DEVELOPMENT OF A DEMAND SCREENING TOOL FOR EXPANSION
OF EXISTING OR CREATION OF NEW PARK AND RIDE FACILITIES

Theodore Ehrlich
Transportation Engineer
534 Anderson Avenue
Wood Ridge, New Jersey, 07075
Telephone: 201-935-0184
Fax: 201-935-6526
email: tedtraffic@optonline.net
(corresponding author)

Submitted: July 31, 2013

Word Count: 3,489 words, 12 exhibits (@250 words each) = 6,489 words
ABSTRACT
Facilitating transit usage is a critical part of maintaining mobility. If transit service is not within walking distance, park and ride accommodations are necessary. Expanding highly used lots can be costlier and less feasible than creating greater additional capacity at new locations. An expeditious method of screening for demand at potential new locations is needed. The method described herein performs that function, using GIS methodology to quickly develop demand estimates for new lots, as well as unmet demand at existing lots. The method uses readily available census data, as well as commonly available lot capacity and usage data. Survey data or model capabilities are not required. The method can be calibrated to observed usage, and is intended to be sensitive to local conditions and transit service levels.

The procedure uses tract level resident worker quantities, and allocates these to segments of geometric shapes, each of which is tagged with market capture percentages. Road buffering is used to separate out developable land for use in allocation. Shape orientation may be set, and overlap of market areas corrected. Calibration is accomplished by comparison of estimates with usage of existing facilities, and adjustment for transit service characteristics and accessibility as observed within the study area.

Evaluation of results for 29 lots in three bus corridors, and 20 lots in two rail corridors, indicated very close correlation of predicted with expected values. Consistency was seen, with outliers attributed to service or accessibility deficiencies and lot capacity constraints, as expected.
INTRODUCTION
This effort has focused primarily on developing and applying analytical techniques to quantify and evaluate deficiencies in the supply of park and ride facilities. The tools developed will assist in estimating the order of magnitude demand for park and ride facilities at defined locations, and establishing the primary market area for those selected locations. This can assist planners in estimating unmet demand at existing sites, predicted usage at possible new sites, and the degree of relationship between sites at different locations. The work met several objectives:

- To estimate market and potential parking demands for a potential transit or car pool parking location.
- To provide a usable tool where there is not a desire to apply a complex travel demand forecasting model.
- To focus on the marketplace (demand) rather than transportation service (supply).
- To provide an indication of where patrons will originate.

The development has involved the following steps:

- Identify candidate procedures and relationships.
- Obtain supply data to support the analysis process
- Obtain demand data to support the analysis process
- Establish a GIS platform upon which to perform computations and illustrate results.
- Construct GIS tools and methods to define market areas and incorporating catchment segments within those market areas.
- Define and apply user-defined rotation and addition procedures.
- Refine the GIS platform to address development density disparities.
- Define and apply an overlap procedure.
- Define the transit type and corridor analysis.
- Apply tract based data to the previously developed platform, and compute market area demand levels.
- Compare predicted usage with actual usage; refine calibration.
- Address additional perspectives.

IDENTIFY CANDIDATE PROCEDURES AND RELATIONSHIPS
The literature provides general information, such as distance profiles for park and ride users and some measures of typical mode share percentages. Two metropolitan areas researched market shed areas of selected existing park and ride facilities, and summarized the results. No generalized application was developed from this data.

A somewhat similar approach has been utilized by the Delaware Valley Regional Planning Commission (DVRPC) on a site or project specific basis. Specific local data on mode share by residence location relative to station location was gathered for each application by DVRPC, but a means of generalizing these demand/supply relationships to other sites was not developed by DVRPC.

In summary, the approach used here respects the information available in the literature, but is an original approach to development of an estimation tool.
OBTAIN SUPPLY DATA TO SUPPORT THE ANALYSIS PROCESS
A Park and Ride geodatabase was created for the New Jersey Department of Transportation (NJDOT) in 2004. The geodatabase is in Access format, which also provides for use within an Excel format, and is linked to an ArcGIS geo-spatial database framework. The database contains information to identify the physical and operational characteristics needed for this investigation.

The geodatabase describes approximately 500 existing park and ride sites, and provides selected attributes for each. The data identifies the location of sites by xy coordinate, and aerial photos are tagged to each site. Data includes the identification of sites by type (rail, bus, pooling), parking capacity and usage, transit service mode and route number, and other supportive data.

OBTAIN DEMAND DATA TO SUPPORT THE ANALYSIS PROCESS
Census tracts contain base data, such as population, resident workers, destination based workers, housing units, zero or one car households, land area, resident mode share (transit, auto, walk bike), destination based mode share (transit, auto, walk bike), and more. It was noted that mode usage is expected to change with park and ride improvements; and the ratio of workers per household or per population varies considerably by location. For this analysis, therefore, Resident Workers by tract was used to support the quantification of potential park and ride patrons. Year 2000 Census information was used. Since the geodatabase describes conditions in approximately the year 2004, the sources are appropriately matched for this investigation. When the relationships are established, they should be applicable to later year applications, as in other transportation planning models.

GIS PROCEDURES
Details of GIS procedures will not be presented in this paper. Rather, descriptions will be given outlining the steps to be taken, in sufficient detail so that a GIS practitioner and others can understand the techniques used. GIS tools used include clip, union, extract, batch, erase, merge, set, ratio and join. These are standard methods included in the ARCGIS toolbox.

DEFINE GIS MARKET AREAS CONTAINING CATCHMENT SEGMENTS
Based upon parameters from the literature, a geometric figure in the shape of a cone, called the “catchment area”, was constructed to represent the potential market area of a park and ride site (Exhibit 1). Five “rings” within this figure were created, proceeding outward from the park and ride site. Each ring is considered a catchment zone within a catchment area. The rings are defined as follows:
- Ring 1 has a radius of 0.25 mi, and represents the Walk In area. No park and ride trips are expected to originate within this ring.
- Ring 2 is the “Kiss and Ride” or drop off area. This ring has an outer radius of 1 mi. A capture ratio of 5% is assumed here (5% of all park and ride trips to the park-ride site originate in this ring).
- 3 is the “High” capture rate area, with an outer radius of 2.5 mi, and a capture rate of 50%.
- 4 is the “Medium” capture rate area, with an outer radius of 4 mi, and a capture rate of 25%.
- 5 is the “Low” capture rate area, with an outer radius of 6 mi, and a capture rate of 20%.
EXHIBIT 1  Catchment area and ring segments
CATCHMENT AREA CONSTRUCTION

Due to the number of sites to be investigated, a custom program (SHAPEGEN) was created to compute the coordinates of a shape file containing the catchment area and its divisions for any single park and ride. Each existing or contemplated park and ride has one such catchment shape file associated with it, and the program is used to compute these shape files for some or all rail/bus/car pool lots in the state or selected corridors. The shape files may also be computed within GIS.

Following the predominant commutation routing, the cones were oriented on an axis emanating from the central attraction area (CBD) to the park and ride site using the xy coordinates of each. Central points were identified as Newark, Trenton, Philadelphia and Atlantic City. This recognizes the fact that the great majority of rail and bus services in the state operate in a radial, rather than circumferential, direction. Placement of additional market areas may be accomplished using the same program, or, preferably, using GIS techniques to copy one or more of the already created areas to represent a new park and ride facility. Exhibit 2 illustrates catchment areas created for the I78 sub corridor.

USER DEFINED ROTATION OR ADDITION PROCEDURE

The axis of each catchment area has been generated to point towards the appropriate major CBD. Thus, the catchment area will be upstream of the park and ride site. At times, portions of major highway corridors are not directly so aligned, and therefore the catchment areas also may not be properly aligned. Notice the catchment locations of the northern park and ride sites of the Rt. 9 bus corridor; they only encompass the population to the west of the corridor. In such cases, with discretion, the user can rotate the catchments to be bisected by the highway (Exhibit 3). There are a number of rotation options. The simplest option is to manually rotate individual catchments, using ArcGIS Editor Tools. Another option would be editing the Shapegen Executable.

In a similar fashion, where more than one road feeds the park and ride site, such as locations near the intersection of two major roadways, additional catchment areas may be positioned to properly include the additional market area serving the site. For example, the Princeton Junction Station encapsulates a larger boundary than the 6 mile default radius (Exhibit 4). Using GIS, the user can add a frontier to the Princeton Junction Station catchment area by appending additional catchment areas, which also may be used to address satellite lot demand.

REFINE THE GIS PLATFORM TO ADDRESS DEVELOPMENT DENSITY DISPARITIES

Although New Jersey is the most densely populated state in the country, many census tracts include significant areas of open land, steep slopes, water bodies, public land, and similar non-residential uses. GIS layers are available to identify some, but not all, of such uses. For allocation of Resident Workers (commuters) to market areas, while accounting for non-uniform distribution of Resident Workers within tracts, a roads layer was used within the GIS platform (Exhibit 5). All roads were buffered by 500’, defining the area within which people may live. The buffered area was used for market allocation (Exhibit 6). Therefore, the proportion of the total road buffered area in the tract that falls within the catchment area would be equal to the proportion of the total tract Resident Workers that live in the catchment area.
EXHIBIT 2 178 corridor bus and rail park and ride capture areas

Rt 78 Corridor Park and Rides

Legend:
- Rt 78
- Rail Lines
- Bus
- Rail
- County
- Municipality

Miles
0 2 4 8 12 16
EXHIBIT 3  Route 9 bus park and rides with non-rotated and rotated catchments
EXHIBIT 4  Appended Princeton Junction catchment areas
EXHIBIT 5 178 rail park and rides with roads
EXHIBIT 6 178 rail park and rides with buffered roads
OVERLAP PROCEDURE

The longest catchment area dimension is six miles. When the park and ride site spacing is closer than six miles, the demand areas may overlap (Exhibit 7). This results in double counting – some demand will be tallied to more than one site.

Exhibit 8 details the New Brunswick and Jersey Avenue catchment areas. Since the New Brunswick catchment area overlaps the Jersey Avenue catchment area, the user must apply the “Overlap Procedure” in order to prevent double counting the overlapping portions of the catchments.

One solution is to work from the furthest site inward. The first catchment area, Jersey Avenue, will remain whole. The portion of the Jersey Avenue catchment area that overlaps the New Brunswick catchment area will be erased from the New Brunswick catchment area (Exhibit 9). The process is continued, moving inward along the corridor. Thus, where the catchments overlap, the outermost catchment will remain whole, and the next inbound catchment will have the overlap area removed to represent its “actual” catchment area.

This is accomplished within GIS by using the “Overlap Procedure”. The result is the creation of unique, reshaped capture areas for each site.

This process can be manipulated to favor certain sites. For example, sites with available spaces and serving express transit stops can be defined as primary and other “competing” sites as secondary (i.e. Princeton Station and Princeton Junction Station).

TRANSIT TYPE WITHIN CORRIDOR ANALYSIS

The process developed herein is best applied separately to specific study area locations rather than for the entire state all at once. Although the relationships have relevance throughout the state, each study area is likely to have unique characteristics that should be recognized. It is suggested that a primary corridor (say Route 78) be first identified. Within that corridor, sub corridors would then be selected (such as west of Route 287). Then, bus sub corridors and rail sub corridors would be separated for the primary investigation. Examples given herein will follow that pattern.

Other factors come into play, as will be described in more detail later in this document. Since each facility displays unique levels of accessibility (distance and visibility from the approach route), modality (bus versus rail, express versus local service), regionality (shorter versus longer trip attraction), and destinationality (main CBD versus more local center or transfer point), further interpretation may be made after the primary analysis.

APPLY CENSUS DATA TO THE PREVIOUSLY DEVELOPED PLATFORM, AND COMPUTE MARKET AREA DEMAND LEVELS

“Predicted Usage” is based on the Resident Worker quantities from the 2000 census tract data. A union is performed between the catchment zones and census tracts to create catchment sectors. A catchment sector represents each census tract within a catchment zone. In a majority of the cases, a catchment sector will overlap only a portion of a census tract. Therefore, the resident worker variable of the census tract does not adequately reflect the actual resident worker population of the catchment sector (e.g. the catchment sector only overlaps 10% of a census tract). The ratio of the catchment sector area to the area of the corresponding census tract is calculated and applied to the resident worker variable to expose a more accurate resident worker
EXHIBIT 7 Northeast corridor rail park and rides
EXHIBIT 8  Northeast corridor overlap example
1 EXHIBIT 9  Northeast corridor erase example
EXHIBIT 10  Catchment sector example - Princeton Junction Station
prediction (e.g. if the catchment sector only overlaps 10% of a census tract, then apply the 10% ratio to the resident worker population to reach “Predicted Usage”) (Exhibit 10).

After calculating the ratio, “Predicted Usage” can be determined for each catchment sector:

- Predicted Usage per catchment sector = 
  Resident workers x Ratio (capture rate) x Weight Effect (% park and ride capture of all trips)
- Predicted Usage per site = \[ \sum \text{Predicted Usage per catchment sector} \]

The sum of the Predicted Usage per catchment sector for each catchment area provides the total predicted usage for parking at each site.

**COMPARE PREDICTED USAGE WITH ACTUAL USAGE**

After determining the process, the “Predicted Usage” for parking at each lot was calculated and tested in a variety of corridors and transit types. Note that vehicle occupancy (persons per vehicle) was not included in the above calculations, so the indicated volumes are slightly different than actual transit ridership / boardings would be.

In addition to calculating “Predicted Usage”, a scoring system was developed to categorize the variety of park and ride stations by transit type, modality, accessibility and regionality (Exhibit 11). During analysis, stations can be grouped by scores. The scores are initially selected based on local knowledge of the service characteristics of each site. Further calibration may be obtained utilizing the comparison of predicted versus actual usage within the corridor.

After comparing the calculated “Predicted Usage” with the observed “Actual Usage”, a reasonable correlation was obtained in most cases. This confirmed the validity of the general concept being examined here. A more detailed correlation within this corridor might be performed using bus and rail survey data from transit operators, where available. Further adjustments might be appropriate in certain corridors to account for local situations, such as differential occupancy and usage of paid versus permit lots, express versus local transit service, and similar factors.

**EXHIBIT 11 Scoring By Attributes**

<table>
<thead>
<tr>
<th>Rail Rank</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>2 Seats</td>
<td>2 Seats</td>
<td>1 Seat</td>
<td>1 Seat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-Express Into NY</td>
<td>Express into NY</td>
<td>Non-Express into NY</td>
<td>Express into NY</td>
<td></td>
</tr>
<tr>
<td>Accessibility</td>
<td>Poor</td>
<td>Default</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regionality</td>
<td>Local to Major Center</td>
<td>Newark / NY</td>
<td>NY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bus Rank</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>Low/No Service</td>
<td>Steady Service</td>
<td>Express Service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility</td>
<td>Not within 500 ft of Main Highway</td>
<td>Within 500 ft of Main Highway</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regionality</td>
<td>Local Trip</td>
<td>Local to Major Center</td>
<td>Express to Major Center</td>
<td>Newark</td>
<td>NY</td>
</tr>
</tbody>
</table>
COMPUTED RESULTS
Calculating demand using the above process will produce results that indicate “big or little, up or down” demand levels for existing and proposed park and ride sites within a study area. It is important to apply local knowledge to the analysis to refine the calculated results.

Detailed analyses of three bus sub corridors and two rail sub corridors were conducted. For each site within each sub corridor, the predicted usage was compared with the actual usage. Plots of predicted versus actual usage are shown in Exhibit 12. The plots show the separation of data by high attribute scoring, low attribute scoring, and all results combined. Commentary is offered below.

- The I78 bus corridor caters to longer distance commuters, some of which come from west of the state line. About half the six park and ride sites are at or close to capacity. Rail service is non existent or poor within most of the corridor. The overall ratio of actual usage to predicted usage was 0.15.
- The Route 9 bus corridor has no rail service. Approximately one third of the 12 park and ride sites are at capacity. The overall ratio of actual usage to predicted usage was also 0.15.
- In the Route 23 bus corridor, all six sites are near or at capacity. The overall ratio of actual usage to predicted usage was 1.05.
- For rail, the closer in portion of the I78 corridor was examined. For the Gladstone Branch four of 10 lots were full. The overall ratio of actual usage to predicted usage was 0.20. For the Raritan Valley line, six of ten lots are full. The overall ratio of actual usage to predicted usage was also 0.20.

In summary, for most sites, the actual usage was 20% of the predicted usage based on total resident workers in the catchment area. The auto occupancy in the area has been consistently measured at 1.32 people per car. The census journey to work data shows that in general, about 65% of resident workers work in the county in which they live, and so 35% commute out of the county. The bus or rail service is generally for the latter group in the areas examined. Therefore, the expectation would be that of 100 total resident workers, 35 commute longer distances in (35/1.32) 26 cars. This compares quite favorably with the 20/100 predicted parkers computed by the methods described in this paper. Further, the 0.20 ratio of actual to predicted usage is low, since the actual demand at lots that are full is higher than the actual usage recorded.

In general, bus demand would be estimated at 20% of predicted, and rail at 25% of predicted as a conservative starting point. The factors previously outlined would then also be considered when doing a detailed analysis of a sub corridor.

The procedure and sample results were presented to a meeting with 12 TMAs, NJDOT, NJ Transit, and other interested parties. The attendees agreed that this procedure would be most helpful to perform a preliminary evaluation of options for expanding or supplementing existing park and ride facilities in corridors exhibiting an apparent need for such facilities.
EXHIBIT 12 Predicted versus actual usage

ADDITIONAL PERSPECTIVES
The following features illustrate the uniqueness of the screening tool developed as described herein:

- The procedure does not require knowledge of origin – destination data for the study sites.
- Proprietary models are not required to perform the estimations.
- The use of GIS allows a greater insight into the effect of nearby geography and land use on the demand at each location. The visual depiction of the nearby corridor supports greater insight into demand and usage.
- Other additional components may include editing the weight of individual catchment zones and refining application procedures.
- Local knowledge may be input to influence the calculations.
- The GIS component is relatively straightforward, and is needed mostly in the initial phase of the investigation.
- The results to date are within the range of accuracy needed for a screening tool.

ACKNOWLEDGEMENTS
This project was performed by AECOM (Theodore Ehrlich – Chief Transportation Engineer, and Matt Kabak – GIS Specialist) for the New Jersey Department of Transportation, Bureau of Commuter Mobility. Sheree Davis, Acting Manager, and William Piedra, Park and Ride Coordinator, were most helpful in inspiring and supporting this effort. We would also like to recognize the early work of the Delaware Valley Planning Commission in applying rail station surveys to comparisons of alternative park and ride improvement scenarios for particular sites.