Park-and-Ride Facilities in New York City

Economic Analyses of Alternative Locations

José Holguín-Veras, Jack Reilly, Felipe Aros-Vera, Wilfredo Yushimito, and Jhael Isa

A procedure is developed to assess the economic feasibility of park-and-ride facilities. Relevant literature is discussed, and a mathematical formulation that can be integrated with a regional planning model is produced and applied to the selection of park-and-ride facilities in New York City. The evaluation procedure is divided into two main stages: candidate selection and candidate evaluation. The candidates are selected according to a set of criteria that includes demand considerations, transit connectivity and design, community integration, and economic viability. Economic assessment of the candidates considers the generalized cost of travel and entails the use of a binary logit model and the computation of four performance measures: expected demand, market share, weighted average savings, and present value of benefits.

Congestion is one of the most vexing problems in urban areas. Park-and-ride facilities foster public transportation and decrease congestion. With the need for sustainable transportation and the possibility of innovative private–public partnerships, park-and-ride facilities play a strategic role in decreasing congestion and providing alternative transportation services. One main appeal of park-and-ride systems is that they enable users to take advantage of the best features of both automobile and transit: The automobile provides connectivity from home to the park-and-ride facility, and transit enables the user to avoid using the automobile for the most congested part of the journey (from the park-and-ride facility to the destination).

Since the 1970s, park-and-ride facilities have been considered a suitable method of reducing corridor congestion (*1, 2*) and a catalyst for public transportation (*3*). From the very beginning, researchers, practitioners, and agencies have recognized the importance of a structured, systematic procedure to evaluate these facilities. Two warrant special mention. Spillar suggests a process that highlights many of the important elements necessary for successful planning of park-and-ride systems (*4*). AASHTO builds on this work and provides several recommendations for the planning of park-and-ride facilities, including evaluating the facility location on the basis of detailed engineering studies and using planning techniques to estimate the demand for park-and-ride facilities (*5*).

J. Holguín-Veras, J. Reilly, and F. Aros-Vera, Department of Civil and Environmental Engineering, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180. W. Yushimito, Department of Engineering and Sciences, Adolfo Ibáñez University, 750 Padre Hurtado, Room A 325, Viña del Mar, Valparaíso Region, Chile. J. Isa, Universidad Ibero-Americana, Santo Domingo, Dominican Republic. Corresponding author: J. Holguín-Veras, jhv@rpi.edu.

Transportation Research Record: Journal of the Transportation Research Board, No. 2276, Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 123–130.
DOI: 10.3141/2276-15

The assessment of park-and-ride facilities with optimization models is common. Faghri et al. propose a method to aid planners in determining the optimal location of park-and-ride facilities using a tool that is an expert system–geographic information system hybrid (*6*). Wang et al. investigate the optimal location and pricing of a park-and-ride facility in a linear city (*7*). Horner and Groves approach the facility location problem as a network flow-based model for the placement of rail park-and-ride facilities (*8*). Finally, Farhan and Murray develop a multiobjective spatial optimization model to account for objectives specific to park-and-ride systems (*9*).

Despite many approaches developed in the literature, the economics of locating park-and-ride facilities have not been thoroughly studied. In this paper, a method is developed that can be easily integrated into a regional planning model. It is based on the generalized cost that users incur when using a personal automobile or public transportation.

The paper is structured as follows. First, basic guidelines are introduced for the identification of candidate sites. Then, the evaluation method and the application to the New York City case are discussed. Finally, conclusions and further research are presented.

CANDIDATE IDENTIFICATION

Identification of an initial potential set of candidates is a crucial step in the process of planning a park-and-ride system. To start, it is important to include any possible candidate to produce a preliminary set that will be refined and evaluated. The literature identifies the key factors: demand considerations, transit connectivity and design, community integration, and economic viability. A preliminary set of candidates can be produced by considering these factors (*5*).

Demand Considerations

A primary consideration for park-and-ride location is the demand that the site(s) could attract. General guidelines suggest that a corridor with a level of service of E or worse has a high potential demand (*4*). Estimated demand is a function of both the total potential demand the facility could compete for and how attractive the facility is for potential users.

Potential demand typically is assessed by defining the catchment area, that is, the geographic region within which users of the park-and-ride system may be drawn. On the basis of real-life case studies, different ways have been proposed to define the catchment area for a single park-and-ride site. Some suggested shapes are conical (*10*), parabolic (*2, 4, 11*), and ellipsoid (*1*). Although the parabolic shape is most frequently suggested, parabolas are defined in very different ways, which is understandable given the fact that shapes are drawn with collected data.

However, recent research by Holguín-Veras et al. proves that the catchment area is the region enveloped by the ellipsoid-like shapes that mark the loci of feasible locations for a park-and-ride facility for the potential origin–destination pairs (*12*). Even though the catchment area could indeed be approximated by a parabola, the corresponding parameters are very different from previous research. A straightforward procedure is proposed to estimate the parameters of the parabola on the basis of transit characteristics, generalized cost, and corresponding destinations.

Consideration of the catchment area implies that the closer the park-and-ride facility is to the congested parts of the city, the larger the potential number of users (Figure 1). In fact, it could be proven that the park-and-ride location that maximizes the number of potential users is the one that is offset from the edge of the congested area by a distance that allow users to travel backwards to the park-and-ride facility and still save money on their journeys to destinations in the central business district (*12*); this location is labeled as P&R_1 in Figure 1.

The second major determinant of park-and-ride demand is how attractive the site is to the users. To a great extent, attractiveness is a function of the generalized cost of using park-and-ride facilities vis-à-vis the generalized cost for the car-only trip. Whereas the car-only costs include only out-of-pocket expenses (e.g., tolls) and time- and distance-related costs, park-and-ride costs include out-of-pocket expenses (e.g., parking fee, transit fare), time-related costs, and the cost of the transfer from automobile to transit at the park-and-ride site (e.g., walking time or scheduled delay). For the park-and-ride alternative to be competitive, its generalized cost must be lower than the generalized cost for automobile only.

However, because the additional transfer cost is almost impossible to eliminate, the user must accrue significant generalized cost savings on the line-haul portion of the trip in the park-and-ride alternative. Otherwise, overcoming the additional transfer costs is not possible. The savings could be achieved by a transit service that is significantly faster than the automobile alternative, a transit service with out-of-pocket expenses that are significantly lower than those for automobile only, or both. The implication is that, in the absence of tolls and high gas prices, park-and-ride systems that are not supported by transit services that travel at the same speed as cars or faster cannot be expected to attract a significant number of users.

Transit Connectivity and Design

A good rule for preliminary site screening is to locate the main arterials and transit connections (i.e., subway or bus) to minimize transfer-related costs. Locations should be easily accessible to drivers traveling to the urban area, so the park-and-ride facility intercepts cars before they enter the congested part of the corridor; candidate sites should be located upstream of congestion. Similarly, park-and-ride facilities should be located within a visible distance of major regional or high-speed arterials that provide radial access to the activity center being served, which allows the facility to be self-promoted and more likely to be used by commuters (*4*).

In addition to visibility and connectivity, park-and-ride facilities should have comprehensive design and supervision. At a successful park-and-ride location, walking distances between the facility and the transit service are short; Burns recommends less than 0.25 mile because users are not willing to walk a great distance to access transit (*3*). The minimum requirements that a facility should provide include a substantial weatherproof shelter (which should have seats and be cleaned on a daily basis), a telephone booth (for emergencies), and adequate lighting (essential for personal security in dark mornings and evenings) (*13*). Park-and-ride facilities that are or can be served by transit services to multiple destinations, directly or with transfers to frequent services, are preferred to those that serve a single downtown destination. Finally, but not less important, park-and-ride locations might be located near green areas to make users more comfortable with walking and biking to the facility, and adding attractive landscapes inside the facility might promote demand.

Community Integration

One of the most important aspects to be considered in implementing a park-and-ride facility is the community's attitude toward the project. Facilities should be located in areas that have compatible land uses and do not require a change in zoning or in the local land

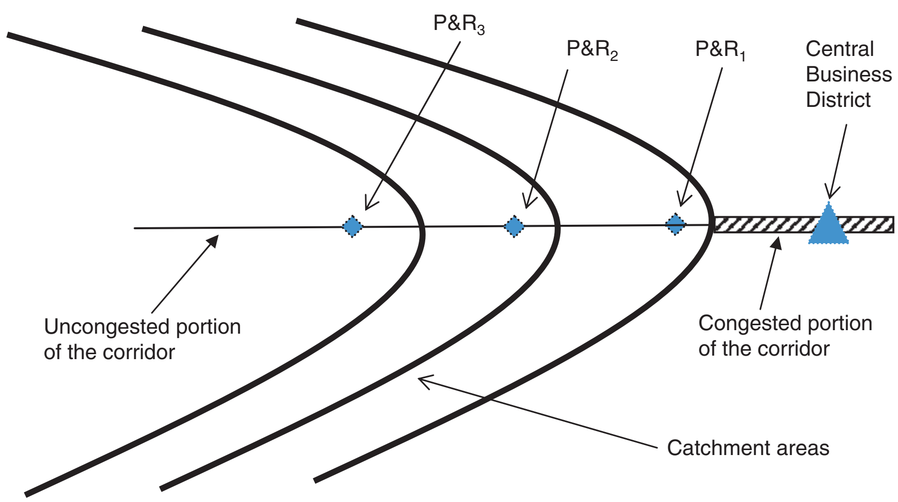

FIGURE 1 Catchment area and park-and-ride location (P&R_x = park-and-ride location).

use plan. Potential facilities should be implemented in such a way that they minimize any adverse effects on neighborhood land values. Furthermore, the implementing agency should be aware of the current goals and concerns of the local community. Site selection should minimize the impacts of noise, traffic, and vehicle emissions that new park-and-ride facilities will introduce.

Potential locations should be free of hazardous waste, drainage and soil problems, brownfields, and other fragile ecosystems. Security may be enhanced with additional lighting and roving police patrols. Cameras and phones are effective security measures and less visually intrusive. Finally, to maximize facility usage, a sidewalk network for pedestrian and bicycle circulation should be provided both within the facility and in the surrounding areas.

Economic Viability

This important criterion has to do with the overall balance between the benefits attributable to park-and-ride (e.g., economic savings to park-and-ride users, congestion reductions for non-park-and-ride users) and the cost of creating and operating the park-and-ride site plus any incremental costs of the supporting transit system. This calculation is not straightforward because the closer the park-and-ride facility is to the congested part of the travel corridor or city, the larger the potential demand (the catchment area) would be—as well as its corresponding user benefits. (However, as illustrated in Figure 1, there is a point beyond which using the park-and-ride system ceases to be a good alternative.) The challenge is that land costs are likely to increase significantly with proximity to the primary travel destinations in the central business district. As a result, the optimal location is likely to be one that offers the best trade-offs between economic benefits and investment costs.

An important factor to consider is the opportunity costs associated with the use of the land for a park-and-ride facility. Thus, the cost of implementing a park-and-ride facility is likely to be a constraint for park-and-ride implementation. To minimize construction costs and delays, a facility must be positioned in accordance with local plans and jurisdiction. Whenever possible, planners should acquire publicly owned land instead of more expensive private property. The implementing agency also should consider both initial and future costs in site development. Even though sites with low initial investments may be attractive, higher long-term transit operating costs attributable to facility access, new routes, and the like could offset the initial cost savings.

Agencies siting a park-and-ride facility can reduce capital investment and operating costs by considering public–private partnerships. For example, churches, malls, museums, theaters, and other private businesses with available parking that is used more intensively at night or on weekends are natural candidates for joint development, thereby reducing the cost of facility implementation. A final consideration regarding future park-and-ride facilities and transit plans: expansion is much less expensive than new lot construction.

METHOD FOR EVALUATING FACILITIES

The economic analysis method developed to quantify the impacts of alternative park-and-ride sites on the basis of generalized cost is discussed in this section. Generalized cost is the sum of all the components of travel impedance, including out-of-pocket expenses and the monetized value of other costs, such as travel time. Although they are not considered in this report, factors such as comfort, reliability, and externalities also can be included.

Figure 2 describes a residential origin (point i), a destination (point j), and a park-and-ride location (point p). Lines between points show the two alternatives: driving an automobile (A) from home i to destination j, and driving an automobile from home i to the park-and-ride p (PR) and then taking transit from the park-and-ride facility to the destination j. The generalized cost (g) for each alternative can be written as for automobiles:

$$g_{ij}^{\mathrm{A}} = \upsilon t_{ij}^{\mathrm{A,IV}} + f_{ij}^{\mathrm{A}} + c^{\mathrm{A}} d_{ij}^{\mathrm{A}} \tag{1}$$

and for park-and-ride facilities:

$$g_{ipj}^{\mathrm{PR}} = \upsilon\left(t_{ip}^{\mathrm{A,IV}} + t_{pj}^{\mathrm{T,IV}} + t_{pj}^{\mathrm{T,W}}\right) + f_{ip}^{\mathrm{A,PR}} + f_{pj}^{\mathrm{T}} + f_{p}^{\mathrm{PR}} + c^{\mathrm{A}} d_{ip}^{\mathrm{A}} \tag{2}$$

where

υ = value of time ($/h),
$t_{ij}^{\mathrm{A,IV}}$ = time of in-vehicle travel for automobile from i to j (h),
f_{ij}^{A} = out-of-pocket expenses for automobile (e.g., tolls) ($),
c^{A} = operating cost for automobile ($/mile),
d_{ij}^{A} = distance by automobile from i to j (mi),
$t_{ip}^{\mathrm{A,IV}}$ = time of in-vehicle travel for automobile from p to j (h),
$t_{pj}^{\mathrm{T,IV}}$ = time of in-vehicle travel for transit from p to j (h),
$t_{pj}^{\mathrm{T,W}}$ = time of walking for transit from p to j (h),
$f_{ip}^{\mathrm{A,PR}}$ = out-of-pocket expenses by automobile from i to p ($),

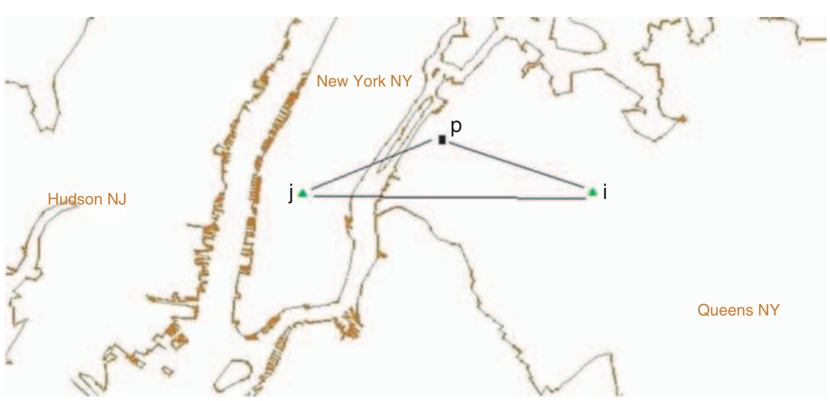

FIGURE 2 Park-and-ride method description.

f_{pj}^{T} = out-of-pocket expenses for transit (e.g., fares) ($),
f_{p}^{PR} = out-of-pocket expenses for park-and-ride facility (e.g., parking) ($), and
d_{ip}^{A} = distance for automobile from i to p (mi).

The method proposed in this paper identifies markets in which the generalized cost of traveling from i to j with park-and-ride is less than the generalized cost of traveling from i to j in an automobile. Mathematically,

$$g_{ipj}^{\mathrm{PR}} < g_{ij}^{\mathrm{A}} \tag{3}$$

Therefore, for each park-and-ride facility that satisfies Equation 3, statistical information can be computed for the level of usage, mode split, savings of users, and present value of benefits.

For a given origin–destination pair, one could expect that the users would select an alternative based on the lowest generalized cost and factors such as habit, reliability, information availability, and so on. As a result, one could assume that the probability of users choosing park-and-ride facilities will follow the logit model,

$$P_{ij} = \frac{e^{-g_{ipj}^{\mathrm{PR}}}}{e^{-g_{ipj}^{\mathrm{PR}}} + e^{-g_{ij}^{\mathrm{A}}}} \tag{4}$$

This model contrasts the value of the generalized cost to predict the proportion of users in each alternative. The negative value of the generalized cost decreases the proportion of the alternative when the cost increases. In this context, expected demand (ED) measures the number of users who choose park-and-ride facilities:

$$\mathrm{ED} = \sum_{i,j} x_{ij} P_{ij} \qquad \forall i, j \big/ g_{ipj}^{\mathrm{PR}} < g_{ij}^{\mathrm{A}} \tag{5}$$

where x_{ij} is the demand between i and j and P_{ij} is the probability from the logit model.

Market share (MS) is the percentage of users choosing park-and-ride facilities and commonly is used to measure the proportion of users on each transportation mode:

$$\mathrm{MS} = \frac{\mathrm{ED}}{\sum_{i,j} x_{ij}} \tag{6}$$

Weighted average savings (WAS) is the monetized value of savings and is given by the difference between using automobile only and park-and-ride mode for park-and-ride users:

$$\mathrm{WAS} = \frac{\sum_{i,j} x_{ij} P_{ij} \left(g_{ij}^{\mathrm{A}} - g_{ipj}^{\mathrm{PR}} \right)}{\sum_{i,j} x_{ij} P_{ij}} \qquad \forall i, j \big/ g_{ipj}^{\mathrm{PR}} < g_{ij}^{\mathrm{A}} \tag{7}$$

Present value of benefits (PVB) is a standard economic analysis method for comparing a future stream of benefits given a rate of interest. Mathematically,

$$\mathrm{PVB} = \sum_{k=1\ldots10} \frac{\mathrm{WA} * \mathrm{ED}}{(1+r)^{k}} \tag{8}$$

The assumed planning horizon considered is 10 years and the discount rate (r) is 6%.

NEW YORK CITY CASE STUDY

Application of the method developed for candidate selection and evaluation of park-and-ride sites in New York City is discussed in this section. An initial set of candidates was identified and screened, then evaluated in terms of the performance measures described previously.

Candidate Park-and-Ride Sites

The first step was to identify potential park-and-ride sites. Vacant plots of land in a 500-meter buffer around transit lines were systematically scanned to ensure a reasonable walking distance between the transit station and the park-and-ride. Applied to the Bronx, Brooklyn, Staten Island, and Queens areas, this procedure led to the identification of an initial set of 109 candidates.

The second step was to examine in detail the feasibility of these sites for park-and-ride use. To do that, the team obtained the basic characteristics of each site from the New York City Department of Finance website, which contains a classification of the type of activity performed at the site (*14*). Data analyses led to the team to determine that the only sites that could be considered as candidates were already in use for park-and-ride facilities; sites at or near shopping malls, where a negotiation for leasing spaces for park-and-ride users might be feasible; vacant land parcels; or commercial and public parking facilities in commercial areas used primarily by shoppers. Sites that did not meet any of these characteristics were discarded. At the end of the process, 59 candidates had been selected for economic analysis (Figure 3).

Potential Demand

Demand data were obtained from the regional demand model, which covers 28 counties in New York, New Jersey, and Connecticut and is based on 3,500 transportation analysis zones (*15*). Important for economic analysis purposes, the demand data were available for 2010 with forecasts for 2020 and 2030. Walking times from park-and-ride sites to transit were estimated from publicly available traffic information websites because the regional model does not include them.

The analysis focused on the highway morning peak period for single-occupancy vehicles (SOVs), which was identified as the primary target park-and-ride market. According to the regional demand model, SOVs or drive-alone vehicles account for 67.8% of automobile trips, whereas two and three users per automobile account for 26.4% and 5.8%, respectively. Moreover, approximately 2.7 million trips are made daily by transit, whereas automobiles make 6.8 million trips in the New York Metropolitan Transportation Council region. The percentage of work trips and the total number of SOV trips going into and within Manhattan are listed in Tables 1 and 2, respectively. Table 2 shows that 33.6% are internal trips within Manhattan, and, as expected, the proportion of trips decreases with the distance to Manhattan. In addition, the surrounding boroughs and suburbs (i.e., Queens, Kings, Bronx, and Westchester Counties in New York and Bergen, County, N.J.) produce 41.2% of the total SOV trips into Manhattan. Importantly, internal trips (i.e., from Manhattan to Manhattan) are not considered in the analysis. The total number of trips is 155,700 (Table 2); disregarding internal trips, total potential demand is more than 100,000 users per day.

Frequency distributions of walking times to reach transit (i.e., from the park-and-ride site to the location where the user must take

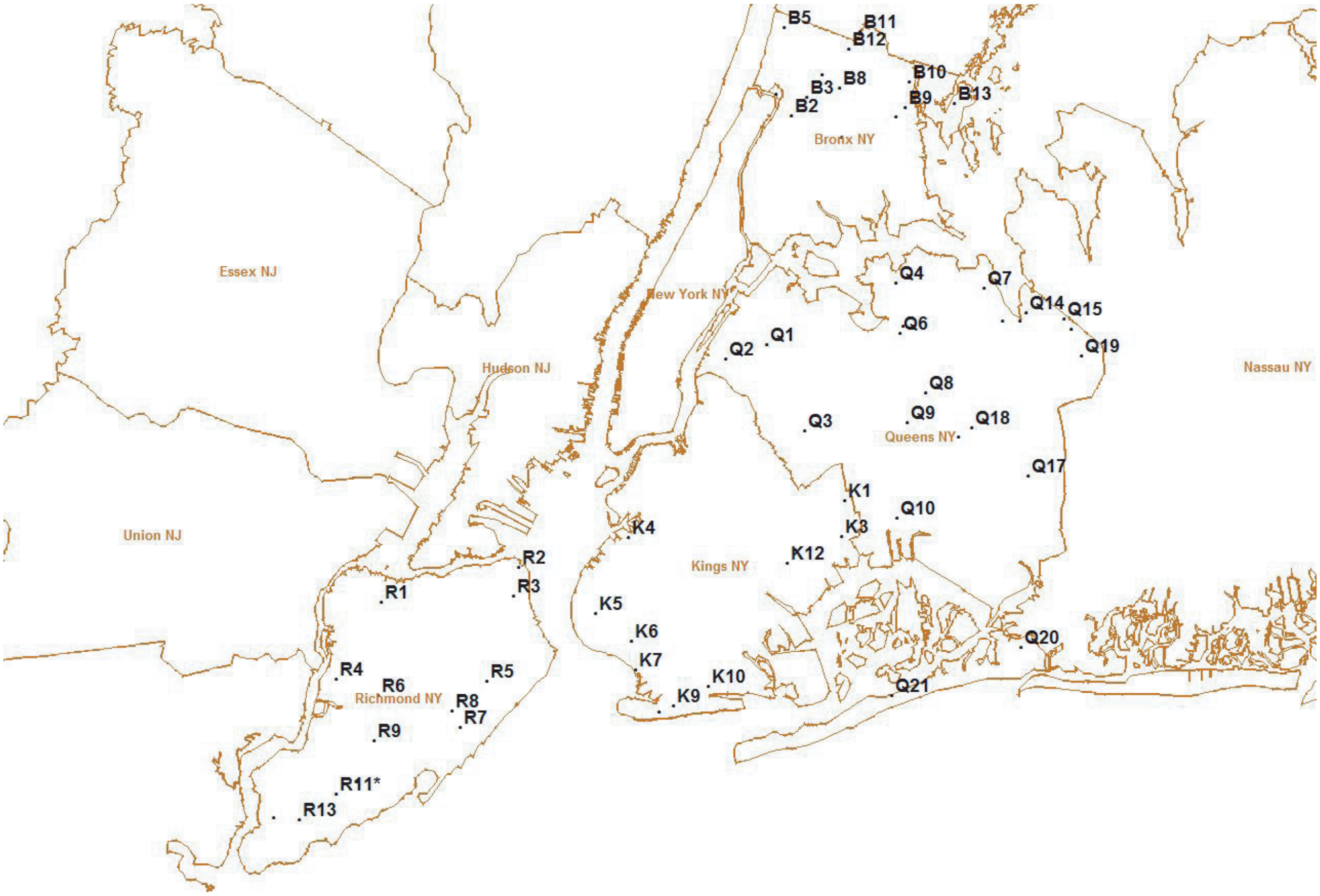

FIGURE 3 Set of 59 park-and-ride candidates, where letters designate borough: B (Bronx), Q (Queens), R (Staten Island), or K (Brooklyn).

TABLE 1 Distribution of Morning Peak Hour Trips by SOVs Into or Within Manhattan, by County

County	% Trips to Manhattan	County	% Trips to Manhattan	County	% Trips to Manhattan	County	% Trips to Manhattan
Manhattan, N.Y.	33.6	Essex, N.J.	2.7	Monmouth, N.J.	1.3	Orange, N.Y.	0.3
Queens, N.Y.	13.4	Hudson, N.J.	2.6	Morris, N.J.	1.2	Ocean, N.J.	0.3
Kings, N.Y.	8.2	Fairfield, Conn.	2.1	Passaic, N.J.	1.1	Putnam, N.Y.	0.2
Bronx, N.Y.	8.1	Union, N.J.	1.8	Rockland, N.Y.	0.8	Sussex, N.J.	0.2
Bergen, N.J.	6.5	Richmond, N.Y.	1.8	Somerset, N.J.	0.5	Mercer, N.J.	0.2
Westchester, N.Y.	4.9	Middlesex, N.J.	1.6	Dutchess, N.Y.	0.5	Hunterdon, N.J.	0.1
Nassau, N.Y.	3.8	Suffolk, N.Y.	1.5	New Haven, Conn.	0.5	Warren, N.J.	0.1

TABLE 2 Total Number of Morning Peak Hour Trips by SOVs Into or Within Manhattan, by County

County	Trips to Manhattan	County	Trips to Manhattan	County	Trips to Manhattan	County	Trips to Manhattan
Manhattan, N.Y.	52,317	Essex, N.J.	4,168	Monmouth, N.J.	2,069	Orange, N.Y.	531
Queens, N.Y.	20,922	Hudson, N.J.	4,051	Morris, N.J.	1,793	Ocean, N.J.	521
Kings, N.Y.	12,814	Fairfield, Conn.	3,227	Passaic, N.J.	1,666	Putnam, N.Y.	355
Bronx, N.Y.	12,599	Union, N.J.	2,873	Rockland, N.Y.	1,231	Sussex, N.J.	307
Bergen, N.J.	10,156	Richmond, N.Y.	2,777	Somerset, N.J.	844	Mercer, N.J.	238
Westchester,N.Y.	7,621	Middlesex, N.J.	2,489	Dutchess, N.Y.	785	Hunterdon, N.J.	199
Nassau, N.Y.	5,866	Suffolk, N.Y.	2,390	New Haven, Conn.	773	Warren, N.J.	118

NOTE: Total number of trips = 155,700.

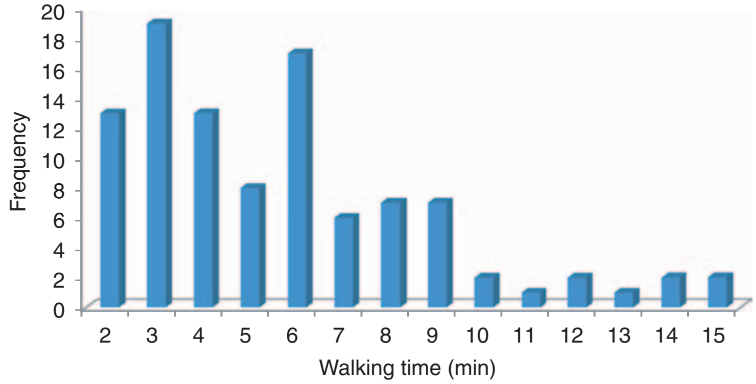

FIGURE 4 Distribution of walking times.

transit) are illustrated in Figure 4 for the identified sites. Because these candidates were selected on the basis of feasible park-and-ride conditions, average walking times generally are low to increase accessibility and reduce the users' generalized cost, thereby making park-and-ride more attractive. Walking times were increased by 2 minutes to include the users' walking time from the specific parking space to the parking lot entrance.

Economic Analyses

Each candidate site was evaluated with the method described in this paper, and generalized cost values were estimated with input from the regional model. To account for the disutility of walking and transfer time, the team applied penalty factors of 2.5 and 3.5 to walking and transfer time, respectively. The value of time used was $20/hour, which is consistent with the values used by the local transportation agencies in economic analyses. The top 20 candidates are listed in Table 3, and are ordered by present value of benefits in a 10-year evaluation with a 6% discount rate. Queens accounts for 9 of the top 20 candidates, and the Bronx, Staten Island, and Brooklyn account for 6 candidates, 4 candidates, and 1 candidate, respectively. All candidates listed exhibit a present value of benefits greater than $44 million, whereas the top eight candidates exceed $100 million. Expected demand ranges between 2,500 and 14,000 users per day. The top five candidates produce a weighted average savings of around $12 per user per day; in fact, all candidates listed produce at least $5.50 per user per day.

As expected, the best candidates combine high values of expected demand and weighted average savings; the top five candidates

TABLE 3 Assessment Results: Top 20 Candidates, by Borough ID

Candidate Site No.	ID	Expected Demand (no. of users)	Market Share (%)	Weighted Average Savings ($)	Present Value of Benefits ($million)
1	Q6	14,676	14.2	12.3	364.7
2	Q18	9,564	9.3	12.5	241.4
3	Q16	8,386	8.1	9.7	164.8
4	B2	10,461	10.1	7.3	154.4
5	K1	8,712	8.4	8.3	146.4
6	R2	5,795	5.6	11.8	138.8
7	B1	7,942	7.7	7.4	118.7
8	Q19	5,272	5.1	9.9	105.6
9	Q17	5,607	5.4	8.8	99.4
10	B3	7,404	7.2	6.2	93.6
11	R1	4,540	4.4	10.1	92.6
12	Q15	4,799	4.6	9.2	89.7
13	R5	4,692	4.5	9.4	88.8
14	B12	5,739	5.6	7.3	84.6
15	Q14	4,290	4.1	7.9	69.0
16	B11	4,769	4.6	6.2	60.0
17	Q20	2,496	2.4	10.1	51.0
18	R11	2,766	2.7	8.9	50.0
19	Q10	4,407	4.3	5.5	49.4
20	B10	3,508	3.4	6.3	44.5

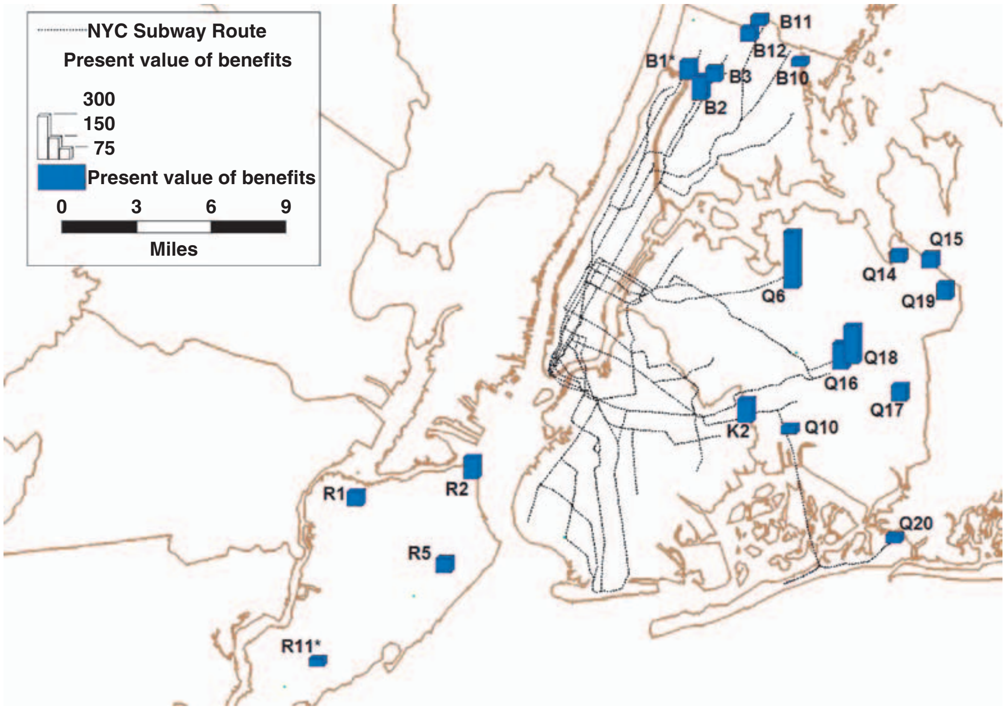

FIGURE 5 Assessment results for park-and-ride facilities.

exhibit at least $7 of savings and more than 8,000 of expected demand. The top five also exhibit a present value of benefits greater than $140 million. However, boroughs are more inclined to exhibit one of these performance measures. For instance, candidates in Queens and Staten Island exhibit high savings values, on the order of $10, whereas Bronx candidates attract high levels of demand. A good candidate must exhibit a high demand, a high level of savings, or both. A site that meets both of these conditions is certainly a good candidate to locate a park-and-ride facility.

The top 20 candidates are listed in Figure 5. The best Bronx candidates—B2, B1, and B3—are located at the edge of this borough and Manhattan. In the Bronx, one can see how the present value of benefits increases as the site location approaches Manhattan, reflecting the increasing catchment area (i.e., demand). The sequence B12, B3, and B2 illustrates this pattern. In Staten Island, the sequence R11, R5, and R2 exhibits a similar pattern. In general, this pattern can be explained because as users approach the congested part of the trip (i.e., Manhattan), savings and level of demand increase. At the edge between congested and uncongested zones—in some cases, the edge is the limit of the borough with the destination zone—the savings are highest. Holguín-Veras et al. explain and analyze this pattern (*12*).

Finally, considering the impact of connectivity on candidate selection also is important. Figure 5 also describes the subway network in Manhattan. The importance of transit connectivity is illustrated by the candidates in Queens. Q6, Q18, and Q16 are the first-, second-, and third-best candidates, respectively. These park-and-ride sites connect to the subway, which provides efficient access to key destinations. A similar situation occurs in the Bronx, where all six candidates are efficiently connected to the subway. In Staten Island, the analysis considers the use of a ferry to reach Manhattan, which explains why R2 is the best candidate in this borough. In summary, the presence of suitable transit systems explains the level of savings generated and the demand attracted by the candidates that would produce large economic benefits.

CONCLUSIONS

Park-and-ride facilities offer the possibility of decreasing congestion by attracting users to transit. Even though relevant literature describing the evaluation process of park-and-ride facilities exists, the economics underlying the behavior of park-and-ride users has not been fully taken into consideration when deciding both whether and where to locate these facilities.

This paper develops a method based on a basic economic principle: users will choose the park-and-ride system if and only if they accrue generalized cost savings. In this context, the concept of generalized cost is used to determine the level of savings and compare modes (i.e., automobile only versus park-and-ride mode). Four performance measurements are computed: expected demand, weighted average savings, market share, and present value of benefits. Expected demand provides an indication of the level of usage that a park-and-ride facility will receive and therefore allows assessment of the capacity needed to accommodate these users. Weighted average savings estimates the level of monetized savings that each user will perceive by using the system. In a different way, market share allows visualization of the impact on the mode partition due to implementing a park-and-ride facility. Finally, present value of benefits consolidates the information regarding demand and savings to estimate the savings that the park-and-ride facility will bring to the community. This value can be used to finally evaluate the installation of a facility according to cost–benefit analysis.

In the case study of New York City, analysis results indicate that park-and-ride facilities could bring significant benefits to commuters. The proposed method started with an initial set of 109 candidates, which resulted in 59 candidates after a more refined analysis. These 59 candidates were evaluated with the proposed measures. Most of the best candidates are located in Queens and the Bronx, according to present value of benefits. Candidates in Staten Island and Queens concentrate the best 10 candidates according to weighted average savings. This situation can be explained given the high monetized cost (primarily travel time) incurred by users traveling from these two boroughs. In the case of Staten Island, three facilities provide savings of greater than $12 per day per user. The remaining 8 of the top 10 candidates exhibit savings larger than $9. Therefore, even though the level of demand can be lower than for other candidates, the amount of money users save is considerably large. For present value of benefits, the top 10 candidates produce benefits of more than $90 million in a 10-year horizon with a discount rate of 6%. Moreover, the top four candidates have benefits greater than $150 million and the top two more than $240 million.

In this paper, benefits of park-and-ride facilities are estimated on the basis of users' savings. However, successful park-and-ride implementation will decrease congestion, a spillover benefit to nonusers. In addition, the motivation for implementing park-and-ride systems resides not only in the potential demand the facility will attract but, more importantly, in the users that will switch modes, thereby reducing congestion and increasing social welfare.

In summary, the assessment method described in this paper is a step toward improving the evaluation of park-and-ride facilities. Despite the reasonable results obtained in the case of New York City, there is still room for improvement in the evaluation of both park-and-ride facilities and systems. For instance, the modal partition deserves a more detailed analysis; in this paper, it was done with a binary logit. Similarly, the presence of competence is another important consideration for further research. This issue might appear when park-and-ride facilities are located close enough to compete for users (e.g., facilities in a corridor). Such extensions certainly would improve the analysis of the impact of park-and-ride facilities and enhance the attractiveness of park-and-ride facilities as a way to overcome congestion.

ACKNOWLEDGMENTS

The research reported in this paper was supported by the New York State Department of Transportation's New York City Park and Ride Study grant. The authors acknowledge contributions of and guidance provided by Judith Peter, Fred Libove, and Uchenna Madu, all of the New York State Department of Transportation's Region 11, who significantly enhanced the quality of the work.

REFERENCES

1. Allen, D. *Estimating the Service Area for Park-and-Ride Operations.* Technical Report Series. FHWA, U.S. Department of Transportation, Washington, D.C., 1979.
2. Christiansen, D., D. Bullard, and R. Peterson. *Houston Park-and-Ride Facilities: An Analysis of Survey Data.* Texas Transportation Institute, Texas A&M University System, College Station, Tex., 1981.
3. Burns, E. N. Priority Rating of Potential Park-and-Ride Sites. *ITE Journal,* Vol. 49, No. 2, 1979, pp. 29–31.
4. Spillar, R. J. *Park-and-Ride Planning and Design Guidelines.* Parsons Brinckerhoff, Inc., New York, 1997.
5. *Guide for Park-and-Ride Facilities.* AASHTO, Washington, D.C., 2004.
6. Faghri, A., A. Lang, K. Hamad, and H. Heck. Integrated Knowledge-Based Geographic Information System for Determining Optimal Location of Park-and-Ride Facilities. *Journal of Urban Planning and Development,* Vol. 128, No. 1, 2002, pp. 18–41.
7. Wang, J., H. Yang, and R. Lindsey. Locating and Pricing Park-and-Ride Facilities in a Linear Monocentric City with Deterministic Mode Choice. *Transportation Research Part B: Methodological,* Vol. 38, No. 8, 2004, pp. 709–731.
8. Horner, M., and S. Groves. Network Flow-Based Strategies for Identifying Rail Park-and-Ride Facility Locations. *Socio-Economic Planning Science,* Vol. 41, No. 3, 2007, pp. 255–268.
9. Farhan, B., and A. Murray. Siting Park-and-Ride Facilities Using a Multi-Objective Spatial Optimization Model. *Computers and Operations Research,* Vol. 35, No. 2, 2008, pp. 445–456.
10. Keck, C., and P. Liou. Forecasting Demand for Peripheral Park and Ride Service. In *Transportation Research Record 563,* TRB, National Research Council, Washington, D.C., 1976, pp. 63–74.
11. Abdul Hamid, N., J. Mohamad, and M. R. Karim. Parking Duration of Fringe Park-and-Ride Users and Delineation of Stations Catchment Area: Case of the Kuala Lumpur Conurbation. *Journal of the Eastern Asia Society for Transportation Studies,* Vol. 7, 2007, pp. 1296–1310.
12. Holguín-Veras, J., W. Yushimito, F. Aros-Vera, and J. Reilly. User Rationality and Optimal Park-and-Ride Location Under Potential Demand Maximization. *Transportation Research Part B: Methodological,* forthcoming.
13. *Transport Planning and Traffic Engineering* (C. A. O'Flaherty, ed.). Wiley, London, United Kingdom, 1997.
14. New York Property Information. The City of New York. http://nycprop.nyc.gov/nycproperty/nynav/jsp/selectbbl.jsp. Accessed March 11, 2011.
15. *NYMTC Best Practice Model.* New York Metropolitan Transportation Council. http://www.nymtc.org/. Accessed March 11, 2011.

This paper does not represent the official position of the New York State Department of Transportation.

The Intermodal Transfer Facilities Committee peer-reviewed this paper.