<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Importance of Trip Destination in Determining Transit Share</td>
<td>Gary Barnes</td>
<td>1</td>
</tr>
<tr>
<td>Impact of High-Speed Lines in Relation to Very High Frequency Air</td>
<td>Andrés López-Pita, Francesc Robusté</td>
<td>17</td>
</tr>
<tr>
<td>Services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Racial Differences and Pedestrian Safety: Some Evidence from Maryland</td>
<td>Randal Reed, Siddhartha Sen</td>
<td>37</td>
</tr>
<tr>
<td>and Implications for Policy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of Statistical Process Control in Bus Fleet Maintenance at</td>
<td>Anna Lynn Smith, Sohail S. Chaudhry</td>
<td>63</td>
</tr>
<tr>
<td>SEPTA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can Trip Planner Log Files Analysis Help in Transit Service Planning</td>
<td>Martin Trépanier, Robert Chapleau, Bruno Allard</td>
<td>79</td>
</tr>
</tbody>
</table>

Our troubled planet can no longer afford the luxury of pursuits confined to an ivory tower. Scholarship has to prove its worth, not on its own terms, but by service to the nation and the world.
—Oscar Handlin
The Importance of Trip Destination in Determining Transit Share

Gary Barnes
Humphrey Institute of Public Affairs, University of Minnesota

Abstract

For a variety of reasons, policymakers in recent years have taken a greater interest in increasing the use of transit. However, it is difficult to substantially impact transit use at a large scale, because it is strongly dependent on development density and other slow-changing features of urban land use. This article argues that policymakers hoping to increase transit use should focus on increasing the size of downtowns and developing suburban job centers at downtown sizes and densities. There are both empirical and practical arguments.

Empirically, large, dense destinations have a very substantial impact on mode choice, regardless of the characteristics of the trip origin. From a practical standpoint, there are two arguments. First, it may be easier to increase densities in commercial areas, both because political opposition is less acute and because developable land is often more available. Second, commercial areas can be developed at much higher densities, with a corresponding impact on transit ridership.
Introduction
There are few options available for policymakers hoping to manage the problem of urban traffic congestion. One of these involves reducing the number of cars on the road by shifting trips to transit. However, although transit use has generally been holding constant over the last few years, there have been few, if any, major examples where transit share has substantially increased as a result of policy intervention.

One likely reason for this is that transit use is highly dependent on the nature of the urban land use in which transit operates. A multitude of studies have confirmed the link between residential population density and the share of trips made by transit. The link is so well established that the most visible recent literature is concerned with identifying specific characteristics of neighborhood design that are important to the decision to use transit. Boarnet and Crane (2001) provide an extensive recent survey of the literature on the effect of urban design characteristics on transit share and other travel behavior measures.

A critical issue in this debate is the relative lack of acknowledgment of the role that trip destinations play in determining transit use. The work of Calthorpe (1993), for example, has been very influential among policymakers, but is focused on residential neighborhood characteristics. Some studies, such as Cervero and Gorham (1995), include measures such as access to downtown in the analysis; however, actual differences in destination choice, as opposed to hypothetical access measures, are usually not considered. Frank and Pivo (1994) are an exception. They find a "dramatic increase" in transit use at high employment densities. However, they do not place this finding within a broader context of overall urbanized area transit share.

A significant work that addressed the destination as a key contributor to transit use was Pushkarev and Zupan (1977). Their conclusions about the importance of employment density in determining transit use do not seem to have had much influence on recent studies, despite the high quality and comprehensiveness of their work. Indeed, many of the results and arguments in the present article appeared in Pushkarev and Zupan 25 years ago. Given recent hopes for using transit as a congestion management tool, this seems like a good time to bring them up again.

Table 1 illustrates anecdotally the importance of the central business district (CBD) in determining overall urbanized area transit share. A more formal analysis
of the 31 largest U.S. urbanized areas in Barnes (2001) found that a measure of the localized density of employment (essentially a proxy for the size and density of the downtown) explained considerably more of the variation in transit share across cities than did measures of residential density.

The omission of destination choice from transit share analyses is important from a methodological standpoint, because differences in transit share across neighborhoods or even urban areas may be inappropriately attributed to residential characteristics when they are really due to differing destination choices. It is also important from a policy perspective, because the overwhelming academic focus on residential characteristics can give policymakers the impression that nothing else matters.

The purpose of this article is to make the case that destination choice not only is a critical variable in the determination of transit use, but that, from a policy standpoint, it is more important than residential characteristics. Empirically, it matters not only because the overall transit share from a given trip origin is strongly dependent on the destination, but also because the impact of increasing residential density is very different as trip destinations change.

Perhaps even more importantly, transit destination matters to policy because it is, as a practical matter, considerably easier to have a substantial impact on commercial areas than on home locations. It is very difficult to increase density in both existing residential neighborhoods and new developments, due to both political and economic reasons. These constraints are not true to the same extent as com-

Table 1. Transit Share and Destination Across Cities (1990)

<table>
<thead>
<tr>
<th>City</th>
<th>Transit Share to CBD</th>
<th>Transit Share to Non-CBD Destinations</th>
<th>Percent of Total Regional Jobs in CBD</th>
<th>Overall Urbanized Area Transit Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles</td>
<td>14.3</td>
<td>3.8</td>
<td>5.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Atlanta</td>
<td>15.7</td>
<td>3.7</td>
<td>9.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Twin Cities</td>
<td>22.0</td>
<td>3.0</td>
<td>15.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>29.0</td>
<td>3.6</td>
<td>20.1</td>
<td>8.7</td>
</tr>
</tbody>
</table>
mercial areas. Downtown areas are routinely developed at extremely high job densities with much less opposition and fewer constraints.

This article is written from the perspective of increasing transit share of worktrips as a way of managing peak period congestion, not to improve transit agency cost recovery. Indeed, without a corresponding increase in off-peak transit use to keep the additional buses and drivers occupied, such a strategy may impose higher costs on the transit agency. This, in turn, may necessitate higher subsidies (justified by reduced congestion costs) or strategic subcontracting of routes with little off-peak demand. These are important issues to consider when developing land use strategies.

The first part of this article contains a simple empirical analysis of transit use in the Minneapolis-St. Paul metropolitan area. The objective is to clarify the impact of trip destination relative to origin neighborhood characteristics and to establish that this is a variable that matters a great deal. The second part of the article discusses, from a theoretical and political perspective, why commercial land use, rather than residential, represents a more viable policy option for influencing transit use.

**Empirical Analysis**

The Minneapolis-St. Paul (Twin Cities) metropolitan area is a seven-county region with about 2.5 million residents. There are two separate downtowns about 10 miles apart; the two central cities abut each other and have about 650,000 residents between them. This analysis uses an aggregation of the 1,165 regional traffic analysis zones into 66 larger zones. These are loosely based on political boundaries with the objectives of maintaining roughly similar populations across zones and uniform land uses within zones. In this way, some small cities and towns are combined, and some large cities are broken into multiple zones. Except for three cases (the two downtowns and the airport), all the zones have at least 10,000 residents. Figure 1 shows the zones and their division, for purposes of this analysis, into non-central city, central city nondowntown, and the two downtowns.

The zone corresponding to the Minneapolis downtown has about 125,000 jobs in about 2 square miles. The St. Paul downtown has about 60,000 jobs in a slightly smaller area. In both cases, the jobs are concentrated in the center of the zone. The Minneapolis campus of the University of Minnesota constitutes a third subcenter of about 35,000 jobs; after this, job densities are much lower in the rest of the
The Importance of Trip Destination in Determining Transit Share

While some suburban zones have many jobs, they are spread out over large land areas, and are very difficult to serve effectively with transit. As a result, much of the transit service in the region is focused around the two downtowns.

The analysis uses 1990 Census Transportation Planning Package (CTPP) data for the Twin Cities to analyze the relative impacts of destination, residential density, and a number of other variables in determining transit share for worktrips. The densest residential zone has about 13,500 people per square mile; the second densest is about 9,000. About a third of the zones are essentially nonurbanized, with densities below 1,000 per square mile. About a third of the zones have overall worktrip transit shares below 2 percent, another third are between 2 and 5 percent, and the final third are higher than 5 percent. About half of these have shares in excess of 15 percent up to a maximum of 27 percent. The overall density of the region.
urbanized part of the region is about 2,000 per square mile; the overall worktrip transit share in 1990 was 5.9 percent.

**A Simple Analysis**

An initial illustration of the importance of the destination aggregates the zones into three area types. The first consists of all zones that are not in one of the two central cities. The second is central city zones, excluding the downtowns. The third area consists of the two downtowns. Table 2 shows the worktrip transit share and the total number of transit worktrips from each origin area type to each destination area type.

<table>
<thead>
<tr>
<th>From Row to Column</th>
<th>Noncentral City</th>
<th>Central City</th>
<th>Downtowns</th>
<th>Total from Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noncentral City</td>
<td>610,090</td>
<td>132,237</td>
<td>101,523</td>
<td>843,850</td>
</tr>
<tr>
<td>Central City</td>
<td>97,391</td>
<td>122,887</td>
<td>72,179</td>
<td>292,457</td>
</tr>
<tr>
<td>Downtowns</td>
<td>2,287</td>
<td>2,430</td>
<td>5,746</td>
<td>10,463</td>
</tr>
<tr>
<td>Total to Destination</td>
<td>709,768</td>
<td>257,554</td>
<td>179,448</td>
<td>843,850</td>
</tr>
</tbody>
</table>

While the importance of the origin is further confirmed by the fact that central city residents are considerably more likely to use transit to access all destinations, the key point for purposes of this article is the very high transit shares into the downtown areas relative to the rest of the central cities. A relatively high share is obtained even from noncentral city origins, which includes a huge area and population, most of which has little, if any, easily accessible transit service. It is also worth noting that this is based on 1990 data. Express service into the downtowns from suburban areas was expanded considerably during the 1990s in the Twin Cities, so the difference between origins may be even smaller now.

Failure to account for differences in destination choice can lead to inappropriate conclusions regarding the importance of various origin characteristics. There is particular reason to be concerned about this issue in studies that compare matched pairs of origins. Table 3 shows an example of two (hypothetical) central city origins, which differ only in the fraction of their workers who commute into downtown versus the suburbs. The fact that origin 2 has more people working
The Importance of Trip Destination in Determining Transit Share

downtown, and fewer in the suburbs, leads to a 5.3 percent increase in transit share compared to origin 1, even when the transit shares broken down by destinations are identical.

Table 3. Impact of Differing Destinations on Transit Share

<table>
<thead>
<tr>
<th>Destination</th>
<th>Transit Share to Destination</th>
<th>Percent Working at Each Destination (Origin 1)</th>
<th>Percent Working at Each Destination (Origin 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Central City</td>
<td>4.78</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Central City</td>
<td>11.13</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Downtowns</td>
<td>31.22</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Total Transit Share</td>
<td>12.6</td>
<td>17.9</td>
<td></td>
</tr>
</tbody>
</table>

Regression Analysis

A second, more detailed analysis involved a series of regressions using origin zone transit shares to various destinations as the dependent variable. The regressors were population density, an income measure, and distance of the origin zone from the nearest downtown. The income measures were average zonal income and the fraction of households in the zone with income below $25,000 (1990 dollars). The second of these turned out to be the superior variable in terms of significance and explanatory power.

The distance of the zone from downtown was never significant when included in a regression with population density; thus, it is omitted here. This is to say that, while distance from downtown strongly influences where people work, it does not apparently influence whether they use transit to get there, given where they work and given the residential density of the origin zone.

One final point is that the downtown zones generated transit shares as origins that were quite disproportionate to their density and income characteristics, to the extent that they substantially distorted the regression results. This happened because residents of these areas could take advantage of the superior transit service created by the high downtown destination densities. These two zones were omitted; the regressions were run using the other 64 origin zones.
For every destination, population density (in thousands of people per square mile) and percent of total households with low incomes were always statistically significant, and no other variable was significant when included with these two. Table 4 shows the regression results for the three destination types, and for overall transit share. The entry of “0” indicates a result that was not statistically significant. All other entries are significant at a 5 percent level or better. The R squared figures indicate that about 80 percent of the variation in transit share across zones was explained by differences in these two variables, given a particular destination.

**Table 4. Regression Result**

<table>
<thead>
<tr>
<th>Destination</th>
<th>Intercept</th>
<th>Population Density Beta</th>
<th>Low Income Beta</th>
<th>R squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Downtown</td>
<td>6.3</td>
<td>2.43</td>
<td>0.70</td>
<td>.76</td>
</tr>
<tr>
<td>To Central City</td>
<td>0</td>
<td>1.15</td>
<td>0.31</td>
<td>.83</td>
</tr>
<tr>
<td>To Suburbs</td>
<td>-1.4</td>
<td>0.63</td>
<td>0.19</td>
<td>.80</td>
</tr>
<tr>
<td>All Destinations</td>
<td>-1.9</td>
<td>1.49</td>
<td>0.45</td>
<td>.86</td>
</tr>
</tbody>
</table>

The interpretation of these numbers would mean, for example, that an extra 1,000 people per square mile in a given area would add 1.49 percentage points to the overall transit share for that area, and an extra 1 percent of the households having low incomes would add 0.45 percentage points, if the work destinations are the average for the region. However, in a hypothetical residential zone where everyone worked in the suburbs, such as might happen in an exurban development, the same density increase of 1,000 per square mile would increase the transit share by only 0.63 percentage points.

**Varying Impact of Residential Density**

The key point of this analysis is that higher residential population density has a much bigger impact on transit share for trips that are going to downtown areas, or, in principle, to suburban areas of similar size and density. The impact is roughly twice as big as it is for other central city destinations and four times bigger than for suburban destinations. Residential neighborhood characteristics matter, but the extent to which they matter is very strongly influenced by where people are going.
The very high intercept value for trips to downtown highlights this point; this represents essentially the worst case transit share. Thus, a population density of just 1,000 per square mile would generate a transit share of 8.73 percent into downtown (the intercept of 6.3 plus the density increment of 2.43). It would take a density of 7,500 per square mile to get the same transit share to other central city destinations (no intercept, and a density increment of 1.15). Even more striking, it would take a density of 16,000 per square mile (denser than any zone in the Twin Cities) to get an 8.73 percent transit share from an origin where everyone works in the suburbs (intercept of –1.4, plus a density increment of 0.63). This could raise questions about the likely efficacy of new high-density residential developments on the urban fringe, in terms of increasing transit use.

There is an important policy point here. There has been much discussion in the literature and among policymakers of the need for higher density residential development as a prelude to higher transit use. But the relationship between residential density and transit use is not as simple as it is often portrayed. The impact of higher residential density is very strongly dependent on the characteristics of the areas where the residents work. Increasing the size and density of work locations, at least beyond some minimum threshold, will increase the likelihood of transit use by the people that work there, even if the residential density around their home does not change at all.

**Using Commercial Development to Impact Transit Use**

The focus of this study is the explicit identification of the work destination as an important variable in determining transit share. It influences both the overall share and how changes to residential density impact transit use. While most of the literature focuses on residential density, the finding in the previous section is that there are two different land use tools for influencing transit use: increases in residential density and the development of large, dense, commercial centers. The second purpose of this article is to argue that the latter of these is actually the better policy tool, both politically and from the standpoint of the potential impact.

**Constraints on Residential Development Density**

While it may be true that in most American cities there is more demand for than supply of high-density residential environments, it is also probably true that the number of people desiring to live in such an environment, who do not already do so, is probably not large enough to impact regional transit use very much.
ing a significant regional increase in transit use would be much easier if somehow transit use could also be increased among all the people who are already housed in lower density environments. From the standpoint of using residential development as the lever, this would require increasing the density of existing neighborhoods.

In this case, there is the problem of convincing the existing residents, who tend to have two issues with new development. First, the reason they moved to the area was because they liked the environment, so they will oppose anything that changes it much. Second, rightly or wrongly, people see high-density and especially rental housing as attracting undesirable types of residents. Therefore, there is a relatively low limit on how much residential densities can reasonably be increased. Many, perhaps most, of the recent examples of high-density residential redevelopment in the Twin Cities have arisen on reclaimed commercial and industrial properties in and near the downtowns and the University of Minnesota, where there are few, if any, neighbors to object to them.

Cervero and Landis (1999), in a study of the land use impacts of San Francisco’s BART rail system, concluded that the system has had little impact on land use outside downtown, in large part for this reason. Existing neighborhoods had no interest in being redeveloped around transit stations. From a transit perspective, it is undoubtedly better to develop residential areas at higher densities rather than lower, but as a political matter there appear to be significant constraints on how much impact this strategy can have.

Even if politics were not an issue, Guiliano (1995) has noted that significant residential land use changes are unlikely, simply because housing structures maintain their usefulness and value and, hence, are very long-lived. It is typically not cost effective to tear down a well-maintained house and replace it with something else, because the house will still have value to someone. Since the housing stock changes so slowly, it will be difficult to have major impacts on overall density patterns by focusing on this exclusively.

But from a transit standpoint, densities should be as high as possible. Given the above findings, an area of 10,000 per square mile would generate about a 15 percent transit share on average, or 1,500 total transit riders per square mile. An area of 20,000 per square mile would generate a 30 percent transit share, or 6,000 total riders. That is, a doubling of density would normally double the transit share and the number of people involved, for a quadrupling of total transit ridership.
The Importance of Trip Destination in Determining Transit Share

In this way, the impact of residential density is limited, because political constraints and the slow turnover of the housing stock place practical limits on the densities that can be achieved. However, these constraints are not true to the same extent as commercial areas.

Effectiveness of Using Commercial Development

Compared to residential redevelopment, political barriers to commercial land use changes seem to be generally less significant. Major commercial developments in the Twin Cities, to the extent that they provoke any public controversy at all, tend to generate concerns about the relatively manageable issues of traffic and parking. Given that these issues can be addressed, surrounding businesses and their workers do not, in general, seem to feel that their quality of life will be negatively impacted by the presence of additional businesses and workers nearby. Empirically, the areas around the two Twin Cities downtowns and the University of Minnesota have accommodated a very sizable amount of new development (both commercial and residential) in the last 10 years. No established residential neighborhood has seen anything remotely comparable.

In addition to the simplified political issues, another possible explanation for why most new infill development seems to take place on reclaimed commercial and industrial properties is that large developable parcels of land seem to be more available in this context. Technologies and markets change over time; as a result, commercial buildings sometimes become inadequate for their intended purpose and cannot easily be adapted for other uses. This relatively frequent availability of significant areas of centrally-located land, which occurs very rarely in residential areas, adds to the potential to aggregate a substantial fraction of the region’s jobs (and at least some of its housing) into a few very large, dense centers, which can be effectively served with transit.

In terms of achievable densities, downtown areas are routinely developed at job densities that exceed the highest residential densities of their cities by a factor of five or more (Barnes 2001). And high densities mean high transit shares; combined with a large number of jobs, this means a lot of transit users. The two Twin Cities downtowns are responsible for 60 percent of the transit work trips in the region, although they contain only 15 percent of the jobs.

As a simple example of the potential impact, suppose that the number of jobs located in the downtowns were twice what it is now—that is, 30 percent of the total rather than 15 percent. Then, given the transit shares into the downtowns
(22%) versus the rest of the region (3%), the overall transit share for the region would rise from 5.9 percent to 8.7 percent. To achieve the same increase through higher residential density would, according to the earlier results, require an average density increase of 2,000 per square mile across the entire urbanized area, or roughly a doubling of the average density. Commercial land use changes of this magnitude are, at least in principle, politically and financially feasible; residential land use changes of this magnitude probably are not.

**Generating High Transit Share**

Many studies have pointed to the cost of parking as a key factor influencing the level of transit use into downtown areas. Therefore, development of large dense commercial centers is probably not enough, in itself, to guarantee high transit shares; there must also be a commitment to the imposition of relatively high parking costs. High parking costs increase transit use by making transit relatively cheaper compared with driving. This effect, however, cannot occur unless reasonable transit service is available in the first place. Attempting to impose parking costs on a sprawling suburban job center where there is little transit service available would be a very hard sell politically.

Frequent transit service to a place becomes viable when there are a lot of customers. This, in turn, requires both a large number of potential customers and a relatively high transit share. A high transit share comes about because transit service is competitive with auto travel; monetary cost is one aspect of this, and travel time is another. Competitive travel times are much more likely when buses can travel on freeways (for longer distance trips) and when they do not have to make many stops at the end of the trip. Nonstop travel on freeways is viable when there is a reasonable load of passengers going to roughly the same place. Typically, only a big destination is likely to generate this load.

Quick discharge at the end of the trip is possible only when most of the destination buildings are close together, so that everyone can reasonably walk to their building from one of a small number of closely-spaced stops. This is critical because, unlike the home end of the trip, where there are many options for accessing transit, generally, walking is the only available option at the work end. In a downtown, because the buildings are tall and close together, there are tens of thousands of jobs within walking distance of any bus route.

Quick discharge in suburban areas is much more difficult, given that buildings in these areas are generally separated by wide, high-speed streets, long distances, and
large surface parking lots. Increasing suburban service frequency to downtown levels will not have the impact that it does in downtown. The buses themselves will still be slow, due to the large number of stops they would need to make and the long travel time between those stops. Of course, providing such service would be financially burdensome in the absence of the high transit use needed to offset costs.

Conclusions

Planners and policymakers hoping to manage urban traffic congestion through increased transit use are limited in the short term by the strong influence that existing land use exerts on mode choice. While this point has been widely acknowledged, most research and policy discussion on this topic has focused on increasing residential densities. However, the conclusion of this article is that the development and expansion of very large, high-density job centers is the best tool available for most cities to achieve substantial increases in transit use.

While there are many ways to improve transit use, achieving the substantial increases necessary to impact congestion levels will probably ultimately require greatly improved service frequency or higher costs of driving, such as parking charges. Higher parking charges will be politically infeasible in the absence of adequate transit service as an alternative; however, improved transit service is hard to justify in the absence of a sufficiently large market.

Creating a large market appears to reduce to two options: the well-known solution of increasing residential density and the less-considered option of focusing on the work end of the trip. While both of these tactics appear to be effective in principle as well as practice, it is, for a variety of reasons discussed in this article, very difficult to have impacts on residential density that are large enough to have regional significance.

The constraints that limit the use of residential density increases as a tool are not in force to nearly the same extent for commercial development. A gradual transition of a relatively small amount of office space from isolated or low-density settings into a few large dense centers could lead to sizable increases in regional transit use in a relatively short time.

The Twin Cities area illustrates the possibilities of this approach. There are two downtowns, but Minneapolis is much larger and is geographically in the center of the developed area. Downtown St. Paul is relatively small and close to the edge by
comparison, yet still attracts a substantial transit share. This hints at the possibility that even suburban locations, if they are developed to a sufficient size and density, can become major transit attractors.

Increased densities at the work end of the trip, by making improved transit service frequency more viable, could also help to increase nonauto access to retail and other nonwork opportunities. While higher density residential development can also have an impact, the effect is much larger when the increased density occurs in or around high-density commercial areas, both because more trips will be made to these high-transit attractors and because these areas support relatively good transit service going out as well as coming in. Increased commercial densities, especially in the suburbs, may be the only tool available for inducing significant transit use from the vast suburban areas of most cities that are already developed at low densities, and which will probably stay that way forever.

Acknowledgments

This research was done as part of the Transportation and Regional Growth project sponsored by the Center for Transportation Studies at the University of Minnesota, and was funded by the Minnesota Department of Transportation. The author would like to thank the many people who have helped to improve this work, especially Robert Johns, Stephanie Erickson, and the anonymous reviewers of this manuscript.
The Importance of Trip Destination in Determining Transit Share

References


About the Author

Gary Barnes (gbarnes@hhr.umn.edu) is a research associate at the State and Local Policy Program, part of the Humphrey Institute of Public Affairs at the University of Minnesota. His research interests include travel behavior and mode choice, specialized transit services, and public involvement in transportation planning. His work has appeared in Transportation Research Record. He has a bachelor’s degree from the Massachusetts Institute of Technology and a Ph.D. in economics from the University of Minnesota.
Impact of High-Speed Lines in Relation to Very High Frequency Air Services

Andrés López-Pita and Francesc Robusté
CENIT (Center for Innovation in Transport)
Technical University of Catalonia

Abstract

The Madrid–Barcelona air route constitutes one of the main aerial routes in the European corridor in terms of traffic demand (4.2 million passengers in 2003). To deal with such a high demand, three airline companies (Iberia, Air Europa, and Span Air) globally offer more than 60 flights per day either way.

Currently, the construction of a high-speed railway line between the two cities is under way. The line is expected to come into commercial service by 2007, covering the whole of the 625 km between the cities.

This article analyzes the impact that high-speed railway services have on air traffic demand. The results are then compared with real data corresponding to the Paris–London line, on the occasion of the launch of the commercial service of the high-speed Eurostar train.
Introduction

In the past decade (1990–2000) the demand for air transport in Spain has increased significantly. A thorough examination of the changes in air traffic in the Madrid–Barcelona route, one with the greatest demand within the Iberian peninsula, is a sufficient indicator of this growth. In fact, in 1990 the flow of air passengers between the two cities was 2 million persons, while last year, this figure reached 4.2 million passengers—an average annual growth of 6.4 percent.

Internationally, the above-mentioned figures place Spain in the vanguard of European air sectors with the greatest air traffic demand (Table 1).

Table 1. Main Passenger Air Traffic Routes Within the Main European Countries (2001)

<table>
<thead>
<tr>
<th>Country</th>
<th>Route</th>
<th>Passenger Air Traffic (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>Frankfurt–Berlin</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Frankfurt–Munich</td>
<td>1.5</td>
</tr>
<tr>
<td>Spain</td>
<td>Madrid–Barcelona</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Barcelona–Palma de Mallorca</td>
<td>1.6</td>
</tr>
<tr>
<td>France</td>
<td>Paris–Nice</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Paris–Toulouse</td>
<td>2.9</td>
</tr>
<tr>
<td>Great Britain</td>
<td>London–Glasgow</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>London–Edinburgh</td>
<td>2.6</td>
</tr>
<tr>
<td>Italy</td>
<td>Rome–Milan</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Source: Original chart using data from the Institute of Air Transport (ITA).

The Madrid–Barcelona sector was opened to air transport liberalization in 1993. Since then, two new companies, Air Europa and Span Air, have offered services along with Iberia, the only operating airline in this route before 1993. The increase in the number of services has given rise to two important factors: (1) a significant increase in mobility in this corridor and (2) an overwhelming alteration in the modal distribution of air traffic among the three companies.

On the other hand, a new railway high-speed line is presently under construction, which, by 2005, will connect Madrid and Barcelona in two and a half hours.
This article explores the effect of air transport liberalization and the foreseen consequences not only by air companies that operate in this corridor, but also by the new railway operator (RENFE), in the modification of the present distribution between modes of transportation demand.

The main commercial routes that have existed for more than 25 years between the two cities can be summarized by the following data: at the beginning of the 1970s, air traffic through this corridor was approximately 900,000 passengers per year. This traffic included 78 percent businesspeople who wanted to take a round-trip on the same day.

To meet this demand, in November 1974 Iberia introduced its shuttle service, the first such service operating in Europe. This service encompassed the Anglo-Saxon concept of “first come, first served.” The first air shuttle of this kind operated between Rio de Janeiro and Sao Paulo (1959), followed by a similar service established shortly thereafter between New York and Washington, D.C. (1961).

For almost 20 years, Iberia was the only airline operating the Madrid–Barcelona connection. In terms of supply, 13 flights per day in either direction were offered in 1974, while 30 flights per day were offered in 1993. Figure 1 shows that passenger traffic grew from 974,000 the first year the air shuttle service operated (1974) to 1,926,000 passengers in 1993. It is easy to see the influence of the economy on the development of air traffic over time. In the first half of the 1980s, air service was affected by a serious economic crisis in Spain. While the year 1991 was especially difficult because of the Gulf War, air service partially recovered due to the Olympics, which were held in Barcelona the following year (1992). In short, air traffic on the Madrid–Barcelona route doubled during the period 1974–1993.
Arrival of New Companies in the Madrid–Barcelona Air Shuttle

The opening of the airline market in Europe began to take effect at the end of the 1980s, and it came into being for the domestic market as of January 1993. For the Madrid–Barcelona corridor, this was characterized by the introduction of a new range of flights provided by two airlines that, until that time, had not operated in this sector: the first, Air Europa, began services on January 31, 1994, and the second, Span Air, on March 14, 1994. Table 2 shows the flights initially offered by each airline.

An analysis of Table 2 shows the following significant features:

- Frequency of service offered by Iberia was notably higher than that offered by the other two companies. Specifically, out of a weekly total (the number of flights on Saturdays and Sundays decreases for any company) of 603 flights, Iberia offered 430 flights (71%); Air Europa, 102 flights (14%); and Span Air, 71 flights (12%).

- Unlike Iberia, Air Europa and Span Air obligated passengers to reserve a seat on a given flight (despite the fact that the flight initially chosen could be changed under certain conditions).
Impact of High-Speed Lines

Table 2. Services Provided in the Madrid–Barcelona Air Shuttle (1994)

<table>
<thead>
<tr>
<th>Airline</th>
<th>Frequency of Service</th>
<th>Type of Fare</th>
<th>Price Level (€) (one way)</th>
<th>Fare Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iberia</td>
<td>every 15 min. on the hour</td>
<td>Business</td>
<td>114</td>
<td>No reservation needed</td>
</tr>
<tr>
<td></td>
<td>every 30 to 60 min. during</td>
<td>Flexible economy rate</td>
<td>90</td>
<td>No reservation needed</td>
</tr>
<tr>
<td></td>
<td>nonpeak hours</td>
<td>Low-hour economy rate</td>
<td>72</td>
<td>9am to 4pm 8pm to 10pm</td>
</tr>
<tr>
<td></td>
<td>regularly scheduled flights</td>
<td>Reduced price</td>
<td>58</td>
<td>Reservation needed</td>
</tr>
<tr>
<td>Air Europa</td>
<td>Every 2 hrs</td>
<td>Regular economy fare</td>
<td>60</td>
<td>Reservation required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced economy fare</td>
<td>54</td>
<td>Bought in a booklet of 20 flights</td>
</tr>
<tr>
<td>Span Air</td>
<td>Every 2-3 hrs</td>
<td>Business</td>
<td>77</td>
<td>Reservation required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regular economy fare</td>
<td>60</td>
<td>Reservation Required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economy fare (round trip)</td>
<td>51</td>
<td>Buying the round-trip ticket at the same time</td>
</tr>
</tbody>
</table>

€ = Euros

- Prior to the arrival of the two new companies, Iberia had a single fare of 90 euros for tourist class. Upon their addition, Air Europa and Span Air offered fares that were 33 percent lower than the existing ones, with normal fares of around 60 euros.
With regard to the demand for air traffic, Table 3a shows the changes experienced by each airline. Note how the arrival of the new companies on the Madrid–Barcelona air shuttle route led to an increase in air traffic by almost one million passengers in its first year of operation (1994) compared to the previous year (1993).

In terms of market share, in 1994 Air Europa and Span Air each captured 15 percent of the total passenger traffic, with Iberia’s share decreasing from 100 to 70 percent. Since then, Span Air has progressed the most, achieving a market share of more than 21 percent in 2002. Subsequently, Iberia’s market share was 64.5 percent, and Air Europa’s was 14.1 percent.

As shown in Table 3a, Iberia’s market share has decreased by 35.5 percent since the arrival of the other airlines in the Madrid–Barcelona route. The impact of Air Europa and Span Air was an overall increase of 30 percent, and in the past eight years both companies (but especially the latter) have captured 5 percent more of the market share.

After examining Table 3a, it is worth exploring why Span Air has experienced such strong growth, especially in the past two years. The reasons include:

1. Ever since its entry into the sector in 1994, Span Air has increased its number of flights per day in either direction, beginning with 7 to 16 currently. In contrast, Air Europa has maintained virtually the same number of flights (9 and 10 flights per day in 1994 and 2002, respectively).

2. In a survey of passengers conducted in 1995, Span Air was the most highly rated airline with respect to treatment by land and flight personnel, in-flight service, ease of boarding, seat comfort, and comfort and cleanliness on board. Seven years later, passenger ratings remain the same.

3. Span Air is considered one of the most punctual European airlines (rated number one in 2002). In addition, in February 2001 it added a commitment to punctuality by promising passengers a free ticket for any delay of more than 15 minutes in the airline’s departure from Madrid or Barcelona.

4. In terms of fare levels, Span Air continues to provide the most competitively priced transport services compared to the other companies (see Table 3b).

Depending on the time of the flight, fare levels offered by Span Air even in business class are at times up to 60 percent less than those of Iberia (Table 3b). Fare differences between the two companies are also significant in economy class.
Impact of High-Speed Lines


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iberia</td>
<td>1.92</td>
<td>1.98</td>
<td>2.07</td>
<td>2.70</td>
<td>2.72</td>
</tr>
<tr>
<td>Traffic*</td>
<td>100</td>
<td>70</td>
<td>67</td>
<td>67</td>
<td>64.5</td>
</tr>
<tr>
<td>Market share (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Europa</td>
<td>-</td>
<td>0.44</td>
<td>0.44</td>
<td>0.54</td>
<td>0.59</td>
</tr>
<tr>
<td>Traffic*</td>
<td>-</td>
<td>15</td>
<td>14</td>
<td>13.6</td>
<td>14.1</td>
</tr>
<tr>
<td>Market share (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span Air</td>
<td>-</td>
<td>0.45</td>
<td>0.55</td>
<td>0.78</td>
<td>0.90</td>
</tr>
<tr>
<td>Traffic*</td>
<td>-</td>
<td>15</td>
<td>18</td>
<td>19.4</td>
<td>21.4</td>
</tr>
<tr>
<td>Market share (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Traffic</td>
<td>1.92</td>
<td>2.87</td>
<td>3.06</td>
<td>4.02</td>
<td>4.21</td>
</tr>
</tbody>
</table>

* Million passengers

Source: A. López Pita using data from Iberia, Air Europa, and Span Air.

Table 3b. Airfare Levels on the Madrid–Barcelona Route (2002)

<table>
<thead>
<tr>
<th>Airline</th>
<th>Normal Business Class</th>
<th>Cheapest Business Class</th>
<th>Normal Economy Class</th>
<th>Cheapest Economy Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iberia</td>
<td>157.45</td>
<td>75.45</td>
<td>136.45</td>
<td>64.45</td>
</tr>
<tr>
<td>Air Europa</td>
<td>168.45</td>
<td>65.45</td>
<td>117 or 136</td>
<td>97</td>
</tr>
<tr>
<td>Span Air</td>
<td>155.45</td>
<td></td>
<td>142.45</td>
<td>35.45</td>
</tr>
</tbody>
</table>

€ = Euros

Iberia’s main attraction continues to be its frequency of flights, with 47 per day in either direction; that is, it has three times as many flights as Span Air. These differences are more pronounced during nonpeak hours and less so during peak hours.

Madrid–Barcelona Corridor Supply and Demand

The two largest Spanish cities, Madrid and Barcelona, form metropolitan areas of more than 5 and 3 million inhabitants, respectively. From a demographic point of view, the cities located along the corridor linking Madrid and Barcelona are Zaragoza (700,000 inhabitants), Lleida (120,000 inhabitants), and Tarragona/Reus (200,000 inhabitants) (Figure 2).
Among the transport services offered to people traveling between Madrid and Barcelona are:

- a highway infrastructure as far as Zaragoza (325 km) and a freeway from there to Barcelona (296km)
- a railway line (692 km) between Madrid and Barcelona, which is 71 km further than the distance by road and 212 km more than that by air
- air service provided by three companies between Madrid and Barcelona

Travel times offered by each mode of transport, average service frequency, and fare levels are given in Table 4. The response of demand to the services offered by each mode is air, 64 percent; private vehicle, 23 percent; railway, 8 percent; and coach, 5 percent.
This supply–demand analysis shows that railways play a very insignificant role in passenger services between Madrid and Barcelona. It is important to note that the existing rail line between the two cities, built in the 19th century, imposes a constraint on the commercial speed to about 106 km/h and does not permit the journey times of even the fastest trains (6h 30min) to be reduced.

Construction of a New Rail Line
Between Madrid and Barcelona at 350 km/h
As discussed above, the existing Madrid–Barcelona line offers low-quality service, especially with regard to the commercial speed achieved between the two cities (for European standards)—100 km/hr. It also comprises only about 8 percent of the distribution among all the services. Improvement of this service is not possible due to the current state of the railway lines which provide a limited turning radius in terms of railway track geometry (300 to 700 m).

Difficulties on the rail route between Madrid and Barcelona, the commercial success achieved with high-speed lines operating between Madrid and Seville with standard gauge, and existing congestion problems at airports in both cities led the Spanish government to plan a new line between the country’s two most important cities.

With respect to air traffic, it is important to remember that the volume of passengers at Madrid airport increased from 15 million in 1991 to 34 million in 2001, an average annual accumulative growth of 8.5 percent. Meanwhile, passenger traffic
at Barcelona airport in the same period increased from 9 million to 20 million, averaging similar annual growth to that of the Madrid airport. It is no surprise, therefore, that the percentage of flights delayed by more than 15 minutes at both airports is almost 50 percent, with an average delay per flight of around 50 minutes.

Based on these data, the new line project between Madrid and Barcelona (standard gauge) will provide a railway service that is very attractive to habitual shuttle passengers. In particular, origin/destination traveling times of two and a half hours are projected.

Looking toward the future, what scenarios can be forecast for this corridor?

**Foreseeable Future Scenario**

An analysis of the impact of high-speed railway services on air transport demand in Europe has been the subject of many studies in the past few decades. Thus, the curve shown in Figure 3 emphasizes rail’s market share compared to that of the airlines, according to how long the trip takes by land transport.

![Figure 3. Effect of Train Journey Time on the Proportion of Air and Rail Travelers](image)

Source: UIC (International Union of Railways).
Based on this curve shown in Figure 3, and more specifically from the experiences on the Madrid–Seville high-speed line (Table 5), it would be tempting to extrapolate the same conclusions about the operation of the new high-speed Madrid–Barcelona line.

**Table 5. Railway Market Share Compared to Airline Market Share on Madrid–Seville Route**

<table>
<thead>
<tr>
<th>Means of Transport</th>
<th>1992 (before high-speed line)</th>
<th>Market Share (%) with High-speed Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>71</td>
<td>20.1</td>
</tr>
<tr>
<td>Rail</td>
<td>29</td>
<td>79.9</td>
</tr>
</tbody>
</table>

Source: RENFE and Iberia.

The distribution by means of transport on the Madrid–Seville route corresponds to a railway travel time between the two cities of two and a half hours, precisely the same amount of time forecast for the Madrid–Barcelona route. Thus, we could initially estimate that the high-speed railway on the Madrid–Barcelona route could also have a market share of more than 80 percent compared to the airlines.

An evaluation of what the potential market share might be has been carried out using the forecasting models that are usually applied in Europe. The need for a more precise estimate essentially comes from the existence of two important elements that differentiate this line from the Madrid–Seville sector:

1. different attributes of the competition between different means of transport in both corridors, as seen in Figure 4, and
2. foreseeable generation of less traffic on the Madrid–Barcelona route since it is primarily a commercial route.

On the other hand, it is important to take into account that present air services between Madrid and Barcelona are noticeably different from that existing in other sectors where a high-speed line was also built (Figure 4). Consequently, for this Spanish scenario, the average waiting time between two flights is only 20 minutes.
Demand for railway transport has been estimated based on the use of the price-time model to determine the distribution between the two means of transport and based on a gravitational model for the evaluation of the traffic generated.

The price-time model provides a means of calculating the share of traffic of the different modes as a fraction of the total traffic. The model elaborated between 1967 and 1973 by C. Abraham and J. D. Blanchet is based on the assumption that passengers choose between two different modes in relation to the value they attach to time, cost, and journey time features of each of the modes. Thus, the user selects the mode with the lowest generalized cost in relation to this value of time.

Time value represents the price (in dollars per hour) a traveler agrees to spare one hour of his or her journey. The higher the number, the more the time is valorised and, therefore, the more inclined the traveler will be to use the fastest transportation mode, irrespective of the price. On the other hand, a traveler whose time value is low will consider the price criteria before the speed criteria.

Figure 4. Scenario of Competition Between Means of Transport on the Madrid–Seville and Madrid–Barcelona Routes

Analytically, generalized costs for traveler $j$ of two modes are:

Mode 1\[ C_{g1} = P_1 + h_j T_1 \]
Mode 2\[ C_{g2} = P_2 + h_j T_2 \]

where:

- $P_i$ is the price of the journey including access/egress cost
- $T_i$ indicates total trip time (travel time from A to B with mode $i$; access/time from A with mode $i$ (air to rail) to the airport or the station, including terminal time; egress time from B with mode $i$ (air or rail) from the airport or the station; time of waiting between two flights
- $C_{g_i}$ equals generalized cost (expressed in dollars)
- $h_j$ is time value

Figure 5 shows the choice between air–auto–high-speed rail according to the respective generalized costs.

**Figure 5. Price–Time Model**
Passenger traffic estimates between Madrid and Barcelona were based on the following assumptions:

- Auto: Fare level similar to the current level ($74.5, petrol and freeway toll)
- Airplane: Fare level similar to the current level (average price equivalent to $90 by passenger)
- Railway: Fare level similar to the Madrid–Seville line (average price equivalent to $0.12/Vkm)
- Value of travel time in 2002 ($)

<table>
<thead>
<tr>
<th>Mobility</th>
<th>Auto</th>
<th>Airplane</th>
<th>High-Speed Railway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obligatory</td>
<td>14</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Non-Obligatory</td>
<td>12</td>
<td>24</td>
<td>19</td>
</tr>
</tbody>
</table>

The gravity model or induced-demand model is designed to forecast the total amount of induced traffic for each of the different modes. Gravity models are single-mode in the sense that they apply only to the mode of transport whose traffic generation is to be estimated. The induced traffic is proportional to the variation in the generalized cost, and is highly dependent on the services offered by the new high-speed rail mode in terms of travel time, fares, frequency, comfort, and accessibility to stations.

Analytically,

\[ T_{ij} = K \left( \frac{P_{0pi} \cdot P_{0pj}}{W_i \cdot W_j} \right)^a \left( \frac{C_{gij}}{C_{gij}^0} \right)^b \]

where:

- \( T_{ij} \) is the traffic between zone \( i \) and zone \( j \)
- \( P_{0pi} \) and \( P_{0pj} \) are the population of zones \( i \) and \( j \)
- \( W_i \) and \( W_j \) indicate the income per capita of zones \( i \) and \( j \)
- \( C_{gij} \) represents the generalized cost of transport between zone \( i \) and zone \( j \)
\( \alpha \) is the elasticity of traffic to the population; 
\( \beta \) is the elasticity of traffic to the income per capita; 
\( \gamma \) denotes the elasticity of traffic demand to the generalized cost of transport; and 
\( K \) is a constant term.

Following a change in the services offered, the variation in traffic \( \Delta T \) is linked to the variation in the generalized cost \( \Delta C_g \) by means of the formula:

\[
\Delta T = -\gamma \frac{\Delta C_g}{C_g}
\]

The analysis undertaken in the different Spanish sectors allows us to make the following conclusions:

1. The elasticity of population is close to the unity (\( \alpha \approx 1 \)).
2. The elasticity of the income per capita is close to 0.9 (\( \beta \approx 0.9 \)).
3. The elasticity of traffic demand to the generalized cost of transport is 1.6 for nonbusiness trips and 1.9 for business trips.

The following results have been obtained based on the preceding hypotheses:

- Air traffic captured by the high-speed railway: 2.20 M travelers
- Highway traffic capture: 0.36 M travelers
- Traffic on conventional railway lines captured: 0.57 M travelers
- Traffic generated: 0.35 M travelers
- **Total**: 3.48 M travelers

Thus, the railway will transport 3.48 million travelers, compared to 2 million travelers by airplane (4.2 – 2.2 Mt), giving rise to a distribution for the means of transport as 64 percent (railway) and 36 percent (airplane).
On the other hand, the forecasts generated by Iberia claim that start-up of the high-speed railway line will mean a loss of 38 percent in all air traffic on the Madrid–Barcelona route compared to current level of traffic (4.2 million travelers).

According to the Iberia forecast, distribution between the airplane-railway systems would be as follows:

- Airplane 2.60 M travelers (54.5%)
- High-speed railway 2.17 M travelers (45.5%)
  - Captured from air transport 1.60 M travelers
  - Captured from conventional railways 0.57 M travelers

Without taking into account the traffic that rail will capture from highway and the traffic generated by the railway itself, airplane traffic will have a market share of 54.5 percent with respect to the railway. The inclusion of the two above-mentioned means of transport, which are not considered by Iberia (highway 0.36 Mt and newly generated traffic 0.35 Mt), would thus invert the preponderance of air traffic—railway (2.88 Mt) and airplane (2.6 Mt)—giving rise to a distribution for the various means of transport as 52.5 percent and 47.5 percent, respectively. The results are summarized in Table 6.

**Table 6. Forecast of Evolution of Rail–Plane Travelers Modal Distribution in Relation to Madrid-Barcelona with New High-Speed Line**

<table>
<thead>
<tr>
<th>Mode</th>
<th>At Present</th>
<th>Forecast with New High-Speed Line</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Author’s Estimate</td>
</tr>
<tr>
<td>Railway</td>
<td>11%</td>
<td>63.5%</td>
</tr>
<tr>
<td>Plane</td>
<td>89%</td>
<td>36.5%</td>
</tr>
</tbody>
</table>

In conclusion, in the initial stages, it seems reasonable to predict that, given the differences in the existing supply between the Madrid–Seville and Madrid–Barcelona routes, the high-speed railway will not—at least initially—reach a market share of 80 percent with respect to air travel. This is a value that might be estimated from the existing European experience (Figure 3) and particularly from the results obtained for the high-speed line between Madrid and Seville. Therefore, we can expect that the impact of the high-speed line between Madrid and Barcelona,
where a high density of air services already exists, will not be as high as the rest of the high-speed lines in commercial services across Europe today.

At this time, it is not possible to predict to what degree the decrease in air traffic will affect each of the companies currently operating between Madrid and Barcelona. However, it is reasonable to believe that both Air Europa and Span Air will withdraw their services, especially the former, leaving Iberia as the sole airline operating this route.

The results of our analysis with regard to the distribution of the high-speed railway services (64%) can be compared to a real-life instance of the Paris–London line. In effect, currently the Eurostar takes 2 hours, 35 minutes to complete the route and dictates about 65 percent of the market, compared to 35 percent by air transport services. Air transport between London and Paris (2.8 million passengers in 2003) is one of the highest in Europe. Nowadays, there are more than 90 flights per day in either direction between the two cities.

With the high-speed railway services, the percentage of the market using private vehicles currently represents about 16 percent of the total passengers.

Conclusions
The Madrid–Barcelona route constitutes one of the most heavily-used air routes by passengers in Europe. From 1974 until 1993, there was continuous flight service (air shuttle) which went from transporting 0.9 million passengers to almost 2 million passengers with a single operating airline—Iberia.

The process of liberalizing air transport in 1994 made it possible for two new companies, Air Europa and Span Air, to offer services along the same route. Their entry into the market generated additional air traffic of almost 1 million passengers in the first year. With each of them attracting almost 15 percent of the market share, these companies reduced Iberia’s share to 70 percent. 2001 and 2002, Span Air’s market share increased considerably, reaching its current share of 21 percent compared to Iberia’s share of 64 percent in the same market.

Within the next two years, the entry into commercial service of a high-speed railway line between Madrid and Barcelona will likely cause an alteration in the transport market. Forecasts predict that the railway line will have a market share of around 53 to 63 percent (compared to its current 11%), thus reducing the airlines’ current market share of 89 to 36 to 47 percent.
References


About the Authors

**Andrés López-Pita** *(andres.lopez-pita@upc.edu)* is a professor of railway engineering and director for the Centre for Innovation in Transport (CENIT) at the Technical University of Catalonia. He has several years of research experience in transportation planning and has been a member of the board of directors of Spanish Railways. He has published more than 250 papers in scientific journals and authored more than 20 books.

**Francesc Robusté** *(frobuste@upc.edu)* received his Ph.D in engineering at the Technical University of Catalonia at Barcelona, a master of science in operations research, and master of engineering in transportation at the University of California at Berkeley. He has been professor of transport since 2002; director of the Civil Engineering School since 2004; and subdirector of research, development, and innovation of the Centre of Innovation in Transport (CENIT) since 2001. His work has appeared in more than 150 publications.
Racial Differences and Pedestrian Safety: Some Evidence from Maryland and Implications for Policy

Randal Reed and Siddhartha Sen
Morgan State University

Abstract

In the 1990s, federal legislation was passed requiring transportation planning to incorporate the interests of all stakeholder groups. One urban transportation mode that is often ignored is pedestrian movement. A group particularly susceptible to difficulties in this mode is the elderly. This study surveys the attitudes of senior citizens in regard to pedestrian safety and motorist interactions. We examine the attitudes of elderly pedestrians concerning many aspects of pedestrian travel. The study finds that this group often views itself as disenfranchised. This study provides insight into what areas of pedestrian activity the elderly find troublesome and looks at the differences between urban and rural attitudes in regard to this issue.

The results show that African Americans and Asians have a much higher rate of positive (safety conscious) responses to the questions in the survey. This indicates that they believe that they are more aware of pedestrian safety and that they comply with laws regarding pedestrian safety at a higher rate than their Caucasian counterparts. In addition, gender and geographical location seem to impact the responses. Urban seniors have a much higher positive response rate than suburban and ex-urban seniors.
A comparison with previous work finds that these attitudes expressed in the survey are at odds with the known demographic data concerning who is at higher risk to be involved in a pedestrian accident. The increased awareness on the part of urban respondents is compatible with the more pedestrian-friendly environment of urban areas, but the racial difference in responses is not compatible with the accident data.

**Introduction**

It is important to analyze the attitudes and needs of senior citizens on pedestrian safety since not much has been written on the topic. This is despite the fact that the elderly are more vulnerable to fatal accidents (Winter 1984; Harrell 1996; Carmeli et al. 2000). In particular, there is a lack of literature that examines the racial differences in attitudes toward safety. This is paradoxical since minorities are at a greater risk of pedestrian accidents (Campos-Outcalt et al. 2003; Surface Transportation Policy Project [STPP] 2002). The changing nature of national transportation policy since the early 1990s creates an emphasis on concerns for the elderly, especially their safety. This changing focus also creates an emphasis on sustainable development and livable cities. The concepts of sustainable development and livable cities are synonymous, and such cities should include compact urban form, reduced automobile use, and creation of livable and community-oriented human environments (Wheeler 2000; Frey 1999; Duany et al. 2000). Clearly, a community-oriented environment would take into account the attitudes and needs of seniors concerning their safety and perceived pedestrian problems.

Given this situation, the article examines the attitudes of senior citizens in Maryland toward pedestrian safety and pedestrian safety campaigns. We examine the differences in attitudes by geographic dispersion (urban vs. rural), gender, and race. We first present a brief overview of the changing nature of the national transportation policy and its implications for the elderly and sustainable cities. This is followed by a review of the literature of pedestrian safety especially as it relates to seniors and various racial groups and effectiveness of campaigns. We then present the data and methodology. This is followed by the results of a survey of more than 800 seniors in the central Maryland region concerning pedestrian safety and attitudes. The next section contains the results of six focus groups that were conducted to hear the opinions of the elderly on transportation and pedestrian safety and maneuverability. The final section contains some concluding remarks, implications for policy, and recommendations.
Changing Nature of U.S. Transportation Policy and Its Implications

For most of the past century, national transportation policy focused on accommodating the demand for travel and the needs of automobiles through the construction of roads and other transportation facilities (Horan and Jordan 1998). Soon after World War II, the United States embarked on construction of a 44,000-mile nationwide system of highways with the passage of the Federal Highway Act of 1956 and the implementation of the Interstate and Defense Highways program. Construction of highways became one of the largest civil engineering feats of the century, but also tore apart the existing urban fabric of the United States (Kay 1997).

Interest in such issues as the travel needs of the elderly has recently taken hold among transportation planners and policy-makers as they address such issues as environmental justice, integration of bicycling and walking into transportation systems, disability, and the Personal Responsibility and Work Opportunity Act of 1996 (welfare to work). Public participation and equity is also central to accomplishing the vision of the Transportation Equity Act of the 21st Century (TEA-21) of 1998, which builds on the Intermodal Transportation Equity Act of 1991 (ISTEA).

Passage of ISTEA by the Congress in 1991 fundamentally altered U.S. transportation policy. As pointed out by Horan and Jordan (1998), ISTEA created an urban transportation planning process that linked it to several policy domains—environmental, economic, and social. The goal was to improve the overall quality of life in communities. Its policy emphasis included improved mobility for the elderly, disabled, and economically disadvantaged. As discussed, this changing focus also creates an emphasis on sustainable development and livable cities that include compact urban form, reduced automobile use, and livable and community-oriented human environments. Certainly, ensuring a safe pedestrian environment for the elderly is a step toward promoting such cities.

Concerns for the elderly, especially their safety, are also central to accomplishing the vision of TEA-21 of 1998, which builds on ISTEA (Passwell 2001). In addition, USDOT adopted strategic goals that emphasize nondiscrimination in implementation of programs, policies, and activities (http://stratplan.dot.gov/archive). The “Human and Natural Environment Strategic Goal,” outlined in USDOT’s “Strategic Plan” (http://stratplan.dot.gov/archive), calls for the protection and enhancement of communities and natural environments affected by transportation.
The evolution of transportation policy includes a concern for the environmental justice issues of equity and the evaluation of impacts on various demographic groups. The origins of government’s attempts to address the environmental justice issue date back to February 11, 1994, when President Clinton signed Executive Order (E.O.) 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. In response to presidential directives concerning E.O. 12898, USDOT issued a proposed Environmental Justice Strategy on February 13, 1995, and then a final order on the subject, Order No. 5610.2 (Order to Address Environmental Justice in Minority Populations and Low-Income Populations), on April 15, 1997. The Federal Highway Administration (FHWA) issued DOT Order No. 6640.23, FHWA Actions to Address Environmental Justice in Minority Populations and Low Income Populations, on December 2, 1998. The order requires the FHWA to implement the principles of the DOT Order 5610.2 and E.O. 12898 by incorporating environmental justice principles in all FHWA programs, policies, and activities (Forkenbrock and Schweitzer 1999).

One of the common modes of urban transportation is by foot—pedestrian. While transportation infrastructure tends to concentrate on public transit and highway and road systems, pedestrian needs are supposed to be considered as important when devising these systems. One group of citizens who tend to use public transportation and pedestrian infrastructures to move about are the elderly. This age group tends to suffer from medical conditions that require extra care, time, or infrastructure to safely maneuver in or near traffic. ISTEA and TEA-21 require jurisdictions to consider the needs of this constituency when planning transportation systems.

The results of this article provide an interesting insight into the opinions of this large stakeholder group’s feelings toward pedestrian transportation problems and the safety of walking in the presence of automobile traffic. The results point to differences in these feelings that are a function of gender, race, and, in some instances, geographical location. Understanding these differences is critical to the implementation of a public transportation infrastructure that incorporates pedestrian traffic.

**Review of the Literature**

Previous work in this area is sparse and focuses primarily on safety initiatives that involve infrastructure, driving patterns, and jaywalking tendencies. Of course,
there are a few exceptions. Harrell (1996), for example, examines the perception of
the elderly on traffic risks especially in signal-controlled crossings in the Canadian
context. Impact of variables such as gender, traffic and pedestrian volume, and
demographic characteristics on perceptions are an integral part of the study.

However, there is an abundance of literature on peripheral subjects. These include
pedestrian walkways and habits (Hess et al. 1999); relationships between pedes-
trian accident locations on state owned facilities such as highways and urban arteri-
als and the presence of riders loading and alighting from bus transit (Hess et al.
2004); effect of travel speeds and locations on pedestrian accidents (Gårder 2004);
leader-follower behavior as it applies to jaywalking (Russell et al. 2001); safety of
elderly pedestrians during street crossing (Carmeli 2002); sociodemographic and
health characteristics and problems of older pedestrians (Langlois et al. 1997);
safety and security of elderly and disabled travelers through the application of
Intelligent Transportation Systems (ITS) (Mitchell and Suen 1998); difference in
accident and fatality rates by race and gender (STPP 2002; Campos-Outcalt et al.
2003); and benefits of educational campaigns on pedestrian safety (Tyrrell et al.
2004; Mendelsohn 1973).

Despite their peripheral treatment, some of these studies have significance for
this article. For example, Hess et al. (1999) found that pedestrian walkways in
urban areas are much more pedestrian friendly than those in suburban areas.
Safe pedestrian activity in suburban areas requires the pedestrian to detour much
more often and for longer lengths than in urban areas. This increases the incentive
to jaywalk and engage in other unsafe practices. We find similar findings in both
the survey responses and the focus group discussions. Langlois et al. (1997) and
Carmeli (2002) discuss the need for consideration of the special needs of elderly
pedestrians such as increased crossing times and reduced traffic speeds. Focus
group discussions highlighted these concerns among the elderly in our sample as
well.

Studies that show racial and gender differences in jaywalking tendencies, pedes-
trian accidents, and fatalities are also of importance to our study since we found
that minorities who are at greater risk have a higher perception of their own safe
behavior and follow safety laws more stringently. Russell et al. (2001), for example,
examined leader-follower behavior as it applied to jaywalking. “Models” were used
to determine if observing someone jaywalking encouraged others to follow suit.
It was found that this was the case. While there were only small differences, the
study did find that African Americans were more likely to follow a “model” and
Jaywalk than Caucasians (5% for women and 7% for men). Our survey responses do not follow this result in that African Americans claim a much higher adherence to pedestrian laws than Caucasians.

An STPP study (2002) contains data describing the high accident rate for minority pedestrians in California. This is a trend that is heuristically observed nationally. Racial and gender differences in fatality rates also were established by other studies. Campos-Outcalt et al. (2003) explored rates of pedestrian fatalities in Arizona and how rates and circumstances of pedestrian deaths differ by race/ethnicity, urban or rural residence, age, and gender. The study found that American Indians had rates of pedestrian deaths higher than those of non-Hispanic whites. American Indian pedestrian death rates and relative risks were higher in rural areas than in urban areas. Compared to non-Hispanic whites, urban Hispanic males, rural Hispanic females, and urban African American females had higher relative risks.

Articles that illustrate the benefits of campaigns are also of special relevance to our study. Tyrrell et al. (2004), for example, states that designing and implementing research-based public education campaigns aimed at reducing pedestrians’ overestimates of their own nighttime visibility could increase pedestrian safety. An earlier study (Mendelsohn 1973) argues that social science research can make public campaigns more effective by determining appropriate targets, themes, appeals, and media vehicles. As suggested by the study, the major task facing the communicator is to recognize, understand, and attempt to overcome public apathy. Here, social science research can be useful in determining appropriate targets, themes, appeals, and media vehicles. Our findings point to some of these targets and themes as expressed by different demographic groups.

**Data and Methodology**

This article draws from a study that was conducted as part of a research project funded by the Maryland State Highway Administration (Reed and Sen 2004) and the National Transportation Center at Morgan State University. The research was aimed at evaluating a public service campaign, “Walk Smart,” concerning pedestrian safety as well as finding attitudes of citizens in regards to pedestrian safety. The results from general attitudes and desires concerning future safety campaigns are presented, but the effectiveness of the campaign is not assessed in this article. For a full discussion of the campaign and attitudes concerning the campaign, see Reed and Sen (2004).
There were 809 valid returned surveys in our sample. Eighteen surveys were completed by people accompanying a senior to the senior center (under the age of 50); and those under the age of 65 completed a total of 110 surveys. Thus, almost 90 percent of the surveys are from people over the age of 65. The basic demographic description of the data is presented in Table 1. Most of the respondents (over 60%) were from Baltimore City. This is partially a function of demographics (a large number of seniors live in Baltimore City) and partially a function of the cooperativeness of the senior center coordinators in the city. In addition, just over two-thirds of the surveys were completed by Caucasians and about 20 percent by African Americans.

Respondents were not selected randomly from the population of senior citizens in the region. Instead, they were contacted through senior citizen centers in the region. While it is impossible to say with certainty, the average respondent would

Table 1. Demographic Summary of Survey Data

<table>
<thead>
<tr>
<th>Number of Responses</th>
<th>809</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age</td>
<td>75</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>84.80%</td>
</tr>
<tr>
<td>Male</td>
<td>12.86%</td>
</tr>
<tr>
<td>No answer</td>
<td>2.35%</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>17.80%</td>
</tr>
<tr>
<td>Asian</td>
<td>6.06%</td>
</tr>
<tr>
<td>Caucasian</td>
<td>67.24%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.12%</td>
</tr>
<tr>
<td>Other</td>
<td>5.32%</td>
</tr>
<tr>
<td>No answer</td>
<td>3.46%</td>
</tr>
<tr>
<td>County</td>
<td></td>
</tr>
<tr>
<td>Alleghany</td>
<td>8.78%</td>
</tr>
<tr>
<td>Baltimore</td>
<td>18.91%</td>
</tr>
<tr>
<td>Baltimore City</td>
<td>62.18%</td>
</tr>
<tr>
<td>Cecil</td>
<td>3.46%</td>
</tr>
<tr>
<td>Charles</td>
<td>4.94%</td>
</tr>
<tr>
<td>Fredrick</td>
<td>1.73%</td>
</tr>
</tbody>
</table>
likely be more active and more mobile than the average senior citizen in the region. It is impossible to accurately predict how this might change the responses to the survey. At worst, the survey should be representative of the opinions and attitudes of active senior citizens. Obviously, more active seniors are more indicative of those who use pedestrian facilities on a regular basis.

Table 1 contains the demographic information about the survey respondents. As can be seen, almost 85 percent of the respondents were female. This overrepresentation is most noticeable in the senior centers in Baltimore City. Approximately 18 percent of the survey responses were from African Americans, and 6 percent were from Asians. Two-thirds of the responses were from seniors who identified themselves as Caucasian. Due to the help we received from administrators, the senior centers in the City of Baltimore are very well represented in the sample. Outlying counties are not as well represented, but the number of responses from outlying areas still allows significant results to be presented.

Survey Results
Results from the survey are presented briefly in a descriptive fashion, and then the racial and gender driven results are highlighted. Attitudes toward pedestrian safety depicted in the survey responses are similar to those that researchers and professionals in the field would expect, with a few notable exceptions.

Table 2 contains the overall results of the responses of seniors to the surveys. Several results are notable, even in this overall portrayal of the results where responses were, generally, as anticipated. While over 60 percent of the seniors were from the city of Baltimore (and another 10% or so from other cities, such as Frederick), less than 50 percent claimed that they walked most often in the city. This implies that many of the seniors who live in the city either do not walk at all or go elsewhere to do their walking. Approximately 60 percent of the sample walked at least once a week. Nearly all, 96 percent, of seniors said that they thought it was important to only cross streets at a crosswalk. This is a fairly high acceptance rate for a law that does not enjoy universal acceptance among professionals or the public. However, slightly less than 75 percent of the seniors say they follow this law when they are mid-block and wish to cross the street. These numbers are not surprising and show what professionals might expect from pedestrians.
## Table 2. Responses to Survey

### Walking Habits of Seniors

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.76%</td>
<td>A few times each week</td>
<td>29.14%</td>
</tr>
<tr>
<td>City</td>
<td>47.22%</td>
<td>At least once a week</td>
<td>8.61%</td>
</tr>
<tr>
<td>City, Suburbs</td>
<td>0.63%</td>
<td>Daily</td>
<td>21.06%</td>
</tr>
<tr>
<td>City, Rural</td>
<td>0.38%</td>
<td>Daily/At least once a week</td>
<td>0.13%</td>
</tr>
<tr>
<td>Don’t know</td>
<td>4.17%</td>
<td>Don’t know</td>
<td>4.90%</td>
</tr>
<tr>
<td>None</td>
<td>0.33%</td>
<td>Less than once a month</td>
<td>24.50%</td>
</tr>
<tr>
<td>Rural Areas</td>
<td>13.26%</td>
<td>Less than once a week</td>
<td>10.86%</td>
</tr>
<tr>
<td>Suburbs</td>
<td>33.08%</td>
<td>N/A</td>
<td>0.13%</td>
</tr>
<tr>
<td>Wal-Mart</td>
<td>0.13%</td>
<td>Never</td>
<td>0.66%</td>
</tr>
<tr>
<td>Within Halls</td>
<td>0.13%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Importance of Crosswalks to Pedestrian Safety

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t know</td>
<td>1.00%</td>
<td>Don’t know</td>
<td>3.14%</td>
</tr>
<tr>
<td>No</td>
<td>3.12%</td>
<td>No</td>
<td>23.27%</td>
</tr>
<tr>
<td>Yes</td>
<td>95.76%</td>
<td>Yes</td>
<td>73.58%</td>
</tr>
<tr>
<td>Yes, not in suburbs</td>
<td>0.12%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Pedestrian Safety and Children

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>38.57%</td>
<td>Don’t know</td>
<td>31.37%</td>
</tr>
<tr>
<td>Yes</td>
<td>61.43%</td>
<td>No</td>
<td>31.37%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>55.31%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t know</td>
<td>22.07%</td>
<td>Don’t know</td>
<td>13.45%</td>
</tr>
<tr>
<td>No</td>
<td>22.38%</td>
<td>No</td>
<td>8.04%</td>
</tr>
<tr>
<td>Yes</td>
<td>55.55%</td>
<td>Yes</td>
<td>78.22%</td>
</tr>
</tbody>
</table>
The answers to question P6 are interesting in that they give insight about why seniors might or might not use a crosswalk. Approximately 50 percent of the seniors answered in a fashion that implied they would always use a crosswalk. Other answers implied that alternatives other than the crosswalk were considered (such as a mid-block crossing). In fact, the answers to question P10 give further insight into these decisions. Almost 80 percent of seniors say they are more likely to use a crosswalk in the presence of their children or grandchildren. This means that they make a conscious decision to use the crosswalk with their children or grandchildren that they might not make if they were not present. This implies both knowledge that using crosswalks is a good habit to “pass on” and an admission that they might consider a mid-block crossing without the children or grandchildren present.

These answers highlight a fairly responsible attitude toward pedestrian safety that matches what professionals would expect from the surveyed group. Once the answers are examined demographically, there are many results that are quite insightful and, at times, surprising.

Regressions were run to determine the impact of various demographic characteristics on the responses of seniors. Table 3 contains the results of the regression for some general questions about pedestrian safety. The regressions were of the form:

\[ R_i = \alpha + \beta_M M + \beta_U U + \beta_B B + \beta_A A + \beta_O O \]

where:

- \( R_i \) is a binary variable that is a 1 if the response is yes and 0 if the response is no
- \( \alpha \) represents a constant that represents the base response (see next paragraph for a full description of the interpretation of this parameter)
- \( \beta \) indicates a vector of parameters measuring demographic impacts on the response
Due to the nature of the data, binary variables with little individual variance, the R-squared values are expected to be very low. However, the F-values show that the included variables (with two exceptions) significantly impact the responses. While individual characteristics could probably be used to more accurately predict the responses of the seniors, these characteristics might not have been willingly disclosed and would not materially contribute to the principle research questions of this article.

The base is the value of $\alpha$ which represents the percentage of the base population that responded “Yes” to the question. In each case, a “Yes” response is the one more compatible with pedestrian safety or law. The base population in this case is a white female from outside of Baltimore City. The demographic results are immediately obvious. Men are significantly less likely to feel that crosswalks are imperative to safety and also less likely to go out of their way to use them. In addition, men are less likely to alter their behavior around children or grandchildren.

All but two of the models show that the included variables were significant in determining the response at the 99 percent level (F-tests). At the 90 percent level, all but one of the models show that the included variables were significant in determining the response to the question. The only question that the included variables seemed to have little impact on was “Do you know and understand the pedestrian laws involving crosswalks?” For this question, there was little deviation from the average response rate by gender or race. For this question, the only sig-
Table 3. Regression Coefficients

<table>
<thead>
<tr>
<th>Base</th>
<th>Male</th>
<th>Urban</th>
<th>AfAm</th>
<th>Asian</th>
<th>Other</th>
<th>Adjusted R Squared</th>
<th>F-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.93425</td>
<td>-0.04109</td>
<td>0.03865</td>
<td>-0.00451</td>
<td>0.03712</td>
<td>0.03031</td>
<td>.0057</td>
<td>1.91†</td>
</tr>
<tr>
<td>0.70464</td>
<td>-0.10862</td>
<td>0.07945</td>
<td>0.04685</td>
<td>-0.22747</td>
<td>0.03753</td>
<td>.0277</td>
<td>5.39**</td>
</tr>
<tr>
<td>0.84052</td>
<td>-0.000041</td>
<td>0.07704</td>
<td>-0.01696</td>
<td>-0.02012</td>
<td>-0.00453</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0.38939</td>
<td>0.02876</td>
<td>0.23171</td>
<td>0.11194</td>
<td>0.19155</td>
<td>0.02630</td>
<td>.0427</td>
<td>6.14**</td>
</tr>
<tr>
<td>0.36986</td>
<td>0.00126</td>
<td>0.27875</td>
<td>0.10743</td>
<td>0.26248</td>
<td>0.06098</td>
<td>.0593</td>
<td>7.36**</td>
</tr>
<tr>
<td>0.65695</td>
<td>-0.05776</td>
<td>0.24297</td>
<td>-0.02272</td>
<td>0.05164</td>
<td>-0.01330</td>
<td>.0443</td>
<td>6.46**</td>
</tr>
</tbody>
</table>

Note: Standard errors are presented in parantheses. Coefficients marked by a † are significant at the 90 percent level, those marked with a * are significant at the 95 percent level, and those marked with a ** are significant at the 99 percent level.
significant coefficient is that for seniors located in urban areas. It might be possible to conclude that seniors in urban areas are more likely to understand (or claim an understanding of) pedestrian laws, but the insignificance of the model makes even that conclusion tenuous. For all other models, the conclusions about the coefficients can be made with confidence since the models themselves are statistically significant.

The responses of urban seniors were significantly more likely to be “Yes” to all questions. The increased level of interaction with motor traffic in urban environments might explain the increased safety orientation of the urban seniors. This increased consciousness of pedestrian safety matters among the urban seniors is not surprising. In addition, the more favorable pedestrian facilities found in urban areas might also contribute to this. This is consistent with Hess et al. (1999). However, the results of the breakdown of responses according to race contain some surprises.

African Americans, a group that is overrepresented in pedestrian injuries and fatalities, are consistently more likely to have given “Yes” responses to the questions. Some of these results are not significant (as most of this increase is captured by the Urban variable), but, in some of these questions, the increase in positive responses is quite significant. In both of the questions concerning the children, African Americans are more than 10 percent more likely to give a positive response. This implies a greater level of care given pedestrian safety as it concerns children or grandchildren in the African American community. More questions are examined later, and this can be viewed in a more full context.

Asians, often the safest group of pedestrians (STPP 2002), had quite remarkable figures in the analysis. Asians were about 23 percent less likely to walk to a corner to use a crosswalk than their Caucasian counterparts (27% less likely than their African American counterparts). This result is even more surprising given the predominantly urban environment that the Asian seniors live in (most were from Baltimore City). However, they were 20 percent more likely to have spoken to their children or grandchildren about crosswalks and 26 percent more likely to believe that their children or grandchildren follow pedestrian laws. They were also 5 percent (not significant) more likely to alter their behavior around their children or grandchildren concerning using crosswalks. This number is quite significant when you realize that almost 100 percent of Asians claimed they always used crosswalks.
The most dramatic differences across demographic groups came in evaluating the safety campaign and the most effective means of moving forward with future campaigns. Table 4 contains the results of the regressions concerning those questions. Similar to the regressions in Table 3, eight of the nine models are statistically significant at the 90 percent level and seven at the 95 percent level. With the exception of the model for those considering radio advertisements to be effective in campaigns, all other coefficients discussed come from significant models.

The “Walk Smart” campaign was a moderately publicized campaign stressing pedestrian safety. The media buy for this campaign was not very large, and it was not viewed by very many people. Results from the survey show a different story, however. It is likely that the seniors felt that any information they received about pedestrian safety from any source was part of the campaign for the purposes of these questions. Missing values are discarded for these regressions, and so the percentages reported can be misleading. For example, 53 percent of the base population recall seeing television ads concerning pedestrian safety. However, 18 percent of the survey respondents did not answer this question. This means that about 45 percent of the base population actually recalled television advertisements.

Approximately 25 percent of the base modified their behavior due to pedestrian safety campaigns. This might be a large number given the very high adherence rates claimed in the answers above. Other questions concerning message recall imply that less than half of the population recalls any messages about safety at all. Further questions, and the focus group results, revealed that many of these were referring to something other than the “Walk Smart” campaign itself.

The most telling results are those concerning the urban and minority populations. Respondents living in the City of Baltimore were about 25 percent more likely to think that the public safety campaigns had an effect on behavior. African American’s were about 15 percent more likely than Caucasians to have this opinion; Asians were 30 percent more likely to have this opinion. These numbers are quite extraordinary. The positive response rate of African Americans and Asians seems to imply that they were reached by the campaigns and feel that behavior was altered. An African American from the city was almost 40 percent more likely to think the messages had a positive impact than a Caucasian from outside the city. An Asian from the city was almost 55 percent more likely to think these messages had a positive impact than the base group.

The recall questions have a somewhat vague policy implication, but the next question is very important. When asked which types of campaigns would be
Table 4. Regression Results for Safety Campaign Questions

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Male</th>
<th>Urban</th>
<th>AfAm</th>
<th>Asian</th>
<th>Other</th>
<th>Adjusted R-Squared</th>
<th>F-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did these messages (pedestrian safety campaigns) change your behavior?</td>
<td>0.24709 ** (0.02299)</td>
<td>0.06454 (0.05293)</td>
<td>0.23257 ** (0.04201)</td>
<td>0.14908 ** (0.05270)</td>
<td>0.31432 ** (0.07654)</td>
<td>0.18076 * (0.08416)</td>
<td>.046</td>
<td>5.6 **</td>
</tr>
<tr>
<td>Are you more likely to use a crosswalk or intersection now?</td>
<td>0.56078 ** (0.02637)</td>
<td>-0.01424 (0.04649)</td>
<td>0.27738 ** (0.03585)</td>
<td>0.06229 (0.04514)</td>
<td>0.14980 * (0.06638)</td>
<td>0.08545 (0.07042)</td>
<td>.0107</td>
<td>2.17</td>
</tr>
<tr>
<td>Do you think these messages changed the attitudes of other people you know?</td>
<td>0.36097 ** (0.02991)</td>
<td>-0.04862 (0.05319)</td>
<td>0.23742 ** (0.04152)</td>
<td>0.15818 ** (0.05226)</td>
<td>0.31353 ** (0.07494)</td>
<td>0.07208 (0.08181)</td>
<td>.0262</td>
<td>3.53 **</td>
</tr>
<tr>
<td>Which types of advertisement campaigns do you remember?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Billboards</td>
<td>0.12588 ** (0.02523)</td>
<td>0.06040 (0.04886)</td>
<td>0.09794 ** (0.03502)</td>
<td>0.07644 † (0.04408)</td>
<td>-0.08978 (0.06320)</td>
<td>0.02912 (0.06500)</td>
<td>.0117</td>
<td>3 *</td>
</tr>
<tr>
<td>Radio</td>
<td>0.13577 ** (0.02543)</td>
<td>0.04184 (0.04521)</td>
<td>0.14158 ** (0.03259)</td>
<td>-0.01397 (0.04443)</td>
<td>-0.24232 ** (0.06370)</td>
<td>0.14853 * (0.06954)</td>
<td>.0012</td>
<td>1.21</td>
</tr>
<tr>
<td>Television</td>
<td>0.52819 ** (0.03013)</td>
<td>0.000061 (0.05556)</td>
<td>0.21050 ** (0.04182)</td>
<td>0.02154 (0.05264)</td>
<td>-0.00515 (0.07548)</td>
<td>-0.06352 (0.08246)</td>
<td>.0353</td>
<td>7.2 **</td>
</tr>
<tr>
<td>Which would be most effective to help you remember the crosswalk/pedestrian law?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Billboards</td>
<td>0.14138 ** (0.02477)</td>
<td>-0.00694 (0.04404)</td>
<td>0.04889 (0.03418)</td>
<td>0.07223 † (0.04127)</td>
<td>0.04150 (0.06209)</td>
<td>0.01288 (0.06774)</td>
<td>.01</td>
<td>2.71 *</td>
</tr>
<tr>
<td>Television</td>
<td>0.40998 ** (0.03146)</td>
<td>-0.05755 (0.05594)</td>
<td>0.02678 (0.03637)</td>
<td>0.03895 (0.05496)</td>
<td>-0.10152 (0.07881)</td>
<td>-0.08842 (0.08604)</td>
<td>.0245</td>
<td>5.26 **</td>
</tr>
<tr>
<td>Finances</td>
<td>0.18199 ** (0.02756)</td>
<td>0.06429 (0.04902)</td>
<td>0.16089 ** (0.03826)</td>
<td>-0.13779 ** (0.04816)</td>
<td>0.04157 (0.06906)</td>
<td>0.00621 (0.07539)</td>
<td>.0098</td>
<td>2.67 *</td>
</tr>
</tbody>
</table>

Note: Standard errors are presented in parantheses. Coefficients marked by a † are significant at the 90 percent level, those marked with a * are significant at the 95 percent level, and those marked with a ** are significant at the 99 percent level.
most effective in helping people remember to use crosswalks, there were large differences across demographic groups. The most important media seemed to be television. Forty percent of the base population felt that television advertisements would have the greatest impact. However, among urban African Americans, billboards ran a fairly close second, with 27 percent saying that method would be the best way to get the message across. None of the other racial groups had a significant deviation in terms of media of choice. However, there is a large difference in opinion concerning the use of fines.

Eighteen percent of Caucasian women outside of Baltimore supported fines as the best way to alter behavior. Men were approximately 6.5 percent more likely to feel this way. Urban white seniors were very much in favor of fines. Approximately 34 percent of urban white seniors felt that fines were the best approach. African Americans were 14 percent less likely to answer this way. This is the only question in the entire survey where African American responses were not more safety conscious or more supportive of safety campaigns. This is a striking result from a group that claims a much higher adherence to the laws. This is a strong indication of a cultural difference in feelings concerning fines and police enforcement since this group claimed that it was safer and followed the law more than their Caucasian or Asian counterparts.

Focus Group Results

The surveys were followed by focus groups conducted at six senior centers in Maryland. Two of these were from Baltimore City, two were from Baltimore County, and two were from outlying counties. In selecting the focus groups, we ensured that various geographic locations (namely, Baltimore City and its inner-ring suburbs and rural counties) were represented. Attention also was given to race in selecting these groups. While the focus groups were predominantly Caucasian in the outlying counties, one inner-city group was predominantly African American, while the other was Korean. The Baltimore County focus groups were attended by a racially-mixed group of seniors.

Our primary analytical framework for the focus groups was drawn from critical ethnography and studies of practice and discourse in public policy (Van Maanen 1988; Forester 1999; Throgmorton 1996; Watson 2002). Such a methodology relies on qualitative interpretative inquiry and seeks to understand the unique and contextual rather than make generalized propositions about the “responses.” The
focus groups were used to augment the results of the survey and to obtain other concerns that the seniors have on pedestrian and driving behavior. The seniors’ concerns were not always focused on the same issues as the survey, but brought up other issues related to accessibility and safety.

The overriding focus of the survey was the use of crosswalks and the efforts of the public service campaign to encourage their use. Seniors had much to say on these topics. Concerning the public service campaigns, most seniors recalled some form of safety campaigns but none recalled the specific “Walk Smart” campaign the study was funded to examine. Most seniors felt that the reason campaigns were likely to have little effect is that they are too broad and tend to focus on issues that “everyone already knows.”

The seniors had much to say concerning the impact of age and age-related handicaps on pedestrian safety. Many seniors said that vision impairment was the major difficulty they faced in getting about. They had many complaints about the accessibility of pedestrian safety tools for the vision impaired. Many echoed the concern of one senior from the Pikesville Senior Center who stated, “I am legally blind so I have trouble with curbs and steps. I have fallen so many times that I am afraid but if I try [to walk] when I can.” A participant from the La Plata Senior Center summed up the views expressed by many other seniors: “You will find if you walk around that there may be a ramp or crosswalk cutout for wheelchair people, but no concern has been shown for the blind and visually impaired pedestrians.” This senior argued that this meant that jurisdictions were not adhering to the Federal Access Act.

Complaints concerning visual impairment and pedestrian safety issues often were linked by seniors to their being afraid, or unwilling, to risk walking in areas with vehicular traffic. The lack of friendly pedestrian facilities for the vision impaired may contribute to the lack of mobility and pedestrian activity on the part of many seniors.

Numerous comments were voiced about the placement and safety of crosswalks. Many seniors complained about the placement or usability of crosswalks. This was primarily a concern in the outlying centers. In Cumberland, one senior complained that a commonly-used crosswalk in a busy commercial district was unusable because “if you ever waited for that walk signal, it would take forever because it never works.” The sheriff of Cumberland County commented, “. . . the majority of traffic here is traffic friendly not pedestrian friendly . . . if you have somebody . . . with a prohibitive handicap, to get across the street you need much more than
the time allowed by the crossing signals.” He also noted that the placement of the crosswalks did not encourage their use. He explained that the distance to the crosswalks in the area immediately surrounding the senior center was such that it encouraged seniors to make a mid-block crossing “and take their life into their own hands.” These comments are directly compatible with the recommendations of Langlois et al. (1997) and Carmeli (2002).

In addition to vision problems, another complaint often mentioned by seniors was the aggressiveness of motorists. This concern was not limited to rural locations but was equally shared by rural and urban seniors. A senior from the Mount Street Senior Center stated, “I don’t know about the laws, but it seems to me that when you try to cross the street that the driver speeds up.” Another senior pointed out that the behavior of the motorist requires the pedestrian to have to “to look out for all ways all the lights are going and get up on the side” rather than just assume a “walk” signal is safe.

The concerns of the seniors clearly show that they are afraid that motorists do not obey the laws protecting pedestrians. This lack of regard for pedestrians making crossings scares seniors to the point that many have changed their habits. Some avoid walking longer distances while others now walk at malls rather than risk vehicular traffic. This fear has further lowered the mobility of these seniors by making it difficult for them to get about on streets they share with vehicles. Interestingly, a major initiative by the Maryland State Highway Administration on just this issue was started shortly after the report was written. A massive and very public enforcement of motorist behavior around crosswalks was conducted with the police forces, highway administration, and local television stations. Citations were given to motorists who failed to slow down for “model” pedestrians and large amounts of publicity were generated.

Most of the seniors stated that they made an effort to stress pedestrian safety with grandchildren when they were young. They felt that schools contributed to this but had mixed feelings as to the effectiveness and motivation of the schools in doing so.

As for effectiveness of campaigns, most seniors felt that an aggressive campaign that was “more focused” would be better. They felt that most public service messages were virtually ignored because they were general and repeated already “known” material. They were nearly uniform, however, in supporting more aggressive enforcement of rules and regulations. They wanted drivers and pedestrians to be held accountable for their actions. A senior from La Plata stated, “Whoever is
wrong should get a ticket.” This opinion held equally for pedestrians and motorists. A senior from Cockeysville said, “I think you wouldn’t do it more than once if you got a ticket for illegally crossing.”

**Conclusions and Policy Implications**

The study shows that seniors consider pedestrian safety an important issue and that they are concerned about their safety when walking on roads. Both the survey responses and the focus group comments underscore this concern. The extra care shown in the presence of their children or grandchildren further highlights the concern given this subject. Yet, this is the group of people most vulnerable to accidents (Winter 1984; Harrell 1996; Carmeli et. al. 2000). This necessitates the need to design cities that are safe for the elderly.

The study also found several key results that are important for understanding the attitudes concerning pedestrian safety. First, attitudes differed across demographic, racial, gender, and geographic groups. Urban seniors were considerably more likely to claim that they act safely than those living in nonurban areas. There is an interesting dichotomy between the groups most at risk of pedestrian accidents and those who believe that they are acting safely. National and regional data both suggest that minorities are disproportionately represented in the pedestrian accident figures. However, minority respondents to the survey felt that they were acting properly more often than their Caucasian counterparts.

It is clear that pedestrian activity differs between urban and nonurban environments. The density of traffic, both pedestrian and automobile, creates a situation in which there are numerous interactions between pedestrians and automobiles in an urban environment. In less urban environments, the number of interactions is lower, but automobiles travel at higher speeds. Urban pedestrians are likely to be more aware of traffic yet they are constantly exposed to potentially dangerous interactions. In less-dense suburban and exurban environments, pedestrian facilities are often more sparse and less well designed.

The results of the study show that urban seniors claim a higher degree of pedestrian safety awareness and conformity with safe practices. This is compatible with the enhanced awareness that comes from repeated interactions and the infrastructure being more amenable to safe practices. Surprisingly, there were strong differences along racial lines, after controlling for geographic location, in the responses to the survey.
Differences along racial lines were striking in their strength and their consistency. African Americans were more likely to give the positive safety response to nearly every question. The magnitude of this difference was also quite stable. For most of these questions, the positive response was approximately 10 percent more likely from an African American respondent. Asian respondents were even more strongly positive than African American responses. This provides a policy dilemma for transportation agencies striving to lower pedestrian accident rates. The very groups that are disproportionately represented in the accident data feel that they are acting safely already. This could make the task of informing and altering behavior more difficult. One of the basic principals of environmental justice is to avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects on minority populations. Clearly, our study suggests that more attention needs to be paid to the safety of minorities if we are to minimize or mitigate relatively higher and adverse affects of fatal pedestrian accidents on this segment of the population. Agencies charged with safety issues should be aware of this dilemma, and future studies should focus on discovering the best means to overcome it.

The differences across racial lines continued into message recall and suggested means of conveying the message. Urban seniors and African Americans were much more likely to have recalled seeing billboard advertisements. In addition, they were more likely to feel that billboards would be an effective means of conveying the message. One interesting deviation from this trend is that urban seniors were much more likely to feel that tickets were a good means of promoting good pedestrian behavior. However, African Americans were much less likely to agree with this method. This is a strong indication of a cultural difference in feelings concerning fines and police enforcement since this group claimed that it was safer and followed the law more than their Caucasian counterparts.

The study found a large difference in attitudes toward pedestrian safety and public safety campaigns across racial lines. This highlights the importance of considering the target audience for any public safety campaign. Differences in attitudes and responses imply that different tactics may be necessary to get the same message across to different audiences. The fact that the differences in responses were racial and not geographic strongly argues for more study concerning the attitudes of pedestrians toward safety and public safety campaigns. This, in combination with the results of Russell et al. (2001), shows that there may be significant differences
in the behavior and attitude of pedestrians along racial lines. Taking this into consideration is critical to achieving stated policy objectives by any planning agency.

In addition, different target groups have different preferred means of receiving information. Urban, and particularly African American, seniors are more likely to think that billboards are the most appropriate means of publicizing safety issues. Nonurban, and particularly Caucasian, seniors are more likely to believe that radio and television advertisements are more appropriate. In contrast to the survey responses, focus group discussions implied that seniors believe that stricter rules and enforcement may be better than public safety campaigns. This suggests that public agencies, transportation and otherwise, have to be more proactive about considering the cultural aspects of campaigns. These include appropriate themes, appeals, and media vehicles.

Although the nature of the focus groups precludes generalized conclusions, the findings imply that the goals ISTEA and TEA-21 may not be fully met as of today. The elderly were annoyed or are unhappy with aggressiveness of the motorists, felt insecure about bicyclists, and were concerned about pedestrian “unfriendliness” of streets and pedestrian crossings.

The trend to include stakeholders’ views in policy has been embraced in some parts of policy-making and is lagging in others. The use of pedestrian facilities is an important part of any public transportation planning process. The views expressed by the seniors in this study show that there is still a considerable distance to go in order to fully incorporate the needs of all groups in transportation policy. If the goal of planning is to create livable communities where all stakeholders are represented in the process, pedestrian safety issues need to be addressed and the concerns of various demographic groups considered.

Endnotes

1 The concept of sustainability emerged in the 1970s, but a large volume of literature on sustainable development began to emerge from the late 1980s, especially in the international context (See, for example, Beatley 1995; Mitlin 1992).

2 Of course, there are other concerns for sustainable and livable cities such as environmental justice, self-reliance, reduced waste and pollution, reuse of and recycling of materials, and development of a locally self-reliant economy (see Wheeler 2000; Haughton 1999).
3 See Bullard and Johnson 1997; Forkenbrock and Schweitzer 1999; Sanchez 1999; and Khisty 2000. This act aims to enhance the mobility of low-income populations to job sites. In addition to job access, other related issues, such as fairness of transit service pricing and quality of service provision, have also been of recent concern.

4 These and other acts, and their stipulations on equity and citizen participation, are discussed below.

5 These were Allegany County Senior Center, Cumberland; Richard R. Clark Senior Center, LaPlata; Greenmount Senior Center, Baltimore; Mount Street Senior Center, Baltimore; Cockeysville Senior Center, Cockeysville; and Pikesville Senior Center, Pikesville.

Acknowledgments

The authors would like to thank the Maryland State Highway Administration and the National Transportation Center at Morgan State for funding the original study. Kinjal Parikh, Sachin Parekh, Julius Maura, Carla Bauer, and Brett Ripkin provided valuable research assistance on the project. We would also like to thank the referees and the editors of the journal for their constructive criticisms, and senior centers and administrative personnel that helped distribute and complete the surveys and accommodate the focus groups.
References


**About the Authors**

**Randal Reed** (*rreed@eng.morgan.edu*) is an assistant professor at the Institute for Transportation at Morgan State University. He has a B.A. and M.A. in economics, and a Ph.D. in economics from Northwestern University. His research focuses on the impacts of congestion and transportation infrastructure on the local population and the users of the facilities.

**Siddhartha Sen** (*ssen@morgan.edu*) is a professor in the Graduate Program in City and Regional Planning at Morgan State University. He has a B.Arch., M.Arch., and an M.CP. and received a Ph.D. in regional planning from the University of Illinois at Urbana-Champaign. His research interests are in equity and transportation planning.
Use of Statistical Process Control in Bus Fleet Maintenance at SEPTA

Anna Lynn Smith, Parsons Brinckerhoff Quade and Douglas, Inc.

Sohail S. Chaudhry, College of Commerce and Finance, Villanova University

Abstract

As a provider of public transportation services in the Philadelphia area, the South-eastern Pennsylvania Transportation Authority operates and maintains a large number of transit vehicles for daily use. In an attempt to improve service quality and reduce costs, the Southeastern Pennsylvania Transportation Authority underwent a program to train staff on the use of Statistical Process Control to track and address quality issues with its bus fleet. This research presents the steps taken by this public transit agency to implement Statistical Process Control on part of its bus fleet as one element of an overall quality improvement program.

Introduction

The public transit industry in the United States is heavily subsidized by Federal, State, and local funds that make up most of a transit agency’s capital and operating funds. With an uncertain future for these subsidies, transit agencies are continually trying to find ways to reduce their costs. Fleet maintenance is one area in
transit operations where opportunities for improving efficiency and experiencing cost savings are readily apparent.

This article describes the Southeastern Pennsylvania Transportation Authority’s (SEPTA) use of Statistical Process Control (SPC) to track quality problems with its bus fleet. SEPTA used SPC as part of an overall quality improvement effort within the organization. SEPTA’s deployment of SPC was relatively unique in the transit industry, and is of potential interest to other organizations in the public sector looking to improve the quality of their work performance.

The article begins with a brief literature review of quality efforts in the transit industry particularly those with SPC applications, and continues with a discussion of SEPTA’s quality initiative and use of SPC. An example of SEPTA’s in-process bus inspection procedure is detailed to illustrate the context of its SPC use. The article concludes with a discussion of the benefits SEPTA experienced from using SPC and the challenges faced with continued use.

SPC in the Transit Industry

The concept of Total Quality Management (TQM) became popular during the late 1980s and through the 1990s. Although its beginnings were in the private sector, some public organizations also embraced the concepts of TQM. In the transit industry, several agencies adopted TQM programs in an attempt to improve the efficiency or effectiveness of the establishment (Bowman and Hellein 1998; Obeng and Ugboro 1996; Schwager and MacDorman 1992; Takyi et al. 1993). To the best of our knowledge, there are no other articles on the application of SPC at public transit agencies in academic publications. However, in the transportation industry, some sort of performance measures including SPC is commonly used to track and monitor systems including on-time performance, vehicle breakdowns, and track condition (Anonymous 1998; Benneyan and Chute 1993; Pohlot 2003).

It was a jump in the private sector from manufacturing to shipping where SPC gained its footing in the transportation arena. Ford Motor Company successfully used SPC to facilitate the measurement and analysis of railroad transportation in its quest for quality improvement (Richards 1984). Ford found that the application of SPC to freight shipment time was a convenient, objective, and thorough method of analyzing car movement data and getting answers to concerns regarding both the speed and consistency of rail transportation.
In the broadest sense, providers of public transit service have a general obligation to the public to offer service that is safe, reliable, and cost-effective. This desire has lead to the development and implementation of various quality tools and programs to fulfill this need. For example, in the United Kingdom, the company formed to revitalize Britain’s railways, Network Rail, implemented Six Sigma for its West Coast Route Modernization Project. The company is using Six Sigma as a quality improvement tool to investigate and quantify causes of delay and establish remedial action. In addition to cost savings, the company is able to offer more predictable performance with less variation (Connolly 2003; Network Rail 2003).

In Hong Kong, the Kowloon Canton Railway Corporation’s (KCRC) infrastructure and building department has undergone efforts to focus on the satisfaction of its internal customers as part of efforts in continuing quality enhancement and as a systematic way to boost quality awareness within the KCRC (Tam and Hui 1996). Transit ride quality and passenger levels are also becoming a common measure of rider satisfaction studied by transit agencies in the United States. The Transit Capacity and Quality of Service Manual (Transit Cooperative Research Program 2003) provides details on how to capture this information based on the transit user’s perspective, but, again, does not provide statistically valid ways to measure and analyze vehicle data.

Some of the larger transit agencies in the United States also have undergone quality training programs for their engineering and construction departments. For example, the Houston Metropolitan Transit Authority underwent training on Federal Transit Administration (FTA) QA/QC requirements for design and construction, which included familiarization with ISO 9000 and review of their quality program (Burridge-Kowalik 2003).

Statistically valid models to measure, monitor, and control vehicle on-time performance also have been developed. These include Total On-Time Operation (TOTO) and Schedule Constraint and Route Analysis Model (SCRAM) by Oregon State University’s Transportation Research Institute and the Department of Industrial and Manufacturing Engineering (Safford 1990). These and other similar tools are being developed and used by transit agencies to monitor their operations, but there are few formalized, statistically-valid systems used to assess the maintenance of transit vehicles, particularly those for bus fleets.
SEPTA's Quality Initiative

SEPTA is responsible for providing and maintaining transit service to the greater Philadelphia area in the form of trolleys, subways, commuter rail, and buses. In addition to the increasing pressure to do more with less, SEPTA, like all other subsidized transit agencies in the United States, must adhere to Federal guidelines in providing its service, including following a strict vehicle maintenance schedule. This helps to ensure that the vehicles will achieve their full useful lives and ultimately demonstrate to taxpayers that funding is being used prudently.

The aging infrastructure of SEPTA's service area, combined with the reductions in funding, created a challenging situation for SEPTA, which essentially needed to find ways to address budget cuts. The authority partially responded to this need through creation of the Quality Assurance Department. The responsibility of this group was to assist with programs and practices that would help improve the efficiency and effectiveness of the agency.

SEPTA's Quality Assurance Department provided appropriate training (Chaudhry and Higbie 1989; Patterson 2003) to many groups within the organization. A course in SPC was developed to train employees who performed vehicle maintenance, and the Statistical Process Control Reference Handbook was produced for use by employees (Patterson 2003). All of the Bus Operations Division received training in SPC, including the Maintenance and Transportation Groups. SEPTA's Safety and Risk Management Group also was given SPC training. The Quality Assurance Department customized the training to meet the needs of each department using its specific data. In terms of the presentation techniques for this information, the same types of techniques, control charts, histograms, and composite diagrams were developed for every group, all grounded in the same SPC philosophy for SEPTA. Additional training was developed to be used as a follow-up to improve processes and detail how to take corrective actions. The intended use of SPC was to serve as a measuring device to help demonstrate opportunities for improvement in existing processes. Actions were to be taken by the specific departments based on these results.

SPC at SEPTA

SPC has been formally defined as a methodology for monitoring a process to identify special causes of variation that signals the need to take corrective action when it is appropriate (Evans and Lindsay 2005). In practical terms, SPC is a statistical
procedure that uses control charts to determine if any part of a production process is not functioning properly and could cause poor quality (Russell and Taylor 2003). SPC is a relatively recent undertaking by transportation organizations to look at their production processes to see if there is variance from typical performance and ultimately prevent poor quality before it occurs (Anonymous 1998; Benneyan and Chute 1993).

SEPTA realized the importance of SPC training as part of its overall quality program and embarked on a comprehensive training plan for several departments concerned with bus maintenance. A major component of this effort at SEPTA was the use of SPC to track problems in the bus fleet. Although the training was implemented over a period of about three years, it was perceived as a complicated process for many of those receiving the training.

At the time, SEPTA called in buses from service to undergo a two-part maintenance procedure. The first part was called the In-Process Inspection. This inspection was performed in the Rering and Teardown shops. The Rering Shop examined the engine, transmission, heating/ventilation/air conditioning system, and the electrical system. The Teardown Shop looked at the undercarriage and the chassis.

The second part of SEPTA’s vehicle inspection was the Final Inspection. The Final Inspection took place in the Body and Paint shops. Areas examined in the Body Shop included the following components of the bus: interior, passenger doors, electrical system (including lights), body and access doors, glazing, windshield wipers, washer and accessories. The Paint Shop inspection entailed examining the bus for defects in the paint and finish and determining areas requiring touch-ups.

Prior to SPC implementation, SEPTA routinely performed inspections of its buses based on required maintenance schedules and completed appropriate repairs, but made no attempt to analyze the data collected as part of its typical maintenance practice. With the implementation of SPC, SEPTA had the ability to determine whether the number of problems or “defects” was under control and within the desired limits. Defects were classified as problems found during the inspection process with particular components that would compromise the operability, safety, or comfort of the vehicle. If the number of defects was determined to be out of control, further investigations were then performed to determine the nature or cause of the increased defects. Then, depending on what the investigations revealed, the appropriate steps were taken to bring the number of defects back under control.
The data gathered from the two inspection stages were presented graphically. These graphs included pie, bar, and control charts. The pie and bar charts were principally for presentation purposes to visually represent the results of the inspections. For example, a pie chart depicting the percentage of defects by component is shown in Figure 1, and a bar chart displaying discrepancies by component, by month is shown in Figure 2.

The SPC training at SEPTA included instruction on several different types of control charts that would be applicable in the various processes for bus fleet maintenance. In some situations, SEPTA’s Operations Support Quality Assurance Department was not only interested in whether the vehicle was defective, but also in the number of defects it had. These defects could be attributable to factors such as route miles, route characteristics, or number of passengers served. C-charts are commonly used to control the total number of defects per unit when the subgroup size is constant (Evans and Lindsay 2005). Therefore, C-charts were the most appropriate type of control chart in SEPTA’s analysis of the number of defects per unit in the two-part maintenance procedure.

Figure 1. Percentage of Defect by Component, Berridge Shop
Figure 2. Discrepancies by Component, by Month, Berridge Shop

In this article, we describe the inspection of vehicles over a four-month period as part of required maintenance schedules. Inspectors were given preprinted inspection sheets to facilitate the process in determining what represented a problem or “defect.” Depending on the specific item being inspected, the defective item would either be replaced or repaired. The inspection sheet broad categories are shown in Table 1. These sheets clearly defined what items were to be inspected and reported on as far as performance or quality. An example of a specific item is shown in Table 2.
Table 1. In-Process and Final Inspection Components Checklist

Southeastern Pennsylvania Transportation Authority
Operations Support

**IN PROCESS INSPECTION CHECK OFF**
A. Teardown Inspection Check Off
   A1. Front Suspension
   A2. Rear Suspension
   A3. Air & Fuel
   A4. Break Reline
   A5. Steering
   A6. Axles
   A7. Structural
B. & C. Rering Inspection Check Off
   B1. Engine Line
   B2. Climate Control
   B3. Electrical
   B4. Cooling System
   B5. Engine Spine
   B6. Air Intake & Exhaust
   B7. Road Test & Functional Test
   C2. Wheelchair Lift

**FINAL INSPECTION SHEETS**
C. Body Shop Inspection Check Off
   C1. Interior
   C2. Exterior
D. Paint Inspection Check Off
   D1. Body & Paint
      - Functional Checks
      - Interior Checks
      - Exterior Checks
   D2. Paint – Check Off Sheets
      - Exterior Checks
      - Interior Checks
Table 2. Front Suspension Checklist

<table>
<thead>
<tr>
<th>A1 FRONT SUSPENSION</th>
<th>CHECK</th>
<th>REPL.</th>
<th>REPAIRED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1.1 CHECK NEW SHOCK ABSORBERS</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>A1.2 CHECK NEW BELLOWS AND PISTONS</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>A1.3 CHECK NEW CONTROL ARM BUSHINGS</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>CHECK NEW UPPER CONTROL ARMS</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
<tr>
<td>A1.4 CHECK FOR NEW HOLLOW SPRINGS</td>
<td>______</td>
<td>______</td>
<td>______</td>
</tr>
</tbody>
</table>

These sheets were collected after each inspection, and the number of defects per bus by shop was totaled. These data were then used in conjunction with Statistical Process Control software (Shewhart 1993) to generate the C-charts. Table 3 shows a sampling of the application at different stages of the two-part maintenance procedure.

Table 3. C-Chart Calculations

<table>
<thead>
<tr>
<th>Shop</th>
<th>LCL</th>
<th>UCL</th>
<th>( \bar{C} )</th>
<th>( Z )</th>
<th>( \sqrt{C} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teardown</td>
<td>0.00000</td>
<td>7.76153</td>
<td>2.76923</td>
<td>3</td>
<td>1.66410</td>
</tr>
<tr>
<td>Rering</td>
<td>2.43182</td>
<td>24.41433</td>
<td>13.42308</td>
<td>3</td>
<td>3.66375</td>
</tr>
<tr>
<td>Body</td>
<td>5.58349</td>
<td>31.37651</td>
<td>18.48000</td>
<td>3</td>
<td>4.29884</td>
</tr>
<tr>
<td>Paint</td>
<td>0.08035</td>
<td>18.23965</td>
<td>9.16000</td>
<td>3</td>
<td>3.02655</td>
</tr>
</tbody>
</table>

Note:  
LCL=Lower Control Limit  
UCL=Upper Control Limit  
\( \bar{C} \)=Mean of Distribution
From this summary table, we chose the Paint Shop to illustrate SEPTA’s experience with SPC. Figure 3 represents an application of C-chart with Upper Control Limit (UCL) and Lower Control Limit (LCL) set at three standard deviations from the mean of the process in the Paint Shop. The C-chart is theoretically rooted in Poisson distribution. Since, on a bus, there could potentially be a very large number of defective places, the proportion of defects relative to the inspection area is usually small. Hence, in applying the Poisson distribution to C-charts, an inspection unit may be of any kind. In the example presented here, SEPTA used the sampling unit of one bus (Duncan 1986).

It can be observed from the control chart that all points are within the control limits and, in fact, they are within two standard deviations of the mean. However, based on the fact that there are seven points below the center line during the month of December, this could be construed as a cause of concern. However, it is good cause of concern since there are less nonconformities per unit. From a control chart perspective, since it is a preventive tool, management still needs to investigate the situation observed and learn from it. In addition, these points...
are within one standard deviation below the mean of the process and hence one could argue that the process is settling down. Therefore, the nature or cause of this trend could be investigated to exploit it. Furthermore, if there is a shift in the process mean, management can then decide to recalculate the mean of the process by eliminating points before the shift. Such exploitation also could reduce the mean number of defects in the Paint Shop, which, in turn, would change the UCL and LCL.

**Benefit of SPC to SEPTA**

In this article we illustrated that SEPTA was able to introduce and implement SPC as part of its quality improvement efforts. From this example, we learn that the use of quality control tools can be employed for fleet inspections in a public transit agency environment. The implementation of such tools, however, requires a substantial effort in terms of developing procedures, training, and other continual means of making the program understandable, real, and useful.

In terms of overall benefits experienced by SEPTA in its use of SPC, the authority first and foremost became aware of the benefit of examining trends versus month-by-month comparisons. SEPTA realized the impact of its decisions and understood that implementing corrective actions would have an effect on subsequent processes and results. After attending the training course, many of the staff truly appreciated the philosophy that there is always room for improvement and became interested in analyzing the data produced from SPC.

With the creation of a Quality Assurance Department, SEPTA’s top management demonstrated its commitment in improving the effectiveness of the operations in the organization. Their use of process control procedures assisted in gathering timely information on whether the vehicles in service were meeting service requirements and enabled them to detect shifts in the quality of service that could potentially be attributable to problems that would be encountered by a portion of the bus fleet at some point in the future. For example, if a problem was found with the rear suspension on a number of the vehicles inspected, and a fleet defect was identified, SEPTA would take proactive action to repair the entire fleet. The actual control phase occurred when a corrective action was taken (e.g., repair, contracting with a new supplier, routine maintenance, etc.).

The use of SPC within SEPTA involved a tremendous education process, and it was hoped that the maintenance and quality assurance supervisors would be able to
put more control in the hands of the employees on the shop floor. As an example, if a recurring problem was noted with electrical systems on vehicles, by using SPC, SEPTA would be able to determine the source of the problem, such as a bad lot of bulbs, and take steps to correct the problem. SEPTA’s goal was to have its maintenance personnel become proactive and think analytically, focusing attention on the source of a problem, not just an immediate solution to a specific defect.

SEPTA used SPC over several years and was optimistic how the use of SPC would provide increased benefit to the organization in terms of cost savings and quality of service. SEPTA’s expectations regarding bus defects was that the use of SPC would accomplish change and impart responsibility on the persons who are involved in the “hands-on” maintenance of the vehicles. With its day-to-day use, SEPTA was able to track problem trends, identify problems with particular bus fleets, and work to obtain compensation or replacement for defective parts or items under warranty.

In the overall picture for using SPC to document defects, SEPTA hoped to influence management, reduce claims, and increase safety. SEPTA’s Surface Division in charge of these vehicles hoped the use of SPC would increase the mean distance between vehicle failures as well as increase the unit reliability of the maintenance shops. It was also anticipated that defect trends would be easily documented and monitored, which would ultimately lead to reduction in costs and maintenance budgets. During the period of study, SEPTA’s Quality Assurance Department was successful in obtaining additional compensation from warranty claims and achieved the resulting cost savings from this initiative. Due to a variety of reasons, the actual cost savings were not made available as part of this study.

While, in the end, the mindset of managers at SEPTA ultimately changed to use trend analyses to implement improvements in a process versus a month-to-month comparison of numbers, there is applicability for future use of SPC in a public transit environment.

This study demonstrates that the use of control charts in the transit industry as an active, real-time tool is viable and has the potential to be replicated in other transit agencies to control costs and monitor problem areas.
References


**About the Authors**

**Anna Lynn Smith** ([smitha@pbworld.com](mailto:smitha@pbworld.com)) is a senior transportation planner with Parsons Brinckerhoff in Philadelphia. She received a B.S. in civil and architectural engineering from Drexel University and an M.B.A. from Villanova University with a concentration in operations management and marketing. Her career experience includes transit system financial analyses, quality system development and implementation, rail engineering, planning, and operations.

**Sohail S. Chaudhry** ([sohail.chaudhry@villanova.edu](mailto:sohail.chaudhry@villanova.edu)) received a Ph.D. from Columbia University in industrial engineering and operations research. He is a professor of operations management and management science in the Department of Decision and Information Technologies at Villanova University. His research interests include supply chain management and management and control of quality. He has published numerous papers in journals such as *Decision Sciences, European Journal*
Can Trip Planner Log Files Analysis Help in Transit Service Planning?

Martin Trépanier, Robert Chapleau, Bruno Allard
Ecole Polytechnique de Montreal

Abstract

Transit trip planners are now found on most transit authority websites. This feature gives transit users a full itinerary from a point of origin to a destination. The web server on which the trip planner is installed usually stores usage logs on a daily basis. Log files contain data on origins, destinations, calculated paths, and other website entries. The main purpose of this article is to determine whether the analysis of trip planner log files can help to improve transit service by providing better knowledge on transit users. A website-oriented analysis and a transit-oriented analysis based on four years of observations on the Montreal Transit Commission website are presented. Results show that, even though not all transit users have access to the Internet or use the planner regularly, log files can be useful for identifying new locations to be accessed by a transit system, for better understanding user behaviors, and for guiding updates of the geographic information system (GIS) and the trip planner itself.

Introduction

Today, most transit authorities provide information to their users through Internet websites, which usually contain detailed information on routes, schedules, fares, and paratransit services. Some of them also provide a “trip planner” (Federal Transit Administration 2002). Trip planners are advanced web tools that create transit itineraries based on user input of a specific origin and destination pair. Of
course, these planners serve a dual function: In addition to providing information to users, they also provide the organization with information about users’ mobility behaviors and trip patterns. Moreover, by examining the logs of the map reference search features of these websites, the subjacent geographical information system (GIS) can be enriched.

This article underlines the potential for the analysis and use of trip planners as tools in transit planning. A background overview of website usability and transit websites also describes the fundamentals that form the basis of this project’s websites in order to support planning: the Totally Disaggregate Approach and Transportation Object-Oriented Modeling. Then, the article describes the trip planning process and the log file structure offered on the websites studied here. Some useful website usage statistics are provided (website-oriented analysis), followed by an in-depth examination of the space-time characteristics of the user’s website declarations and possible resections with origin-destination survey data (transit-oriented analysis). There is also a section on possible bias and limitations of this research. Finally, the principal results of this research are given.

Background

Website Usability and Logging

It is usually difficult to adequately track user behaviors on a website because of the different “surfing paths” that can be followed by Internet users, depending on their needs (Piroli and Pitkow 1999). Some tools are designed to evaluate usability for general-purpose websites (Ivory and Hearst 2001), but a few authors have tried to use website logs to improve the website functions themselves, and not just the interface. Tan and Kumar (2002) have studied web navigational patterns in the case of web robots for a better knowledge of website usage. Smith and Ng (2003) have worked on a web page clustering method to evaluate the usability of websites. Usability refers to ease of use, access to website functions, and the extent to which user needs are met. Murphy et al. (2001) report that website log files can reveal valuable marketing information on customer habits and preferences. All these works are valuable for traditional “commercial” websites, but are not suited for application-specific websites like trip planners. Golob and Regan (2001) believe that in the transportation field, the Internet, with the help of adequate websites, can be a powerful survey tool for tracking people trips.
**Transit Trip Planners**

In public transportation, websites are seen as a natural extension of normal service activities and public relations tools. Efforts have been made to describe the elements that could be used to feed a transit information website for transit users. Lee et al. (1999) presented a web-based bus information system (WBI) implementation with data stored in a Microsoft Access database. Peng and Huang (2000) have also used Access to store route and transit networks, bus stops and time-point data, and their database is linked to a GIS and to network servers. Karimi et al. (2004) have developed a web interface to help the user to mount his or her own transit trip along with information. Maclean and Daily (2002) have made significant work about the measurement of the utility of a real-time information system using log file analysis, but this work does not refer to website usage.

The Federal Transit Administration (2002) reports that about 20 percent of American transit websites have a trip planner, but it does not rate these in terms of features. The Montreal Transit Commission (MTC) and the Laval Transit Commission (LTC) both have implemented transit trip planners on their websites (http://www.stm.info and http://www.stl.laval.qc.ca). At first glance, few of these trip planners have a true planning function such as those in Montreal and Laval, where users can specify any location on the territory (address, intersection, trip generator, station, and maps) and where they are not limited to lists of stations. In recent work (Trépanier et al. 2002), we have shown that a trip planner must rely on a comprehensive geographic information system (GIS) and the Totally Dissagregate Approach (TDA) to meet the needs of transit users. GIS are extremely useful and powerful for transportation modeling and operation (Arampatzis et al. 2004).

**Totally Dissagregate Approach**

The Totally Dissagregate Approach (TDA) is a transportation planning methodology used in the Montreal region since the beginning of the 1980s. The main principles of TDA are (Chapleau 1986):

- Every single piece of information from origin-destination surveys is kept in “tripfiles.” These flat files contain data on households (size, home location, number of cars), people (age, gender, car ownership) and trips (trip chain, origin and destination locations, junction points, mode, purpose, transit routes, and time of departure). The data are normalized and coded so that they can be retrieved rapidly and analyzed by software developed for the individual processing of trips. For the trip planners, simplified trip files are used in which information on origin and destination locations, date and
time, and transit routes is retained. The core information is the individual transit trip, as seen in Figure 1.

**Figure 1. The Individual Trip in the Totally Dissaggregate Approach**

- Spatial districting, such as Traffic Analysis Zones (TAZ), is rejected for analysis in favor of the examination of individual trips, and trip extremities are geocoded at the most refined level of resolution. This is an essential feature of the trip planner because it enables users to specify precise origin and destination locations (such as addresses, intersections, monuments). Geographical information systems are thus essential at this point.

The use of the TDA for storage, validation, and analysis of large household origin-destination surveys constitutes the foundation of the data structure and the data itself for both the MTC and the LTC trip planners. In recent years, a new approach, the Transportation Object-Oriented Modeling (TOOM), has facilitated the integration of the TDA within multiple applications.

**Transportation Object-Oriented Modeling**

Transportation data processing generates several problems because it involves spatial components that are related together and have multiple time-dependent attributes. These problems have been partially reported by Goodchild (2000):
• Temporality: Transportation data always contain strong intrinsic temporal components (speed, time of movements), as well as extrinsic temporal components (date of effectiveness, time of collection).

• Geography: Transportation data are spatially referenced, without zones if general usage is the goal.

• Structure: Transportation data must be normalized so that they can be analyzed over time, by different software programs, and for different purposes.

• Collection: Transportation data are usually collected for a single purpose; far-sighted data collection can help to widen their range of use.

An object-oriented approach is well suited in this case because of its openness and its flexibility. Based on traditional OO approaches (computer science), the Transportation Object-Oriented Modeling is characterized by its special metaclasses of objects (dynamic, kinetic, static, and system), which are used to describe every transportation system (see Trépanier and Chapleau 2001 for more details). In this study, TOOM structures the database and the software environment in such a way as to link the Geographic Information System (GIS), the Operational Information System and the planner log files.

Methodology for Trip Planner Design and Implementation
In this section, we will explain the design choices for the trip planner: methodology for design, trip planning process, and log file structure. These choices have helped the log file analysis because they are based on the same background elements (TDA and TOOM). The system architecture that is needed to obtain both the trip planner and the related log files are described in Chapleau et al. (1997) and Trépanier et al. (2002).

Methodology for Design
The methodology for both the construction and the operation of trip planners is a blend of the Totally Dissaggregate Approach (TDA) and TOOM. The use of the TDA for the storage, validation, and analysis of large household origin-destination surveys constitutes the foundation of the data structure and the data itself for both the MTC and the LTC planners. TOOM always attempts to create a wide view of every system, even though the data for each object may not be available. Figure 2, for example, presents the general TOOM for transit trip planning. At the top of the model is the transit user, who uses two major systems to complete his
Trip Planning Process

To better understand the analyses presented below, let us describe the typical trip planning process on the MTC website (Figure 3). First, the user specifies his or her origin and destination locations in one of three ways: browsing through generator and stop lists; clicking on a map; or searching the database for a given intersection or address (the most common). Then, the user indicates the day and the time of the trip, and has the option of applying penalties on certain transit modes (subway or train).

The rest of the process is handled by the planning engine beneath the website. Access and egress are calculated using the pedestrian network. This determines the shortest walking path between the trip extremities and the transit network (which is reached through bus stops, train stations, or subway stations). Then, there is a path planning on the transit network (more than 50 paths can be calculated at a time, depending on the network complexity). A final selection of the best possible paths is made based...

Figure 2. A TOOM for Transit Trip Planning
Can Trip Planner Log Files Analysis Help

on the schedule, which is fully integrated into the paths. Figure 4 shows the kind of result that can be obtained on the MTC website: route selection, walking distances, path chronology, sequence of bus stops, and subway stations.

Figure 3. Trip Planning Process on MTC and LTC Websites

Figure 4. Trip Planning Results Page on the MTC Website
Log File Structure
Log files are kept for every transit trip planning. They typically contain the date and time of the visit, location of the origin and destination points (expressed in terms of identification, source and coordinates), parameters specified by the user, a summary result of the planning (route sequence), and the number of trip planning calculations made in a single visit. Only the last calculation of the visitor is retained in the log files. Table 1 shows a sample entry in the Laval’s website. At the MTC, there is also a full entry log file, containing all text entries and clicks made by users during their visits. Since there is only one file per log with normalized data, simple queries were made for the analysis.

Website-oriented Analysis
This section presents the principal results that can be obtained from website-oriented analysis. These analyses are intended to show the popularity of the trip planner function among users, to examine evolving trends in usage, and to improve the website functions themselves with the help of appropriate indicators.

Table 1. Sample Log File Entry for LTC Website

<table>
<thead>
<tr>
<th>Field</th>
<th>Sample Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>idsession</td>
<td>12P0K1USS</td>
<td>Visitor’s web session ID</td>
</tr>
<tr>
<td>date</td>
<td>19-Oct-03 09:33:33</td>
<td>Date and time of visit</td>
</tr>
<tr>
<td>codeorg</td>
<td>FINT22999/24775</td>
<td>Code for origin location (FINT → intersection)</td>
</tr>
<tr>
<td>codedest</td>
<td>FGEN16015</td>
<td>Code for destination location (FGEN → trip generator)</td>
</tr>
<tr>
<td>orig</td>
<td>boul. Chomedey / boul. Cartier ouest&lt;br&gt; (Chomedey)&lt;/br&gt;</td>
<td>Textual identification of the origin (for website display)</td>
</tr>
<tr>
<td>dest</td>
<td>métro Charlevoix / BR (Montreal)</td>
<td>Textual identification of the destination (for website display)</td>
</tr>
<tr>
<td>xorig</td>
<td>286516</td>
<td>X coordinate at origin (UTM, meters)</td>
</tr>
<tr>
<td>yorig</td>
<td>5044373</td>
<td>Y coordinate at origin</td>
</tr>
<tr>
<td>xdest</td>
<td>611797</td>
<td>X coordinate at destination</td>
</tr>
<tr>
<td>ydest</td>
<td>5036849</td>
<td>Y coordinate at destination</td>
</tr>
<tr>
<td>result</td>
<td>{7606} [24] [1] 1002 [36] 1001 [37]</td>
<td>Result of the calculation (sequence of stops and routes)</td>
</tr>
<tr>
<td>nbcal</td>
<td>2</td>
<td>Number of calculations for this user</td>
</tr>
<tr>
<td>c_triparc</td>
<td>di</td>
<td>Day for trip planning (here, di → Sunday)</td>
</tr>
<tr>
<td>c_hdep</td>
<td>12:00</td>
<td>Time of departure for trip planning</td>
</tr>
<tr>
<td>c_pmarc</td>
<td>n</td>
<td>Parameter for walk (n → user do not want to penalize walk)</td>
</tr>
<tr>
<td>c_utrain</td>
<td>n</td>
<td>Parameter for train (n → user do not want to use train)</td>
</tr>
</tbody>
</table>
Statistics on Visits

Table 2 shows monthly statistics for the trip planning sub-website of the MTC website. A visit occurs when an Internet user accesses the website and performs a trip planning. As we can see, users usually calculate about two trips per visit. The number of clicks and the average time per visit are good indicators of the usability of the website. There is a click for every web request sent (change of web page). Between 2002 and 2003, these indicators are quite stable events, although there was a 57 percent increase in the number of visits.

Table 2. Monthly Statistics for the MTC Website (trip planner sub-website)

<table>
<thead>
<tr>
<th>Month</th>
<th>Calculations</th>
<th>Visits</th>
<th>Average Clicks per Calculation</th>
<th>Average Time per Visit(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2000</td>
<td>9,158</td>
<td>4,970</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Jan 2001</td>
<td>32,321</td>
<td>14,738</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Jan 2002</td>
<td>62,355</td>
<td>27,625</td>
<td>5.41</td>
<td>241.16</td>
</tr>
<tr>
<td>Jan 2003</td>
<td>93,758</td>
<td>43,316</td>
<td>5.12</td>
<td>247.17</td>
</tr>
<tr>
<td>Jan 2004</td>
<td>129,609</td>
<td>62,289</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

The number of people using the trip planner is relatively small, compared to the total number of MTC users (there are about 300 million trips per year on the MTC network). There were 333,611 visitors to the entire MTC website during March 2002. Of this total, 27,625 (8.3%) used the trip planner.

Trends

The number of users of the MTC and LTC trip planners has been increasing steadily since these applications were launched in 2000. In 2001 alone, there was an increase of 221 percent for the MTC site. During the same period, CyberAtlas (2003) reported a 7.3 percent increase in the number of Internet users in general, and the average monthly web usage had increased from 8 hours and 17 minutes to 19 hours and 57 minutes.

Figure 5 shows the increase in the number of visitors between January 2000 and March 2002. The time series decomposition function starts at x=0 on January 1, 2000. In addition to the increase in the number of visits related to the growth of the Internet itself, two time-related effects can be observed. In a regular week, the number of trip planning calculations is 40 percent lower on the weekends. In
Figure 5. Number of Visitors to the MTC Website Planner, January–March 2002

Time series decomposition (7-day period)

- Observed values
- Adjusted values

\[ y = 171.73e^{0.8021x} \]

\[ R^2 = 0.9702 \]

Figure 6. Average Number of Visitors per Day to the MTC Website Planner, January–May 2004
Figure 6, we observe that the peak period is on Monday and Tuesday. We can also see that there is a slight yearly peak during August and September, when most of the transit network changes are made, and students use the site to access new schools.

**Location Specification**

Also of interest is a look at the location specification mode itself to gain a better understanding of the use of the tools provided in the planner, and, when possible, to improve GIS data and the search engine. Figure 7 presents the distribution of location specification modes for the Laval website (2001). Note that there is no address search on this website. The study shows that the map-based search is much less used than the intersection or trip generator searches, which are more popular.

**Figure 7. Location Specification Mode Distribution for the LTC Website, 2001**
The same type of analysis has been conducted on the MTC website and shows that few visitors use only one type of location mode when they calculate their trip. Only 9.3 percent of all trip planning are from civic address to civic address. The number of calculations made with intersection pairs represents less than 5 percent of the total. The main finding is that users need a wide choice of location modes to adequately specify their origin and destination points. For this reason, these features were retained on the studied websites. Nevertheless, the preferences were taken into account in the design of the interface of the web pages.

**Entry Log Analysis for GIS Updating**

On the MTC website, the search functions have been thoroughly analyzed to search for the causes of data errors and typographical errors. A log file collects all keyboard entries and clicks on the planner sub-website. There were about 2,760,000 data inputs between June 2001 and March 2002. About 8.1 percent resulted in the display of an error message due to incorrect use of the interface by users, or because the desired location was not found (see Table 3). Of the 528,000 trip-planner visits made during this period, there was an abort-search rate of 3.9 percent which could be related to these error messages.

**Table 3. Distribution of Entry Error Messages for the MTC Website, June 2001–March 2002**

<table>
<thead>
<tr>
<th>Location Type</th>
<th>Error Message</th>
<th>Error Type</th>
<th>Count</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>Address not found</td>
<td>G</td>
<td>44,806</td>
<td>19.9%</td>
</tr>
<tr>
<td>Address</td>
<td>Unspecified civic number</td>
<td>I</td>
<td>15,284</td>
<td>6.8%</td>
</tr>
<tr>
<td>Address</td>
<td>Unspecified street name</td>
<td>I</td>
<td>2,115</td>
<td>0.9%</td>
</tr>
<tr>
<td>Address</td>
<td>Street not found</td>
<td>G</td>
<td>76,228</td>
<td>33.9%</td>
</tr>
<tr>
<td>Trip generator</td>
<td>Not found</td>
<td>G</td>
<td>21,444</td>
<td>9.5%</td>
</tr>
<tr>
<td>Intersection</td>
<td>Unspecified 1st street</td>
<td>I</td>
<td>847</td>
<td>0.4%</td>
</tr>
<tr>
<td>Intersection</td>
<td>1st street not found</td>
<td>G</td>
<td>21,458</td>
<td>9.5%</td>
</tr>
<tr>
<td>Intersection</td>
<td>Unspecified 2nd street</td>
<td>I</td>
<td>7,257</td>
<td>3.2%</td>
</tr>
<tr>
<td>Intersection</td>
<td>2nd street not found</td>
<td>G</td>
<td>19,065</td>
<td>8.5%</td>
</tr>
<tr>
<td>Intersection</td>
<td>Intersection not found</td>
<td>G</td>
<td>16,204</td>
<td>7.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>224,708</td>
<td>100%</td>
</tr>
</tbody>
</table>

* G = GIS-related, I = interface-related
Table 3 shows that a small proportion of the errors were due to incorrect use of the website interface by users. Missing fields, for example, are common, and one of a number of problems which can be easily corrected by changing the behaviors of the web pages. GIS errors, commonly features not found, are harder to tackle. A spelling error or language mismatch (both French and English are used on MTC website) can be the cause. Geographical corrections can help reduce missing intersection problems. For example, “virtual intersections” were coded at level intersection between freeways and streets, even though there is no physical intersection at these places. Based on most common errors, aliases were added for some street names, so that spelling variations would be accepted. With the help of these error entries and other inputs, more than 1,000 features are updated each year in the MTC’s GIS (e.g., street geometry, feature naming, new intersections, new address ranges).

Transit-Oriented Analysis
Although statistics on the number of visitors and their lengths of stay on the websites are useful for Internet designers, they do not provide information on the trip behavior of transit users. Let us now examine the log files to characterize the origin and destination locations, and also the use of the transit network.

Bias and Limitations of the Analysis
It is clear that the results of this study rely on the behaviors of only a portion of all transit users. A recent study (CEFRIIO 2003) shows that about 60 percent of Canadians use the Internet on a regular basis. About 80 percent of them are between 15 and 25 years old, as are many of the transit users in the Montreal area. An internal survey of the Laval Transit Commission shows that about 70 percent of its users visit the authority’s website, and about 70 percent of these individuals use the trip planner. This translates into a trip planner usage of about 50 percent of all transit users in the Laval territory. The same survey reports that about 20 percent of them use the trip planner once a week, 45 percent a few times a month, and 20 percent at each schedule change (about once every three months). Finally, the underlying hypothesis is that website planner users do, in fact, make the trip that they calculated. This cannot be verified at the present time because no specific survey has been carried out for this purpose.
Main Destinations

In 2001, Montreal International Airport in the suburb of Dorval was the destination most often selected on the MTC website trip planner (4,514 trip planning calculations), followed by major subway terminal stations (Henri-Bourassa, Longueuil, Berri-UQAM, and Côte-Vertu). The relative difficulty in accessing the airport via the public transit network could be an explanation for the popularity of this destination. The map in Figure 8 shows all destinations related to more than 100 trips for 2001. Here, we can see some local concentrations in four places: A—the airport zone, B—the Saint Laurent industrial zone, C—the University of Montreal, and, of course, D—the Central Business District (CBD) zone.

On the Laval website, it is possible to obtain a path that leaves the LTC to go into the Montreal territory, and vice-versa. In Figure 9, the map shows the distribution of destinations over Laval’s urbanized area for the whole of the year 2001. While the distribution is more spread out, there is a concentration in the CBD of Laval (A). On the Island of Montreal, calculations are made toward subway terminal stations, where users can easily find their way to their final destination (B—Henri-Bourassa and C—Montreal CBD stations).

Network Usage

Evaluation of transit network usage from individual trip declarations is a common feature of the TDA. The software MADITUC was used for this task. The following steps were carried out to obtain network load profiles and data on network components (MTC website):

- Individual trips are extracted from the website log file (pairs of origin and destination X-Y coordinates). Data are used “as is” and fully compatible to the TDA-based software.
- Each trip is simulated using MADITUC’s trip simulator, which is basically the same as the website planner.
- The trips are “loaded” into the transit network objects to obtain the load profile.
Figure 8. Map of Major Destinations of Planner Users, MTC Website
The load profile for the trips calculated on the MTC website in January 2003 is shown in Figure 10. It is significant on the subway network (enclosed map), which is considered normal for transit usage in Montreal. There is also an increased load on bus routes going to the western part of the Island of Montreal, compared to the normal load profile (not shown).
Table 4 presents statistics on transit network usage by users of the trip planner (based on calculated trips) and regular MTC transit users (data from 1998 household survey). The average total travel time and the average in-vehicle time are higher for the trip planner user. This would suggest that the trip planner is used to plan longer trips. However, the average access time (time to walk from origin to nearest bus stop or station) is lower for the trip planner, possibly because the locations specified in the planner are mostly intersections (many bus stops are located directly at intersections). The proportion of subway users is higher for the trip planner due to the concentration of destinations at the CBD.

### Table 4. Transit Network Load Statistics for Website and Regular Transit Users

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of trips loaded</td>
<td>43,297</td>
<td>35,533</td>
</tr>
<tr>
<td>Average total travel time (min)</td>
<td>49.99</td>
<td>46.28</td>
</tr>
<tr>
<td>Average access time (min)</td>
<td>10.05</td>
<td>11.71</td>
</tr>
<tr>
<td>Average waiting time (min)</td>
<td>17.57</td>
<td>15.88</td>
</tr>
<tr>
<td>Average in-vehicle time (min)</td>
<td>19.51</td>
<td>16.59</td>
</tr>
<tr>
<td>Average no. of transit routes per trip</td>
<td>2.02</td>
<td>1.84</td>
</tr>
<tr>
<td>Prop. of subway users (%)</td>
<td>63.0</td>
<td>57.6</td>
</tr>
</tbody>
</table>

### Comparison with Origin-Destination Survey Matrices

Even though the websites do not collect any information on trip attributes, such as purpose or trip mode habits, we can compare the O-D matrices obtained from the website trip planner to those obtained from the 1998 O-D survey, to better characterize the website users. The goal is to know if the behavior of the website user is different from the regular transit user.
Table 5. Correlations Between Survey and Website Matrices

<table>
<thead>
<tr>
<th>O-D Matrices for Trip Calculation on STM Site</th>
<th>WEB2000</th>
<th>WEB2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>STM website, 2000 (WEB2000)</td>
<td>1.000</td>
<td>0.982</td>
</tr>
<tr>
<td>STM website, 2001 (WEB2001)</td>
<td>0.982</td>
<td>1.000</td>
</tr>
<tr>
<td>1998 survey O-D matrices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All trips, Montréal residents (TOT98MTL)</td>
<td>0.694</td>
<td>0.689</td>
</tr>
<tr>
<td>All trips, all residents (TOT98TOT)</td>
<td>0.707</td>
<td>0.701</td>
</tr>
<tr>
<td>Transit trips, Montréal residents (TC98MTL)</td>
<td>0.790</td>
<td>0.825</td>
</tr>
<tr>
<td>Transit trips, all residents (TC98TOT)</td>
<td>0.795</td>
<td>0.830</td>
</tr>
<tr>
<td>Work trips, Montréal residents (TRAV98MTL)</td>
<td>0.797</td>
<td>0.812</td>
</tr>
<tr>
<td>Work trips, all residents (TRAV98TOT)</td>
<td>0.822</td>
<td>0.834</td>
</tr>
<tr>
<td>Study trips, Montréal residents (ETUD98MTL)</td>
<td>0.586</td>
<td>0.581</td>
</tr>
<tr>
<td>Study trips, all residents (ETUD98TOT)</td>
<td>0.592</td>
<td>0.587</td>
</tr>
<tr>
<td>Transit trips, work trips, Montréal residents (TCTRAV98MTL)</td>
<td>0.565</td>
<td>0.610</td>
</tr>
<tr>
<td>Transit trips, work trips, all residents (TCTRAV98TOT)</td>
<td>0.571</td>
<td>0.616</td>
</tr>
<tr>
<td>Transit trips, study trips, Montréal residents (TCETUD98MTL)</td>
<td>0.683</td>
<td>0.709</td>
</tr>
<tr>
<td>Transit trips, study trips, all residents (TCETUD98TOT)</td>
<td>0.688</td>
<td>0.713</td>
</tr>
</tbody>
</table>

In this case, we defined 41X41 O-D matrices. Table 5 presents the correlation coefficient (R at a 95% confidence level) between these matrices, obtained by single-cell couple comparison. First, it shows a strong correlation between 2000 and 2001 for the website, confirming that the planner user’s behavior remains constant, in spite of a 221 percent increase between these two years. Next, it shows that the correlation is stronger for transit-trip and work-trip matrices. This would identify the main characteristics of the Internet users, who are, we suppose, mostly transit users.
A quick look at Figure 11 demonstrates the similarity between the website usage matrix and the matrix developed from the transit trips in the O-D survey (the cells are shaded at proportional scales). The upper right-hand part of matrix A is the airport zone, and shows the importance of this zone for Internet users. Our hypothesis is that the website captures users who are not interviewed in O-D surveys, such as tourists and nonresident business travelers. In Figure 12, a comparison based on the importance of the matrix diagonal and CBD destinations confirms our previous analysis. The pattern for transit trips (TC98MTL) is similar to the pattern of users’ website declarations (WEB2001). The 2001 matrix to better fit the household survey data conducted three years before.

**Departure Time**

The distribution of the departure time is also a measure that can be used to compare website users’ behaviors with behaviors from household survey data. Figure 13 shows the distribution of departure times for three categories: calculated trips on the STL website in 2000, declared trips by Laval residents (1998 survey), and declared trips by STL users (1998 survey). Results show that the proportion of departure times in the morning is higher for the trip planner than for the declared trips. This would suggest that the great proportion of planned trips are home-based (homeplace as origin).

**Figure 11. Matrix Pattern for MTC Website 2001 and 1998 Survey (transit trips)**
Figure 12. Matrix Comparison Based on Diagonal and CBD Destinations (MTC website)

Figure 13. Distribution of Departure Time for Declared and Calculated Trips
Conclusions
The aim of this article was to determine whether trip planner log file analysis could help to improve the transit service, and, if so, how. The question cannot be completely resolved until we find methods to overcome, or at least evaluate, the following bias and limitations that were identified:

- Transit users do not all have access to the Internet; thus, they do not all visit the transit authority website.
- Visitors to the website do not all use the trip planner, although, in the case of Laval, more than 70 percent of the visitors have used it.
- The trips that have been calculated are only “planned” trips, and users can, of course, choose not to make the trip.

Nevertheless, it seems that relevant findings can be gleaned from the huge amount of data collected in the trip planner log files. In this project, examination of the log files of the transit trip planners of the Montreal Transit Commission and the Laval Transit Commission websites has led to the following observations:

- The growth in usage of this kind of website is faster than the growth of Internet usage itself, showing that there is an interest in the availability of transit trip planners on the Web.
- The Internet user usually performs more than one calculation during a visit. The tool can be accessed whenever it is needed.
- The trip planner is used to access destinations that are more difficult to reach by public transit. Such a tool is useful when the transit network is complex (several transfers) or when the areas are not well serviced.
- The user of a trip planner is typically a regular commuter and a worker. The trip planner also can be accessed and used by other regular users and by tourists relatively easily.

In addition to these observations, trip planner log files were found to be useful in some specific cases. The MTC had a better knowledge of its most popular destinations. The trip planner entry log helps to improve the underlying GIS and the website interface (the design of the new 2004 STL website has been based on findings from this project). Often, trip planners are used to access newly built structures or new developments; the GIS must, in this case, be updated as soon as possible.

This article has shown some potential usages of trip planner log files. Actually, with the help of the Totally Disaggregate Approach and appropriate data structures,
similar user behavior analysis are performed on other individual data, such as log files obtained from the usage of smart cards in transit systems.

**Acknowledgments**

The authors thank the Montreal Transit Commission, the Laval Transit Commission, and the Natural Sciences and Engineering Research Council of Canada (NSERC) for their supporting of this research project.
References


**About the Authors**

**Martin Trépanier** (mtrepanier@polymtl.ca) is professor of industrial engineering at the Ecole Polytechnique de Montreal. His research is mainly related to logistics, information systems, object-oriented modeling, GIS development, and Internet applications. He worked along with the MADITUC group in this research project.

**Robert Chapleau** (rchapleau@polymtl.ca) is professor of civil engineering (transportation planning) and founder-director of the MADITUC group, Civil Engineering Department, Ecole Polytechnique de Montreal. He developed the Totally Disaggregate Approach in transportation and is participating in several research projects in the Montreal area.

**Bruno Allard** (ballard@polymtl.ca) is research associate in the MADITUC group, Civil Engineering Department, Ecole Polytechnique de Montreal. He is an experienced system developer and manager, with applications in origin-destination surveys, transit operation, and GIS-T-based websites.