makers should aim to achieve all five attributes of a planned transfer. Route generation should be created from two points of view: user and operator. For users, the route should be designed to minimize transfer time and maximize the comfort and convenience of the connection. For operators, the route should minimize the cost of operation and maximize revenue (ridership) of transfer routes (Verma and Dhingra 2005). Use of this guideline is demonstrated with an example by providing recommendations for Auckland Transport Regional Public Transport Plan, as shown in Table 4.
Table 4. Recommendations for Auckland Transport Regional Public Transport Plan

<table>
<thead>
<tr>
<th>Planned Transfer Elements</th>
<th>Achieved/Partially Achieved</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network integration</td>
<td>Achieved</td>
<td>-</td>
</tr>
<tr>
<td>Fare integration</td>
<td>Achieved</td>
<td>-</td>
</tr>
<tr>
<td>Integrated timed-transfer</td>
<td>Partially achieved</td>
<td>The plan (Auckland Transport 2010), on page 21 under Policy 2.1, states that connection between services will be timed to minimize transfer waiting times. This is planned to be achieved by providing frequent and reliable services (Objective 1 and 4 on page 14). Increasing the frequency of services will improve reliability and reduce transfer waiting times, but it will not minimize transfer waiting times. Therefore, it is recommended that to achieve “seamless” transfers in Auckland’s multimodal PT network, PT operators must focus on methods of synchronizing their scheduled routes to minimize transfer waiting times.</td>
</tr>
<tr>
<td>Integrated physical connection for transfers</td>
<td>Partially achieved</td>
<td>The plan (Auckland Transport 2010), on page 4, states that Policy 4.2.2 aims to make provisions for new modal interchanges. It is recommended that policy makers provide physical connections such as sheltered walkways between stations/stops at transfer locations to increase user comfort during transfer walking times.</td>
</tr>
<tr>
<td>Information integration</td>
<td>Partially achieved</td>
<td>The plan (Auckland Transport 2010), Objective 8.2 on page 27, states plans to provide users with timetables at terminals and stops, a journey planner website, customer self-service options, call centers, and real-time displays at all RTN and QTN stations. A study by Grotenhuis et al. (2007) showed that users desire en route (real-time) information when making transfers, particularly non-frequent PT users. Therefore, it is recommended that policy makers offer transit users with an integrated information system that provides real-time guidance en route (from start to end of trip) for travel support. This can be a self-service option.</td>
</tr>
</tbody>
</table>

**Guideline B: Existing Transfer Routes**

To improve existing transfers, PT operators need to assess the existing facilities and change any possible attributes to make the connections more closely aligned to being planned. Use of this guideline is demonstrated with an example by providing recommendations for transfers at Britomart and Northern Busway, as shown in Table 5.
Definition of Planned and Unplanned Transfer of Public Transport Service

Table 5. Recommendation to Make Transfers More Planned

<table>
<thead>
<tr>
<th>Britomart</th>
<th>Northern Busway</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network integration &amp; integrated timed-transfer:</strong> It is recommended that further network integration is required at Britomart to provide users with more flexibility in reaching their desired destinations using PT. Operators should aim to minimize the transfer waiting times by synchronizing scheduled routes.</td>
<td>Fare and ticketing integration: Findings suggest that further integration among operators is required to make transfers of no extra cost to the user (Sharaby and Shiftan 2012). This provision should be incorporated into the normal ticketing system instead of requiring transit users to purchase separate tickets such as the Northern Pass to use transfer routes.</td>
</tr>
<tr>
<td><strong>Information integration:</strong> Site observation revealed that transit users making transfers at Britomart were often unclear about how to make the connection. This finding indicates that more information on connections, such as better signage, is required to improve transit users’ ease of making transfers.</td>
<td></td>
</tr>
<tr>
<td><strong>Integrated physical connection of transfers:</strong> More sheltered waiting and walking areas should be provided for the bus service to improve the level of comfort for users making transfers.</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion

The objective of this study was to provide policy makers and PT network planners with a more in-depth understanding of (1) the attributes that create “seamless” transfers in a multimodal public transport network and (2) transit users’ perceptions of planned/unplanned transfers and, thus, their decision to use transfer routes. The following five attributes have been proposed to define planned transfers: network integration, integrated timed-transfer, integrated physical connection of transfers, information integration, and fare and ticketing integration.

Results of the analysis support the definition of planned transfer developed. Findings suggested that transit users have a higher willingness to use transfer routes when the connections are closely aligned to being planned. A theoretical general guideline has been developed to assist policy makers in designing “seamless” connections for new and existing transfer routes.

References


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A Novel Transit Rider Satisfaction Metric: Rider Sentiments Measured from Online Social Media Data

Craig Collins, Samiul Hasan, Satish V. Ukkusuri, Ph.D.
Purdue University

Abstract

The goal of this paper is to demonstrate the use of an innovative social media-based data source, Twitter, to evaluate transit rider satisfaction. Transit authorities have access to vast amounts of performance metrics that measure ridership, timeliness, efficiency, safety, cleanliness, and service, to name a few. These performance metrics, however, are generally one-sided; they represent the interests of the business and are not customer-based. This paper recognizes the limitations of standard performance metrics and attempts to gauge transit rider sentiments by measuring Twitter feeds. Sentiment analysis is used to classify a population of rider sentiments over a period of time. Conclusions are drawn from totals of positive and negative sentiments, normalized average sentiments, and the total number of Tweets collected over a time period.

Introduction

With the advent of social media, people are able to express their opinions on a subject instantaneously. Researchers are beginning to “mine” these opinions from social media outlets (i.e., Twitter, Facebook) to form general public perceptions, or sentiments, on a number of subjects. Sentiment analysis, or opinion mining, is the examination of a text through software to understand the positive or negative connotations surrounding it. Sentiment analysis can assist companies in determin-
ing how a brand is perceived in relation to value and quality. Subtasks of sentiment analysis include determining subjectivity, polarity (positive or negative), and degree of polarity, and classifying the subject matter and author. Sentiment analysis, through the monitoring of social media, can change the way transit agencies measure rider satisfaction.

For trips with similar distances, transit agencies are in direct competition with automobile services as well as pedestrian modes such as walking and bicycling. Commuters are likely to choose modes that maximize their utility and provide the most satisfaction (Andreassen 1995). Studies have been conducted that show commuters are more likely to choose modes that are more economical, comfortable, work-friendly, punctual, and safe (Hanna and Drea 1998). Thevathasan and Balachandran (2007) found that transit passengers consider improvements to safety and stations, improvements in facilities, and cleanliness to be important. Unfortunately for transit agencies, there is often a lack of compatibility between passenger needs and management perception of those needs. Management runs the risk of misallocating scarce resources and not being aware of growing passenger dissatisfaction with transit services that are measured by performance metrics (Koushki et al. 2003).

Performance metrics are constructed to encourage performance improvement, effectiveness, efficiency, and appropriate levels of internal controls. Traditionally, performance metrics are measured through quantities related to ridership, timeliness, efficiency, safety, cleanliness, service, and courtesy (Chicago Transit Authority 2011; Metropolitan Transit Authority 2011). The Transit Capacity and Quality of Service Manual (TCQSM) (1999) recognizes that there is a distinct difference between transit agency and passenger point of view for quality of service. TCQSM indicates service coverage, hours of service, amenities, safety, and travel time as relevant to passengers, whereas annual ridership, vehicles operated in maximum service, passenger miles/revenue hour, and vehicle operating expenses are relevant to transit agencies. An analysis of Portland, Oregon’s, local transit provider (TriMet) shows how technology can be used to develop an archival system that directly relates bus transit performance to performance indicators through the use of its bus dispatch system (Bertiniand and El-Geneidy 2003).

With the ever-growing complexities of urban transit and decreasing of federal and state funding, many transit authorities may not have the means to monitor zones with high amounts of activity. Through the use of online social media, commuters can voice their concerns in real time about current conditions in service, safety,
sanitary conditions, etc. Outside of surveys and focus groups, there are few ways to gauge customer satisfaction, let alone in a practical and timely fashion. The purpose of this study was to show a proof of concept using an emerging data source, such as Twitter, and conduct a sentiment analysis using SentiStrength (Thelwall et al. 2010) to evaluate transit rider satisfaction. This study is intended as a pilot test and demonstrates the usefulness of social media data for measuring rider perception.

The data used in this work were obtained from the riders of the rapid transit system of the Chicago Transit Authority (CTA). CTA is an ideal setting for analysis because of its large volume of riders who depend on its rapid transit system for commuting to work and for navigating the city of Chicago. CTA operates the nation’s second largest public transportation system and serves a population of 3.8 million (Chicago Transit Authority 2011). In addition to serving the city of Chicago, 40 suburbs also rely on the CTA’s transit system. On the rapid transit system, CTA’s 1,200 rail cars operate over 8 lines (Blue, Brown, Green, Orange, Pink, Purple, Red, and Yellow) and 224.1 miles of track. CTA trains make about 2,145 trips each day and serve 143 stations. On average 641,261 riders rode the CTA rail system per weekday in 2010. CTA’s rapid transit system is referred to as the “L,” having gained its nickname from large parts of the system being elevated, although segments of the network are underground, at grade level, and open cut. CTA has rail service in proximity to two airports (O’Hare International and Midway), professional sporting arenas (Wrigley Field, Soldier Field, United Center), city government buildings, and many recreational sites (parks, zoos, waterfront).

CTA possesses a strong need for sentiment analysis because of its recent fiscal restraints. The State of Illinois has once again cut funds to CTA due to a lack of funds at the state level. In 2010, CTA cut 9 percent of its rail service and laid off nearly 1,100 employees. It has been forced to use much of its capital funds to maintain day-to-day operations. Sentiment analysis can provide customer feedback on fare increases, services, and provide a means of monitoring safety due to a lack of personnel.

To analyze rider sentiment of CTAs “L” system, a large population of data is needed. In this work, Twitter texts, or “tweets,” were collected and analyzed to quantify and compare performance. Twitter is a real-time information network that connects users to the latest information about what they find interesting. Users share opinions and general statements through “tweets,” short texts of 140 characters or less. Given the wide prevalence of Twitter data, it provides rich data sources to measure
the sentiment of transportation systems. Twitter currently receives around 140 million tweets on average daily.

Twitter’s most appealing feature is that information can be viewed and analyzed using specialized crawlers that collect the data in real time. Searches by keyword and proximity to a location are only a few of the ways Twitter allows for searches of relevant tweets. Twitter provides a time-stamp to tweets, which is beneficial in determining the relevance of a text and organizing sentiments over a time frame. Twitter is popular for its accessibility and mobility because it allows its users to upload and view comments via laptop, tablet, and smart phone. While Twitter can provide a vast amount of information on a given topic, not all the data returned are relevant. Keyword searches can bring up material unrelated to the desired topic. For example, in our research, one of the keywords used was “red line.” Red line is not only associated with a particular CTA “L”; many tweets were retrieved with views on a 1998 movie called “The Thin Red Line.” Because tweets can have a maximum of 140 characters, users must often abbreviate words and phrases, and the overall message of these texts can be lost or misunderstood. It was observed that roughly 25 percent of the data collected on a topic is relevant and opinion-based. Other data come in the form of Twitter applications such as FourSquare, company advertisements, and factual statements by users.

**Related Works**

With the advent of the Internet and social media, research has intensified in the field of sentiment analysis. Sentiment classification subtasks revolve around determining subjectivity, polarity (positive or negative), and the degree of polarity, and classifying the subject matter and author. Sentiment analysis is based on two techniques: the use of linguistic resources, where each word is assigned a value, and machine learning techniques, which use counting methods to determine the sentiment of a body of text. Machine learning techniques are concerned with the construction of algorithms to allow computers to model behaviors based on available data. This literature review focuses on past studies that have used sentiment analysis over a wide range of applications.

Thomas et al. (2006) determined whether discussions among speakers in U.S. Congressional debates were in support of or opposition to the topic being discussed. Niu et al. (2005) evaluated the problem of detecting the presence of a clinical outcome in medical texts, and, when an outcome was found, determining whether it was positive, negative, or neutral, as shown in the following examples.
Text summarization can be used in information filtering. It is important for data miners to be able to find relevant information that suits their needs. Kim and Hovy (2004) presented a system that, given a topic, automatically finds the people who hold opinions about that topic and the sentiment of each opinion. Their system contained a module for determining word sentiment and another for combining sentiments within a sentence.

The research of sentiment analysis has been conducted on many applications and is just the beginning in understanding how sentiment analysis can be applied to a variety of fields. Future applications include Web mining for consumer opinion summarization, business and government intelligence analysis, and improving text analysis applications such as information retrieval, question answering, and text summarization (Finn et al. 2002). Sentiment analysis uses real-time data from blog posts, reviews and opinions posted on Web sites, and status messages and comments posted in social media that provide feedback on current happenings in relation to a topic. Examples of sentiment analysis include determining sentiment characteristics in Web blogs (Pang and Lee 2008), polarity detection in Congressional debates (Thomas et al. 2006), summarizing movie reviews (Turney 2001; Zhuang et al. 2006), spam detection in product reviews (Jindal and Liu 2007; Jindal and Liu 2008), and predicting the stock market (Bollen and Mao 2011).

**Methodology**

**SentiStrength: A Sentiment Strength Detection Algorithm**

In this study, we used SentiStrength (SentiStrength 2011; Thelwall et al. 2010), a machine learning program that detects the sentiment value of a short text, for analyzing the sentiments of rider tweets about the transit system. Users input one or more texts, and the general strength of the sentiment behind each text was quantified. Output from the software can document the average negative and positive sentiment or the minimum negative or maximum positive sentiment. SentiStrength uses machine learning techniques to conduct sentiment analysis. The core of its algorithms is the sentiment word strength list (Thelwall et al. 2010), which can be updated with new words relevant to a specific topic. These words can then be updated, or optimized, allowing SentiStrength to better judge sentiment polarity.

SentiStrength contains an original collection of 298 positive terms and 465 negative terms classified with relative sentiment strength. Ratings of 1 to 5 indicate a positive sentiment and -1 to -5 indicate a negative sentiment, with -5 and 5 being the maximum negative and positive sentiments that can be attained. The word list
was combined with the AFINN word strength list to bring the total word strength list to 2,509 terms. AFINN is an English word list with 2,477 words constructed by Finn Årup Nielsen for sentiment analysis of Twitter messages (Hansen et al. 2010). Each word is rated by a valence value from -5 to +5, excluding 0. AFINN was ideal because it uses a numerical system identical to SentiStrength, placing word strength values between 1 and 5 for either positive or negative sentiment strength. Allowing the user to update the word strength list is important because, initially, the list is relatively small, in comparison to every other imaginable word. Also, allowing the user to update the word strength list enables SentiStrength to be functional over a multitude of topics.

Key to allowing the user to update the word strength list, SentiStrength has developed an algorithm to fine-tune the sentiment strengths using a set of training data. This training algorithm to optimize the sentiment word strengths uses baseline human-allocated term strengths to assess whether an increase or decrease in the term strength of the word strength list would increase the accuracy of the classifications. Table 1 identifies 12 of the 117 words that were optimized. The algorithm tests all words in the word strength list at random and is repeated until all the terms have been verified.

### Table 1. Sample Word List

<table>
<thead>
<tr>
<th>Word</th>
<th>Sentiment Range: -5 to -1, +1 - +5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Previous Value</td>
</tr>
<tr>
<td>ugh</td>
<td>-3</td>
</tr>
<tr>
<td>hate</td>
<td>-3</td>
</tr>
<tr>
<td>heavenly</td>
<td>4</td>
</tr>
<tr>
<td>obnoxious</td>
<td>-3</td>
</tr>
<tr>
<td>petty</td>
<td>-1</td>
</tr>
<tr>
<td>scary</td>
<td>-2</td>
</tr>
<tr>
<td>well</td>
<td>2</td>
</tr>
<tr>
<td>worse</td>
<td>-3</td>
</tr>
<tr>
<td>worst</td>
<td>-3</td>
</tr>
<tr>
<td>wtf</td>
<td>-3</td>
</tr>
<tr>
<td>yay</td>
<td>2</td>
</tr>
</tbody>
</table>

Other term lists are used to help predict the connotation behind a term relative to the context of the text. A booster word list contains words that boost or reduce
the emotion of subsequent words, whether positive or negative. A negating word list contains words that invert subsequent emotion words (including any preceding booster words). Negating words include *not, won’t, couldn’t, shouldn’t, wouldn’t*, etc. A comprehensive list of emoticons annotated with sentiment values is incorporated in the analysis. The emoticon list assigns values to emoticons; for instance, a smiley sign, :), was assigned a value of 1, while a frown was assigned a value of -1. A questions word list was used to help remove questions that do not contain sentiment when a negative sentiment was indicated. Positive sentiments were not treated in this manner because many question sentences appeared to contain mild positive sentiment (+1) (Thomas et al. 2006).

One of the limitations of SentiStrength is that the sentiment values are highly context-dependent. For instance, sentiment measurements from blog posts may not be appropriate to classify sentiments for social media conversations. Therefore, SentiStrength needed to be calibrated properly before applying it to a specific context.

SentiStrength incorporated algorithms to help correct Tweeting “norms.” A spelling correction algorithm was included to correct user tendencies of adding extra letters to a word. For example, “mooove” would be identified as “move” by the algorithm. If a spelling mistake is made, the algorithm attempts to correct the spelling based on English word list. The algorithm also gives additional strength values of + or -1 when repeated letters are used. Exclamation marks carry a minimum positive strength of 2, and repeated punctuation marks can boost the preceding word or sentence. Few examples of the sentiment calculation of the tweets are given in Figure 1.

Results from the data analysis are presented in several ways. The total positive and negative sentiments were analyzed to identify if a time period had a significant increase or decrease. After identifying significant changes in total positive or negative sentiment over a time period, the specific time period was further scrutinized to identify contributing factors to the change in sentiment. Normalized average sentiment, Equation 1, was computed to identify an average, overall, sentiment. It is important to characterize the overall experience of all riders for a particular time period. The benefit of using a normalized average sentiment is that one or two tweets alone cannot greatly impact the average during a time period. Standard error of the average was calculated to determine the error from the mean during a specific time period, Equation 2.
Figure 1. Sample tweets and SentiStrength weights
A Novel Transit Rider Satisfaction Metric

\[ \text{Normalized Sentiment Strength} = \frac{\sum x_i}{n} \]  \hspace{2cm} (1)

\[ \text{Standard Error of the Average} = \frac{s}{\sqrt{n}} \]  \hspace{2cm} (2)

Where,

\( x_i \) = sentiment strength of a tweet

\( n \) = total number of tweets

\( s \) = standard deviation of the sentiments

Sentiment values for each text were reduced by 1 for positive sentiments and increased by 1 for negative sentiments. This modification to the data is in response to some tweets having both positive and negative sentiments. These tweets tended to be factually based or gave no sentiment. The subtraction or addition of a point of sentiment allows for these tweets to not be included in the total sentiment strength and normalized sentiment strength figures, but to still contribute to the total number of tweets.

Quantifying sentiment is of primary importance, but there is also a need to obtain information from the texts without having to scan each individual text. Tag clouds, or word clouds, are used to better visualize significant words found in the data (Feinburg 2009). The tag clouds are generated by the frequency of words in a body of text. The frequency, or number of occurrences, in which a word appears during a time period can provide details on the overall sentiment or reasons behind a sentiment. Many words are redundant for analysis and can be deleted. For example, in the tag clouds generated in this report, the words line, CTA, Chicago, and rt (retweet) were deleted. These words have a high frequency, and their presence may hide more descriptive words.

Data Collection

A text collection was collected manually for tweets containing the keywords of all combinations of “L” train names near the city of Chicago to optimize, or fine-tune, the terms’ positive and negative values in the term strength list. For example, when looking for tweets relative to the Blue Line “L” in Chicago, the search command was given “Blue Line near:Chicago.” This method of manual searching was used to collect relative tweets for each of the other seven differently-colored lines. SentiStrength recommends collecting at least 500 texts related to a project in order to use those texts to optimize SentiStrength’s text strength list. In this analysis, 557 texts
(tweets) were classified and allowed to run through SentiStrength’s algorithms to optimize the term strength list.

To observe and collect real time data, the Streaming API method, allowed by Twitter, was used. Streaming API allows members of Twitter to monitor public statuses from all users, filtered in various ways: by user identification number, by keyword, by random sampling, by geographic location, etc. Data were collected using tracking statuses containing the names of each line. After a certain time period, the data were condensed to account for user identification number, location, time, and text. A number of texts were received that contained locations from around the world. Only texts associated with user locations relevant to Chicago and its suburbs were used to ensure that only data relevant to CTA lines were analyzed. There is a chance that a user from Chicago made a comment on another city’s transit system but, having reviewed the data, it seems unlikely. Advertisements and GPS monitoring texts, such as FourSquare, were deleted unless a user sentiment was attached to the text. For example, on July 11 at 8:49 AM, an uploaded text “Stuck on the platform :-(( @ CTA - Addison (Red Line)) http://4sq.com/pwzy8y” was not deleted because it contained sentiment in the form of the emoticon. Table 2 lists the dates and time intervals evaluated.

Table 2. Observed Time Intervals

<table>
<thead>
<tr>
<th>Date</th>
<th>Time Interval</th>
<th>Number of Relevant Tweets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday, July 11, 2011</td>
<td>7am–11pm</td>
<td>158</td>
</tr>
<tr>
<td>Tuesday, July 12, 2011</td>
<td>8am–11pm</td>
<td>28</td>
</tr>
<tr>
<td>Wednesday, July 13, 2011</td>
<td>7am–12pm</td>
<td>23</td>
</tr>
<tr>
<td>Thursday, July 14, 2011</td>
<td>11am–12am</td>
<td>70</td>
</tr>
<tr>
<td>Friday, July 15, 2011</td>
<td>11am–7pm</td>
<td>67</td>
</tr>
<tr>
<td>Monday, July 04, 2011</td>
<td>1pm–9pm</td>
<td>65</td>
</tr>
<tr>
<td>Saturday, July 23, 2011</td>
<td>6am–12pm</td>
<td>46</td>
</tr>
</tbody>
</table>

Sentiment Analysis Results

Figures 2 through 8 illustrate the total positive and negative sentiments, normalized sentiment strength, and total number of tweets. Throughout the graphs of total sentiment, negative sentiment strengths are more abundant. Riders express their sentiment negatively more than positively when an event occurs. The normalized sentiment strength is predominantly negative for each time period because
there are higher totals for negative sentiment strength than positive sentiment
strength. Unusually high totals for a given hour compared to other hours in the
time period give indications of significant incidents.

Data streams from 7/11/2011 contain the most number of tweets in the shortest
time period observed, as shown in Table 1. Figure 2 shows that the normalized
sentiment strength is continuously negative throughout the interval, yet there
remains some positive sentiment strength. The number of incoming tweets
reached a maximum at 8:00 and then decreased. The standard error during this
time was also the least over the time period. Reasons as to why the maximum
occurred at 8:00 are evident in the individual texts. There were numerous tweets
containing negative sentiment about delays on the Red, Purple, and Brown lines.
The Red line was experiencing power outages while debris, or reportedly a fallen
tree, had caused delays on the Purple line. The Brown line appeared to be wait­
ing out the storm before proceeding on its scheduled route. The individual texts
indicate the predominant negative sentiments present in the majority of the texts.
The individual texts indicate negative sentiment across the performance measures
of service and safety. The poor weather had caused delays affecting service while
also putting commuters at risk from power outages and debris covered tracks.
Figure 9 illustrates the tag cloud generated for 8:00. Words like red, purple, brown,
tree, weather, fail, and yelling gave details to the trains involved, the reasons for the
incident (weather, tree), and the general mood (yelling).

At 22:00 in Figure 7, there was a strong negative normalized sentiment strength
and total negative sentiment. The tweets indicated both a location and a cause
of this strongly negative sentiment. This value resulted from fires due to fireworks
alongside the Blue line, which caused delays. The tweets indicated that the fires
were near the intersection of California St. and Fullerton St. All the information
was from tweets collected over this time period. A tag cloud was generated for the
22:00 hour (Figure 10). It too indicates a high frequency for the words fire, delay,
and blue. From the tag cloud, we are able to see problems in relation to security
(fire), safety (fire), and mobility (delay). At 20:00, the average sentiment was slightly
positive, but only because there was only one tweet recorded at this time period.
The lack of a sufficient number of tweets skewed the results by giving the total
sentiment for the system based solely on one rider. This fact shows the importance
in the number of tweets recorded. A more thorough account of the sentiment is
derived from greater participation among the users.
Figure 8 shows a huge spike in total number of tweets at 9:00. The total negative sentiment strength is at a minimum as well at 9:00. After generating a tag cloud (Figure 11), we find words such as red, blue, flooded, broken, and stuck. The negative sentiments indicate that high rains had caused flooding and delayed service to the Red and Blue lines. There was great dissatisfaction with the lack of service due to this disruption. As early as 6:00, there were tweets coming in that expressed dissatisfaction due to a disruption in the Red line service.
Figure 2. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/11/2011
Figure 3. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/12/2011.
A Novel Transit Rider Satisfaction Metric

Figure 4. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/13/2011
Figure 5. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/14/2011
Figure 6. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/15/2011
Figure 7. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/04/2011.
Figure 8. Total sentiment strengths, normalized sentiment strength, and total number of tweets for 7/23/2011
Figure 9. Tag cloud for 7/11/2011

Figure 10. Tag cloud for 7/04/2011

Figure 11. Tag cloud for 7/23/2011
Summary and Conclusions
This paper presents a method for evaluating transit rider satisfaction, which can indirectly indicate the quality of the service provided by the system. The method uses sentiment analysis of transit riders’ short messages shared on online social media. The benefits of measuring sentiment in comparison to using traditional surveys for measuring transit riders’ satisfactions include:

- The cost of data collection is minimal.
- Data can be collected in real time.
- User-specific needs can be assessed.
- Data can provide meaningful insight as to why a particular sentiment is felt.

Analysis showed that transit riders are more inclined to assert negative sentiments to a situation than positive sentiments. Surely, a lack of total negative sentiment is more desirable to a transit authority than a low total positive sentiment. It is the opinion of the authors that the findings indicate that sentiment analysis can successfully detect rider sentiments in real time of a transit system. Most important, rider dissatisfaction related to such incidents can be quantified through the sentiment analysis of the social media data. Thus, this paper demonstrates a novel method of measuring rider satisfactions using an innovative data source.

This proof of concept should be strengthened with a larger data set to negate possible sample biases in the future. Sample bias should be carefully addressed due to the insufficient amounts of data collected on certain lines, mainly Orange and Pink. The data collected are limited to English only, which may exclude Chicago’s large Latino and Polish communities. The city of Chicago provides numerous maps organizing local communities by race, age, English fluency, etc. (City of Chicago 2011). Based on review of a map titled “Distribution of Households Where English is Poorly Spoken,” there is a large community of poor English speakers that run alongside both the Orange and Pink lines. Populations of lower income may have been ignored because they do not have access to the technology needed to use Twitter’s services due to phone type or limits on available service. It is no secret that Twitter is used more among those below 40 years of age than above. There may also limits on how many older users participated in the present study. A larger sample size would assist in limiting sample bias. Other issues of sample bias are in the form of overlapping tweets from Metra customers. Metra is a rail service that provides transportation outside of the city of Chicago, as well as nationally. There may be certain instances where texts meant for Metra were inferred as being about CTA.
Social media serves as a prediction tool to make informed decisions in every facet of daily life. This research can help transit authorities better operate and manage their system and help riders to have a better travel experience. Obtaining the data is very cost effective and would provide insights not found in traditional performance metrics. The concept of using social media data for measuring perceptions can be applied to other applications where one might want to know the opinions of a large population in real time. Social media can play a role in deciphering the enormous amount of opinions generated daily by filtering the data and then quantifying the opinions on a range of topics. Further research is needed to predict rider destinations and the behavioral factors that influence destination choices. Knowing these factors will serve as a beneficial modeling tool for transit authorities for extending existing networks or services.

An area that needs to be addressed in the future is how social media can be used to enhance a rider’s ability to make informed decisions about travel scheduling to travel more efficiently and comfortably. Suppose a rider wants to travel by train, but there are power outages affecting rail lines. Having the ability to receive real-time information on disruptions and disturbances can allow riders to make informed decisions and increase their overall utility.

In the future, exploration into combining opinion mining with this analysis would assist in the manually deletion of advertisements and GPS applications. A continued updating of the word strength list with other available data such as customer hotline data and feedback on transit agency websites and Facebook pages would give valuable addition to the Twitter data. Developing a tool to assign highly-occurring words over a given time period to a list of specific transit concerns would allow for the describing and quantifying overall sentiment to service, safety, weather, etc., without having to manually investigate individual tweets. Working with a transit authority directly to advertise that sentiment may help increase rider awareness and, thus, increase the total number of tweets received.

References


**About the Authors**

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Exploring Comparative Ridership Drivers of Bus Rapid Transit and Light Rail Transit Routes

Graham Currie and Alexa Delbosc
Monash University

Abstract

A major research gap is the relative ridership performance of Bus Rapid Transit (BRT), Light Rail Transit (LRT), and streetcar (SC). This paper assesses ridership influences of 101 routes in Australia, Europe, and North America using multiple regression examining the influence of transit mode, vehicle capacity, service level, employment/residential density, car ownership, speed, stop spacing, right-of-way, vehicle accessibility, and integrated fares on ridership (boardings/vehicle km; BVK). Average ridership is higher for LRT/SC routes than for BRT routes, and although service levels vary greatly, they are lower on BRT systems. Residential/employment density is higher for LRT/SC routes compared to BRT. A regression model predicting BVK was significant ($R^2 = 0.83$) with six predictors: being in Europe, speed, vehicle capacity, employment density, service level, and integrated ticketing. Results suggest that the transit mode does not directly impact ridership but rather acts through vehicle size and service levels. Limitations and opportunities for future research are identified.

Introduction

Cities facing the challenge of expanding transit often find themselves weighing the relative costs and merits of Bus Rapid Transit (BRT) versus Light Rail Transit (LRT). However, a major research gap is empirical assessment of the comparative merits of BRT versus LRT. Although the relative costs of LRT and BRT have been analyzed
(U.S. General Accounting Office 2001; UK Commission for Integrated Transport 2005), there is almost no research that explores relative ridership impacts of one mode over the other.

This paper presents the findings of an empirical route level analysis of the factors influencing ridership on a series of BRT, LRT, and streetcar (SC) routes in Australia, Europe, and North America. Its aim is to provide an objective base to determine whether the transit mode has a significant influence on ridership above and beyond the influence of other important variables such as service level or urban density. The research integrates the data sets from two separate studies predicting the ridership of BRT systems in Australia (Currie and Delbosc 2011) and LRT/SC ridership in Australia, Europe, and North America (Currie, Ahern, and Delbosc 2011). The analysis will help inform cities that are comparing the relative merits of a BRT or LRT system for their needs.

The paper is structured as follows. The first section overviews previous research associated with route-level ridership drivers. This is followed by a discussion of the methodology used to collate and analyze the data. Results are then presented, followed by conclusions from the research.

**Previous Research**

A summary of previous research on factors that influence LRT and BRT ridership is presented in Table 1.

High service levels, measured in terms of frequency and span of hours covered, has often been cited as an important driver of patronage on all public transport modes. Urban density is also identified as an important influence: “Nearly every study that has focused on transit ridership has provided evidence that density is the primary determinant of transit ridership” (Johnson 2003, 32). Much research cites the importance of an integrated public transport network as a key driver of high light rail patronage (FitzRoy and Smith 1998; Denant Boemont and Mills 1999; Babalik-Sutcliffe 2002) and transit patronage in general (Nielsen et al. 2005). Patronage drivers in this case involve service and fare integration as well as the wider “network effects” these can generate. A range of other factors has been suggested that might also influence light rail ridership. Cheap fares were cited in two reports (FitzRoy and Smith 1998; Kain and Liu 1999). A number of researchers cite the importance of a strong policy context as a basis for high light rail ridership (e.g., Knowles 2007). Several researchers have suggested that high car ownership can
reduce light rail usage (Mackett and Babalik-Sutcliffe 2003; Babalik-Sutcliffe 2002). Hass-Klau and Crampton (2002) suggested that pedestrian zone length in cities, average speed, stop distance, and the density of the light rail network were also related to their index of light rail performance (based on ridership per route km). Correlation analysis suggested better performance (ridership) at slower speeds and short stop distances (Crampton 2002). This counter-intuitive result is because LRT systems tend to have higher ridership in inner city areas where speeds and stop spacing are lower/shorter (an outcome of higher ridership rather than a driver).

Table 1. Ridership Drivers Identified in Previous Research

<table>
<thead>
<tr>
<th>Identified Driver</th>
<th>Resource Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Density Residential Development</td>
<td>Johnson 2003; Babalik-Sutcliffe 2002; Kain and Liu 1999; Kain, Barranda, and Upchurch 2004; Seskin and Cervero 1996</td>
</tr>
<tr>
<td>Modal Integration and Network Effect</td>
<td>Mackett and Babalik-Sutcliffe 2003; Kain, Barranda, and Upchurch 2004; Babalik-Sutcliffe 2002; Denant Boemont and Mills 1999</td>
</tr>
<tr>
<td>Ticket Integration</td>
<td>Crampton 2002; Hass-Klau and Crampton 2002; Mackett and Babalik-Sutcliffe 2003</td>
</tr>
<tr>
<td>Low Car Ownership</td>
<td>Mackett and Babalik-Sutcliffe 2003; Babalik-Sutcliffe 2002</td>
</tr>
<tr>
<td>Low Fares</td>
<td>Mackett and Babalik-Sutcliffe 2003; Kain and Liu 1999; Hensher and Golob 2008</td>
</tr>
<tr>
<td>High Speed</td>
<td>Hass-Klau and Crampton 2002; Crampton 2002</td>
</tr>
<tr>
<td>Stop Distance</td>
<td>Hass-Klau and Crampton 2002; Crampton 2002</td>
</tr>
<tr>
<td>Light Rail Network Density</td>
<td>Hass-Klau and Crampton 2002; Crampton 2002</td>
</tr>
<tr>
<td>Reliable Service</td>
<td>Mackett and Babalik-Sutcliffe 2003</td>
</tr>
<tr>
<td>Pedestrianization</td>
<td>Hass-Klau and Crampton 2002</td>
</tr>
<tr>
<td>Strong Economic Conditions</td>
<td>Babalik-Sutcliffe 2002</td>
</tr>
<tr>
<td>High Employment</td>
<td>Kain and Liu 1999</td>
</tr>
<tr>
<td>Strong Policy Support</td>
<td>Knowles 2007</td>
</tr>
<tr>
<td>Easy Station Access</td>
<td>Kain and Liu 1999</td>
</tr>
<tr>
<td>Number of Stations</td>
<td>Hensher and Golob 2008</td>
</tr>
</tbody>
</table>
The results of two sets of empirical studies are worthy of closer attention. The first (Hass-Klau and Crampton 2002; Crampton 2002) concern system-wide (rather than route-level) data from 24 light rail systems (75% from Europe). The authors report that major explanatory variables include travel card use (ticket integration), CBD pedestrianization, population density, and low fares. The second noteworthy empirical source examines BRT system performance (Hensher and Golob 2008). This involved a comparative assessment of system-wide data from 44 worldwide BRT systems. The authors found that more stations and higher service levels (measured as headway and capacity) increased ridership, whereas higher fares were negatively correlated with ridership.

Overall, empirical research has uncovered many factors that influence LRT or BRT ridership; however, results vary between studies and also by context. None consider the relative influences for BRT or LRT systems within the same analysis. There is clearly room for research to explore ridership drivers between BRT and LRT in a more consistent manner.

Research Approach and Methodology

Route-level data for 44 BRT routes and 57 LRT lines were collated (Table 2). Rail-based routes were further subdivided into light rail transit (LRT) and streetcar (SC) routes to further explore the nature of these modes (defined as light rail if over 50% of the route had segregated right of way). Every SC/LRT in Australia was included. Light rail routes in North America and Europe were chosen based on the availability of reliable data at the route level. Further details about collecting these data are available (see Appendix A, Currie, Ahern, and Delbosc 2011; Currie and Delbosc 2011).

Due to limitations in available data, only Australian BRT data could be included in this analysis. Although this is an acknowledged limitation of the data, Australian BRT includes a wide range of service characteristics. The key features that distinguish BRT from traditional route buses include a mix of runningways, quality stations and vehicles, intelligent transport systems, and high-frequency service patterns (Levinson et al. 2003). Australian systems vary from major commuter busways with grade-separated corridors (Brisbane and Adelaide) to dedicated bus lanes (Sydney) to primarily on-street “BRT light” (Melbourne) (Currie and Delbosc 2010).
Table 2. Route Services Selected For Analysis

<table>
<thead>
<tr>
<th>Routes Selected</th>
<th>BRT Australia</th>
<th>LRT/SC Australia</th>
<th>North America</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td># Routes Analyzed</td>
<td>44</td>
<td>24</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Melbourne – 700i, 703, 888, 889, 900, 901</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Adelaide – 503, 506, 507, 521, 541, 542, 545, 546, 548, T500, T501</td>
<td></td>
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<td></td>
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<tr>
<td>Sydney – T61, T62, T63, T64, T65, T70, T71, T75, T80</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Brisbane – 100, 111, 120, 124, 125, 139, 135, 140, 150, 155, 160, 170, 180, 200, 210, 212, 250, 555</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toronto – 501i, 502-503i, 504-505, 506-507, 509-510, 511i, 512i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston – Green Line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltimore – only one route</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Charlotte – Lynx Light Rail</td>
<td></td>
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<tr>
<td>Dallas – DART</td>
<td></td>
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<tr>
<td>Minneapolis – Hiawatha Line</td>
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<tr>
<td>Tacoma – Tacoma Link</td>
<td></td>
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<tr>
<td>Buffalo – Niagara Frontier</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Tampa – Hillsborough</td>
<td></td>
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<tr>
<td>Portland – OR – MAX</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Sacramento – Regional Transit</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>San Diego – trolley</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Saint Louis – Metrolink</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dublin – Red, Green Croydon – Wimbledon, Beckenham and New Addington lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheffield – Meadowhall, Halfway, Middlewood lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyne and Wear – Green and yellow lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midland Metro – Birmingham to Wolverhampton</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manchester – Bury, Altrincham, Eccles Lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nottingham – Hucknall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lyon – Line 1, Line 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montpellier – Line 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rouen – Line 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 In 2008, this was route 700, and it has since been re-branded the 903 SmartBus route. For the purpose of this analysis, it was included as a SmartBus service.

2 These lines analyzed as a group due to poor data availability.

3 Light rail.

4 Streetcar.

Analysis included simple comparative analysis, correlations and linear regression modeling.

Boardings per vehicle kilometer (BVK) was the dependent variable selected for analysis in the regression modeling. BVK enables ridership to be examined relative to the level of service (vkms) operated, controlling for the strong influence of service levels on ridership found in previous research (e.g., Stopher 1992; Currie and Wallis 2008). Explanatory variables were selected based on those used in previous research (Table 1), and available data and are detailed in Table 3. Data were not all available for the same year and ranged from between 2001 and 2009.
Table 3. Explanatory Data Collected

<table>
<thead>
<tr>
<th>Data</th>
<th>Derivation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Level</strong></td>
<td>Vehicle trips per annum was adopted and calculated by dividing the annual vehicle kilometers by route length in one direction. This is a broad indicator of service levels, encompassing service frequency, service span, and coverage of nights and weekend services. Unlike vehicle kilometers, this measure controls for route length.</td>
</tr>
<tr>
<td><strong>Vehicle Capacity</strong></td>
<td>Vehicle capacity was classified into one of five categories: 100 or less, 101–150, 151–200, 201–250 and 250+. Non-crush standing and sitting capacity was used.</td>
</tr>
<tr>
<td><strong>Employment &amp; Residential Density</strong></td>
<td>Residential density and employment density (expressed in residents or jobs per square km) were calculated within an 800m catchment of the route alignment using mainly GIS analysis where available. Some North American and European routes had to be calculated based on city-wide data.</td>
</tr>
<tr>
<td><strong>Car Ownership</strong></td>
<td>This is expressed as cars per 1,000 people and was calculated for residents within 800m of route alignment using GIS analysis where available. Some North American and European routes had to be calculated based on city-wide data.</td>
</tr>
<tr>
<td><strong>Average Speed</strong></td>
<td>In some cases, this was provided by operators or other sources (see Appendix A). When not directly available, average speed was calculated by dividing route length by run time. Run time was taken at the 8 AM peak. Values are expressed as km per hour.</td>
</tr>
<tr>
<td><strong>Stop Spacing</strong></td>
<td>Calculated by dividing route length by number of stops minus one. This was calculated using each stop, not just timing stops. Values are expressed in meters.</td>
</tr>
<tr>
<td><strong>Separate Right-of-Way Share</strong></td>
<td>Right-of-way was defined as the share of route separate from mixed traffic. This includes both ROW-A (fully grade-separated) and ROW-B (cross-traffic at intersections).</td>
</tr>
<tr>
<td><strong>Vehicle Accessibility</strong></td>
<td>For BRT routes, defined as the proportion of buses on a route that were low-floor or otherwise wheelchair-accessible (for Brisbane, this had to be estimated as a proportion of total fleet, e.g., all routes were assigned the same accessibility level). For LRT, defined as the proportion of stops that were wheelchair-accessible.</td>
</tr>
<tr>
<td><strong>Integrated Fares</strong></td>
<td>Routes were classified as having “fully integrated ticketing” if passengers were able to transfer between modes without having to buy a separate ticket.</td>
</tr>
<tr>
<td><strong>Region</strong></td>
<td>Regions may have further intangible differences in culture and expectations. For this reason, dummy variables accounting for Europe, North America, and Australia were included.</td>
</tr>
<tr>
<td><strong>Mode</strong></td>
<td>A major research aim is to determine if mode (BRT, LRT, or SC) has a significant influence on ridership above and beyond the influence of other variables.</td>
</tr>
</tbody>
</table>
Regression Methodology

A linear regression modeling approach was adopted using the following model:

\[ Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_n X_{in} + \varepsilon_i \]

Where:

\( Y_i \) = Dependent variable \( i \)

\( X_i \) = Independent variables predicting \( Y_i \)

\( \beta \) = Regression coefficients to be estimated

\( \varepsilon \) = Error

Step-wise regression was used to test the relationships between ridership (BVK) and the explanatory variables measured for each route. Explanatory variables were included in the model based on their level of statistical significance (a significance probability of 95% was adopted for inclusion, and removal was based on a significance threshold of below 90%). A number of statistical tests were undertaken to assess the reliability of the analysis. Mahalanobis distances (distance of cases from the mean of the predictor variables [Barnett and Lewis 1978]) and leverage values (also called hat values, which gauge the influence of the observed value of the outcome variable over the predicted values [Stevens 2002]) determine whether a single case is having an undue influence on the significance of the model. Collinearity tests whether predictors in the model are so highly correlated as to be interchangeable (Myers 1990).

Explanatory variables were those identified in Table 3. Mode, continent, and integrated ticketing were coded using dummy variables. Capacity was encoded as a five-category variable.

Analysis

Summary Statistics

Table 4 shows summary statistics from the routes analyzed by mode and continent. Average route ridership (BVK) is higher for LRT (6.7) than SC (6.5) and is considerably higher than for BRT (1.3). Service levels vary greatly between mode and regions. Vehicle trips per annum are 4.2 times higher on LRT than BRT and 3 times higher on SC. Vehicle trips are highest in North American LRT, which has higher service but considerably lower ridership than European LRT.
Table 4. Average Route-Level Statistics By Mode And Continent

<table>
<thead>
<tr>
<th></th>
<th>BRT</th>
<th>LRT/SC</th>
<th>LRT Total</th>
<th>SC Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Australia</td>
<td>Australia</td>
<td>N. America</td>
<td>Europe</td>
</tr>
<tr>
<td>Dependent Variables (Ridership)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boardings/ Veh Km BVK)</td>
<td>Mean</td>
<td>1.3</td>
<td>6.4</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.4</td>
<td>2.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Explanatory Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Level (veh trips/ annum)</td>
<td>Mean</td>
<td>23,784</td>
<td>64,260</td>
<td>114,877</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>16,974</td>
<td>15,341</td>
<td>58,811</td>
</tr>
<tr>
<td>Residential Density</td>
<td>Mean</td>
<td>1,848</td>
<td>3,713</td>
<td>3,222</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>303</td>
<td>942</td>
<td>3,948</td>
</tr>
<tr>
<td>Employment Density</td>
<td>Mean</td>
<td>3,266</td>
<td>7,611</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1,701</td>
<td>2,455</td>
<td>3,296</td>
</tr>
<tr>
<td>Car Ownership</td>
<td>Mean</td>
<td>529</td>
<td>434</td>
<td>531</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>33</td>
<td>53</td>
<td>156</td>
</tr>
<tr>
<td>Average Speed (kph)</td>
<td>Mean</td>
<td>26</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>6</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Stop Spacing</td>
<td>Mean</td>
<td>1,068</td>
<td>279</td>
<td>841</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>589</td>
<td>98</td>
<td>642</td>
</tr>
<tr>
<td>% Accessible</td>
<td>Mean</td>
<td>62%</td>
<td>21%</td>
<td>54%</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>21%</td>
<td>26%</td>
<td>50%</td>
</tr>
<tr>
<td>% Segregated Right-of-Way</td>
<td>Mean</td>
<td>41%</td>
<td>24%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>29%</td>
<td>23%</td>
<td>46%</td>
</tr>
<tr>
<td>Integrated Fares</td>
<td>Percent</td>
<td>80%</td>
<td>96%</td>
<td>76%</td>
</tr>
<tr>
<td>Capacity (category)</td>
<td>100 or less</td>
<td>75%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>101–150</td>
<td>25%</td>
<td>63%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>151–200</td>
<td>0%</td>
<td>29%</td>
<td>52%</td>
</tr>
<tr>
<td></td>
<td>201–250</td>
<td>0%</td>
<td>4%</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>250+</td>
<td>0%</td>
<td>4%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Residential density tends to be higher for LRT/SC compared to BRT. This may be due to inner-city concentration, whereas many of the Australian BRT systems extend to the suburbs. Employment density is highest amongst Australian LRT/SC systems for similar reasons. Interestingly, European residential and employment density...
densities are relatively low, which is consistent with previous research (Hass-Klau and Crampton 2002).

Car ownership is lowest amongst European LRT routes. The car ownership in American LRT cities is nearly identical to that in Australian BRT systems, but higher than Australian LRT/SC systems. This, again, is a reflection of the inner urban concentration of Australian LRT/SC.

BRT systems tend to have smaller vehicles, although Brisbane uses articulated vehicles that placed their capacity into the second category. European LRT/SC systems employ the largest vehicles, with 83 percent with a capacity of more than 200. North American systems tend to use mid-sized vehicles, followed by Australian LRT/SC.

Australian BRT routes are characterized by fast run speeds (higher than LRT/SC), larger stop spacing, relatively accessible buses, mostly integrated fares, and some segregated right of way.

There are major differences between LRT/SC routes in different regions. Australia is dominated by Melbourne’s SC routes, which reflect in the slowest running speeds, smaller vehicles, and smallest average stop distance of only 279m. Only a small proportion of the routes have segregated right-of-way, and the vehicles are unlikely to be accessible. However, they are the most likely routes to have integrated ticketing systems. European systems are dominated by high-capacity LRT rather than SC and have high running speeds and high ROW share, all vehicles are considered accessible, and half the ticketing systems are integrated. North American routes have long stop distances but mid-sized vehicles and only moderate run speeds despite being dominated by LRT systems with high separate ROW share.

Initial Correlations

Initial analysis explored links between ridership and service levels because previous research suggested strong influences (FitzRoy and Smith 1998; Currie, Ahern, and Delbosc 2011; Stopher 1992; Currie and Wallis 2008; Mackett and Babalik-Sutcliffe 2003; Kain and Liu 1999). Figure 1 graphs each route based on BVK and transit vehicle trips per annum (a measure of service frequency/level). A strong relationship between the two is apparent: routes with low vehicle trips tend to have lower ridership (correlation $r = 0.57$, statistically significant at $p < 0.001$). In general, higher service levels generate higher BVK; however, some other patterns are evident in the data. BRT routes cluster at lower BVK (below 2.0) and service level below 50,000 p.a., while LRT/SC are all higher than this (above 2.0/50,000 p.a.). European LRT has
the highest BVK values at modest service levels, whereas American LRT ridership lies within the 2.0 to 8.0 BVK range but with considerably higher service levels (mostly above the 100,000 vehicle trips p.a. range).

![Figure 1. Boardings per vehicle km by vehicle trips per annum](image)

**Regression Analysis**

Step-wise regression resulted in a statistically significant model, adjusted $R^2 = 0.82$, $F(7, 93) = 67.0$, $p < 0.0001$, with seven explanatory variables: Europe, employment density, average speed, integrated ticketing, vehicle capacity, vehicle trips per annum, and stop spacing. An analysis of possible influential cases was conducted to determine whether any of the data points were significant outliers or had an unduly large influence on the model results. Two Toronto routes (509/510 and 512) were found to have an unduly large influence, and so did the Charlotte Lynx LRT system. The Mahalanobis distances were over 20 and leverage values were over 3 times the average, indicating unambiguously that these three data points were having an unusually large influence on the model.

The model was re-run without these three data points, and this time the model changed slightly with their removal; stop spacing was no longer significant. The results of the model without these three data points are shown in Table 5. The
model has the same explanatory power, adjusted $R^2 = 0.83$, $F(6, 91) = 78.6, p < 0.0001$. Collinearity was not evident.

Table 5. Boardings per Vehicle Kilometer Multiple Regression Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>Beta ($\beta$)</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.13</td>
<td>0.82</td>
<td>0.52</td>
<td>9.31a</td>
</tr>
<tr>
<td>Europe</td>
<td>5.55</td>
<td>0.60</td>
<td>0.32</td>
<td>-6.70a</td>
</tr>
<tr>
<td>Average speed</td>
<td>-0.17</td>
<td>0.03</td>
<td>0.20</td>
<td>4.10a</td>
</tr>
<tr>
<td>Vehicle capacity</td>
<td>0.78</td>
<td>0.19</td>
<td>0.28</td>
<td>5.19a</td>
</tr>
<tr>
<td>Employment density (1,000s)$^c$</td>
<td>0.30</td>
<td>0.06</td>
<td>0.26</td>
<td>3.16b</td>
</tr>
<tr>
<td>Vehicle trips per annum (1,000s)$^c$</td>
<td>0.02</td>
<td>0.006</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Integrated ticketing</td>
<td>1.53</td>
<td>0.39</td>
<td>0.18</td>
<td>3.91a</td>
</tr>
</tbody>
</table>

$^a$ Significant $p < 0.001$; $^b$ significant $p < 0.01$; $^c$ unstandardized B values converted to 1,000s for ease of interpretation; this does not change the standardized Beta values ($\beta$).

The six significant predictors were (in order of influence): being in Europe, average running speed, vehicle capacity, employment density, vehicle trips per annum, and integrated ticketing. Being in Europe ($\beta = 0.58$) had a large influence on BVK; if everything else was equal, routes in Europe had 6.1 more boardings per vehicle km than routes elsewhere.

**Discussion and Conclusion**

Being in Europe was the most influential ridership driver identified in the analysis ($\beta = 0.52$), suggesting that European LRT achieves a bonus ridership factor of some considerable size. The cause is intriguing since the analysis has already allowed for differences in car ownership, residential and employment density, and other system design features known to be different in Europe. Pedestrianization is high in Europe and has been linked to higher LRT usage in other studies (Hass-Klau and Crampton 2002). Public transport mode share is also considerably higher in Europe with 12/15 percent in France/UK compared to 5 percent in Australia, 3 percent in the U.S. and 8 percent in Canada (Kenworthy and Laube 2001). Higher mode share, in turn, may be a proxy for a greater “network effect.” European transit networks have greater scale than the others examined, which is partly related to mode share.

Employment density is also significant with an effect size of $\beta = 0.26$. This is consistent with previous research (Kain and Liu 1999) and suggests that penetrating
high trip attractors such as CBD employment sites is important for both BRT and LRT/SC ridership.

The results collectively support the case for high service levels as a driver of ridership regardless of the transit mode (LRT, SC or BRT) adopted (effect size of $\beta = 0.20$), which supports much past research (e.g., Currie and Wallis 2008; Hensher and Golob 2008; Kain and Liu 1999). This is particularly interesting in this context where boardings per vehicle kilometer was used as the outcome variable, as BVK controls for service level. This suggests that routes with higher service levels are more efficient and attract more ridership than low-service routes, all other things being equal. Note that BVK does not distinguish between service frequency and service span; for example, extending transit service hours can provide higher-than-expected ridership growth (Currie and Loader 2009).

Integrated ticketing was also shown to be important but had a relatively modest effect size of $\beta = 0.18$. This is consistent with much of previous research, demonstrating the need to plan networks (and associated fares/ticketing) on a network-wide basis to improve the passenger transfer performance of major corridor modes like BRT/LRT and SC.

Interestingly mode (BRT/LRT/SC) is NOT significant in this model. Instead, the effect of vehicle capacity ($\beta = 0.28$) is a significant predictor of BVK. Of course, it is important to consider that BRT systems are often (but not always) constrained by smaller vehicles, and indeed some of the more successful BRT systems are facing great challenges in expanding their capacity (e.g., Jaiswal et al. 2007). In addition, modal decisions need to consider the relative costs of implementing modes and other factors such as the impact on land use. The costs of a BRT system vary between US$5 million to more than US$50 million per kilometer (Hensher and Golob 2008), but, in most cases, are far lower than the cost of fixed rail systems.

Negative speed impacts on ridership ($\beta = -0.32$) imply that slower routes achieve higher ridership. Negative outcomes of this kind are common in analysis of this kind (Hass-Klau and Crampton 2002; Crampton 2002) and can be caused by longer dwell times due to higher ridership and operations in high-density congested areas, which slow operations. This finding does not support a policy for slowing LRT/SC/BRT systems down but rather supports the principle of penetration of high-density trip attractors in route design and transit-oriented development around stops and stations.
There are clearly many opportunities for research of this kind to be expanded. Analyzing only Australian BRT systems is a major limitation that would be overcome by exploring North American and European BRT routes. Inclusion of more European as well as South American and Asian BRT/LRT systems would broaden the analysis. A within-region analysis may give specific insight within a comparable geographic context if enough BRT/ LRT routes were available for analysis. Fares, vehicle capacity, pedestrianization, and city-wide transit mode share would be useful additions as explanatory variables if available. It would be particularly useful to explore the causes of the “European” ridership boost factor through the inclusion of a wider set of explanatory variables.

Overall, the results suggest that transit mode does have a significant ridership impact, at least in regards to boardings per vehicle kilometre. The cost effectiveness of this when constructing and operating BRT and LRT/SC systems is the subject of other research. Regardless of transit mode, service levels, employment density, and integrated ticketing are also influential factors in achieving high ridership transit systems.

Endnotes

1 As noted by a reviewer, BVK somewhat favors routes with higher-capacity vehicles. For example, a tram carrying 50 people every 10 minutes would have a higher BVK than 2 buses arriving every 5 minutes carrying 25 people per bus. The implications of this point are discussed.

2 Early versions of this analysis did not include vehicle capacity, and this variable was replaced by transit mode (BRT lower than other modes). When capacity is taken into account, mode is no longer a significant predictor.
### Appendix A: Data Sources

<table>
<thead>
<tr>
<th>Variable/Measure</th>
<th>Australia (BRT)</th>
<th>Australia (LRT/SC)</th>
<th>North America</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boardings per Year</strong></td>
<td>2008 data provided by operators</td>
<td>2007 data provided by operators</td>
<td>Toronto – TTC¹ US – FTIS²</td>
<td>Based on SYPTE³ and website data⁴</td>
</tr>
<tr>
<td>Used to calculate boardings/ route and vehicle km</td>
<td>2008 data provided by operators except Sydney T80 - based on timetables</td>
<td>Melbourne provided by operator; others estimated from published timetables</td>
<td>As above for Boardings p.a.</td>
<td>Based on SYPTE³ and website data⁴</td>
</tr>
<tr>
<td><strong>Vehicle Kilometers</strong></td>
<td>2008 data provided by operators</td>
<td>Melbourne provided by operator; others estimated from published timetables</td>
<td>As above for Boardings p.a.</td>
<td>Based on SYPTE³ and website data⁴</td>
</tr>
<tr>
<td>Used to calculate boardings / vehicle km</td>
<td>2008 data provided by operators except Sydney T80 - based on timetables</td>
<td>Melbourne provided by operator; others estimated from published timetables</td>
<td>As above for Boardings p.a.</td>
<td>Based on SYPTE³ and website data⁴</td>
</tr>
<tr>
<td><strong>Service Level</strong></td>
<td>Provided by operators</td>
<td>Provided by operators</td>
<td>Toronto – TTC¹ US – FTIS²</td>
<td>Based on SYPTE³ and website data⁴</td>
</tr>
<tr>
<td>Vehicle trips per annum</td>
<td>Provided by operators</td>
<td>Provided by operators</td>
<td>Toronto – TTC¹ US – FTIS²</td>
<td>Based on SYPTE³ and website data⁴</td>
</tr>
<tr>
<td><strong>Vehicle Capacity</strong></td>
<td>Provided by operators</td>
<td>Provided by operators</td>
<td>Various Internet sources</td>
<td>Various Internet sources</td>
</tr>
<tr>
<td>Five categories based on sitting and standing room</td>
<td>Provided by operators</td>
<td>Provided by operators</td>
<td>Various Internet sources</td>
<td>Various Internet sources</td>
</tr>
<tr>
<td>Residents per square metre</td>
<td>ABS⁵</td>
<td>ABS⁵</td>
<td>Toronto – SC⁶, US – FTIS²</td>
<td>Dublin: CSO⁵ UK: census⁹ Others: based on SYPTE³ Selected European centers using data from INSEE¹⁰</td>
</tr>
<tr>
<td><strong>Employment Density</strong></td>
<td>ABS⁵</td>
<td>ABS⁵</td>
<td>Toronto – SC⁶, US – FTIS²</td>
<td>Dublin: CSO⁵ UK: census⁹ Others: based on SYPTE³ Selected European centers using data from INSEE¹⁰</td>
</tr>
</tbody>
</table>
### Car Ownership

<table>
<thead>
<tr>
<th>Cars per 1,000 residents</th>
<th>ABS(^5)</th>
<th>ABS(^6)</th>
<th>Toronto – TT Survey(^11) US – census(^7)</th>
<th>Dublin: CSO(^8) UK: census(^9) France– CERTU(^12)</th>
</tr>
</thead>
</table>

### Route Length

<table>
<thead>
<tr>
<th>Used to calculate service level, speed, stop spacing &amp; ROW</th>
<th>Calculated using Google Earth</th>
<th>Melbourne provided by operator; others Google Earth</th>
<th>Toronto – TTC data Google Earth</th>
<th>Mix of website data and Google Earth Route Inspection UK/Dublin – website data(^4)</th>
</tr>
</thead>
</table>

### Speed

<table>
<thead>
<tr>
<th>Average travel time divided by route length (kph)</th>
<th>Published timetables</th>
<th>As above for service level</th>
<th>As above for service level</th>
<th>As above for service level</th>
</tr>
</thead>
</table>

### Stop Spacing

<table>
<thead>
<tr>
<th>Route length divided by number of stops minus 1</th>
<th>Published timetables</th>
<th>As above for service level</th>
<th>As above for service level</th>
<th>As above for service level</th>
</tr>
</thead>
</table>

### Share Segregated Right-of-Way

<table>
<thead>
<tr>
<th>Proportion of track out of mixed traffic</th>
<th>Calculated using Google Earth</th>
<th>Data provided by VicRoads and an analysis of Google Maps</th>
<th>Toronto: based on route inspection; others: visual inspection of Google Maps</th>
<th>Visual inspection of Google Maps Dublin: Data provided by RPA UK systems: website data(^5)</th>
</tr>
</thead>
</table>

### Share Accessible Stops

<table>
<thead>
<tr>
<th>Proportion of stops that are wheelchair accessible</th>
<th>Published timetables and operators</th>
<th>As above for service level</th>
<th>As above for service level</th>
<th>As above for service level</th>
</tr>
</thead>
</table>

### Integrated Fares

<table>
<thead>
<tr>
<th>No fare on mode transfer</th>
<th>Operator website</th>
<th>Operator website</th>
<th>Operator website</th>
<th>Operator website</th>
</tr>
</thead>
</table>

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Based on 2006 data and GIS analysis (Statistics Canada 2007).


Transport Tomorrow Survey (University of Toronto 2006).


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University of Toronto. 2006. *Transportation Tomorrow Survey*. Toronto, Canada: Data Management Group, University of Toronto.

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Determinants of Bicycle-On-Bus Boardings: A Case Study of the Greater Cleveland RTA

Bradley J. Flamm, Temple University

Abstract

Transit agencies around the country have made significant investments since the late 1990s to provide improved service to cyclist-transit users (CTUs), that is, transit riders who bring bicycles with them by using bicycle racks installed on buses. Use of these bus bicycle racks appears to vary significantly from transit system to transit system. It is unclear, however, what specific factors contribute most to bicycle-on-bus boardings (BoBBs). Using multi-variate regression analysis and a detailed data set of 2008–2011 BoBBs for Northeast Ohio’s Greater Cleveland Regional Transit Authority (GCRTA), this study compared daily BoBBs to general ridership (measured by unlinked passenger trips) in light of key weather, transit service, and travel cost variables. Rates of BoBBs rose during the study’s time period and were strongly associated with weather conditions, though even in wet and cold weather, dozens of transit users traveled with their bicycles. To a lesser extent, BoBBs are also associated with transit service levels and travel costs.

Introduction

Beginning in the 1990s, transit system managers, planners, bicycling and environmental advocates, and funders have embraced the goal of coordinating bicycling and transit service. Public transit systems throughout the United States have made large capital investments (often with generous federal financial assistance) to place bicycle racks on buses, install bicycle parking and services facilities at transit sta-
transit systems now have bicycle racks installed on a majority of buses—72 percent, according to the 2011 edition of the American Public Transit Association Fact Book (APTA 2011). Seven of the eight largest North American transit systems have installed bicycle racks on 100 percent of transit buses (New York City Transit is the exception, with no bus bicycle racks installed). Policies regarding bicycle access to rail cars vary from agency to agency, with frequent prohibitions during peak commuting hours, but a growing number of transit systems are finding ways to accommodate bicycles on trains and streetcars.

The principal goals of such efforts are to increase transit use and cycling trips and give travelers more choices and greater flexibility. Environmental, health, and traffic congestion-mitigation benefits are expected as a result. By welcoming cyclists—allowing them to become what Krizek et al. (2011) term cycle-transit users (CTUs) and Hagelin (2005) identifies as bike-on-bus users—transit agencies create opportunities for more people to conveniently use buses, trains, and trolleys.

In some cases, this coordination between transit and cycling is so successful that capacity limits are reached, with racks on transit vehicles unable to accommodate additional demand for bicycles due to space constraints. Transit agencies in several states, particularly where there are high levels of recreational bicycling, have had to address this challenge in recent years (Krizek and Stonebraker 2010). Most transit agencies, however, are like Cleveland, Ohio’s Greater Cleveland Regional Transit Authority (GCRTA), which has bicycle racks installed on every bus but no significant capacity problems. Transit riders who want to travel with their bicycles can make that decision without worrying that there will be no room for them on their bus or train.

The presence of bus bicycle racks and supportive transit-bicycle policies, however, is only one factor in a transit user’s decision to travel with a bicycle. Other factors come into play as travel behavior choices are made, but there is little empirical evidence as to what those factors are. How do weather conditions, travel costs, transit service levels, employment, and other variables affect the number of daily bicycles-on-bus boardings (BoBBs) for a major public transit agency like GCRTA? (GCRTA is the 34th largest U.S. transit agency, as measured by annual unlinked passenger miles [APTA 2011], with more than 350 buses in service on a typical weekday covering 35,000 vehicle miles and serving tens of thousands of riders.) Do such factors affect transit users without bicycles in the same ways they affect CTUs?

A detailed 2008–2011 dataset of more than 160,000 BoBBs maintained by North-east Ohio’s GCRTA gives us an opportunity to study these factors in more detail.
This question can be asked: On a typical day in the operations of a large public transit system, what determines the number of bus riders who decide to travel with their bicycles? The opportunity is there for transit customers who would like to do so, since a bicycle rack with the capacity for two bicycles is installed on every revenue bus. Yet, some days, fewer than two dozen CTUs place their bikes on a bus bicycle rack, and on other days 300 or more will do so. What factors influence the highly variable number of BoBBs observed on GCRTA’s motor bus network in recent years?

The analysis of GCRTA’s data set of BoBBs, reviewed in conjunction with data from other sources, permits a detailed assessment of these questions. To take a comprehensive approach, this paper addresses three key research questions related to GCRTA’s operations:

- What are the determinants of bicycle-on-bus boardings?
- What are the determinants of general transit ridership?
- How do the determinants differ for the two categories of transit users?

The remainder of this paper is organized as follows: First is a discussion of the history of bicycle-transit coordination in the United States, with an emphasis on GCRTA’s bicycles and transit investments and policies. Second, the analytical methodologies and data sets used are described, followed by descriptions of the results of the quantitative analysis. Finally, the paper concludes with a discussion of some implications of the findings and suggested future analytical steps.

**Background**

Cycle-transit users have been the subject of several studies in the past decade, each of which highlights a clear trend: transit agencies are making important changes to their vehicles, facilities, and policies to accommodate transit riders who are also cyclists (Hagelin 2005; Pucher and Buehler 2009; Schneider 2005). Schneider’s detailed and comprehensive report on behalf of the Transit Cooperative Research Program of the Transportation Research Board (2005) categorized and documented a variety of capital investments and policy changes transit agencies in North America have adopted. These include services and amenities for both CTUs who leave their bicycles at transit stops or stations and CTUs who travel with them on transit vehicles. Bicycle racks on buses, bicycle racks and lockers at transit stops and stations, bicycle kiosks (usually at larger transit stations where bicycles are for sale and repairs are made), and policies granting bicycle access to rail vehicles are the most common coordination methods transit agencies have implemented.
Krizek and Stonebraker (2010, 2011) and Bachand-Marleau et al. (2011) have examined this “marriage” of transit and bicycling and identified opportunities for improving coordination to benefit both transit riders and cyclists. Paradoxically, the transit agencies that experience the most significant difficulties are those in which the integration of the modes has been most successful, where demand sometimes outstrips the capacity of transit vehicles to accommodate bicycles. Krizek and Stonebraker (2010), for example, report that transit providers in California (Caltrain), Colorado (Boulder County), and Washington (Puget Sound Regional Council) have been motivated by CTU capacity limitations to develop programs to improve the quality of transit service while reducing incidences of CTU overcapacity.

Missing from most of these studies, however, are consistently-administered counts of BoBBs on transit agency’s vehicle fleets. The Philadelphia region’s largest transit service provider, SEPTA, for example, conducts counts infrequently, relying on vehicle operator manual tallies. The resulting data are not considered highly reliable nor do they provide sufficient detail to identify trends and variations in CTU behavior.

GCRTA, however, is an exception. Beginning in 2000, bus bicycle racks were regularly installed on new revenue buses, with complete coverage of the transit agency’s revenue bus fleet accomplished within a few years’ time. Collection of data on CTUs began in 2005 with a somewhat cumbersome system that required bus operators to call dispatchers each time a transit user placed a bicycle in a rack. In 2007, with the installation of improved farebox technology, the system was simplified with on-board computers. At first, and through 2010, only the date, time, and bus route number or name were recorded; beginning in 2011, location data have also been collected.

Methodology and Data Analyzed
To answer this project’s research questions, analytical methods were developed that reflect a straightforward conceptual model, the availability of detailed data for the time period January 1, 2008, to December 31, 2011, and statistical analysis conducted using SPSS software (version 19).

Conceptual Model
The conceptual model used in this project (Figure 1) incorporates five categories of variables that have been identified as useful predictors of transit ridership in previous studies.
• Travel costs, because of their importance in consumer economics theory, have consistently been included in analyses of transit ridership (Lane 2012; Taylor et al. 2009; Chen et al. 2011). Travelers have choices to make with clear time and money implications, so they weigh the comparative costs and benefits of transit, driving, bicycling and using other travel modes.

• Employment, measured in this study by the number of people with paid jobs in the region, reflects demand for travel and is important for a study of public transportation, a mode with a high proportion of commute-related trips.

• Transit service levels are included because they reflect the opportunities travelers have to take public transportation.

• Weather variables, though they have only infrequently been included in studies of transit ridership (Stover and McCormack 2012), are logical to include in a study examining BoBBs, given the discomfort of riding in very cold or hot, very wet, or snowy weather.

• Bicycle ridership is directly related to bicycle-on-bus boardings: the more cyclists on the road, the more likely that BoBB numbers will rise too.

![Figure 1. Conceptual model relating explanatory to outcome variables](image-url)
Data

The geographic area of analysis in this study is the GCRTA service area, located primarily in Cuyahoga County, Ohio, including the city of Cleveland and its older suburbs. Each of the 1,461 records in the data set represents a calendar day in 2008, 2009, 2010, and 2011, with variables related to daily GCRTA ridership, fares, and service levels, weather conditions, regional employment, the cost of gasoline, and bicycle ridership. Consequently, the unit of analysis for this data set is the calendar day. Several data preparation steps, briefly described below, were required to develop the final database used for the analysis.

Bicycle-on-bus boarding data provided by GCRTA included more than 160,000 records for the four-year time period of this study, each representing a single occurrence of a transit rider placing a bicycle in a bus bicycle rack. These records were summed to obtain daily BoBBs.

Unlinked passenger trips (UPTs), vehicle revenue miles (VRMs), and vehicle revenue hours (VRHs) for GCRTA motor buses are reported on a monthly basis by the National Transit Database program of the Federal Transit Administration. Monthly data are not reported separately for work days versus non-work days (Saturdays, Sundays, and federal holidays), but the distinction is made in annual statistics, and these values were used to create workday/non-workday ridership ratios. These ratios were applied to UPT, VRM, and VRH data for each month and the results used to estimate daily ridership and service levels.

The standard, on-board fare for an unlinked trip represents the cost of riding GCRTA buses. This fare changed twice during the time period of this study, starting at $1.75 on January 1, 2008, rising to $2.00 in October 2008, and then increasing to $2.25 in September 2009.

Employment data are based on monthly figures for the Cleveland–Elyria–Mentor Metropolitan Statistical Area, obtained from the Bureau of Labor Statistics of the U.S. Department of Labor.

Weather data were obtained from the National Weather Service. Temperature, humidity, wind speed and direction, precipitation, air pressure, and dew point data are reported on a daily basis. Only mean daily temperature and precipitation data, however, were used for this analysis.

Weekly gasoline prices for Cleveland (average for all grades) were obtained from the Energy Information Administration of the U.S. Department of Energy. Weekly prices were assigned to each day of the week for purposes of this analysis.
Finally, bicycle ridership data were obtained from two sources: the U.S. Census Bureau’s American Community Survey and the Northeast Ohio Areawide Coordinating Agency (NOACA), the Metropolitan Planning Organization for the Cleveland metropolitan area.

**Findings**

The time period of this analysis was one of significant economic challenges at the regional and national levels that seriously impacted GCRTA’s ability to provide service to its riders. While managerial decisions made prior to the economic downturn of 2008 created efficiencies that softened the blows of the recession (Freilich 2011), GCRTA was, nevertheless, obliged to raise fares and make significant service cuts. The standard bus fare rose 29 percent, from $1.75 to $2.25, between January 1, 2008, and the fall of 2009, then remained at $2.25 through the end of 2011. Vehicle revenue miles of service and vehicle revenue hours of service were 32 percent and 30 percent lower, respectively, in 2011 than they were in 2008.

Ridership, as measured in unlinked passenger trips (UPTs), not surprisingly dropped significantly as these fare increases and service cuts were implemented. From 2008 levels of ridership of 134,000 per day, UPTs fell 24 percent, to about 102,000 per day in 2011.

The recession contributed to GCRTA’s difficulties in other ways. Regional employment was down 2.6 percent from 2008 to 2011, from an average of 1,026,222 employed workers to an average of 999,611, reducing demand for daily commute trips. Gasoline prices showed great variability, creating uncertainty and significant out-of-pocket expenses. The lowest price (in current dollars) during the period 2008 to 2011 of $1.60 for a gallon of gasoline was less than half of the highest average pump price of $4.16 per gallon. Annual gasoline price averages were $3.23 per gallon in 2008, $2.34 in 2009, $2.76 in 2010, and $3.50 in 2011.

The relationship between ridership and transit service levels was very close during 2008–2011, as indicated by a Pearson correlation coefficient (PCC) of 0.908. While more variability in UPTs is evident in Figure 2 than in vehicle revenue miles, the overall trend of higher values earlier in the period of analysis and lower values later on is quite close. Economic conditions, however, were less directly related to ridership: unlinked passenger trips and employment have a relatively weak PCC of only 0.200, indicating that ridership and employment did not display similar patterns of high and low values.
The relationships between UPTs and both gasoline prices and bus fares reflect standard economic theory: that is, higher gasoline prices are positively associated with UPTs (as it becomes more expensive to drive, taking transit becomes more attractive to commuters), and higher bus fares are negatively associated with transit ridership (as riding transit becomes more expensive, it is less attractive to commuters) (Figure 3). However, while the direction of the association of these variables is as expected, the strength of these associations is relatively low: UPTs and bus fare are associated with a PCC of -0.289 and UPTs and gasoline prices with a PCC of only 0.082, suggesting that bus ridership during this time period in northeast Ohio was not particularly sensitive to fares or to the cost of gasoline.

The drop in ridership from 2008 to 2011 was more pronounced on work days, with a 24.9 percent decrease, than on non-work days where the decline was “only” 18.1 percent (Table 1). BoBBs also declined over the same period of time, though, significantly, not to the same degree, dropping 10.5 percent from 2008 to 2011. In fact, the difference in rates of decrease between general ridership and CTUs reflects an
Figure 3. GCRTA daily ridership (unlinked passenger trips) and fare and gasoline prices, 2008 to 2011

The number of transit users boarding GCRTA buses with bicycles reflects seasonal patterns: BoBBs are at their lowest levels in December, January, and February, with a daily average of 48. In the summer months (June, July, and August) the average rises to 165 daily BoBBs. Utilization also varies significantly by bus route. Two routes each accounted for 7 percent of total BoBBs (an average of 6–7 BoBBs per day) and 12 routes accounted for half of all BoBBs. Just 36 routes averaged one or more BoBBs per day, with dozens more in the less-than-one-BoBB-per-day category.
Table 1. GCRTA Ridership and BoBBs, 2008–2011

<table>
<thead>
<tr>
<th></th>
<th>BoBBs</th>
<th>UPTs</th>
<th>BoBBs/1,000 UPTs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-Work Days</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>9,185</td>
<td>5,880,700</td>
<td>1.56</td>
</tr>
<tr>
<td>2009</td>
<td>8,621</td>
<td>5,675,931</td>
<td>1.52</td>
</tr>
<tr>
<td>2010</td>
<td>7,803</td>
<td>4,735,601</td>
<td>1.65</td>
</tr>
<tr>
<td>2011</td>
<td>8,755</td>
<td>4,794,631</td>
<td>1.83</td>
</tr>
<tr>
<td><strong>Change 2008–11</strong></td>
<td>-4.7%</td>
<td>-18.5%</td>
<td>16.9%</td>
</tr>
<tr>
<td><strong>Work Days</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>36,170</td>
<td>43,167,714</td>
<td>0.84</td>
</tr>
<tr>
<td>2009</td>
<td>30,385</td>
<td>32,520,479</td>
<td>0.93</td>
</tr>
<tr>
<td>2010</td>
<td>30,298</td>
<td>31,580,559</td>
<td>0.96</td>
</tr>
<tr>
<td>2011</td>
<td>31,858</td>
<td>32,404,132</td>
<td>0.98</td>
</tr>
<tr>
<td><strong>Change 2008–11</strong></td>
<td>-11.9%</td>
<td>-24.9%</td>
<td>17.3%</td>
</tr>
<tr>
<td><strong>All Days</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>45,355</td>
<td>49,048,414</td>
<td>0.92</td>
</tr>
<tr>
<td>2009</td>
<td>39,006</td>
<td>38,196,410</td>
<td>1.02</td>
</tr>
<tr>
<td>2010</td>
<td>38,101</td>
<td>36,316,160</td>
<td>1.05</td>
</tr>
<tr>
<td>2011</td>
<td>40,613</td>
<td>37,198,763</td>
<td>1.09</td>
</tr>
<tr>
<td><strong>Change 2008–11</strong></td>
<td>-10.5%</td>
<td>-24.2%</td>
<td>18.1%</td>
</tr>
</tbody>
</table>

**Multi-Variate Regression Analysis**

Prior to running the regression models, the two outcome variables and eight candidate explanatory variables were examined for accuracy of data, missing values, and fit between their distributions and the assumptions of multivariate analysis. Descriptive statistics for these variables are found in Table 2.

Four problems required resolution before running the regressions. First, the inclusion of both VRMs and VRHs contributed to multi-collinearity in the models. The PCC between the two variables was so high (0.99) that the inclusion of both would have been redundant, so VRHs were dropped from the final version of the analysis.

Second, 17 multi-variate outliers (assessed using Mahalanobis distance scores assessed at the p < .001 level) were identified, all for days with very high levels of precipitation. To resolve this issue, the precipitation data were transformed into a dummy variable in which days with no precipitation or very little precipitation (less than 0.1 inches)
Determinants of Bicycle-On-Bus Boardings: A Case Study of the Greater Cleveland RTA

Table 2. Descriptive Statistics for Outcome and Explanatory Variables, 2008–2011

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycles-on-bus boardings (daily BoBBs)</td>
<td>0</td>
<td>302</td>
<td>111.6</td>
<td>62.9</td>
</tr>
<tr>
<td>Unlinked passenger trips (daily UPTs)</td>
<td>35,752</td>
<td>212,851</td>
<td>110,034.1</td>
<td>47,792.9</td>
</tr>
<tr>
<td><strong>Explanatory Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature (°F)</td>
<td>-5</td>
<td>88</td>
<td>51.8</td>
<td>18.8</td>
</tr>
<tr>
<td>Precipitation (dummy variable, 1 &gt;= 0.10 in.)</td>
<td>0</td>
<td>1</td>
<td>0.27</td>
<td>0.44</td>
</tr>
<tr>
<td>Regional employment (1,000s)</td>
<td>958.6</td>
<td>1,050.3</td>
<td>1,000.3</td>
<td>20.6</td>
</tr>
<tr>
<td>Standard bus fare (cents)</td>
<td>175</td>
<td>225</td>
<td>209.5</td>
<td>20.1</td>
</tr>
<tr>
<td>Price of gallon of gasoline (cents)</td>
<td>159.8</td>
<td>415.7</td>
<td>296.0</td>
<td>61.7</td>
</tr>
<tr>
<td>Vehicle revenue miles of service (100s of mi)</td>
<td>195.0</td>
<td>628.7</td>
<td>423.1</td>
<td>144.7</td>
</tr>
<tr>
<td>Vehicle revenue hours of service</td>
<td>1,629</td>
<td>5,264</td>
<td>3,602</td>
<td>1,233.0</td>
</tr>
</tbody>
</table>

were coded “0” and other days coded “1.” A total of 392 days—26.8 percent of the four-year period—were identified as having had significant precipitation.

Third, the difference in minimum and maximum values for regional employment (2.6% during the study’s time-period) demonstrated too little variation to have a significant impact on the results of the regression models. Consequently, this variable was removed from the analysis.

Finally, the bicycle ridership data from the American Community Survey and from NOACA proved to be insufficiently detailed for use in the model: estimated numbers of bicyclists were available only on an annual basis and with high margins of error. Therefore, this variable too could not be included in the final analytical model (see Figure 4).

With data problems resolved, two multi-variate regression models to examine the factors hypothesized to affect both BoBBs and UPTs were finalized. The results of these analyses are shown in Tables 3 and 4. Unstandardized coefficients with their standard errors, standardized coefficients (beta), t-statistic and p-values are displayed, along with overall model fit statistics (R^2 and F values). Both models proved to be statistically significant, as were all variables. The models’ explanatory powers were high, with R^2 values indicating that 67.4% of the variability in daily BoBBs was accounted for by the first model and 88.5% of the variation in daily number of UPTs was accounted for in the second model.
Explanatory Variables

- Travel Costs
  - GCRTA Bus Fare (in cents)
  - Price of gasoline (in cents)

- Transit Service
  - GCRTA vehicle revenue miles (in 100s)
  - GCRTA vehicle revenue hours

- Employment
  - Regional employment

- Weather
  - Daily mean temperature (in Fahrenheit degrees)
  - Daily precipitation (dummy variable, 1 = 0.1 inches or more)

Outcome Variables

- General Ridership
  - Daily GCRTA unlinked passenger trips

- Cycle-Transit Users Ridership
  - Daily GCRTA bicycle-on-bus boardings

- Bicycle Ridership
  - Daily trips by bicycle in GCRTA service area

NOTE: Variables identified in light grey text not included in final regression models.

Figure 4. Analytical model relating explanatory to outcome variables

Table 3. Model 1, Outcome Variable BoBBs, GCRTA, 2008–2011

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstd. Coeffs.</th>
<th>Std. Coeff.</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-197.38</td>
<td>14.66</td>
<td>-13.47</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean temperature (°F)</td>
<td>2.21</td>
<td>0.05</td>
<td>0.66</td>
<td>41.69</td>
</tr>
<tr>
<td>Precipitation (dummy variable, 1 &gt;= 0.1 in.)</td>
<td>-22.06</td>
<td>2.13</td>
<td>-0.16</td>
<td>-10.34</td>
</tr>
<tr>
<td>Standard bus fare (cents)</td>
<td>0.31</td>
<td>0.05</td>
<td>0.10</td>
<td>5.71</td>
</tr>
<tr>
<td>Price of gallon of gasoline (cents)</td>
<td>0.19</td>
<td>0.02</td>
<td>0.18</td>
<td>11.35</td>
</tr>
<tr>
<td>Vehicle revenue miles of service (100s of mi)</td>
<td>0.19</td>
<td>0.01</td>
<td>0.44</td>
<td>25.78</td>
</tr>
</tbody>
</table>

R Square = 0.674, F = 601.355, df = 5, Sig. = 0.000

Weather proved to be the most important variable in predicting the number of daily BoBBs: every increase of 1 °F in the mean daily temperature saw an average
of 2.21 more BoBBs, and the occurrence of significant levels of precipitation was associated with an average of 22.06 fewer. With a quarter of the year in Greater Cleveland rainy or snowy and a difference of 60˚ or more between average daily temperatures in the winter and in the summer, these factors can make very large differences.

Transit service levels, bus fare, and the cost of gasoline also proved to be statistically significant predictors of BoBBs. VRMs and gasoline prices both showed the expected relationship: as they increased, so, too, did BoBBs. Bus fare association with bicycle-on-bus boardings, however, was unexpected: even though the cost of riding the bus rose twice during the time period of this analysis, so, too, did BoBBs. There is no logical reason to believe that more CTUs are taking their bicycles with them on the bus because bus fares have risen. It is likely that transit users, whether traveling with or without a bicycle, are simply not sensitive to the cost of travel when fares rise only modestly, as they did during the time period of this study.

### Table 4. Model 2, Outcome Variable UPTs, GCRTA, 2008–2011

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unstd. Coeffs.</th>
<th>Std. Coeff.</th>
<th>t</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-168,150.32</td>
<td>6,607.39</td>
<td>-25.45</td>
<td>0.000</td>
</tr>
<tr>
<td>Mean temperature (˚F)</td>
<td>-159.75</td>
<td>23.96</td>
<td>-6.67</td>
<td>0.000</td>
</tr>
<tr>
<td>Precipitation (dummy variable, 1 &gt;= 0.10 in.)</td>
<td>2,021.04</td>
<td>961.66</td>
<td>2.10</td>
<td>0.036</td>
</tr>
<tr>
<td>Standard bus fare (cents)</td>
<td>445.41</td>
<td>24.06</td>
<td>18.51</td>
<td>0.000</td>
</tr>
<tr>
<td>Price of gallon of gasoline (cents)</td>
<td>174.32</td>
<td>7.47</td>
<td>23.32</td>
<td>0.000</td>
</tr>
<tr>
<td>Vehicle revenue miles of service (100s of mi)</td>
<td>333.35</td>
<td>3.33</td>
<td>99.96</td>
<td>0.000</td>
</tr>
</tbody>
</table>

R Square = 0.885, F = 2,241.615, df = 5, Sig. = .000

In the second model that assessed general bus ridership as measured by unlinked passenger trips, levels of transit service proved to be far and away the most important determinant. For every increase of 100 miles of vehicle revenue service (an average day for GCRTA in 2011 saw almost 35,000 VRM), an additional 333 UPTs were observed. No other factor came close to being as important, the price of gasoline being a distant second in relative importance; as gasoline prices rose, so, too, did UPTs, but only in relatively small amount. As was the case with bicycle-on-bus boardings, bus fare association with UPTs was positive, contrary to theoretical expectations, suggesting that, at least in difficult economic times, a simplistic rela-
tionship between demand (for travel via transit) and price (the cost of a bus fare) does not reflect real-world conditions. Interestingly, precipitation was associated with an increase of 2,021 UPTs (about 2% of a typical day’s UPTs), and each rise in temperature of 1 °F was associated with a drop in UPTs of 160. The direction of the association between weather variables and UPTs (the opposite of their associations with BoBBs) may simply be a reflection of the reduction in the number of high school and college students using public transit during the warmer, drier summer months.

Table 5 summarizes the results of these analyses.

Table 5. Summary of Effects of Explanatory Variables Associated with BoBBs and UPTs, GCRTA, 2008–2011

<table>
<thead>
<tr>
<th></th>
<th>BoBBs</th>
<th>UPTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean temperature (°F)</td>
<td>(+) Large positive</td>
<td>(-) Very small negative</td>
</tr>
<tr>
<td>Precipitation (dummy variable, 1 &gt;= 0.10 in.)</td>
<td>(-) Small negative</td>
<td>(+) Very small positive</td>
</tr>
<tr>
<td>Standard bus fare (cents)</td>
<td>(+) Small positive</td>
<td>(+) Small positive</td>
</tr>
<tr>
<td>Price of gallon of gasoline (cents)</td>
<td>(+) Small positive</td>
<td>(+) Small positive</td>
</tr>
<tr>
<td>Vehicle revenue miles of service (100s of miles)</td>
<td>(+) Medium positive</td>
<td>(+) Large positive</td>
</tr>
<tr>
<td>Percentage of outcome variable variation explained by model</td>
<td>67.4%</td>
<td>88.5%</td>
</tr>
</tbody>
</table>

Note: Large effects are 67% or more of the largest standardized coefficient (beta) value; medium effects are 33% up to 67% of the largest standardized coefficient; and small effects are less than 33%.

Discussion

Bicycle-friendly policies implemented by public transit agencies have successfully expanded access to transit to riders who combine their travel with bicycling. Many transit users ride bicycles to transit stops and stations and leave their bicycles there, but others prefer or need to travel with their bicycles. Widespread installation of bicycle racks on buses responds to this small but growing segment of the population of transit users.

GCRTA is a good example of an agency that has committed to facilitating cycle-transit coordination, with its rising rate of bicycle-on-bus boardings over the time period of 2008 to 2011. Even as the absolute numbers of annual BoBBs fell over the time period, from about 45,000 to 41,000, service levels and unlinked passenger trips fell even more, resulting in rising numbers of BoBBs per 1,000 UPTs (from 0.92 to 1.09).
This research project allows us to answer the question, “What affects the daily systemwide number of bicycle-on-bus boardings?” BoBBs are clearly influenced by weather conditions. If it is cold, rainy, or snowy, fewer BoBBs are recorded. While not surprising, the model confirms what common sense would suggest: warmer and drier days are associated with higher levels of BoBBs. Still, even in the coldest months in northeast Ohio, an average of almost 50 daily BoBBs was recorded. Hardy souls use the bus bicycle racks in fair weather and in foul—intentionally and perhaps sometimes unintentionally when a dry morning trip is followed by a damp return best avoided by taking the bus.

On the other hand, weather does not appear to be a terribly important predictor of general ridership, an interesting and important distinction between the two types of transit users. Though in colder and wetter weather conditions GCRTA sees higher transit ridership—probably because of greater numbers of high school and college students taking transit in cooler months—the strength of the statistical association is not high. This suggests not only that transit riders are undeterred by bad weather (and should probably carry umbrellas and wear warm clothing when the forecast is bad), but that transit shelters are necessities, not simply amenities.

Other factors also influence BoBBs, transit service levels being particularly important. The results of this analysis suggest that bus bicycle racks provide a valuable service to transit riders. For those transit users who would ride the bus even if they could not travel with their bicycles, transit trips may be all the more convenient when racks are installed on buses. For those transit users who would not ride the bus without the bike racks, their presence is even more important, facilitating transit trips that would not have been possible otherwise.

What does not seem to have a large impact on BoBBs is travel cost. Bus fares are positively associated with BoBBs, and the cost of gasoline is as well, though in each case regression analysis reveals the association to be weak. Undoubtedly the prices of bus fare and gasoline influence some rider decisions, including some who travel with their bicycles, but the impacts are not nearly as important as the other factors assessed in these models.

This analysis suggests several very interesting follow-up questions. To what extent do bicycle-friendly transit policies and facilities expand geographic access to public transit? How many CTUs are new transit riders who could not or would not use public transit otherwise? What trip purposes are most important to cycle-transit users? How highly do transit users value the ability to travel with their bicycles, and
how is that value best measured? And at what systemwide threshold do BoBBs exceed capacity on bus bicycle racks, creating frustration and unmet demand?

This last question concerning the point at which demand exceeds capacity has important implications for transit agencies. At the systemwide level, even on the days of heaviest use, GCRTA has little to worry about, as plenty of excess capacity exists. But systemwide excess capacity does not help the would-be cycle-transit user whose preferred bus already has two bicycles in the front rack. This may already occur frequently on the bus routes that have the highest rates of BoBBs, but we do not know this with certainty.

Still, with rising rates of BoBBs, it is clear that, at some point, either the supply of bus bicycle rack space, demand for it, or both, will need to be addressed. Bicycle racks with the capacity for three bikes could create a larger supply and are already in use in some regions. These could be considered for installation on GCRTA bus routes with the largest numbers of daily BoBBs. Addressing demand could involve the establishment of bike-share programs and the installation of sheltered and secure bicycle parking at stations. In this way, more CTUs could combine bicycles and transit, without having to travel on transit vehicles with their bicycles. Getting to the point where more riders are clamoring for bus bike rack space than is available would be a difficult problem to address, and a good problem to have—a demonstration that the service is valued and needed by a large number of people.

Acknowledgments

This research project would not have been possible without the assistance of the following staff members of the Greater Cleveland Regional Transit Authority: Joel Freilich, Assistant Director of Service Management; Floun’say R. Caver, Ph.D., Director of Service Quality; Heather Bates, Planner III, Service Management Department; and Kay Sutula, Senior Budget Management Analyst. Appreciation is also due to Richard Heiberger, Professor of Statistics at Temple University; Robert Cervero, Professor of City and Regional Planning at the University of California, Berkeley; and Jacob VanSickle, Executive Director of Bike Cleveland. Finally, the author would like to acknowledge the valuable contributions of two anonymous reviewers for the Journal of Public Transportation.
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Women-Only Transportation: How “Pink” Public Transportation Changes Public Perception of Women’s Mobility

Amy Dunckel-Graglia
SUNY Stony Brook

Abstract

It is well documented that women often face sexual harassment and violence during their daily commutes, particularly in countries with extreme levels of gender inequality. A popular reaction to this problem is to issue women-only transit services. Despite this growing trend, we know very little about it. Looking at the case of Mexico City, this study examines, analyzes, and evaluates women-only transportation, focusing on the roles of culture and public opinion. Drawing from both qualitative and quantitative data, it finds that the violence women face in public transit leads them to always opt for women-only services, encouraging local policy makers to increase their numbers. Local feminist groups have advanced this system by arguing that violence in regular public transit is gender discrimination. Consequently, they have positioned themselves as administrators of women-only transportation, using it as a campaign to defend women’s equal right to urban mobility.

Introduction

It has been well documented that women’s fear of using public transportation causes them to modify their travel behavior (Loukaitou-Sideris 2008; Schulz and Gilbert 2000). Feminist groups argue that real and perceived violence, constrain-
ing women’s mobility, is a form of gender inequality embedded within the public transit system (Garibi et al. 2010; Valentine 1992; Wade 2009). In order to ensure women’s security and equal rights to mobility, transportation alternatives have been implemented or are currently being implemented in dozens of cities across the world, including Rio de Janeiro, Brazil; Lahore, Pakistan; Jakarta, Indonesia; Dubai, UAE; and Tokyo, Japan. This paper looks at the case of women-only transportation in Mexico City in order to shed light on this growing phenomenon, paying particular attention to how the public views the use of women-only transit services as a resolution to issues of gender inequality.

Women-only transportation provides a unique opportunity to return to an older discussion on the relationship between the architectural design of urban transit and women’s fear of traveling. Primarily based on theories such as Oscar Newman’s defensible space theory (1972), which states that spatial design is directly related to levels of crime, scholars have examined the effects of environmental changes on women’s fear of traveling. This line of reasoning has led to research, for example, on the effects of adding cameras or better lighting in public transportation in order to improve women’s commuting experiences (Loukaitou-Sideris 2008). However, after major critiques arose in the 1990s by feminist geographers on the ability to “design out fear” (Koskela and Pain 2000), the current general thought on women’s mobility is that changing the physical design of transit systems will have little to no effect on reducing women’s “feelings of fear.” Their conclusions were drawn from years of empirical data showing that fear is the outcome of gendered social and power relation rather than actual crime (Bondi 2005; Koskela and Pain 2000; Pain 2001; Valentine 1993). These findings moved transit scholars away from studying the relationship between “transportation design alternatives” and women, instead concentrating on riders with special needs, such as those with cognitive or physical disabilities (Carmien et al. 2005; Turkovich et al. 2011; Wu et al. 2011).

This paper argues that the global emergence of women-only transportation is a symptom of larger gender inequalities in cities, particularly surrounding issues of women’s mobility. It focuses on how public transportation limits women’s equal access to urban resources (Amedee 2005; Blumen 2010; Crane 2007) and how this problem is being addressed by issuing transportation alternatives for women. In the case of Mexico City, real violence and crimes against women using public transportation cause them to modify their travel behavior, reinforcing their role in the household. Women-only subway cars, buses, and taxis were launched as a
measure to keep women safe, hoping that it would also increase their participation in urban life.

While scholars have addressed the issue of women’s security in public transit (Blumen 2010; Hsu 2009; Loukaitou-Sideris 2008), as of today, no study has examined women-only transportation as a solution to this problem. This paper draws from three years of ethnographic research, a public opinion survey among women riders, and 250 online comments by Mexican citizens on the issue of women-only transportation. It analyzes how violence in public transportation has led to the implementation of women-only transit in Mexico City, and how both men and women in Mexico view this transportation alternative as a solution to the cultural problem of violence against women. Specifically, this article looks at the relationship between women and Mexico City’s public transit system, focusing on 1) violence and 2) public opinions on violence and women’s equal right to urban resources.

Research and Design
The first portion of this paper contextualizes the emergence of women-only transportation, drawing on statistics on violence against women in public transportation, gender inequality in urban mobility, the ascendancy of feminist thinking, and legal reforms.

The second portion analyzes empirical data on women-only transit systems in Mexico City accumulated over a period of three years. Both qualitative and quantitative methods were used, including 5 structured interviews with key decision makers responsible for implementing women-only and “pink” transportation, 7 informal interviews with women commuters, 3 informal interviews with men who are decidedly against “pink” transportation, a short survey among 125 women who routinely use women-only transportation, and 250 comments posted online in response to the launching of “pink” transportation.

The survey was designed to accumulate the following information from women riders:

1. What are women’s attitudes towards public transportation?
2. How often and for what reasons do they choose women-only transit over mixed transportation?

This survey was given to 125 members of our target audience, defined as female riders of public transportation in Mexico City. The participants were randomly selected using a convenience sampling approach. Around 20–22 participants were
selected across 6 different transit points throughout the city, including bus and subway stops.

Additionally, 250 open-ended comments—posted on online newspaper sites by Mexican citizens on the issue of women-only “pink” transit—were coded and incorporated into the analysis of public opinion. These comments were taken from over 15 different news articles from one of Mexico City’s largest papers, *El Universal*. The comments were posted between the years 2007–2011 and covered the city’s decision to implement “pink” taxis and “pink” buses. It should be clarified here that “pink” transportation was issued after women-only subway cars and buses had already been established. “Pink” transportation is one of several modifications made to the public transit system. These modifications were largely implemented by feminist organizations within the government, with the goal of reducing gender discrimination in urban mobility, a point that will be clarified later in this paper. As the local news covered the emergence of “pink” transit, hundreds of readers posted comments, vocalizing their opinions on issues of violence and discrimination in public transportation. These opinions were coded (see Appendix I) and used to measure the general public’s feelings towards women-only transit and women’s mobility in Mexico City.

While three years of ethnographic methods allowed the accumulation of thick descriptive data on the situation of public transportation in Mexico City, there were weaknesses in some of the other data techniques used. First, it was extremely difficult to conduct formal, structured interviews. Despite several modifications to the interview format, informants were far less inclined to discuss their opinions openly when the interview was structured. For this reason, there are very few formal interviews and, instead, a large portion of the ethnographic data came from three years of observations and hundreds of short conversations conducted on buses or subways or in taxis. Second, the survey of 125 women riders was administered only to clarify some of the findings from the ethnographic data. Therefore, there are several weaknesses in the survey technique used. Particularly due to time and financial constraints, the survey was given to only 125 people, using convenience sampling instead of random sampling. With the convenience sampling, the data were analyzed through cross-tabulations in order to explore potential patterns among public transportation, safety, and gender. Those data do not, unfortunately, allow for generalizable conclusions.

To summarize, the combination of comments, statistical data, and interviews allowed the analysis and exploration of a specific urban context from which
women-only transportation emerges and a look at public opinions on using women-only transportation as a solution to the problem of gender violence.

Historical Context
There is a lingering perception in Mexico that women are household figures and not public ones. Olcott (2005) captured this sentiment well in her book that shows the history behind the public/private divide that kept women revolutionaries out of the public political scene once Mexico had established its independence. She quotes the ruling party’s newspaper from 1931:

But while she prepares herself and organizes herself, we men prefer to continue ceding our seats on the buses, finding the soup hot in the household olla, and listening to the broom dancing under conjugal songs, than to hear falsetto voices in Parliament or to entrust the suffragist ballots to poetic hands (p. 5).

It is within Mexican women’s continuing battle over the public/private divide from which the following two themes are understood: 1) violence against women in public transportation and 2) the use of women-only buses and subways.

Spatial theorists emphasize “the culture of a place” when analyzing social phenomena (Castells 1983; Lefèbvre 1991; Soja 1996), particularly how each place affects the behavior of individuals differently. Understanding the household as a “woman’s place” and public transportation as a “man’s place” helps explain the levels of violence towards women in buses, taxis, and subways, as well as how women are expected to behave during their daily commutes. According to feminist geographers, public and private spheres are very often defined as “feminine” or “masculine” spaces. Therefore, when a place becomes labeled as masculine it normalizes “masculine behaviors” within this space, such as sexual harassment and violence towards women (Koskela and Pain 2000), and forces women to adapt to the situation. Public transportation is the gateway to urban public life, which has long been considered a man’s place. Taking into consideration the gendered nature of the public/private divide, as well as the high levels of violence against women that occur within this space, the public transit system in Mexico City is considered to have a hyper-masculinized culture.

The culture of public transportation in Mexico City has two major repercussions for women. First, it makes urban mobility something that is entitled to men and
not women. Second, it normalizes masculine behavior, making the violence against women a “woman’s problem.” Take the following quotes as examples:

- “I don’t think the behavior of men is normal,” a husband and father of daughters explains. “It is wrong how they treat woman. And I don’t treat women like that at all. But the fact is that they do, and it is very dangerous to be traveling alone or when it is dark, and women know that it is dangerous, so if they get hurt, it’s their fault. You wouldn’t wear a miniskirt at 2AM down a dark alley, would you?”

- “The first thing you should do before you get into the taxi is look at the plates,” a female informant explains regarding how a woman should behave in order to keep safe. “If you are wearing a skirt or a low-cut blouse, make sure to cover it with a sweater so as to not draw too much attention, and have the money ready to pay so that you can get out and get your change. And last, don’t go anywhere until the taxi has pulled away. These tactics work most of the time.”

Here, we see how violence and harassment against women is considered “normal,” “inherent,” and “unchangeable.” Women, therefore, are responsible for recognizing the situation and modifying their behavior accordingly.

Government agencies for the promotion of women’s rights have recognized that violence against women in public transportation is preventing them from breaking traditional gender barriers. In fact, a spokeswoman from INMUJERES—the federal institute for gender equality and equal opportunity for women—stated that “because women are responsible for dropping off and picking up the children, grocery shopping, and having part-time jobs, the average woman’s commute is two hours longer than that of a man’s. Yet, women face more violence in public transportation than any other group.”

In response to the deeply-embedded gender inequality in the public transit system, INMUJERES has been a major force behind the implementation of women-only public transportation, arguing that the violence women face is not normal, but rather a form of gender oppression. In a study supported by INMUJERES, Garibi et al. (2010) note,

Among all public spaces, public transportation is the place where women must face the greatest levels of violence. It represents a grave problem of discrimination that limits security, freedom to travel, and mobility for
women in urban spaces, all of which affect their capabilities and opportunities for success (p. 12).

Although women-only transportation had been implemented in 2002, administrators of the program were beginning to realize that it had little effect on reducing violence against women and, therefore, changing women's urban equality. In 2009, in partnership with the National Board for the Prevention of Discrimination, INMUJERES conducted a study on the violence against women in public transportation in Mexico City. They found that 9 out of 10 women will have been a victim of some type of sexual violence in her lifetime. In 2008, 8 out of 10 women had been a victim of sexual crime, 43.8 percent having suffered 4 or more violent situations and 10 percent having suffered 7 or more (Garibi et al. 2010). Using these startling figures, they built a new campaign that openly criticized public transportation in Mexico City as a place that routinely disempowers and demobilizes women. They demanded that women-only transit programs be strengthened and redesigned, arguing that simply issuing a few subway cars and buses was not going to change the deeply-embedded culture that supported violence against women.

As part of their strategy to change women's mobility in Mexico City, INMUJERES targeted two systems: judicial and transit. The first thing they did was to paint all women-only transportation bright pink, turning it into a public campaign for women's rights and equal mobility. In addition to issuing fleets of bubble-gum pink buses and taxis, they also created a program called Viajemos Seguras (We Women Travel Safely). The program established monitoring stations throughout the subway system, encouraging women to report any form of harassment. Additionally, they maintain billboards, posters, bumper stickers, and more throughout every type of public transit in Mexico City. Each announcement has the title "Es nuestra derecha a viajar sin miedo" ("It is our right to travel without fear") with a toll-free, 24-hour hotline number below it to report harassment. Viajemos Seguras acts as a feminist institution within the transit system, overseeing all issues concerning women and urban mobility in Mexico City. It monitors levels of violence against women, gathering and reporting all gendered crimes that occur in public transportation, data that previously had been unavailable to the public.

In addition to implementing Viajemos Seguras, in 2010, in celebration of Mexico’s Bicentennial Independence, INMUJERES launched a city-wide transit line called Athena, named after the Greek goddess of war, courage, and independence. All Athena buses are bright pink, and each has a historical woman painted on the side, giving special tribute to her pivotal role Mexico’s political and economic history.
The “pink-afying” of women-only transportation has become the principal means by which INMUJERES is attempting to change public perception on women’s role as public figures, arguing that women are equally entitled to urban mobility.

In addition to redesigning the public transit system and making it more pro-female, INMUJERES needed to legally establish that violence against women in public transportation was a form of gender discrimination, denying women from equal access to urban resources. They demanded that legislators amend old laws that guaranteed a person’s equal right to urban resources, specifying in the new ones that public violence against women was a direct violation of this law. Before the amendments, sexual harassment in public transportation was considered a non-discriminatory misdemeanor, like pickpocketing or public disputes. However, by attaching sexual harassment in public transportation to laws that guaranteed a person’s equal right to urban resources, INMUJERES shifted the view on violence against women, making it an issue of institutionalized discrimination. In total, nearly 20 laws were amended, and the new reforms were publicized throughout the country to ensure that both men and women understood that sexual harassment in public transportation is an institutionalized form of gender discrimination. A woman is not to be blamed nor held responsible for any violence she faces during her daily commute.

### Table 1. Reported Criminal Activity in Mexico City Subway System, January 4–September 30, 2008–2010

<table>
<thead>
<tr>
<th>Year</th>
<th>All Reports Attended to in Viajemos Seguras Booths</th>
<th>Cases Dealing Specifically with Sexual Abuse</th>
<th>Cases Dealing with Other Crimes</th>
<th>Arrests/Charges Brought Against Offenders</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>314</td>
<td>291</td>
<td>23</td>
<td>117</td>
</tr>
<tr>
<td>2009</td>
<td>311</td>
<td>273</td>
<td>32</td>
<td>124</td>
</tr>
<tr>
<td>2010</td>
<td>225</td>
<td>197</td>
<td>23</td>
<td>13**</td>
</tr>
</tbody>
</table>

Note: It should be noted that these statistics were posted in 2010. Therefore, it is likely that pending charges and arrests were not included, which could explain the low figure reported here.

Source: Viajemos Seguras

While crimes against women do appear to be only slightly decreasing since the new reforms, the real effect of the “pink” transit campaign seems to appear in public opinion. As the following section demonstrates, using “pink” public transportation, INMUJERES is sparking a debate among riders that positions women as public figures and not household ones. This shift in perspective redefines the issue of vio-
lence against women in public transportation as an issue of gender discrimination and not an issue of normal city life that women must learn to negotiate.

Data Analysis

Contrary to popular belief that women fear dark, unlit, or empty spaces in public transportation (Hsu 2009; Loukaitou-Sideris 2008), this study found that women in Mexico City are fearful of being “a woman in public.” As mentioned before, because of deeply-embedded cultural values that promote women as household figures and men as public figures, women do not fear crime per se, but rather they struggle to become mobile, public figures. Therefore, sexual harassment on public transportation is an obstacle that they must face when breaking through these barriers. As the following quote demonstrates, rather than linking their fear to factors such as time of day, lighting, or criminal behavior in general, women often described their mobility as a struggle for gender equality:

If there wasn’t so much machismo, if men cab drivers had never broke the law, if there wasn’t so much inter-family violence generated by years of believing that men are the owners of women (allowed by those same women and by the Church, I can admit), we would not have to go to such extreme measures. Sadly, while many men continue seeing women as an object, without giving her the value or the respect that she deserves, we will continue creating these types of programs. And I do not bother wasting time reading the classic machismo comments that women drive badly. In my 10 years of driving, I have never had an accident, nor provoked one, unlike young men, taxi drivers, and microbus drivers, who I am sure are all men. When both sexes are respected, we will not need “pink” and “blue.”

Throughout this section, the data show a strong gender divide in public opinion towards women-only transportation. Where women see violence as an issue of gender inequality, men respond negatively, claiming that women are whining and demonstrating their inability to cope with “natural” difficulties that accompany urban mobility. In fact, 70 percent of the women surveyed explicitly stated that they fear the normal public transit system, linking crime in public transportation to issues gender. That is, women believe that the streets are safer for men because women are the target of sexualized crime.
Table 2. Safety Opinions of Women Transit Users

<table>
<thead>
<tr>
<th></th>
<th>Agree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel safe in normal transportation.</td>
<td>19</td>
<td>83</td>
<td>17</td>
<td>119</td>
</tr>
<tr>
<td>Taxis driven by women are safer than</td>
<td>59</td>
<td>41</td>
<td>16</td>
<td>116</td>
</tr>
<tr>
<td>taxis driven by men.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streets are more dangerous for women</td>
<td>63</td>
<td>30</td>
<td>16</td>
<td>119</td>
</tr>
<tr>
<td>than for men.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women-only transportation is safer</td>
<td>76</td>
<td>25</td>
<td>15</td>
<td>116</td>
</tr>
<tr>
<td>than regular transportation.</td>
<td>66**</td>
<td>21%</td>
<td>13%</td>
<td></td>
</tr>
</tbody>
</table>

N=Number of respondents

In general, women believe that their gender attracts violence during their daily commutes, and until this situation is changed, women should be given their own transit alternative. More than half (66%) of the women surveyed said that women-only transportation is safer. Among the 44 percent who did not unwaveringly agree with this statement, 48 percent made a special notation on the side of the survey saying that they disagreed only because they felt that women-only buses, and subway cars in particular, were not well guarded. That is, they believe women-only transit to be safer, but only if the men were forced to respect it. Some of these comments included:

- “It is still safe, even though sometimes men board the women-only sections and try to intimidate the passengers.”
- “It’s supposed to be for women only.”
- “There are many times when the women-only sections are not respected [by men].”

Because of the fast-paced nature of public transit, where people are coming and going very quickly, women see public transportation as an opportune moment for men to be aggressive towards them with little or no repercussions. Facing gender inequality, women believed that until the culture of men can change, the city is responsible to provide them with a separate transit system that allows them to commute safely and without fear and harassment.
Table 3. Use of Women-Only Transportation among Women Transit Users

<table>
<thead>
<tr>
<th>Used Never/Almost Never</th>
<th>Used Sometimes</th>
<th>Used Almost Always/Always</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>%</td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>30</td>
<td>25%</td>
<td>29</td>
<td>24%</td>
</tr>
</tbody>
</table>

N=Number of respondents

More than 50 percent of the women reported that they always take women-only transit. Among the 25 percent who stated that they never or almost never use women-only transit, half (51%) clarified at the end of the survey that a principal reason for not using it is because it does not circulate along their commuting route or that it is inconveniently located.

Men, on the other hand, do not see gender inequality as the root problem. Although their opinions are deeply shaped by gender views, they strongly emphasize that violence in public transportation is normal. In this sense, the views reported by men reflect the masculine culture of public transportation. In fact, this topic has been studied in other scenarios of women entering traditionally-masculine spaces, a common example being the sport of rugby (Fallon and Jome 2007). When women enter traditionally-masculine spaces, the initial reaction by men is to use hyper-masculine behaviors to push women out, rather than changing the culture of the space in order to include women. Likewise, the reaction by men to “pink” transportation is to defend the status quo, arguing that it is not the culture of transportation that needs to change, but rather that women are not “tough enough” to survive in the city. Going back to the analogy of women rugby players, the general attitude of men towards “pink” transportation is, “if women don’t want to get hurt, they should not join the game.” As always, when attempting to change that which has traditionally been viewed as “normal,” we see a backlash against the changing factor. In the case of “pink” transportation in Mexico City, men have been aggressively against the implementation of women-only services, particularly “pink” transportation, which claims that violence in city buses, subways, and taxis is a form of gender discrimination. Take the following quotes as an example:

- “What a shame the level of feminism; hopefully, we can go back to the 1900s when we men were always the dominant figures.”
- “This is only about women getting an opportunity to feel ‘lady-like,’ and the whole idea is a bit of a joke.”
- “Also, they should implement buses for grandparents (Program Methuse-
lah), another for men (Program Apollo), another for couples who are in love (Program Cupid).”

- “For this, they are hauling in our taxes! I am not paying any more. Now they are going to give ... their own purple car with rainbows. How disgusting of our government and these ... people.”

Table 4. Does “Pink” Transportation Resolve the Issue of Security?

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
<th>Gender Unspecified</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>9</td>
<td>Yes</td>
<td>Yes</td>
<td>N</td>
</tr>
<tr>
<td>No</td>
<td>38</td>
<td>No</td>
<td>No</td>
<td>113</td>
</tr>
<tr>
<td>Yes</td>
<td>27</td>
<td>14</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>No</td>
<td>14</td>
<td>20</td>
<td>18%</td>
<td>100%</td>
</tr>
</tbody>
</table>

N=Number of respondents. Comments made online.

Despite the staggering reports of rape, violence, and harassment towards women where 100 percent of the violations are reported to be men violating women (Garibi et al. 2010), men tended to view public transportation as a dangerous place in general and not a dangerous place for women.

Table 5. Why Does “Pink” Transportation Resolve the Issue of Security?

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>%</th>
</tr>
</thead>
</table>
| Offers a guaranteed way to travel safely.                      | 46 | 40%
| Women can be dangerous, too.                                   | 17 | 15%
| Women are weak; they become targets when they travel without men. | 28 | 24%
| Because it has nothing to do with the men and women, but rather with the general level of security. | 24 | 21%
| Total                                                          | 115|     |

N=Number of respondents.

Table 6. What is Your Opinion of Women-Only Transportation?

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>In favor</td>
<td>15</td>
<td>46</td>
<td>61</td>
</tr>
<tr>
<td>Against</td>
<td>63</td>
<td>22</td>
<td>83</td>
</tr>
<tr>
<td>TOTAL</td>
<td>78</td>
<td>68</td>
<td>144</td>
</tr>
</tbody>
</table>
A chi-square test for independence was conducted to measure the strength of the relationship between gender and if the respondent favored or disapproved of women-only transportation, where the null hypothesis was defined as “gender is independent of approval or disapproval of women-only transportation,” where alpha was set at 0.05, and the P value 7.879. The calculation was 34.4, therefore rejecting the null hypothesis and concluding that one’s gender is strongly correlated with one’s opinion about women-only transportation.

In summary, men and women have starkly different views about public transportation. Men continue to see it as a place that is dangerous in general and therefore not necessarily the best place for women to be commuting. They state that women’s complaints are signs of weaknesses and their inability to survive in the city. Men almost exclusively tended to blame women, or they degendered the issue altogether, claiming that women-only transportation would not work or was a joke because 1) “women can be dangerous, too” (18%), 2) women are weak (20%), or 3) women-only transportation has nothing to do with men and women, but rather general issues of security and government corruption (29%). Women, on the other hand, see violence as being targeted against them and, therefore, an issue of gender inequality. In general, women believe that until the machismo culture changes, the city must provide women with a safe travel alternative. In fact, 77 percent of women concluded that “pink” transportation would not need to exist if men were educated to respect women.

**Conclusion**

Using women-only transportation to ensure women’s safety is a highly-controversial idea. Advocates for women’s rights have suggested that segregation tactics are likely to deepen gender divides (Associated Press 2009), making long-term equality between men and women difficult to achieve. Despite the risks involved, the transit administration in Mexico City believes that women-only transportation not only provides women with safe travel, but also has the potential to bring public awareness to the problem of violence and harassment towards women.

Based on the findings, this author believes that, in the case of Mexico City, women-only transportation will likely reduce gender inequality embedded in the public transit system. In fact, the negative responses that men gave to the feminization of the public transit system are a predictable reaction when attempting to change the culture of a place. Additionally, the comments made by women linking violence...
to gender discrimination shows a fracture in traditional thinking that the violence is normal and something that women need to learn to negotiate.

This paper concludes by stating that women-only transportation can be positive if it also has the potential to change the root causes of violence against women in normal public transportation. However, if women-only buses, subway cars, and taxis are used only to alleviate daily harassment and violence against women, then it may never force commuters to recognize the deeply-embedded gender inequalities within the transit system itself. While providing alternative transportation for women in order to ensure their security is an understandable solution to a very serious problem, it does not guarantee that the public transit system will eventually become degendered. In order to measure if women-only transportation is changing deeper gender inequalities, which provoke the need for women-only transit services, it is crucial that future studies of transit alternatives for women take into consideration public opinion.

Endnotes


6 Pink transportation is a new version of women-only transportation, where instead of simply demarcating women-only buses and taxis with signs cities have begun to paint them bubble-gum pink.

7 See Appendix I, quote 2 for the original Spanish version.

8 This quote taken from an interview with director of INMUJERES, an institution responsible for the administration of women-only transportation. Her quote complements a study conducted by the Consejo Nacional para Prevenir la Discriminación (Advisory Board for the Prevention of Discrimination), who conducted
an investigation in 2009 on the depth of violence against women in public transportation.


11 See Appendix I, quote 7 for the original Spanish version.

12 See similar studies on women entering traditionally male occupations or sports.

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Times Online. 2007. Jobs for the girls: Pink taxis are hailed for safer journeys. www.timesonline.co.uk/tol/driving/news/article2943525.ece.


**Appendix I: Coding Format**

**Determining Gender**
There were three principal ways for determining gender. The first was if the person explicitly said they were a man or a woman; this accounted for around 15 percent of the comments coded. If the person did not explicitly say, “I am a man” or “woman,” then we looked towards the conjugations of the person talking: *nosotras* vs. *nosotros*, for example; this accounted for another 30 percent of the comments coded. If neither of these two methods worked, then we used the name to determine the sex, e.g., obvious male and female names (Diego, Jorge, Ana, Fernanda, etc.). Ambiguous names such as Ale (which would be Alejandra or Alejandro) were coded as “gender unknown.”

**Favor or Against**
A comment was coded as in favor, against, not sure, or don’t care if the commenter specifically stated his/her viewpoint in one direction or another—for example: “I absolutely do not agree with this program” or “I think this is a wonderful program that will help women feel more secure.”
1. In favor of “pink” transportation.
2. Against “pink” transportation.
3. Don’t care either way.
4. Not sure if it is good or bad.

Reasons Given for the Need for Women-Only Transportation

1. Women are weak, need protection, and, therefore, need special space.
   a. Example comment: Nunca existira la igualdad para hombres y mujeres porque las mujeres son mas debiles en todos los sentidos, y la cordura es para los debiles ya lo dijo.
   b. Most common: women are more likely to be raped or violated because they lack the presence of a man.

2. Men are violent and disrespectful to women.
   a. Two ways of assessing this variable:
      i. Men are responsible for the level of crime and insecurity in Mexico. Women tend to be less likely to rob, rape, or kidnap passengers and therefore can change the current issues of security in taxis.
      ii. Men are generally violent towards women.
      iii. Men are the cause of women feeling insecure.

3. Other. Here, we looked for any comment that degendered the issue. Most of these comments were government-oriented. That is, the commenter believed that this is a dubious government intervention to make it look like it is doing something, or that the reason security is an issue at all is because the government cannot control the streets. The second most common “other” was that it was neither because of women or men, but rather a general lack of education among Mexican people. If there is any reference to one’s sex, gender, or sexual orientation, this variable was not used.
   a. El problema de la delincuencia, e falta de educacion y de la ingobernabilidad en el pais no se resuelve pintando de colores ni el carro ni las corbats de los politicos.

4. The greater population, older adults, and children, too.
5. Combats discrimination against women.
6. Just a service for women and nothing more.
**Resolves Issue of Security?**

1. Yes
2. No
3. Wasn't sure, it could make things worse.

**Reasons it Resolves Issues of Security**

1. Offers security.
2. Women can be dangerous, too, i.e., “pink” taxis assume that only men are dangerous.
3. Women are weak, they will stand out as targets, and without the protection of men (i.e., women traveling alone), they become a greater target for rape, etc.
4. Because it has nothing to do with men and women, but the general level of security in Mexico.
5. Other

**Women-Only Transportation**

1. Feels safer.
2. Is safer.
3. Stays the same.
4. Is more dangerous.

**Pink Represents**

1. Weak.
2. Independence for women and equal work opportunities.
3. Greater inequality and difference between men and women.
5. Women need to change to protect themselves, or women need to be segregated to stay safe. A form of blaming the victim.

**Sexualization/Objectification of Women**

1. Yes
2. No
About the Author

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Crowding in Public Transport: A Review of Objective and Subjective Measures

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Abstract

Crowding in public transport is becoming a growing concern as demand grows at a rate that is outstripping available capacity. To capture the user benefits associated with reduced crowding from improved public transport, it is necessary to identify the relevant dimensions of crowding that are meaningful measures of what crowding means to travelers. There are a number of objective and subjective measures of crowding promoted in the literature, with some objective measures being used as the basis of a standard of acceptable levels of practice. There is a disconnection between objective measures and subjective measures, the latter representing what matters to users. We illustrate the difference in a comparison of monitored crowding levels using crowding measures defined by the rail operator/authority in Sydney and Melbourne, Australia, and the level of crowding experienced by rail passengers from two recent surveys to reveal the significant gap between objective and subjective measures of crowding.

Introduction

Two influences on public transport modal choice that are growing in relevance are trip time reliability and crowding. These sources of additional user benefits should be included with the traditional travel time and out-of-pocket cost attributes to represent the wider set of user benefits from investment in public transport. In
a benefit-cost framework, justifying investment in public transport is becoming increasingly challenging, and any additional sources of user benefit that can assist in improving the prospect of such investments should be included. Li and Hensher (2011) reviewed the literature on willingness to pay for reduced crowding and concluded that the benefits from reduced crowding (variously defined) are significant and often as great as travel time savings. However, to be able to apply the available willingness to pay estimates, it is necessary to collect data on the experienced levels of crowding (in contrast to applying some objective standard), since this provides the reference point for opportunities to improve crowding as a significant source of user benefit.

Currently, however, there is a dearth of data collected on crowding levels that aligns with what matters to users in terms of their behavioral response and, hence, user benefit streams; what is typically collected are data on crowding against a standard such as the number of standing passengers per square meter, which, although informative, is not necessarily an appropriate representation of user subjective preference (and, hence, willingness to pay) for improved levels of crowding. This paper reviews the evidence, limited as it is, on objective measures of crowding that typically are used to establish standards of practice, as well as the evidence on subjective measures of crowding, as the basis of highlighting the gap between the two dimensions of crowding—the standard (i.e., objective) and the perceived (i.e., subjective) metrics. We are not in a position to definitely map the two dimensions, which is a crucial requirement for translating objective improvements into equivalent subjective gains that then can be applied, via willingness to pay estimates, to obtain the additional user benefits of public transport investment. This paper focuses on promoting the case for research to ensure the mapping, providing one possible way forward using an example from recent research by Tirachini et al. (2012).

What exactly is the meaning attributed to crowding? Evans and Lepore (2007, 90) suggested that crowding occurs “when the regulation of social interaction is unsuccessful and our desires for social interaction are exceeded by the actual amount of social interaction experienced.” In the specific context of railways, Mohd Mahudin et al. (forthcoming) reviewed a number of studies on crowding and concluded that crowding has a negative impact on passengers in terms of psychological or emotional distress. A survey conducted in London showed that public transport passengers were willing to stand for up to 20 minutes if the service is fast and reliable; however, crowding outweighed these benefits (The Transport Commit-
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tee 2003). According to a recent Australian survey, the time limit for standing in a crowded rail carriage is approximately 15 minutes on average (Thompson et al. 2012). Thompson et al. also found that crowding is the problem most frequently encountered by Australian train passengers. Crowding is also a major issue in other countries such as the UK (see Cox et al. 2006).

From a passenger’s perspective, experienced crowding leads to increased dissatisfaction (e.g., stress and less privacy) during traveling. From an operator’s perspective, the service frequency or vehicle size is significantly influenced by the level of ridership, which sends a signal to respond if the monitored crowding level exceeds the benchmark standard. Crowding is regarded as a key service attribute for public transport, along with other factors such as travel time and reliability (see, for example, the service quality index developed by Hensher et al. 2003). Given the increasing importance of crowding on both the disutility to existing public transport users and the influence it has on whether to use public transport or not, it is timely to review the current measures of crowding defined by transport authorities/operators, and to evaluate whether they appropriately reflect traveler experiences and perceptions of crowding. We have not found a single study that examines whether monitored crowding by an authority can reflect public transport user experiences and is an appropriate metric for obtaining crowding reduction benefits, given willingness to pay estimates. A better understanding of crowding would, in turn, help design more appealing public transport systems to attract more users. This is especially important to the modal shift from car travel to public transport, given that a reason that cars are used for commuting instead of public transport is a loss of privacy in public transport due to crowding (Joireman et al. 1998; Ibrahim 2003; Evans and Lepore 2007). The paper complements Li and Hensher (2011), which reviewed the literature on the willingness to pay to reduce crowding.

**Measures of Crowding:**

**Conventional Bus and Bus Rapid Transit (BRT)**

The number of standing passengers per square meter (m²) is an objective standard measure for crowding used by many conventional bus services around the world. However, the benchmarks that define the unacceptable crowding levels vary across different countries or regions. For example, four standees per m² is the benchmark for Europe (UITP 2009) and for Australia (Diec et al. 2010). This number increases to five standees per m² for the USA1 (TRB 2006) and reaches eight per m² for China’s bus sector (AQSIQ 2004). Just like the crowding measure used in the conventional
bus industries, ITDP (2012) also used standing passengers per square meter to measure the level of crowdedness for bus rapid transit (BRT) systems, where overcrowding on BRT buses is defined as more than five standing passengers per square meter (0.46 per square foot) during the peak hour.

Despite the standards, many systems are experiencing overcrowding that is non-compliant with the standard. Overcrowding has become a major issue for conventional and BRT systems, especially in the developing world. For example, there was a major protest against overcrowded services provided by Bogotá’s BRT system (Transmilenio) on March 9, 2012. This system became far too overloaded, given that its actual patronage grew to double its design capacity. In another example, Curitiba’s BRT system also became overcrowded (see Duarte and Ultramari 2012). The influence of overcrowding on BRT performance is highlighted in ITDP (2012): “Many BRT systems which are generally well-designed are being operated such that buses are so overcrowded that the systems become alienating to passengers” (45).

**Measures of Crowding: Passenger Train**

Compared to bus, much more diverse crowding measures are defined in the passenger rail industry. For passenger rail, different specifications for measuring crowding are found across countries and even within a country, which are summarized below.

**Rail Crowding Measures in the UK**

The passengers in excess of capacity (PiXC) is a crowding measure that applies to all London and South East operators’ weekday train services arriving at a London terminus during the morning peak from 07:00 to 09:59, and those departing during the afternoon peak from 16:00 to 18:59 (Office of Rail Regulation 2011). The overall PiXC figure, derived by combining the PiXC of both peaks, considers the planned standard class capacity of each train service, as well as the actual number of standard class passengers on the service at the critical point (i.e., the location on a train’s journey with highest passenger load). PiXC is the number of standard class passengers that surpass the planned capacity for the service. The PiXC is given in percentages, calculated as the difference between the number of actual passengers and the capacity of the train divided by the actual passenger number. It is zero if the number of passengers is within the capacity.

The UK Department for Transport (DfT) monitors the crowding levels annually. Under the historic PiXC regime, the current benchmarks to define the acceptable PiXC levels are 4.5 percent on either the morning or afternoon peak and 3.0 per-
cent for both peaks (Office of Rail Regulation 2011). The Office of Rail Regulation (2011) reports the calculated PiXC figures on a typical weekday from 2008 to 2010. Out of 60 observations for morning or afternoon peak, 11 observations exceed the defined acceptable PiXC level (4.5%). Out of 30 observations for the overall performance, eight PiXCs surpassed the benchmark of 3.0 percent.

The PiXC can be converted into a common measure for crowding, i.e., the number of standing passengers per square meter (standing passengers per m²). For example, a PiXC of 40 percent is equivalent to five standing passengers per m² (London Assembly Transport Committee 2009). The standing passenger density is used by many rail industries around the world (Hirsch and Thompson 2011). Figure 1 provides the crowding levels based on standing passenger density, prepared by Transport for London for a morning peak in 2009, where Transport for London define a service as crowded if it has 2–3 passengers per m². This figure illustrates a spatial pattern, i.e., in London, train services in suburbs tend to be less crowded than services in inner-city areas. According to Office of Rail Regulation (2011), the benchmark for train crowding is 2.22 passengers per m² for most train operators in the UK.

Another crowding measure used in the UK is the percentage of standard class passengers standing, which is similar to PiXC, with the difference being the use of the planned number of standard class seats as the capacity for a rail service which has no allowance for standing. The Office of Rail Regulation (2011) reported the percentage of standard class passengers standing on a typical weekday in autumn 2010 varied from 1.0 percent (afternoon peak departure at Nottingham) to 14.0 percent (morning peak arrival at Leeds).

The difference between the PiXC and the percentage of standard class passengers standing is that the calculation of the former allows standing for journeys of up to 20 minutes as an additional component of capacity; the latter makes no allowance for standing where the capacity includes only the number of seats. The PiXC is mainly used to measure the crowding levels of commuter train services (e.g., within London), while for regional services with long journey times, the percentage of standard class passengers standing is used in the UK. It seems acceptable to have standing passengers (and, hence, standing allowance) for shorter journeys (e.g., commuting). This difference also has an impact on the design of rolling stock—for example, fewer seats and a higher standing capacity for services with shorter journey times so as to carrier more passengers (Office of Rail Regulation 2011). There-
fore, these two measures (with and without standing allowance) service different trip purposes.

**Rail Crowding Measures in the USA**

A key measure used by many U.S. transit authorities to evaluate in-vehicle crowding is load factor (passengers per seat), which is calculated as the number of passengers divided by the number of seats. A load factor of 1.0 indicates that all seats are occupied. With regard to load factor, different benchmarks are defined according to the nature of the service—for example, 1.0 for long-distance commute trips and high-speed mixed-traffic operations, 2.0 for inner-city rail service, and in between for other services, according to the current *Transit Capacity and Quality of Service Manual (TCQSM)* (TRB 2003).

The TCQSM (TRB 2003) defined the thresholds for the level of service (LOS) with respect to in-transit crowding, shown in Table 1. At LOS levels A, B, and C (>0.51 m² per standing passenger), all passengers can sit, while some passengers need to stand at LOS load level D. LOS E is the defined crowding threshold, i.e., 0.20–0.35 m² per standing passenger, which is equivalent to 2.86–5 standing passengers per m². LOS F (>5 standing passengers per m²) represents crush loading levels.

**Table 1. LOS Thresholds for Crowding**

<table>
<thead>
<tr>
<th>LOS</th>
<th>Load Factor (passengers/seat)</th>
<th>Standing Passenger Area (ft²/passenger)</th>
<th>Standing Passenger Area (m²/passenger)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0–0.50</td>
<td>&gt;10.8^</td>
<td>&gt;1.0^</td>
<td>No passenger need sit next to another</td>
</tr>
<tr>
<td>B</td>
<td>0.51–0.75</td>
<td>8.2–10.8^</td>
<td>0.76–1.0^</td>
<td>Passengers can choose where to sit</td>
</tr>
<tr>
<td>C</td>
<td>0.76–1.0</td>
<td>5.5–8.1^</td>
<td>0.51–0.75^</td>
<td>All passengers can sit</td>
</tr>
<tr>
<td>D</td>
<td>1.01–1.25*</td>
<td>3.9–5.4</td>
<td>0.36–0.50</td>
<td>Comfortable standee load for design</td>
</tr>
<tr>
<td>E</td>
<td>1.26–1.50*</td>
<td>2.2–3.8</td>
<td>0.20–0.35</td>
<td>Maximum schedule load</td>
</tr>
<tr>
<td>F</td>
<td>&gt;1.50*</td>
<td>&lt;2.2</td>
<td>&lt;0.20</td>
<td>Crush load</td>
</tr>
</tbody>
</table>

*Approximate value for comparison, for vehicles designed to have most passengers seated. LOS is based on area.

^ Used for vehicles designed to have most passengers standing.

In addition to load factor, another crowding measure used in the U.S. is standing passenger area (space [m²] per standing passenger), which can be easily converted into the number of standing passengers per square meter (standing passengers per
m²) (see Table 1). As an example, for the crowding level of maximum schedule load (which is the defined crowding threshold), the load factor range is 1.26–1.50, while the corresponding measure of standing passenger area is 0.20–0.35 square meter per standing passenger (or 2.86–5 standing passengers per m²).

**Rail Crowding Measures in Australia**

There are five major metropolitan rail systems in Australia: CityRail, Metro Trains, Transperth, Adelaide Metro, and Queensland Rail, located in Sydney, Melbourne, Perth, Adelaide and Brisbane, respectively, and each has its own measure of crowding. Therefore, the measures for rail crowding in Australia are not consistent. For example, Sydney’s CityRail, operated by RailCorp, uses the number of standing passengers per square meter to measure crowding, and its benchmark is 1.9 standees per m² (The Audit Office of New South Wales 2011). An alternative crowding measure for CityRail is load factor (passengers per seat), and the corresponding target set by the Minister in the Rail Services Contract⁶ is no more than 5 percent higher than 135 percent of seat capacity during the peak hours (The Audit Office of New South Wales 2011). Melbourne uses the rolling hour average loads to measure crowding in its Metro trains, and if the number of average passengers per train during a given hour, as counted at the Melbourne city cordon, exceeds 798, a railway line is considered overcrowded (Department of Infrastructure 2008). For Queensland Rail, the target of the length of standing time is no more than 20 minutes (Queensland Rail 2011).

**Monitored Crowding vs. Experienced Crowding: Evidence from Melbourne and Sydney**

Melbourne Metropolitan Train Load Standard Surveys are conducted twice a year to measure passenger loads, which are used to determine when and where extra services are needed to reduce crowding. The Metropolitan Train Load Standard survey⁷ by the Department of Transport (2011) shows that in 2011, the number of trains exceeding the crowding benchmark (when rolling hour average loads >798) were lower than the previous four years,⁸ for both morning peak (city-bound) and afternoon peak services (outbound), as shown in Figures 2 and 3.
Crowding in Public Transport: A Review of Objective and Subjective Measures

Figure 2. Passenger loading levels for the morning peak, May 2007 to May 2011

Figure 3. Passenger loading levels for the afternoon peak, May 2007 to May 2011
Figure 2 shows that only 18.2 percent of AM peak services (or 25.8% passengers on services) exceeded the defined benchmark, and the corresponding statistics for PM peak services are 13.5 percent of services or 23.0 percent passengers according to Figure 3. The results would suggest that there were no serious crowding problems on Melbourne train services in 2011. However, this is the opposite of findings from a survey conducted by Canstar Blue in 2011 (http://www.canstarblue.com.au/travel/city-trains/). This survey sampled 2,500 train commuters and asked them to provide feedback on a range of categories of rail services (e.g., fare, reliability, safety). This independent survey shows that Melbourne commuters are least satisfied with their train services, and 55 percent of surveyed Melburnians believed that “overcrowding was substantially impacting their quality of life,” which is higher than people living in other cities (e.g., 27% for Adelaide). Victorian Greens MPs have regularly collected travelers’ real experiences of crowding on Melbourne trains and published results on their website (http://mps.vic.greens.org.au/wewontstandforit). The collected data show that trains were overcrowded even during off-peak hours, and many passengers were being left behind at stations due to overcrowding.9

In Sydney, load factor is the crowding measure defined in the Rail Services Contract. RailCorp also has its internal crowding measure (i.e., the number of standing passengers per square meter). RailCorp have been monitoring the crowding levels based on the two measures. Figure 4 shows the monitored rail crowding from 2007 to 2011 in terms of standees per m². Figure 5 provides the load factors from 2005 to 2011.
The monitored crowding levels between 2007 and 2011 in terms of standees per m² (RailCorp’s internal crowding measure) are given in Figure 4, which illustrates that during the survey periods (March each year), the monitored crowding levels were well below the crowding benchmark of RailCorp (1.9 standees per m²) between 8 and 9 AM, where the highest monitored crowding occurred in 2008 close to the benchmark. This suggests no crowding issues on CityRail.

However, Figure 5 tells a different story, where the horizontal axis is the time period when the survey was conducted (conducted every six months, with the most recent in September 2011), and the vertical axis is the level of crowding higher than 135 percent of seat capacity (for example, 6% means that the crowding level is the number of passengers carried is 6% higher than 135% of seat capacity). In Figure 5, the dashed line is the target set by the Rail Services Contract (i.e., no more than 5% higher than 135% of seat capacity); and all observed crowding levels are above this target, suggesting the presence of crowding, despite the fact that there is a decreasing trend (linear line which is best fitting regression of load factors over time) in load factors, where the lowest level of crowding was 7 percent higher than 135 percent of seat capacity, as monitored in September 2011.
According to RailCorp’s own crowding benchmark, overcrowding is not an issue for Sydney’s CityRail, given that the observed density was well below its benchmark. However, the Canstar Blue survey revealed that overcrowding on Sydney train services is similar to the situation in Melbourne. On February 12, 2012, 7News reported that complaints about Sydney train services (particular on overcrowding) reached a record high.10

The comparison shows that there is a huge gap between the monitored crowding by the rail authority/operator and the experienced crowding by rail passengers in Melbourne and Sydney, and we suspect that the same evidence would apply if it were collected on all systems discussed above. A potential contributor to this gap is that the monitored result is too aggregate, which is reported as an average number over a period of time (e.g., one hour) and across several stations (e.g., North Melbourne, Jolimont, and Richmond for Melbourne).11 Moreover, the density-based measure fails to accommodate other important factors such as the length of journey in a crowded environment and whether standing or seated. The experience of crowding is more complicated than a density measure. For example, evidence from the psychology literature suggests that personal space invasion rather than overall density is the key factor to perceived crowding (see, e.g., Sundstrom et al. 1975; Worchel and Teddlie 1976). In the context of transport, Evans and Wener (2007) investigated personal space invasion and crowding, where 139 New York City train commuters were sampled. They found that seat density (the number of people sitting in the same immediate row the passenger was seated in to the number of total seats in the row) is related to stress rather than overall load factor (the ratio of the number of passengers to the number of seats) and, hence, claimed that the close presence of other passengers in a train carriage is more important to the experience of crowding than the overall train passenger density.12 Most important, passenger perceptions of crowding may be subjective, which cannot be accommodated by the objective measure of density.

Subjective or Psychological Components of Crowding

The above review shows that density (the ratio of passengers to space) is commonly used as the measure of crowding by many transport authorities. Mohd Mahudin et al. (2012) conducted a comprehensive literature review on existing studies of rail crowding and concluded that crowding is also defined and accessed based on measurements of passenger density and train capacity in the literature. Li and Hensher (2011) reviewed public transport crowding valuation research, with a focus on ways of representing crowding in stated preference (SP) experiments such as seat occu-
pance rate, load factor, and the number of standing passengers per square meter, which is in line with Mohd Mahudin et al.’s conclusion.

However, in the broader literature, it has long been recognized that density cannot fully capture the experience of individuals in a given space (Day and Day 1973; Evans 1979). A number of studies also claimed that the major limitation of using density as a crowding measure is a lack of consideration of individual perceptions of in-vehicle crowdedness (see, e.g., Turner et al. 2004; Cox et al. 2006). In the context of passenger rail, Cox et al. (2006) concluded that the perception of crowding is created “from an interplay of cognitive, social and environmental factors, whereas density refers to objective physical characteristics of the situation” (248). Evans and Lepore (2007) claimed that although perceived crowding is related to passenger density, they are not identical. Passenger perceptions are subjective, which are influenced by many factors, such as their personal characteristics and previous experience. Turner et al. (2004) highlighted that there are two dimensions of crowding: (1) objective—density and the available space, and (2) subjective—perceived crowding.

Sundstrom (1978) proposed four categories of possible factors that may have an impact on the perception of crowding: physical antecedents (e.g., room size, noise, heat, partitions, complexity, light), interpersonal (e.g., distance, social density, interference, proximity), individual (gender preferences, experience of crowds, personality) and modifiers (e.g., duration, activity, desire for contact). Van Der Reis (1983) added some other factors such as density, expectations, experience of crowding, fear, and nature of crowd. Culture also plays a role in the perception or tolerance of crowding. Evans et al. (2000) found that residential crowding has a negative effect in terms of psychological distress across different cultures; Mexican Americans and Vietnamese Americans perceive their homes as less crowded (based on a given number of people per room) relative to African Americans or Anglo American individuals. In the transport literature, Hirsch et al. (2011) found that Australian rail passengers who are between 18 and 24 years of age, not mobility-impaired, frequent users, and willing to stand, tend to be more tolerant of crowding. Cox et al. (2006) developed a theoretical model with the relationship between density, perceived crowding and impact on health (see Figure 6). Cox et al. listed two moderating factors that might influence the impact of high density on perceptions of crowding, namely perceptions of control and predictability of events. They also claimed that crowding is a possible threat to the health of the rail industry and passengers.
In Australia, Hirsch and Thompson (2011) identified eight factors that may influence the perception of rail crowding: (1) expectations based on previous travel experiences; (2) environment, which includes weather (for example, perceived crowding would be overweighted in rainy conditions), and carriage, such as the quality of the air conditioning system, air flow within the carriage, the presence and design of handholds for standing passengers, the seating layout and arrangement, the cleanliness of the carriage; (3) communication—poor quality of information provided to passengers would lead to increased feelings of crowding, along with frustration; (4) control/ options/ choice—the more perceived control a passenger has to make choices, the more positive view on his/her rail experience; (5) delays, identified as a primary factor influencing perceived crowding and would exaggerate the feeling of crowding; (6) risk (safety and public health), which is strongly related to the perceived cleanliness of the carriage environment, especially the holds and the seat coverings; (7) emotion—the perception and tolerance of crowding is influenced by a passenger’s emotions prior to embarkation; and (8) behavior of fellow passengers (e.g., loud phone conversations, the odor of unclean passengers, noisy school children, and a general lack of etiquette), which would also exaggerate crowding.13
Thompson et al. (2012) conducted a study to understand rail passenger perceptions of crowding across the five metropolitan railways in Australia, where the data were collected between 2009 and 2010. A number of potential factors were investigated, following Hirsch and Thompson (2011). Thompson et al. found reduced availability of fresh air, undesirable odors, and compromised personal space as the three most significant factors that would exacerbate passenger feelings of crowding, while participants indicated that the presence of secure poles and fixed handholds is one of the most mitigating factors to improve their tolerance of crowding. Crowding is a key issue to overall satisfaction with the service, and Thompson et al. found that a 10 percent increase in satisfaction with crowding alone would lead to a 4.6 percent increase in satisfaction with the overall train service experience.

With regard to the subjective dimension of crowding, two measures are used to capture it in the literature: (i) how crowded people feel, and (ii) how crowded people rate sitting. For example, Kalb and Keating (1981) conducted a study in a dense setting (a bookstore) and asked 201 students to answer questionnaires consisting of a series of items with a 10-point bipolar semantic differential response scale that measured perceived crowding. Factor analysis suggested that two crowding measures are conceptually different, where the feel crowd item (i.e., how crowded people feel) is associated with perceived density, constraint, distraction, and stress, while the environmental rating item (i.e., how crowded people rate seating) is loaded only with perceived density. The former is more sensitive to changes in physical density than the latter.

Mohd Mahudin et al. (2012) developed an instrument that is capable of capturing the subjective components of crowding in the context of the rail passenger. This survey instrument has three different scales, namely (1) evaluation of the psychosocial aspects of the crowded situation—“How crowded is the train that you are on today?”; (2) affective reactions to the crowded situation—“How do you feel inside the train that you commute on today”; and (3) evaluation of the ambient environment of the crowded situation—“The physical environment inside the train that you commute on today,” where each has a five-point construct-specific response scale format. The survey was conducted in Kuala Lumpur, where 525 frequent rail commuters were asked to respond on the five-point scale (see Appendix A for the full details). The passenger density variable was used as an objective measure of crowding, where respondents were presented with a scale made up of four pictorial representations (see Figure 7) with increasing passenger density developed by the UK Rail Safety and Standards Board (2004), and asked to rate the overall density.
Meanwhile, the stress subscale of the Stress and Arousal Checklist (SACL) (Gotts and Cox 1988) and the worn-out subscale of the General Well-Being Questionnaire (GWBQ) (Cox and Gotts 1987) were used as the outcome measures of crowding, where a high score indicate a higher level of psychological stress and a greater feeling of exhaustion.

Based on the evidence, Mohd Mahudin et al. (2012) concluded that:

(1) commuters' evaluations of the psychosocial aspects of the crowded situation and of its ambient environment, alongside their rating of passenger density, significantly predict affective reactions to the crowded situation; (2) these affective reactions, in turn, significantly predict stress and feelings of exhaustion; and (3) evaluations of the psychosocial aspects of the crowded situation and of its ambient environment as well as passenger density do not directly predict stress and feelings of exhaustion (38).
They also suggested that the relationship between rail passenger crowding and the negative outcomes is mediated by affective feelings of crowdedness.

The above review has two major implications for public transport authorities. First, crowding is two-dimensional: objective (e.g., passenger density) and subjective (perceived). The latter reflects individual travelers’ assessment based on the objective crowding, as well as their previous experiences with crowding, tolerance of crowding, and personal opinions. Although it is much more difficult to continually measure perceived crowdedness, given that a traveler’s perception on crowding is in her or his mind, which may directly influence choice behavior and, hence, ridership, it is important to gain information on perceived crowding, if for no other reason to understand the extent to which the (objective) standards are in line with what users perceive as acceptable levels of crowding. Opinion questions on crowding can add value in gaining insights into the acceptability of experienced levels of crowding, based on a series of questions such as: How would you describe the level of crowding on your local train services in the morning peak? (1 = Extremely untolerable, 2 = Untolerable, 3 = Tolerable, 4 = No crowding at all). These questions might be preceded by a visualization of the recent objective data on the vehicle configuration and the amount of standing (such as Figure 8). This will give the transport authority the percentages of public transport users who have experienced crowding (or overcrowding) recently, which then can be compared with the monitored objective crowding levels. If there is a significant gap between them, transport authorities should question whether the defined crowding measures are appropriate and develop measures that can better reflect travelers’ experiences.

Another significant implication is associated with the management of crowding. One way to reduce crowding is to increase frequency or capacity so as to reduce passenger density (objective crowding), which is a common solution to overcrowding. Another strategy is directly linked to the subjective component of crowding. Given a level of objective crowding, traveler tolerance of crowding can be improved through better design or better services. Evans and Wener (2007) recommended...
that public transport designers should provide pairs of proximate seats, rather than three across seating; meanwhile, larger carriages or vehicles should be used to help compensate for the loss of seat space. Cox et al. (2006) suggested that design innovations should focus on passenger control over elements such as space, choice of seat, point of entry and exit, and others that enhance their perceptions of safety and security. In addition to the design of the carriage, Thompson et al. (2012) suggested a number of ways that may relieve crowding and improve the tolerance of crowding through providing better service, such as improving air quality and air circulation, establishing optimum frequency of trains, improving quality of communication, and improving cleanliness (especially of handholds and floors). Other strategies may also contribute to the reduction of perceived crowding, including improving reliability of services/reducing delays and discouraging or banning loud conversations and music in buses/train carriages.

**Linking Subjective and Objective Measures to Measurable Users Benefits for Inclusion in Benefit-Cost Analysis**

The discussion of objective and subjective measures of crowding in previous sections is informative in identifying ways to capture more than a measure of physical passenger density. There clearly are underlying user perceptions as to whether crowding is present or not (on an appropriate scale). This is all fine; however, it does not provide a quantitative metric of perceived crowding that can be converted, using a willingness-to-pay estimate, to a benefit improvement consequent on some change in service level.

The limited empirical evidence on the subjective dimensions that signal when crowding is present provides strong support for a measure of crowding that is not simply the defined standard but, rather, some metric that is in units that is correlated with the subjective influences and yet can be used in a modal choice model to proxy for the underlying derivatives of perceived levels of crowding. The literature on willingness to pay (see Li and Hensher 2011), together with a recent study by Hensher et al. (2011), suggest that visualization of the condition (capacity and crowding) of a carriage or bus together with a descriptor of the number seated and standing (as in Figure 8) can provide a rich definition of the situation often faced by travelers. How they perceive this in terms of a source of disutility (or dissatisfaction) should be obtained from the parameterization of an appropriately-specified crowding variable or function in a model choice model. Hensher et al. (2011) and Tirachini et al. (2012) find that two good proxy variables are density of standees per
square meter and the proportion of seats occupied. These are specified by Tirachini et al. (2012) as linear and quadratic terms, and both are interacted with in-vehicle travel time in order to recognize that the marginal disutility is both a function of the level of crowding as defined by the two crowding dimensions and the amount of time in public transport.

The inclusion of these additional attributes in a mode choice model enables practitioners to assess the impact of improvements in capacity on the density of standees and the proportion of seats being used that matters to travelers (i.e., the subjective dimension). We have developed macros that enable feedback in a travel demand and supply model system, since it is not possible to predict the levels of these two variables without some equilibration. Once identified, associated willingness-to-pay estimates can be applied to convert the two sources of change in crowding to dollar net benefits.

Conclusions and Recommendations

This paper has reviewed the specifications of crowding measures defined by transport authorities in different countries (UK, U.S., and Australia). The bus industry, including BRT, tends to use a generic measure, namely the number of standing passengers per square meter, while for the rail industry, there are some variations in crowding measures (e.g., the number of standing passengers per square meter, load factor, rolling hour average loads). We suggest that for short journeys (e.g., commuting services), standing allowance should be treated as an additional component of capacity when defining crowding measures, while for long journeys (e.g., regional services), only the number of seat should be used as the capacity.

The broad transport crowding literature tends to focus on objective measures (e.g., passenger density). Only a few transport studies (see, e.g., Turner et al. 2004; Cox et al. 2006; Mohd Mahudin et al. 2012) have argued that the objective treatment of crowding (equivalent to density) cannot fully represent the experience of crowding, given that the perception of crowding is subjective. Given this, in addition to the objective measures (e.g., density), public transport operators/authorities should conduct perception surveys to obtain information on passenger subjective evaluations of crowding. Through surveys on perceived crowding, the transport authorities/operators can obtain the real experiences of passengers, which can be used to design more appealing measures to capture crowding and to calibrate the defined crowding thresholds to reflect the experienced crowding. Incorporating subjective measures of crowding can contribute to (1) a more accurate represen-
tation of crowding, which would help operators manage and reduce crowding in time by implementing strategies such as increasing the frequency of service and using larger vehicles, and (2) a better understanding of crowding, which is beneficial to the design of more appealing public transport systems to attract more users.

This evidence can be used on an ongoing basis to ensure that proxy measures of perceived preferences for specific levels of crowding (as illustrated above by, e.g., Tirachini et al. 2012) that are incorporated in formal modal choice models that deliver the necessary outputs for benefit-cost analysis remain relevant. The challenge is to establish how much users are willing to pay to reduce crowding (to a specific level), as they perceive it, regardless of the standard, since this is a clear source of user benefit. Mapping this evidence, if available, to the standard, will enable a clearer picture to emerge of how the system is complying with the standard; however, this is not the basis of extracting the set of crowding-related benefits that exist regardless of the standard. If a move towards the standard ensures a gain in perceived user benefit, then it needs to be captured through a preference study. Simply imposing a desired standard does not capture the user benefit.

**Endnotes**

1 In the U.S., load factor (the ratio of the number of passengers to the number of seats) is an alternative measure for bus crowding, which is specified not to exceed 1.2.


3 The standard class capacity is based on the booked formation of the service and includes the number of standard class seats on the train and an allowance for standing for a service where there is a stop within 20 minutes, which is typically approximately 35% of the number of seats.

4 The PiXC is a measure equivalent to the number of standing passengers per square meter.

5 The TCQSM was initially published in 1999 as a comprehensive reference resource for U.S public transit practitioners and policy makers. The current TCQSM, 2nd Edition, was published in 2003 is widely used by transit service providers, metropolitan planning organizations, and state DOTs. In addition, the TCQSM is often used as a source of transit definitions and transit capacity and quality-of-service concepts.
The 3rd edition, which addresses important changes that have occurred in public transit technologies, policies, practices, and procedures, is expected to release at the end of 2012.

In accordance with the requirements of the Passenger Transport Act, Transport for NSW and RailCorp entered into a rail services contract that commenced on July 1, 2010. This contract includes a range of Key Performance Indicators (KPI) to ensure service standards.

The May 2011 survey was conducted from May 9–26, 2011.

On May 8, 2011, 635 additional services were added across Melbourne’s rail network (http://www.metrotrains.com.au/news/2011/feb/14/new-may-timetable-delivers-635-weekday-services). This improvement may be a reason that Melbourne’s rail services were less crowded in May 2011 than previous years.

Some rail passengers’ comments on crowding collected in 2011 include “We are like sardines in here. I am SO uncomfortable!”; “Completely packed train, every time, people having to skip and wait for next one”; “Max crush load, yet they still keep getting on the train”; “Not ok! I paid $19, I should not have to sit on the floor”; “Too crowded in the aisles to access empty seats.” The situation has not been improved in 2012. The worst overcrowding was observed on the Frankston line (away from Melbourne city center at 6 PM on January 23, 2012), with 200 people standing up in one carriage.

Melbourne’s measure (see, e.g., Figure 2) can tell only the number (percentage) of services that exceeded the crowding benchmark. However, the number of passengers that exceeded the benchmark is crucial to the extent of crowding, which was ignored in Melbourne’s crowding measure.

Load factor and seat density were candidate variables to predict stress (the dependent variable, e.g., mood, during the commute to work, measured by five-point semantic differential scales [carefree–burdened; contented–frustrated]) in the regression model where seat density was statistically significant, while the overall load factor is not.

A reviewer pointed out that some of the factors that have an impact on perceived crowding are completely outside the control of a transit agency (e.g., weather, body odor, and noisy school children).
The pictorial display of Figure 7 is a representation of objective measures of crowding (passenger density). However, when traveling in a bus or train with the same level of objective crowding, the perceived crowding levels may vary across public transport users, given that their previous experiences on crowding and tolerance of crowding may be different. In Mohd Mahudin et al. (2012), Figure 7 was presented to their subjects, who were required to rate the given density. As an example, with regard to the fourth level of crowding, some subjects may rate it as “extremely overcrowded” and some may rate it as “crowded.”

For example, the monitored crowding by the authority indicated that 25.8% and 23% of Melbourne train passengers were traveling on the crowded services during the morning and afternoon peak hours in 2011 (see Figures 2 and 3); however, an opinion survey conducted by Canstar Blue showed that 55% of surveyed Melburnian commuters reported that they experienced overcrowding on train services. This huge gap suggests that the crowding measure used in Melbourne (rolling hour average loads, where overcrowding is defined as more than 798 passengers per train during a given hour, on average) cannot correctly indicate experienced crowdedness. This example, in turn, illustrates the limitation of using only objective measures for representing crowding.

Given that it allows for subjective perceptions of crowding, using visualization along with description is better than description only (e.g., “trips out of 10 for which you have to stand” in Hess et al. 2011) for the representation of the crowding attribute in the choice experiments.

Acknowledgments

Discussions with Alejandro Tirachini are greatly appreciated. We also thank a referee for some insightful comments and suggestions, which have contributed materially to improving this paper.

References


Crowding in Public Transport: A Review of Objective and Subjective Measures


Mohd Mahudin, N. D., T. Cox, and A. Griffiths, A. (Forthcoming). The effects of rail passenger crowding on health and stress: A systematic review. Accepted pending minor revisions.


**Appendix A: Measuring Subjective Evaluations of Crowding or Perceived Crowdedness (Mohd Mahudin et al. 2012)**

1. Below are 7 categories of items that ask you about “How crowded is the train that you are on today?” (A, B, C, D, E, F, & G). Please circle or tick one answer in each of these categories.

![Diagram of subjective evaluations categories](image-url)
2. Below are 9 categories of items that ask you about “How you feel inside the train that you commute on today?” (A, B, C, D, E, F, G, H, & I). Please circle or tick one answer in each of these categories.

A
5 Extremely squashed
4 Very squashed
3 Squashed
2 Slightly squashed
1 Not squashed

B
5 Extremely tensed
4 Very tensed
3 Tensed
2 Slightly tensed
1 Not tensed

C
5 Extremely distracted
4 Very distracted
3 Distracted
2 Slightly distracted
1 Not distracted

D
5 Extremely uncomfortable
4 Very uncomfortable
3 Uncomfortable
2 Slightly uncomfortable
1 Not uncomfortable

E
5 Extremely frustrated
4 Very frustrated
3 Frustrated
2 Slightly frustrated
1 Not frustrated

F
5 Extremely restricted
4 Very restricted
3 Restricted
2 Slightly restricted
1 Not restricted

G
5 Extremely irritable
4 Very irritable
3 Irritable
2 Slightly irritable
1 Not irritable

H
5 Extremely hindered
4 Very hindered
3 Hindered
2 Slightly hindered
1 Not hindered

I
5 Extremely stressful
4 Very stressful
3 Stressful
2 Slightly stressful
1 Not stressful

3. Below are 4 categories of items that ask you about “The physical environment inside the train that you commute on today” (A, B, C, & D). Please circle or tick one answer in each of these categories.

A
5 Extremely hot
4 Very hot
3 Hot
2 Slightly hot
1 Not hot

B
5 Extremely stuffy
4 Very stuffy
3 Stuffy
2 Slightly stuffy
1 Not stuffy

C
5 Extremely smelly
4 Very smelly
3 Smelly
2 Slightly smelly
1 Not smelly

D
5 Extremely noisy
4 Very noisy
3 Noisy
2 Slightly noisy
1 Not noisy
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Paratransit Business Strategies: A Bird’s-Eye View of Matatus in Nairobi

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Abstract

Nairobi’s paratransit vehicles—called matatus—provide most of the City’s public transport. They are operated as private for-profit businesses with varying levels of investment, labor, and strategic thinking. The vehicles are subject to regulation but have little regard for laws, regulations, or the comfort of the traveling public. Interviews of informed observers—the “bird’s-eye view”—underscored the business character of matatu firms and revealed considerable variation in business structure, modes of operation, levels of organization, and attitudes towards regulation, and they highlighted ways that government and industry institutions affect matatu organization and operations. This study identified eight elements of matatu business strategy and a continuum of business organization; it also noted an emerging trend towards higher levels of organization through franchising, networking, and ownership of multiple vehicles. The paper suggests that further development of varied organizational forms could hold the key to a more user-friendly public transport system for Nairobi.
Introduction
Paratransit is the main form of public transport in many African cities. The vehicles go by various names, such as “matatus” in Nairobi, “dala dala” in Dar es Salaam, and “minibus taxis” in Cape Town. In developed countries, paratransit is, as its name suggests, a mode of transport that operates parallel to an organized, usually large-scale government-run or government-subsidized transport system. In many African countries, for a variety of reasons, the parallel system has become the main public transport system available. It is, therefore, crucial to understand how it operates.

The matatu mode of transport provides most of Nairobi’s public transport services (Aligula et al. 2005). The matatus are owned by individuals and private companies, and so form part of Nairobi’s private sector. An important characteristic of Nairobi’s paratransit is its almost total lack of adherence to traffic rules, prescribed routes, and regulatory requirements. The resulting chaotic behavior has long been referred to as “matatu madness” (see East African Standard 1998; Daily Nation 1999). Yet, despite this apparent similarity in behavior, matatu businesses differ from each other in important ways. Some of these differences are readily observable. Equipment ranges from shabby vans and buses that have long been battered by encounters with other vehicles to brightly-painted minibuses equipped with hostesses and built-in DVD players. Many have music systems, but the volume and the type of music played vary from one to another. Youth form the bulk of the passengers for some, while others carry mainly older commuters and shoppers. Differences in the propensity to break speed limits, vary fares, deviate from approved routes, harass passengers, and/or obstruct traffic are also easy to see.

Less observable are differences in owner characteristics, age and history of the business, forms of internal organization, linkages with other actors, amount and type of financing, type of vehicle ownership, route assignment, and number and types of external linkages that businesses form with other actors within and outside their own sector of operation. Theories of institutions and firm strategic behavior suggest that these and other differences may not simply be “matatu madness” but are, in fact, part of the market and business development strategies of matatu firms.

The project’s overall research question is, therefore: To what extent do firms with different strategies respond differently to actual or proposed regulations, and what are the implications of these differences for the government’s ability to implement change? The questions driving this paper were, however, somewhat more limited because the paper seeks to provide a basic understanding of the main elements...
of paratransit business strategies in Nairobi. The research covers public transport operating in Nairobi City. Matatus are its subjects, and its sources of data are informed observers of the matatu sector. The paper aims to provide a basic understanding of the institutional context and the main elements of paratransit business strategies in Nairobi as preparation for a more detailed firm-level study.

Research for this paper took the form of a scoping study that aimed at identifying the main features of strategy development and implementation among Nairobi’s paratransit operators as seen by knowledgeable observers. It took, in other words, a “bird’s-eye view” of the matatu industry. Primary data were gathered through in-depth interviews of 18 purposively-selected key informants and feedback during a stakeholders workshop. Data analysis was qualitative and thematic.

The paper is organized into six parts. The following section reviews relevant literature. Part 3 puts the study into a theoretical context and briefly examines empirical findings on urban transport strategies. Part 4 outlines the research methodology. Part 5 presents the findings, and Part 6 summarizes and draws conclusions from the findings.

**Urban Paratransit**

Paratransit vehicles are part of Kenya’s urban public transport system. Public transportation is a service provided by public or private entities and is available to all persons who pay the prescribed fare (Vuchic n.d.). Urban public transport has been defined as a system that provides for the movement of people and goods within an urban area and also links the city to its environs (Aligula et al 2005). Paratransit operators in the global North and South spring up to fulfill unsatisfied demand for public transport as result of urban growth. However, whereas in the global North they form a tiny minority (Cervero 1997; Lee 1990; Örn 2005), in the global South, in most cases, the share of demand served by such paratransit operators is often 50 percent and sometimes accounts for all public transport services in the urban areas (Cervero 2000; Boudreaux 2006; Chitere and Kibua 2004). Paratransit vehicles vary from human-powered pedicabs to mid-sized motorised buses (Cervero 2000; Illes 2005).

Most paratransit operations in developing countries are supplied by the private sector rather than the public sector (Sclar et al. 2007). Many observers attribute the shift to private-sector transport to inefficiencies in the major public transport companies (Khayesi 2002; Cervero and Golub 2007; Sclar et al. 2007; Schalekamp et al., 2008). Some point out that in much of Africa and in smaller Asian cities where
municipal budgets are stretched thin and technical capacities for planning, administration, and regulation are insufficient, almost by default, informal transport offers the only dependable services available (Cervero and Golub 2007). An earlier study by Golub (2005) also confirmed that, in many cities, regular public transportation systems do not meet all of the demands of the marketplace, and small-scale operators, legally or illegally, enter the market to fill these gaps. Such small operators typically have little transportation business expertise (Chitere 2006; Finn et al. 2011). Mũnoz and Gschwender (2008) argue that atomized ownership leads to increased traffic rule violations and a deterioration of services.

Where large numbers of private-sector operators provide public transport, regulating and controlling such individually-owned small vehicles is a serious challenge (Sohail et al. 2004). This is especially so because the vehicles represent a multiplicity of small businesses, each of which is trying to make a profit. This has led authorities in some African cities to focus on the question of whether an effort should be made to “formalize” or regulate paratransit operations and to try to identify the obstacles to such formalization (Kumar and Barrett 2008; Wilkinson 2008; Wilkinson et al. 2011). A range of options for managing competition have been advanced, including public monopolies, management contracting, public-private partnerships, concessioning, and quality licensing (Sohail et al. 2004; Wilkinson 2008; Kumar and Barrett 2008; Chitere 2009). Choosing among these options requires a good understanding of the variety and, especially, the private-sector nature of paratransit operators. Research in various countries has shown that urban bus services respond to changing contexts in many different ways. In other words, there is no unique solution to the problems facing paratransit in developing countries (Finn and Mulley 2011).

Business Strategies of Urban Transport Firms

Business Strategies

Understanding a business strategy requires a clear notion of what a business is. This is particularly important in the case of urban public transport, because the experience of industrialized countries is that transport operators are usually public, rather than private, entities. A business is simply a private firm that aims to make a profit.1 There is no universal definition of business strategy (Kelly and Kouzmin 2009). We adopt a basic definition that can fit large and small firms: A strategy is a plan of action that is intended to move a firm toward the achievement of its shorter-term goals and, ultimately, toward the achievement of its fundamental purposes (Harrison and St. John 2008).
Strategy aims to achieve advantages for the organization by using available resources to meet the needs of the market and fulfill stakeholder expectations (Johnson and Scholes 2004). Business-level strategy defines an organization’s approach to growth and competition in its chosen business segments (Harrison and St. John 2010). A firm’s resources and capabilities determine its competitive advantage, which, in turn, gives rise to strategies for realizing that advantage (Grant 1991). The strategies describe how businesses compete in areas they have selected. The strategies may vary widely from business to business because they are shaped by competitive forces as well as the resources possessed by each of the units of the firm. If an organization is involved in only one area of business, then all of its business strategy decisions tend to be made by the same people. Such strategies are implemented through day-to-day decisions made at the operating level of a firm (Hrebiniak and Joyce 1984).

Business strategies are also shaped by forces external to the firm. The international literature on national business systems has shown how business organization and behavior varies from one country to another (Whitley 1992, 2008). Part of this variation can be observed in the type of strategies adopted by businesses in different places. Most of the work on business systems has emanated from industrialized countries and emerging economies in Asia and Eastern Europe, but there is a small, but growing literature on African business systems that points to similar differentiation in African economies (Pedersen and McCormick 1999, McCormick and Kimuyu 2007).

The collective day-to-day decisions made and actions taken by employees responsible for value activities create functional strategies. Functional strategy contains the details of how the functional areas such as marketing, operations, finance, and research & development should work together to achieve the business level strategy (Harrison and St. John 2010). The competitive advantage and distinctive competences that are sought by the firms are often embedded in the skills, resources, and capabilities at the functional level. Functional strategies are the plans for matching those skills, resources, and capabilities with functional goals and activities.

**Strategy as a Framework for Analysis**

Functional strategies touch on the details of what will be done in each area of the business. In large businesses, such functional strategies are developed and implemented in functional departments. In smaller firms, the entrepreneur will be the main architect of strategy. In such small firms, neither the overall nor the functional
strategies are necessarily written down. Whether written or not, the elements of a strategy can be identified and used as a framework for understanding the variations among firms.

Methodology

Research for this paper took the form of a scoping study that aimed at identifying the main features of strategy development and implementation among Nairobi’s paratransit operators as seen by knowledgeable observers. It took, in other words, a “bird’s-eye view” of the matatu industry. The scoping study was the first phase of a larger study of paratransit business strategies and regulatory compliance. The research team gathered primary data through 18 interviews of purposively-selected key informants and feedback during a stakeholder workshop. Interviewees, who were chosen based on their institutional affiliation, were drawn from the Kenya Government (7), the private sector (9), and donor agencies (2) (see Table 1).

Table 1. Key Informants in Public Sector, Private Sector, and Donor Agencies

<table>
<thead>
<tr>
<th>Public Sector (KG)</th>
<th>Private Sector (KP)</th>
<th>Donor Agencies (KD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ministry of Transport</td>
<td>• Citi Hoppa Ltd.</td>
<td>• World Bank</td>
</tr>
<tr>
<td>• Ministry of Roads and Public Works</td>
<td>• Double M Services Express Connections Ltd.</td>
<td>• Japan International Cooperation Agency (JICA)</td>
</tr>
<tr>
<td>• Ministry of Nairobi Metropolitan Development</td>
<td>• Smart Bus Company</td>
<td></td>
</tr>
<tr>
<td>• Kenyan Urban Roads Authority (KURA)</td>
<td>• MOA Compliant</td>
<td></td>
</tr>
<tr>
<td>• Kenya Bureau of Standards</td>
<td>• Star Bus Company</td>
<td></td>
</tr>
<tr>
<td>• Transport Licensing Board (TLB)</td>
<td>• KBS Management Ltd.</td>
<td></td>
</tr>
<tr>
<td>• Nairobi City Council</td>
<td>• Africa Merchant Assurance Co. Ltd.</td>
<td></td>
</tr>
</tbody>
</table>

Primary data collection used face-to-face interviews and observation. Interviewing of key informants ran from April to July 2010. Using pre-prepared interview guides, researchers asked all key informants to give their impressions of the basic operating strategies of the matatu business and to identify ways in which these strategies differ from one operator to another. Respondents were also asked additional questions, which were tailored to each informant’s area of operation or expertise. A stakeholder’s workshop was held in the month of July 2010 to discuss the initial findings of the scoping study and collect additional information. Researcher observations on matters such as driving behavior, the crowding of vehicles, and the nature of matatu driver and conductor interactions with passengers, other motorists, pedestrians, and police officers supplemented the interview material.
Sources of secondary data included published literature, Web-based materials, government documents, and maps. The literature review covered books on urban transport, journal articles, newspaper articles, websites, reports, Government of Kenya documents, working papers, and discussion papers. Data analysis was qualitative and thematic. Themes were derived from the literature and the interview guides.

**Matatu Industry Organization and Business Strategies**

The research findings fall into two main categories: the general organization of the industry and/or industry segments and the business strategies of *matatu* firms.

**Strategy and Industry Organization**

To understand the general organization of the *matatu* industry in Nairobi, it is helpful first to look at organization as a concept and at its manifestations at the firm level. An organization in its simplest form is a person or group of people intentionally organized to accomplish an overall, common goal or set of goals. Business organizations can range in size from one person to tens of thousands and can be structured as one-person enterprises, partnerships, or multi-layered corporations (Nicolescu, 2009; Ricketts, 1994). The term “organization” is used in its basic dictionary sense of having an orderly structure or being systematized (Concise Oxford Dictionary 1990). The type and complexity of firm organization is sometimes taken for granted or considered as a simple function of business size, but size itself can be the outcome of decisions concerning the scope of the firm (Ricketts 1994). In other words, the type and level of organization are clearly related to the conscious decisions and strategies of the firm, and different strategies may be pointers to different levels of organization.

Analysis of the responses to questions about the strategies of *matatu* business yielded an overall picture of an industry made up of firms that vary considerably in their levels of organization. Using the main strategy types and the rough yardstick of “low,” “moderate,” and “high” levels of organization highlights some of the key differences found among firms in the sector (see Table 2).

The early research revealed three important points along what is expected to be a continuum of organization (see Figure 1). Based on our key informant interviews, we identified three main groupings. At the low end of the business organization scale was the typical *matatu*; next came the first group in the moderate organization range, the management companies. Finally, more organized but still in the
moderate range, were Nairobi’s larger transport business with multiple vehicles. No Nairobi operators were considered to be highly organized.

Table 2. Strategy and Organization of Matatu Businesses

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Low Organization</th>
<th>Moderate Organization</th>
<th>High Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business ownership, structure</td>
<td>• Individual, owning one or more vehicles</td>
<td>• Group ownership (family, partnerships, cooperatives, limited companies)</td>
<td>• Limited companies</td>
</tr>
<tr>
<td>and levels of investment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financing</td>
<td>• Self, family, and friends</td>
<td>• Self, family and banks</td>
<td>• Investors and banks</td>
</tr>
<tr>
<td>Routes and vehicle types</td>
<td>• Operate in one route allocated by TLB/ control of routes by gangs</td>
<td>• Operate in one or more than one routes; routes controlled by cooperatives or management companies; some deviation from routes</td>
<td>• Routes controlled by legally mandated transport authorities; complete adherence to assigned routes.</td>
</tr>
<tr>
<td></td>
<td>• Considerable deviation from routes</td>
<td>• Mainly 25–55 seater minibuses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Mainly 14-seaters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pricing</td>
<td>• Flat zoned, variation with traffic and weather</td>
<td>• Flat zoned, monthly coupons and smart cards</td>
<td>• Seasonal tickets which are transferable, no deviations allowed</td>
</tr>
<tr>
<td>Operations – repair and</td>
<td>• Individually undertaken by each operator</td>
<td>• Done by management companies</td>
<td>• Centralized</td>
</tr>
<tr>
<td>maintenance, recruitment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulatory compliance</td>
<td>• Low or non-existent compliance</td>
<td>• Complies with some, but not all, regulations</td>
<td>• Full compliance</td>
</tr>
<tr>
<td>Promotion and advertising</td>
<td>• Individual promotion through touting at stages</td>
<td>• Some advertising on vehicles</td>
<td>• Centralised advertising strategy</td>
</tr>
<tr>
<td>Customer relations</td>
<td>• Not emphasized</td>
<td>• Guidelines given</td>
<td>• Emphasized</td>
</tr>
<tr>
<td>Business linkages and networking</td>
<td>• Mainly personal ties and linkages through informal groups</td>
<td>• Mix of formal and informal linkages</td>
<td>• Predominance of formal linkages</td>
</tr>
</tbody>
</table>

Source: Authors’ conceptualization from field data.
Firm-level Organization

The notion of a continuum of organization in the matatu industry that emerged in the previous discussion provides a backdrop for a more detailed understanding of the organization and behavior of individual firms in each of the three categories.

Low Business Organization: The Typical Matatu

The “typical” matatu is a 14-seater van owned by an individual who is involved in the transport business as a sole owner/driver or as side venture to employment or other types of business. The vans are bought second-hand in Kenya or directly from Japan and represent an investment of just over Kshs 1 million ($12,820 US).\(^2\) In the “typical” category also—mainly because they are very common on some routes—are the larger mini-buses that are usually bought new from Kenyan assemblers, mainly General Motors Kenya. The latest of these to enter the market has 37 seats and carries a price tag of Kshs 3.8 million ($48,718 US) (Daily Nation, 16 June 2010). Our observations suggest that older large buses are being recycled into use as matatus on some routes, while, in some cases, the mini-buses are converted Lorries. Installing an entertainment system can considerably increase the investment in any type of matatu.

The fare strategy is designed to maximize profits and minimize the owner’s direct involvement in the management of the vehicle. The common use of a “target system,” however, means that the vehicle owner receives a fixed daily amount while increases or decreases in revenues mostly affect the amount retained by the crew (KG).\(^3\) The crew is responsible to pay for fuel and other daily expenses except repairs.
and maintenance from the daily collections. The target system allows the crew to keep anything above the agreed amount, thus increasing their incentive to do whatever is necessary to maximize their revenues (KG). The fare itself is usually a flat-zoned fare, which is increased in peak periods and doubled or more when it rains or the vehicle is caught in heavy traffic jams. The owner’s profit goal, however, is not always realized because the crew sometimes fails to meet the target.

Key informants emphasized that the typical matatu is poorly managed. Its daily operations are in the hands of the crew with little or no supervision from the owner. Owners lack management skills and the crew lacks basic training. There is little banking or record keeping (KG). Vehicles shun timetables in order to travel with a full load. Cutthroat competition results in vehicles over-speeding, picking and dropping passengers anywhere along the route, and deviating from prescribed routes to avoid obstacles or traffic jams (KG, KP, SW). Owners condone over-speeding, in some cases authorizing the removal of speed governors (KG). Profit rather than service is the main concern (KG). The typical matatu hires unqualified crew, over which the owner has little control. Respondents say that most are dropouts from secondary school (KG, SW).

Many vehicles are uninsured (KG). Those with insurance mostly have only third-party cover (KP). This leaves owners vulnerable to damage caused by accidents and, in some cases, penalties for failing to comply with regulations requiring at least third-party cover. The typical matatu’s frequent accidents are blamed on the carelessness of the drivers (KG). Vehicles are constantly on the road, because owners are reluctant to rest them. One industry player observed that it is not possible to employ crew on contracts providing for time off because when a vehicle is off the road there is no income to pay the crew (SW). Maintenance costs for the vehicles are high, and a vehicle’s useful life is fairly short.

Crew members display unruly behaviour and a “don’t-care” attitude towards both passengers and the vehicle itself (KG, KP). Customer relations are poor. Drivers and conductors rarely see passengers as “customers.” Although conductors show and/or call out the number and destination to attract passengers into the matatu, once passengers board the vehicle they may be harassed or treated badly. Some 14-seaters have music systems, but the choice of music and control of its volume is at the discretion of the crew. Passengers’ occasional complaints are usually disregarded. Many mini-buses have more elaborate entertainment systems in an effort to attract the youth market on some routes.
The typical matatu operates on its own, with little interaction between its owner and the owners of similar vehicles. Only a small proportion of owners belong to an association, and 14-seater matatus are not included in existing franchise arrangements. This is changing as a result of the Transport Licensing Board’s 2010 directive requiring public service vehicle (PSV) owners to join organized groups such as savings and credit co-operatives (SACCO) or companies in order to be registered (Daily Nation, 23 December 2010). Since the beginning of 2011, stand-alone matatus are not eligible for registration.

**Moderate Business Organization: Matatu Management Companies**

Three companies presently operating in Nairobi as management companies fit into the moderate business organization category. All three of these manage buses on behalf of individual investors, providing a range of services.

The basic concept underlying the management companies is franchising. A franchise can be loosely defined as an authorization to sell a company’s goods or services in a particular place. The person or entity who owns the business, its trademark, and the system is the franchisor. The entity authorized to sell is the franchisee. In this case, the management company (franchisor) generally holds a trademark and a set of operating procedures, services, and/or standards that the individual matatu owner (franchisee) buys the right to use.

Two of the franchise companies interviewed operate solely as managers of vehicles for individual owners. The third has both franchised vehicles and owned vehicles. The companies differ in their requirements for obtaining a franchise, the services offered, funds management procedures, vehicle specifications, and operating rules. In all cases, the public can easily recognize the franchised buses by their color and design. One of the management companies originally required that its franchisees have at least five vehicles, but found difficulty in enforcing this rule (KP). Other industry stakeholders refer to them as examples of what a more organized transport system might look like.

**Moderate Business Organizations: Bus Companies**

A bus company can usually exert more control over its operations than a management company. Bus companies represent a second form of moderate business organization. Our research identified two companies with fleets of buses. A “fleet” can be defined as group of buses operating together under the same ownership. These are, therefore, companies that own and operate their own vehicles, includ-
ing hiring and training their own staff. Both are private companies offering public transport services.

Defining a fleet as a group gives considerable latitude for variations in size. One Nairobi bus company has only 15 vehicles but aspires to have 300 in the future; another already has 200. The next stage of the research may yield data that will enable us to estimate the size of fleet necessary for a viable company.

Formulating strategy in a unified company is basically the task of the owners, who can put in place appropriate measures to implement their ideas. Our bus company interviews focused on the respondent views of matatu operations and, therefore, did not yield full information on the companies’ own strategies. Further interviews to fill the gaps on company strategy will be conducted in the next phase.

Although the bus companies are better organized than most public transport players in Nairobi, they cannot be considered to be highly organized for two reasons. First, most lack the ticketing and fleet management systems that would be necessary for the highest degree of organization (SW). Second, although company vehicles follow regulations to a greater extent than matatus in either the low or moderate organization groups, researchers have observed enough violations to support their judgment that these firms have not yet achieved the “full compliance” expected of highly-organized transport providers.

Summary and Conclusions

Summary

Interviews of informed observers – the “bird’s-eye view” – provided new information about matatu industry organization and its individual business enterprises. The first and perhaps most important finding is that the industry shows considerable variation in business structure, modes of operation, levels of organization, and attitudes towards regulation. To highlight this finding, we proposed a continuum of organization, with the “typical” individually-owned matatu at one end and the multi-vehicle bus company near the other end. We noted that no Nairobi bus company could be called “highly organized” by international standards.

The second finding has to do with the strategies of individual businesses. Eight elements of a business strategy appear to apply to matatu businesses: 1) business ownership and investment; 2) financing; 3) routes and vehicle types; 4) pricing; 5) operations; 6) promotion and advertising; 7) customer relations; and 8) business linkages and networking. The findings suggest that these elements are present in
varying degrees and combinations. In theory, at least, each *matatu* business can develop its own unique strategy by combining the elements in different ways. The extent to which this actually happens and which strategies seem to work best in the Nairobi environment require further research.

**Conclusions**

The study has yielded three main conclusions. First, this “bird’s-eye view” demonstrates that keen observers can identify various elements of business strategy in the *matatu* sector. It is not possible, however, at this level to know all of the variations and commonalities of these strategies, nor to understand the motivation behind their adoption by particular firms. More importantly, it is not possible, without detailed case studies, to understand the links between business strategy and firm choices to comply or not comply with traffic and operational regulations.

Second, it is clear that Nairobi’s public transport system has grown, adapted, and reorganized itself many times in the past few decades. It appears that this evolutionary process is continuing with the emergence of franchising, networking, ownership of multiple vehicles, and, most recently, the promotion of transport savings and credit cooperative organisations (SACCOs). It is possible that further development of varied organizational forms could hold the key to a more user-friendly public transport system for Nairobi.

Finally, the findings have implications for the formation and application of policies and regulations. In what appears to be a quite varied landscape of *matatu* businesses, policymakers and regulators need to listen keenly to the full range of *matatu* voices. This is difficult in the present, somewhat disorganized industry structure. The directive calling for improved organization through SACCOs and transport companies has the potential to improve communication channels, but it also runs the risk of putting into place organizations that lack credibility across different *matatu* types. Nevertheless, the development of varied organizational forms is a hopeful sign that could hold the key to a more user-friendly public transport system in Nairobi.

**Endnotes**

1 We take the classic definition of a firm as “the system of relationships which comes into existence when the direction of resources is dependent upon an entrepreneur” (Coase 1937).
At the time of the research, the exchange rate was approximately Kshs 78 to the US dollar.

K = data from key informant interviews; SW = data collected from the stakeholder’s workshop; G, P, D = interview data from government, private sector, and donors.

Third-party cover is liability insurance purchased by an insured (the first party) from an insurer (the second party) for protection against the claims of another (the third) party. The first party is responsible for its own damages or losses whether caused by itself or the third party. A matatu carrying third-party cover will be insured against damages to other persons and their property in accidents it causes. See http://www.businessdictionary.com/definition/third-party-insurance.html#ixzz2BbpfOh62.

For purposes of this research, a “bus company” is a company that 1) owns some or all of the vehicles it operates and 2) has or aspires to have a large fleet of vehicles operating on multiple intra-city routes. The bus companies included in this research generally operate mini- and/or full-size buses. The term is preferred to its logical alternative—a matatu company—because it is recognized in the industry in Nairobi as a specific group of operators.

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Paratransit Business Strategies: A Bird’s-Eye View of Matatus in Nairobi


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Eliminating Bus Stops: Evaluating Changes in Operations, Emissions and Coverage

Ranjay M. Shrestha and Edmund J. Zolnik
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Abstract

Bus systems in the United States are unattractive to many potential riders because of their lack of efficiency, especially with regard to travel time. One of the reasons services are not more efficient has to do with the spacing of bus stops. After using a nearest facility algorithm with an 800 m walking distance threshold to identify eligible bus stops in the current bus system in the city of Fairfax, Virginia, the impacts of their elimination on operations, emissions, and coverage are estimated. Results indicate that eliminating some bus stops (about 40% of current stops) could improve travel times and reduce operating costs by the same percentage (23%). In addition, bus-related emissions such as CO (34%), VOC (18%), and NOx (10%) could all be substantially lower. Surprisingly, the loss in coverage due to eliminating stops would not be large (10% of the total population of the city of Fairfax).

Introduction

One of the reasons bus service in the United States is unpopular is because it is inefficient; it takes too long to get riders to their destinations. Many attribute this inefficiency to the spacing of bus stops (Furth et al. 2007). Densely-spaced bus stops improve geographic coverage and rider accessibility, but they also increase in-vehicle time and supply costs (Chien and Qin 2004). Sparsely-spaced bus stops,
on the other hand, yield faster services and lower operating costs even if ridership accessibility is lower (Murray and Wu 2003).

This study focused on bus service in the city of Fairfax, Virginia, also known as the City-University-Energysaver (CUE) bus system, which serves George Mason University (GMU). Currently, the CUE bus provides service to local residents and GMU students in the city of Fairfax who need access to campus as well as other modes of transportation such as light rail. The primary objective was to estimate the operating costs savings and emission reductions that could be realized by eliminating some stops on CUE bus routes. The secondary objective was to determine if it is possible to eliminate some CUE bus stops without adversely affecting service coverage. To meet the latter objective, equity and tradeoff analyses were performed by looking at the characteristics of stops and the people who would lose coverage if some of the stops on the current CUE bus routes were eliminated.

The second section provides background on bus stop spacing and the costs and benefits (economic, environmental, and social) of eliminating some of them. The third section discusses the data used in the study and the study area. The fourth section discusses the methods used to identify bus stops eligible for elimination and explores the service improvements which could result from their elimination. The fifth section presents the results of the study and the effect that eliminating some stops could have on the populations currently served by the CUE bus. The last section presents the conclusions of the study and avenues for future research.

**Background**

*Public Transportation Today*

The quality of bus service is perceived differently by different users. From the user’s perspective, bus service quality is usually based on availability, frequency, travel speed, reliability and safety (Pratt 2000; Rood 1999; Phillips et al. 2001; Kittelson & Associates 2003; Kihl et al. 2005; Marsden and Bonsall 2006; Litman 2007; 2008; Stradling et al. 2007; Kenworthy 2008). Although these are equally important for bus service evaluation, due to data availability and time constraints, this study evaluated the service quality improvements that could be realized by eliminating some stops on CUE bus routes in terms of travel time. In addition, it explored how operating costs, transit-based emissions, and population coverage would change if some CUE bus stops were eliminated.
Stop Spacing

One way of improving the efficiency of bus service is via the appropriate spacing of stops. The proper spacing of stops can significantly improve the quality of bus service by decreasing travel times (Wirasinghe and Ghoneim 1981; Kocur and Hendrickson 1982; Fitzpatrick et al. 1997; Kuah and Perl 2001; Saka 2001; Chien and Qin 2004; Alterkawi 2006; Ziari et al. 2007). One of the key issues for determining the appropriate locations of bus stops is to have an understanding of how far people are willing to walk to get to the facilities (Ziari et al. 2007). Determining walking distance to and from bus stops presents two issues: knowledge of rider origins and destinations, and feasible walking distances along street networks (Furth et al. 2007).

One common method of identifying origins and destinations within bus service areas is to use the centroid of the population in those areas (Murray 2001; Saka 2001; Murray 2003; Furth et al. 2007). Because it is difficult to find the center of a population, the center points of individual blocks are often used to approximate population centers (Bielefeld et al. 1995; McElroy et al. 2003). Generating parcel-based centroid points using the parcel-network method would provide a highly detailed level of spatial accuracy regarding population coverage (Biba et al. 2010). However, due to a lack of parcel-level data, this study used block-level data to create service areas. Furthermore, unlike past research that used Euclidean distance to measure walking distances between origins and destinations (Okabe et al. 2008; Gutierrez and Gracia-Palomares 2008), the study used actual road network distances.

Another key issue is the appropriate walking distance to the facility. Accessibility to public transit is typically characterized as a reasonable walk under normal conditions (Murray 2003). Usually, facilities are located based on the simplified demand in the service areas (Wirasinghe and Ghoneim 1981; Brouwer 1983; Fitzpatrick et al. 1997). Others assume that it depends on population density—lower density corresponds to longer walking distances (Saka 2001; Ziari et al. 2007). Typical walking distances range from 400 m to 800 m. In this study, different walking distances between 400 m and 800 m were used to see how they impact bus service coverage.

Calculating bus travel times is also important for measuring improvements in bus service. Two basic delay factors—dwell time and acceleration/deceleration time—make buses slower; that is, they increase total bus travel times (Saka 2001; Chien and Qin 2004; Ziari et al. 2007). Although Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are frequently used to estimate these delays
(Srinivasan and Jovanis 1996; Hellinga and Fu 1999), the study used different delay variables to calculate them.

**Costs and Benefits**

Besides understanding the primary benefit of more efficient travel times that could be achieved by eliminating bus stops, it is also important to understand what other costs and benefits could be associated with this course of action (Savage 2009). This is known as impact analysis and entails an analysis of the impacts of changing transit services (Litman 2004). Research on public transit system improvements tends to adopt different perspectives. Most focus on the economic, environmental, and spatial effects of improving public transit service (Polzin 1999; Kennedy 2002; Bento et al. 2005; Brownstone and Small 2005; Harford 2006). Therefore, this study focused on the following tradeoffs of improved service on the CUE bus: economic effects (operating cost reductions), environmental effects (emission reductions), and spatial effects (residential service coverage). By analyzing the tradeoffs of reduced travel times that could be achieved by eliminating stops on the CUE bus routes, the study estimated the different impacts that could result from the change in transit service.

**Economic Effects: Operating Cost Reductions**

There are various ways to perform an economic analysis of a bus system. However, to estimate the financial impacts of two different routes, the differences in their operating costs provide a direct monetary comparison (Karlaftis and McCarthy 1999). Benjamin and Obeng (1990) found that reductions in operating costs for public transit could be achieved by increasing vehicle efficiency. In the United States, all operating costs that are not covered by bus fares come from either taxation through dedicated revenues or local, state, and federal government tax-derived monies (Harford 2006). It was, therefore, important to understand the financial savings that could be achieved by eliminating some stops on the CUE bus system.

**Environmental Effects: GHG Emissions Reductions**

Transportation is one of the major contributors to air pollution in the United States. Among the different sources of air pollution, on-road vehicle emissions are responsible for about 45 percent of the Environmental Protections Agency’s (EPA’s) 6 criteria pollutants (National Research Council 1995). Of the different greenhouse gases (GHGs) emitted by vehicles, carbon monoxide (CO), volatile organic compounds (VOCs), and nitrogen oxide (NO\textsubscript{x}) contribute the most (Grant et al.
CO and VOCs are emitted from the incomplete combustion of fossil fuels, whereas NO, is the product of high-temperature chemical processes that occur during the combustion process in the engine itself (National Research Council 1991). Even though emissions from diesel-fueled vehicles such as buses are only five percent of on-road vehicle emissions, emission rates for such heavy-duty vehicles are higher since they operate at higher combustion pressures and temperatures than gasoline-fueled vehicles (Lilly 1984). This means that even though their relative contribution to on-road vehicle emissions is limited, heavy-duty vehicles such as buses are highly hazardous to the environment. This study, therefore, explored the environmental benefits that could be realized by eliminating stops on CUE bus routes in terms of GHG emission reductions.

There are many ways to measure the amount of GHGs emitted by different types of vehicles. In fact, vehicle emissions are a function of several variables grouped into four main categories: travel-related factors, driver behavior, highway network characteristics, and vehicle characteristics (National Research Council 1995). In this study, only travel-related factors varied between the old (all current stops) and the new (without some stops) CUE bus routes, whereas the rest of the variables (driver behavior, highway network characteristics, and vehicle characteristics) remained the same. Travel-related factors included trip/vehicle use and speed/acceleration, which were used to calculate and compare the emissions between the two routes (National Research Council 1995). Trip/vehicle use emissions are simply a function of the total number of trips and total distance traveled by the vehicle. Speed/acceleration emissions are a function of the speed and acceleration of the vehicle over the distance of the trip. Eliminating some bus stops will yield improvements only in the travel speeds of buses. This means that other travel-related factors such as vehicle miles traveled and numbers of trips will not be affected by eliminating some bus stops. This study, therefore, used only the speed/acceleration factor to calculate and compare the emissions differences between the old and the new CUE bus routes.

**Spatial Effects: Residential Service Coverage**
 Eliminating some stops on the CUE bus routes could have an effect on residential service coverage. It was, therefore, important to explore the characteristics of riders who use the CUE bus to evaluate the costs of eliminating some of the bus stops that serve them. Exploring the demographic profiles of riders also helps to characterize the people who use public transit (Neff and Pham 2007) and derive
a relationship between public transit and the people that could be affected by changes in service (Polzin 1999).

Data

**GMU Commuting Survey**

GMU conducted a survey of faculty/staff and students in 2007 to better understand their commuting behavior. They were particularly interested in the factors that most influenced mode choices to campus for those living in the city of Fairfax. Results suggest that among 1,000 respondents, more than 75 percent of those who lived up to six miles from campus reported that commuting time was one of the main reasons for driving to campus. They further felt that current CUE bus service was not efficient enough, especially with respect to travel times.

**Data Sources**

Demographic data for the block groups in the study area are from the United States Bureau of the Census. Block group boundaries and road network data are from Environmental Systems Research Institute (ESRI). Two CUE bus routes (Gold and Green) along with their corresponding bus stops were created from the road network data from ESRI. Current CUE bus travel times and schedules were obtained from the City of Fairfax. Financial information on the CUE bus service for the year 2008 are from the National Transit Database (2008). The data include different operational and non-operational expenditures associated with the CUE bus service. Information on the fuel types used on the CUE buses was from the City of Fairfax. For the GHG emissions estimates, factors based on the speed of the CUE buses are from the Metropolitan Washington Council of Governments (MWCOG) (2010).

**Study Area**

The study area included the block groups served by the CUE bus routes within the city of Fairfax. In addition, several block groups from within the jurisdiction of Fairfax County were included because they are also served by CUE bus routes. Two of these block groups from within Fairfax County include GMU and the Vienna/Fairfax-GMU Metro station, which is the last westbound stop on the Orange Line. Figure 1 is a map of the study area including the CUE bus routes.
Figure 1. CUE bus routes with stops and block-level population
Methods

Equity Analysis

It appeared that analyzing the tradeoffs of eliminating some stops on the CUE bus routes may be amenable to standard cost-benefit analysis (Litman 2009). However, further reflection revealed that some of the costs of eliminating some stops was not easily monetized. For example, costs attributable to shrunken residential service coverage are usually classified as social costs. Monetizing such social costs is difficult. Therefore, standard cost-benefit analysis may not provide an accurate estimate of the tradeoffs related to residential service coverage.

One way to account for such social costs is via equity analysis (Litman and Doherty 2009). In simple terms, equity refers to the distribution of various social and/or economic impacts and whether those distributions are considered appropriate (Litman 2002). Equity analysis generally is considered a complicated procedure, as there is no single way to evaluate equity. Evaluation usually depends on the type of equity, the way people are categorized, which impacts are considered, and how equity is measured.

In the study, transportation equity was measured by the reduction in operating costs, the reduction in GHG emissions and the improvement in overall fleet speed that could result from eliminating some stops on the CUE bus routes. Access to bus service was measured by estimating the extent of the changes in residential service coverage that could result from eliminating some stops on the CUE bus routes. Additionally, the demographic profiles of the residents who would no longer be serviced by the CUE bus routes after their stops had been eliminated was also taken into consideration in the equity analysis. This helped to assess the potential social costs of eliminating some of the stops on the CUE bus routes.

Walking Distance Thresholds

Using block group centroids to represent service areas and bus stops to represent facilities, a network analysis was undertaken to find the nearest facilities within different walking distances from the centroids. The network analysis used a shortest path algorithm to find the closest facility for each service area. In less densely-populated areas, such as the city of Fairfax, the most realistic walking distance threshold is 800 m (Demetsky and Lin 1982; Saka 2001; Ziari et al. 2007). It is also the most conservative walking distance threshold, given that most riders in North America (75–80%) walk 400 m or less to bus stops (Kittelson & Associates 2003). However, to better understand how different walking distances change residential
service coverage, walking distances of 200 m, 400 m and 600 m were also tested. In addition, the network analysis was undertaken without any walking distance threshold to ensure that all of the service areas were covered. This latter analysis offered a glimpse of the maximum number of facilities required to provide complete coverage in the study area.

**Eliminating Bus Stops**

After undertaking the nearest facility analysis for all five walking distance thresholds (200 m, 400 m, 600 m, 800 m and none), the minimum number of bus stops used at each walking distance was obtained. Those facilities that were not selected at any of the walking distance thresholds were assumed to be eligible for elimination. The reasons that some bus stops were never selected, no matter the walking distance threshold, was because some of the census block centroids were beyond the maximum walking distance threshold (800 m) or the closest census block centroid was already served by another bus stop. In either case, those bus stops that were never selected were labeled as eligible for elimination. Figure 2 is a map of the study area including the CUE bus routes and the stops that were eliminated.

![Figure 2. CUE bus routes, stops, and eliminated bus stops](image-url)
Based on previous research (Demetsky and Lin 1982; Saka 2001; Murray 2003; Ziari et al. 2007) and given that many of the block groups in the study area are sparsely populated, 800 m was an appropriate walking distance benchmark for the study. Using the 800 m walking distance threshold, therefore, those bus stops that were not selected were eliminated from the CUE bus routes.

**Bus Stop Delays**

Two factors that contribute significantly to time delays at bus stops are acceleration/deceleration delay and dwell time delay. These delays can consume up to 26 percent of total bus travel times (Rajbhandari et al. 2003). Acceleration/deceleration delay occurs when the bus is pulling in or out of the bus stop. Dwell time delay refers to the time delay to load and unload riders at bus stops. The two factors are calculated from the following equations (Saka 2001; Chien and Qin 2004; Ziari et al. 2007). The first equation calculates the time delay due to decelerating/accelerating:

\[
T_{acc/dec} = \left( \frac{V}{acc} \right) + \left( \frac{V}{dec} \right),
\]

where

\[
T_{acc/dec} = \text{acceleration/deceleration delay}
\]

\[
V = \text{bus cruising speed (m/s)}
\]

\[
acc = \text{bus acceleration (m/s}^2\text{)}
\]

\[
dec = \text{bus deceleration (m/s}^2\text{)}
\]

By multiplying the total number of riders by the dwell delay for each rider, the following equation calculates the total dwell time delay for each bus stop:

\[
T_w = Q \times w,
\]

where

\[
T_w = \text{dwell time delay (s)}
\]

\[
Q = \text{number of riders at the stop}
\]

\[
w = \text{time to board/unboard each rider}
\]

Cruise speed (\(V\)) and acceleration/deceleration (\(acc/dec\)) were from the current CUE bus schedule. The cruise speed was about 12 m/s (~27 mi/hr), and acceleration and deceleration was about 2 m/s\(^2\) (Furth and SanClemente 2006). Data for
other time delay variables were from direct observation on the CUE bus: the average number of riders at the stops \( Q \) was 4; and the time to board/unboard each riders \( w \) was 5 s. Using the above equations and data, the time delay at each stop on the CUE bus route \( T_w \) was 20 s. It is important to note that this time delay was based on an observed number of riders per stop who on-boarded and off-boarded the CUE bus. Because it was an average for all stops, it masked differences between stops in the number of riders who on- and off-boarded the bus, the speed with which subsequent riders were able to board the bus after the initial rider boards the bus and the effects of near- and far-side stops on time delays. Each of these issues was important in the calculation and sensitivity of the time delay estimates and is, therefore, worthy of future research.

**Total Travel Time**
The following equation calculates total travel time for the new bus routes (Saka 2001):

\[
T_{\text{bus}} = N \times \left( T_{\text{acc/dec}} + T_w \right) + T_v,
\]

where

- \( T_{\text{bus}} = \) total bus travel time
- \( N = \) total number of bus stops
- \( T_v = \) time for CUE bus to make a one-way trip at cruise speed (s)

Total travel time is the time it took the CUE bus to make a one-way trip on the new and old routes. The first part of the equation calculated the total delay at each stop; multiplying that expression by the total number of stops \( N \) resulted in the total delay for a one-way trip. The total delay depends on the number of stops on the route. Using the network analyst tool in GIS, the total route distance estimate was 42,890 m (26.65 mi). Therefore, the time for the CUE bus to make a one-way trip at cruise speed \( T_v \) was 3,574.16 s. Using Eq. (3), the total travel time for both the old and the new CUE bus routes was calculated. The number of bus stops on the old CUE bus route was 121, and the number of bus stops on the new CUE bus route was 68. One assumption of Eq. (3) is that the CUE bus does not skip any of the available stops on either the new or the old routes—an assumption that is not realistic. This means that the total travel time estimates from Eq. (3) for the new and old routes would be higher than the observed total travel times, given that the CUE bus was already making one-way trips faster than expected.
**Operating Cost Reductions**

Annual operating cost data for the CUE bus are from the National Transit Database (2008). The database includes operating costs for the CUE bus from 2001 to 2008. However, only operating costs for the year 2008 appear in the study to reflect the most recent expenditures. Annual operating costs are in four different categories: operations, maintenance, non-vehicle, and general administrative. Operations costs include operator’s wages, fringe benefits and services. Maintenance costs include fuel and lube, tires, and other. Non-vehicle costs include casualty and liabilities and utilities. Administrative costs include other wages and salaries. Vehicle fleet size is the total number of vehicles available for operations in a given year. Vehicle revenue hour is the hours that vehicles are scheduled for or actually are in revenue service (including layovers and recovery times).

A simple mathematical approach to estimate the total operating costs is to sum all of the costs and then divide by the Vehicle Revenue Hour (VRH), which was $34,602, to get the total cost per hour to operate the CUE bus (Bruun 2005). Following this approach, total operating costs (TOC) and total operating costs per hour (TOCH) were $2,980,627 and $86.14, respectively. TOCH provides a calculation of total operating costs for any given hour of operating the CUE bus. However, it may not accurately reflect total operating costs for the purposes of the study. One of the objectives of the study was to estimate the cost savings in operating the CUE bus that could be realized by eliminating some stops on the route. To that end, some of the subcategories of costs, such as administrative salaries, operations fringe benefits and non-vehicle casualties and liabilities would not be affected by the elimination of some CUE bus stops. The exclusion of the above costs from the calculation of the TOC and TOCH, therefore, provided a more accurate calculation of the costs of operating the CUE bus for the study. The more accurate TOC and TOCH were $1,791,127 and $51.76, respectively.

**Emissions Reductions**

To calculate CUE bus emissions at cruise speed, emissions factors for diesel buses from the Metropolitan Washington Council of Governments (2010) and the United States Environmental Protection Agency (2003) were used. MWCOG’s approach is based on the EPA’s Mobile6 emissions factors model, which estimates emissions factors based on the average speed of diesel buses. It calculates CO, VOCs, and NOx—including both NO and NO2—depending on average vehicle speed. Even though emissions factors were available from 1990 to 2005, only data for the most recent year were used to make it timelier.
The emissions analysis in the study would be more accurate if carbon dioxide (CO$_2$) emissions were included. However, because sufficient information on the speed of the vehicle was not available, only CO, VOC, and NO$_x$ emissions were calculated in the study. Besides, CO, VOC, and NO$_x$ are the predominant air pollutants from road transportation sources (Grant et al. 2007). On average, in the United States, road transportation sources are responsible for 55 percent of CO, 27 percent of VOC, and 35 percent of NO$_x$ towards overall GHG emissions.

As mentioned above, the total, one-way route distance for the CUE bus was 42,890 m (26.65 mi) and the total, one-way travel time for the CUE bus was 7,440 s (2.07 hr). Therefore, the cruise speed of the bus was ~13 mi/hr. With this information and the emissions factors from MWCOG, the following equation calculated CO, VOC, and NO$_x$ emissions from the CUE bus at different cruise speeds:

$$ E = EF \times D, $$  

where

- $E =$ CO, VOC, or NO$_x$ emissions (g)
- $EF =$ CO, VOC, or NO$_x$ emissions factors at different speeds (g/mi)
- $D =$ total CUE bus route distance (mi)

The results section shows the calculations for emissions reductions that could be realized after eliminating some of the stops on the CUE bus route.

**Results**

**Travel Time Reduction**

Table 1 shows how facility usage and service area coverage would change at different walking distance thresholds. Clearly, eliminating some CUE bus stops has the potential to reduce travel times without unduly affecting service area coverage. At the ideal walking distance threshold (800 m), 56.2 percent of the available facilities were used, but fully 82.5 percent of the service area was covered. This translates to a potential travel time reduction of 23 percent (approximately 28 min) (Table 2). It is important to qualify this estimate because it assumes, as mentioned above, that the CUE bus stops at all available stops. This is not likely, especially during the summer when demand is lower than during the fall and spring semesters. This means that the potential travel time reduction would probably be less than 28 min because the CUE buses would already be skipping some stops.
Table 1. Facility Usage and Service Area Coverage at Different Walking Distance Thresholds

<table>
<thead>
<tr>
<th>Walking Distance Threshold (m)</th>
<th>Total Facilities</th>
<th>Facilities Used</th>
<th>Facilities Used (%)</th>
<th>Total Area (acs)</th>
<th>Service Area (acs)</th>
<th>Service Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>121</td>
<td>29</td>
<td>24.0</td>
<td>251</td>
<td>51</td>
<td>20.3</td>
</tr>
<tr>
<td>400</td>
<td>121</td>
<td>52</td>
<td>43.0</td>
<td>251</td>
<td>112</td>
<td>44.6</td>
</tr>
<tr>
<td>600</td>
<td>121</td>
<td>66</td>
<td>54.5</td>
<td>251</td>
<td>177</td>
<td>70.5</td>
</tr>
<tr>
<td>800</td>
<td>121</td>
<td>68</td>
<td>56.2</td>
<td>251</td>
<td>207</td>
<td>82.5</td>
</tr>
<tr>
<td>None</td>
<td>121</td>
<td>71</td>
<td>58.7</td>
<td>251</td>
<td>249</td>
<td>99.2</td>
</tr>
</tbody>
</table>

Table 2. Travel Time Reduction between Old and New CUE Bus Routes

<table>
<thead>
<tr>
<th>CUE Bus Route</th>
<th>Stops (n)</th>
<th>Total Delay (s)</th>
<th>Total Travel Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old</td>
<td>121</td>
<td>3,872</td>
<td>7,446</td>
</tr>
<tr>
<td>New</td>
<td>68</td>
<td>2,176</td>
<td>5,750</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td></td>
<td></td>
<td>23</td>
</tr>
</tbody>
</table>

Operating Cost Reduction

The impressive travel time reduction means that operating costs could also be reduced by eliminating some of the CUE bus stops. The total operating cost per hour (TOCH) for the CUE bus was $51.76. Multiplying TOCH by the old and new total travel times (2.07 hrs and 1.60 hrs, respectively), the old and new operating costs were $108.70 and $82.82, respectively. Overall operating costs for single, one-way trips by CUE buses could therefore be reduced by $25.88 if some of the stops were eliminated. Because CUE buses made 312 trips per week, the total weekly projected operating cost reduction would be $8,074.56.

Emissions Reductions

Using Eq. (4) and the emissions factors for diesel buses, the GHG emissions reductions that could be realized by eliminating some CUE bus stops are as follows. For the old route with a cruise speed of 13 mi/hr, emissions of CO, VOC, and NO\textsubscript{x} are 1.23 lb, 0.11 lb, and 1.21 lb, respectively. For the new route with a cruise speed of 17 mi/hr, emissions of CO, VOC, and NO\textsubscript{x} are 0.82 lb, 0.09 lb and 1.09 lb, respectively. GHG emissions could, therefore, be reduced by eliminating some of the stops on the CUE bus—CO could be reduced by 33.34 percent, VOC could be reduced by 18.18 percent, and NO\textsubscript{x} could be reduced by 9.92 percent. Interestingly, Table 3 and Figure 3 show that annual emissions of the GHG emissions CO and NO\textsubscript{x} would
decrease the most over the range of eliminated stops on the CUE bus (0 to 53 stops eliminated).

### Table 3. Number of Stops Eliminated and Changes in Population, Costs, Travel Times, and Emissions

<table>
<thead>
<tr>
<th>Stops Eliminated (n)</th>
<th>Population Coverage (%)</th>
<th>Annual Cost Reduction ($)</th>
<th>Travel Time Reduction (min)</th>
<th>Emissions (lb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CO</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NO₂</td>
</tr>
<tr>
<td>53</td>
<td>89</td>
<td>407,517.59</td>
<td>29</td>
<td>12,292.60</td>
</tr>
<tr>
<td>50</td>
<td>99</td>
<td>384,450.56</td>
<td>27</td>
<td>13,610.76</td>
</tr>
<tr>
<td>30</td>
<td>99</td>
<td>230,670.34</td>
<td>16</td>
<td>16,896.57</td>
</tr>
<tr>
<td>20</td>
<td>99</td>
<td>153,780.22</td>
<td>11</td>
<td>17,508.31</td>
</tr>
<tr>
<td>10</td>
<td>99</td>
<td>76,890.11</td>
<td>5</td>
<td>18,065.10</td>
</tr>
<tr>
<td>5</td>
<td>99</td>
<td>38,445.06</td>
<td>3</td>
<td>18,325.16</td>
</tr>
<tr>
<td>0</td>
<td>99</td>
<td>0.00</td>
<td>0</td>
<td>18,472.43</td>
</tr>
</tbody>
</table>

**Figure 3. Changes in annual emissions by number of stops eliminated**
Tradeoffs

Eliminated Bus Stops by Category

All of the CUE bus stops, both eliminated and retained, were categorized as either commercial, recreational, residential or shopping stops. The categorization of bus stops was based on inspection of the CUE bus route map and observations from riding the CUE bus. Stops close to major commercial landmarks such as restaurants, banks, metro stations and schools were categorized as commercial stops. Stops close to housing units were categorized as residential stops and stops close to park and recreational facilities are categorized as recreational stops. Finally, stops close to shopping centers were categorized as shopping stops. Table 4 shows the tally of these bus stops. Among the 53 bus stops that were eliminated from the old route, 15 were commercial, 21 were recreational, 3 were residential, and 14 were shopping stops. Similarly, among the 68 bus stops that were retained from the old route, 35 were commercial, 10 were recreational, 3 were residential, and 20 were shopping stops.

Table 4. Categorization of Eliminated and Retained Stops

<table>
<thead>
<tr>
<th>Category</th>
<th>Eliminated</th>
<th>Retained</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>14</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Recreational</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Residential</td>
<td>15</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Shopping</td>
<td>21</td>
<td>10</td>
<td>31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>53</strong></td>
<td><strong>68</strong></td>
<td><strong>121</strong></td>
</tr>
</tbody>
</table>

Looking further into the categories of bus stops that were eliminated, 68 percent ([21 ÷ 31] × 100%) of the shopping stops were eliminated. Furthermore, 41 percent ([14 ÷ 34] × 100%) and 30 percent ([15 ÷ 5] × 100%) of the commercial and residential stops, respectively, were eliminated. Fifty percent ([3 ÷ 6] × 100%) of the recreational stops were eliminated, but because recreational stops make up such a small percentage of all CUE bus stops ([6 ÷ 121] × 100% = 5%), the loss of recreational stops was actually small. The loss of shopping stops means that residents would have to walk further to either the next nearest bus stop or to the shopping center itself. However, because most people do not use public transit for shopping trips, particularly food shopping trips, the elimination of these stops would not be as significant as it first appears.
Residential Service Coverage

One difficulty of capturing the residential population that lives within proximity of the eliminated bus stops was choosing the appropriate buffer distance between the bus stop and the population center. Murray (2003) suggested that 400 m would be an ideal buffer distance for a city area to estimate the effect of eliminating bus stops. Others have suggested suitable buffer distances from 200 m to 300 m (Ziari et al. 2007). In this study, a middling buffer distance of 300 m was used to capture the population that would be most affected by the elimination of some CUE bus stops.

The coverage analysis using a 300 m buffer distance around the 15 residential bus stops that were eliminated shows that 3,588 residents (approximately 10% of the city of Fairfax’s population) would be affected. The demographic analysis on the residential population was further broken down into various racial groups living within proximity of the eliminated bus stops. White residents (57%) would be most affected, followed by Hispanic (20%), Asian (15%), and African American (5%) residents. Other residents, including Native Americans and Asian and Pacific Islanders, made up the remaining 3 percent of the affected resident population. Further demographic analysis shows that none of these racial groups would be disproportionately affected by eliminating those 15 bus stops.

Residents living within proximity of the eliminated bus stops who are members of other groups may also be adversely affected. In particular, residents who are 65 years of age or older and no longer participating in the labor force may prefer more accessible stops over faster bus service. For these residents, time is not as important as access. Demographic analysis on the resident population, however, showed that few residents in the study area were 65 years or older. This is consistent with the housing pattern at the Fairfax campus of George Mason University, where off-campus accommodations for undergraduate and graduate students makes up for a lack of on-campus accommodations. This also makes the results of the study less generalizable to different geographies with a more balanced demographic profile of younger and older residents.

Conclusions

According to our model, eliminating some of the stops on the current CUE bus route could reduce one-way travel times and operating costs by a projected 23 percent. The observed magnitude of the travel time reductions needs to be verified with data on speed differences based on bus stop densities; however, improving
travel times would boost ridership. In addition, savings from lower operating costs could be used to improve other aspects of the CUE bus service (for example, reducing fares or improving bus stop facilities) to further boost ridership. In addition to the operations benefits, eliminating some bus stops would be good for the environment. The new route could reduce GHG emissions of CO, VOC, and NO\textsubscript{x} by 34, 18 and 10 percent, respectively. On average, the new route could reduce annual GHG emissions of CO, VOC, and NO\textsubscript{x} by 6,278, 241, and 1,789 lbs, respectively. For year 2008, the total amount of on-road vehicle emissions nationwide of CO, VOC and NO\textsubscript{x} was approximately 38, 2.5 and 4.2 mil tons (United States Environmental Protection Agency 2009). While the potential GHG emissions reductions that could result from eliminating some stops on the CUE bus route may pale in comparison to nationwide GHG emissions, these reductions would be significant for the city of Fairfax. Finally, only 10 percent of the resident population of Fairfax would be directly affected by eliminating some of the CUE bus stops. This latter finding suggests that resident service coverage would likely not be a problem.

Transit riders are sensitive to comfort and convenience improvements in service (Phillips et al. 2001; Litman 2004; Litman 2008). And, surely, they are sensitive to the elimination of service. One limitation of the study, therefore, is that the tradeoff of lost ridership due to the elimination of more accessible bus stops was not taken into consideration. For example, the policy of the CUE bus is not to stop between stops to load or unload riders. This policy could raise objections from riders who are fearful of walking longer distances to the next nearest bus stop, especially in the dark (though adoption of a more flexible policy to stop at night between stops could address such objections). Another limitation is that the study did not attempt to account for the potentially adverse effects that eliminating some CUE bus stops could have on commercial, recreational and shopping trips by residents. These trips are important for households in the service area who do not have private vehicles. Surveys of CUE bus riders could help to address these limitations and ultimately provide a more detailed assessment of the potential tradeoffs of eliminating some CUE bus stops.

References


Litman, T. 2009. Transportation cost and benefit analysis: Techniques, estimates and Implications. Victoria Transport Policy Institute, Victoria, BC.


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