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by

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ABSTRACT

A park and ride facility provides an option to car drivers to park their cars and switch to public transportation for the remaining portions of their trips. Although park and ride has been implemented in many cities in the United States and integrated with different modes of transportation, no comprehensive approach has been developed in published literature to assess the feasibility of a potential park and ride site. This research proposes a comprehensive approach, which consists of the following tasks, to evaluate potential park and ride facilities:

1. Site location analysis
2. Bus system reliability analysis
3. Parking supply and usage analysis
4. Mode choice model
5. User demand and ridership estimation
6. Cost estimation and economic impacts analysis

The application of the proposed tasks was demonstrated through a case study of a site in the City of El Paso, Texas.

1. INTRODUCTION

A Park and Ride (P&R) facility may be defined as "a facility which provides places where car or carpool users can park their vehicles during the day, and using a transit or carpool or vanpool system to reach their travel destinations" [1]. P&R facilities have existed in many different forms that serve as intermodal transfer facilities from private cars to high occupancy vehicles, bus rapid transit, light rail transit, mass rapid transit, commuter rail systems, and/or ferry services [1, 2]. Overall, P&R facilities encourage users to switch from private to public transportation, which usually lead to a reduction in urban congestion. P&R facilities have been implemented in many cities in the United States (for examples Washington D.C., San Francisco, Houston, Los Angeles,

Seattle, to name a few) and integrated with many different modes, becoming an integral part of many transit systems.

At present, the approaches to evaluate the feasibility of potential P&R facilities are not sufficiently comprehensive. Published literature to date has covered only certain aspects of P&R facility planning and analysis. The most comprehensive guide to date is the Florida State Park & Ride Lot Program Planning Manual [3] which contains site selection, demand estimation and economic impact analysis. When evaluating a P&R facility, planners and engineers often face a dilemma on what analyses to perform on different aspects of P&R to form a holistic evaluation. This study proposes a new approach to analyze the attractiveness of a P&R facility. This proposed approach covers the analyses of site location, transit reliability, parking supply and usage. It also includes the estimation of user demand and ridership, cost and economic impacts. Although the methodology is developed for the car-bus or car-bus rapid transit mode, it is also applicable to other mixed modes (e.g., car-light rail transit, car-mass rapid transit) and likewise for other cities.

2. LITERATURE REVIEW

A literature review was conducted in the early stage of this research. The purpose of the literature review was to learn from past experiences in other cities, as well as tools or techniques used in different aspects of P&R planning. Although a comprehensive P&R planning approach was not found, the different aspects of the planning components were later integrated into the proposed evaluation approach. Important findings in the articles and reports are organized in the following subsections.

2.1. Park and Ride Site Location

A number of researches have helped to define an optimal location for a P&R facility. Spillar constructed guidelines for the identification of alternative P&R sites [2]. The report recommended an analysis procedure to identify the needs for the community with respect to the new facility's placement. A computerized tool has been proposed to ranks several P&R sites based on survey findings to determine the optimal location [4]. This approach was further developed into a multi-objective spatial optimization model taking into consideration the demand, accessibility to a major highway and availability of existing facilities [5].

Determining the best location for placing a P&R facility may consist of a two-level process:

1. The first level consists of determining some potential locations. The location should be able to accommodate most of the demand (i.e., having enough parking spaces for the car users, bicycle users, and etc.). It should also be place near the trip origins (residential areas) and far from the trips destinations (employment areas). The travel times for users from home to the P&R lot followed by transit to the destinations) are not so far from their typical driving times from home to work.
2. After some locations are chosen, an assessment is made in order to rank them depending on their attributes. The Florida's State Park and Ride Lot Program Planning Manual [3] offers a table that provides a series of criteria that should be taken into consideration.

2.2. Transit Reliability

To make P&R an attractive option to car drivers, the bus service must be reliable [6]. Reliability is a measure of the quality of service of public transportation systems. Reliability of bus service is influenced by several factors including waiting time, schedule adherence and service frequency. There have been studies to determine the reliability of a transit system [6–8].

For fixed route transit service, the Transit Capacity and Quality of Service Manual (TCQSM) [9] contains reliability measures at the stop level, route segment and system levels. For the purpose of evaluating bus service reliability associated with P&R, only three performance measures are considered: (i) on-time performance; (ii) hours of service; and (iii) transit system travel time compared to vehicle's travel time.

For on-time performance at the stop level, TCQSM uses the Level of Service (LOS) measures as shown in Table 1(a). The LOS reflects passenger's perception on the quality of schedule adherence. The term "on-time" refers to a bus arrival no more than five minutes after the schedule time and no more than one minute early.

The hours of service reflects the availability of transit service in a day. It is defined by TCQSM as simply the number of hours during the day when transit service is provided along a route, a segment of route, or between two locations. Table 1(b) exhibits the LOS criteria for the hours of service for a fixed transit route.

The last measure corresponds to how much longer the trip time by transit will take in comparison with using a private vehicle. The LOS measure is called transit-auto travel time which encompasses the door-to-door travel time of the entire trip. Table 1(c) exhibits the LOS criteria for transit-auto travel time for a fixed route.

2.3. Parking Study

Prior to the design process, a site investigation is recommended in the case of placing a P&R facility inside the vicinity of an existing parking lot. A useful method for measuring and evaluating the site's performance is to conduct a parking study. A parking study consists of various steps that examine the capacity of the existing parking facility, location and extent of demand for parking by present parkers, the adequacy of access and egress (for buses), the influence of such facilities on traffic flow in the main streets, and the effect and desirability of modifying the parking supply [10]. Some of the steps included: delineating the area that will be analyzed, making an inventory of the parking spaces, proceed with continuous observation, and conducting parking interviews to the users, and etc [10].

A parking study may consist of three major parts: proximity, parking inventory, accumulation and duration [11]. Proximity covers the facility's location and the maximum walking distance that the users are willing to walk in order to reach the bus (or any other transit mode). Additional information may be collected concerning parkers (parking users) such as their trip purpose, trip duration, distance walked, and etc [11]. Information about parkers will provide a greater insight into how parking conditions affect users.

In 2012, the New York State Department of Transportation sponsored a P&R Study to review existing practices in P&R planning [12]. This report provided a series of data collection and analysis to proceed in order to conduct a parking study, including parking

Table 1. Fixed-route bus system reliability level of service criteria [9]

(a) On-time performance		
LOS	On-time Percentage	Comments
A	95.0–100.0%	1 late transit vehicle every 2 weeks (no transfer)
B	90.0–94.9%	1 late transit vehicle every week (no transfer)
C	85.0–89.9%	3 late transit vehicle every 2 weeks (no transfer)
D	80.0–84.9%	2 late transit vehicle every week (no transfer)
E	75.0–79.9%	1 late transit vehicle every day (with a transfer)
F	<75.0%	1 late transit vehicle at least daily (with a transfer)
(b) Hours of service		
LOS	Hours of Service (hours)	Comments
A	19–24	Night or "owl" service provided
B	17–18	Late evening service provided
C	14–16	Early evening service provided
D	12-13	Daytime service provided
E	4-11	Peak hour service only or limited midday service
F	0-3	Very limited or no service
(c) Transit-auto travel time		
LOS	Travel Time Difference (minutes)	Comments
A	≤0	Faster by transit than by automobile
B	1–15	About as fast by transit as by automobile
C	16–30	Tolerable for choice riders
D	31–45	Round-trip at least an hour longer by transit
E	46–60	Tedious for all riders; may be best possible in small cities
F	>60	Unacceptable to most riders

inventory, parking accumulation, parking duration, license plate-origin information and parking interviews.

2.4. Park and Ride Demand Estimation

P&R demand estimation is used to determine the user demand, the resulting transit ridership and in decisions concerning the lot size. There are two major concerns that need to be taken into account when calculating the demand for a P&R facility.

The first issue to consider may be explained as the demand that the P&R facility could attract. Researchers have most frequently used the term "catchment area" in this estimation, while TCQSM [9] uses the term "market area". Shapes of cones, parabolas,

ellipses, semi-circular and even pears shapes have been used to demarcate the catchment areas [2, 12, 13].

The second consideration is the attractiveness of the site (and the P&R mode) to the potential users. This is similar to the concept of mode choice. P&R demand could be estimated from the regional four-step modeling approach (by offering P&R as a mode) [2]. Li et al. proposed a model that considered three major aspects: the commuters' choices on travel mode, the travel paths or routes as well as their transfer points (i.e., a P&R facility), and finally their parking choice behavior [14]. The common approach has been a mode choice model.

After reviewing the different methodologies in P&R demand estimation, the following steps adopted in the proposed approach:

1. Define a P&R catchment area;
2. Calculate the number of potential users that may use the facility in the catchment area from the regional transportation planning model;
3. Develop or adopt a P&R mode choice model;
4. Convert the number of potential users into an actual number of P&R users and transit ridership; and
5. Make adjustments for changes in demand that may be caused by weather, day-of-week, season, and etc.

2.5. Park and Ride Economic Impact

Park and ride will not only bring benefits to the users. It will also bring benefits to the bus operators (with additional ridership) and store operators near the P&R lot. A survey conducted to capture the spending patterns of P&R users at seven facilities in Florida found that approximately 40% of the P&R users shopped at nearby stores while waiting for buses, and those who shopped spent an average of $21 (2004 dollar) [15].

On the other hand, implementation of P&R may require infrastructure improvements at the site. The cost of infrastructure improvements is usually paid for by the local transportation agency or government.

2.6. Summary of Literature Review

A major finding in the literature is that, although the articles and reports found describe the respective analysis methodologies in details, none of them prescribes a comprehensive approach in the evaluation of potential P&R facilities. Therefore, a comprehensive approach was proposed in the next section of this article.

3. PROPOSED APPROACH

An attractive P&R facility should be located in a neighborhood in which several factors exist to motivate car users to switch to P&R. A P&R facility not only has impact on potential users, it also has impact on the bus operator, existing parkers (if the proposed P&R facility is located in an existing parking lot) and surrounding stores. All these factors should be considered when evaluating the feasibility of a P&R site.

This research proposes a comprehensive approach, which consists of the following tasks, to evaluate potential P&R facilities:

1. Site location analysis
2. Bus system reliability analysis
3. Parking supply and usage analysis
4. Mode choice model
5. User demand and ridership estimation
6. Cost estimation and economic impacts analysis

The sequence of the tasks is shown in Figure 1. Site location analysis should first be conducted. This is followed by bus system reliability analysis and parking supply and usage analysis, which may take place simultaneously. At the same time, a mode choice model may be developed. In the next task, the results of bus system reliability analysis and parking supply and usage analysis will be entered into the mode choice model, combining with site data to estimate the P&R user demand and transit ridership. Finally, with the estimated user demand transit ridership, the economic impact to the stakeholders may be estimated. The six-step analysis approach may be repeated for the design year and for any future year.

The proposed approach is not a detailed engineering study. It is a systematic methodology for planners to assess the merit of a potential site, or to compare the merit of several potential sites in early stage of the planning process.

The application of the proposed tasks was demonstrated through a case study of a site in the City of El Paso, Texas, which is described in the next section.

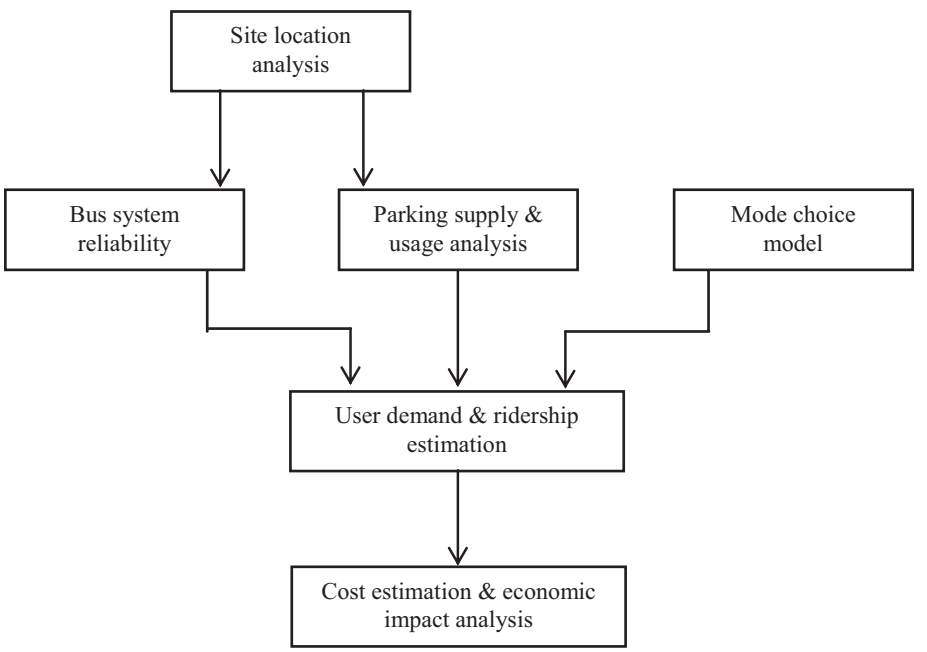

Figure 1. Flow chart of tasks in the proposed analysis approach

4. CASE STUDY

A site in El Paso, Texas, was selected in consultation with El Paso Metropolitan Planning Organization (MPO) for the case study. The planned site chosen for the study is located at the southeast of the intersection of Joe Battle Boulevard and Montwood Drive, a major intersection in El Paso approximately 18 miles from the downtown.

4.1. Site Location Analysis

The intersection of Joe Battle Boulevard and Montwood Drive had an average daily traffic of 340,000 vehicles/day (2011 data). It is a major intersection that feeds traffic into the Loop 375 Freeway towards the downtown. Figure 2 provides an aerial view of the site and its nearby residential areas which forms the P&R catchment. Figure 3 shows that the site is located in a shopping mall bounded by stores such as Super Target, Ross, Marshalls, Office Depot, Pet Smart and several other retail shops and restaurants. These stores provide addition attraction for potential P&R users. The site is served by a major bus route (Route 53) that runs westward to the Eastside Terminal from which riders can transfer to Route 59 to the downtown. The parking lot at the site appears underutilized during the weekdays and has sufficient capacity for part of it to be converted into a P&R facility. The parking lot is owned by a private property company.

4.2. Bus System Reliability Analysis

Figure 4 presents an aerial view of the existing bus routes connecting the potential P&R lot to the downtown. The dark purple line represents Route 53 while the light green line represents Route 59. Route 53 runs every hour while buses on Route 59 run every 14 minutes or at smaller headways. The one-way distance of Route 53 is approximately 10 miles.

The objective of measuring bus service reliability is to gather data and make suggestions in order to make the bus service more consistent and dependable, that will potentially attract P&R users. The data gathered may also be entered into the mode choice model to predict the P&D user demand and ridership.

For on-time performance LOS in this case study, the arrival times were measured for the two bus routes (Routes 53 and 59) for two weeks in the morning peak hour.

For Route 53, on-time data was gathered by having a surveyor ride the bus and record the arrival and departure times at the stops of interest (especially those near the P&R lot and the terminals). The arrival times were compared with the printed schedule. Furthermore, the number of passengers boarding and alighting at each bus stop and terminal were collected to give statistics of the passenger load along the route. An average of LOS A was found for Route 53's on-time performance. At several bus stops near school zones, LOS E was determined. The degradation of on-time LOS was because when the buses passed through the school zones, they slowed down and sometimes were obstructed by other vehicles during the school drop-off hours. It was recommended that adjustments be made to the printed arrival times at these bus stops to take into account the actual traffic conditions. In addition, Route 53 may have to operate more frequently (currently hourly) during the peak hours in order to attract P&R users. For Route 59, since most of the P&R riders are expected to ride the bus for the entire route, only the departure and arrival times at both ends of the routes were

Figure 2. Aerial view of the site

captured. This was done by stationing surveyors at both terminals. An overall LOS A was found for on-time performance of Route 59.

Hours of service plays an important role in determining the availability of transit service to potential P&R users. The LOS criteria for hours of service are presented

Figure 3. Close up view of the site with bus route and bus stops

Table 1(b). On weekdays, Route 53 operates from 5:30 a.m. to 11:30 p.m. This converts to LOS A. However, Route 59 runs from 5:10 a.m. till 8:43 p.m. According to Table 1(b), this yields LOS C. As most of the P&R users are expected to be daily commuters, the impact of not having Route 59 after 8:43 p.m. on weekday should be minimal.

A study was performed to compare the P&R user's total trip travel time with that of an automobile by using the TCQSM's transit-auto travel time LOS criteria as presented in Table 1(c). The travel time by P&R mode was estimated from the published schedule. Without knowing where a P&R user originated his auto trip from, this case study calculated the transit travel time from the proposed P&R facility. This included the average waiting and transfer times at the P&R facility and at the transfer point from Route 53 to Route 59. The travel time by auto was obtained by having a driver making

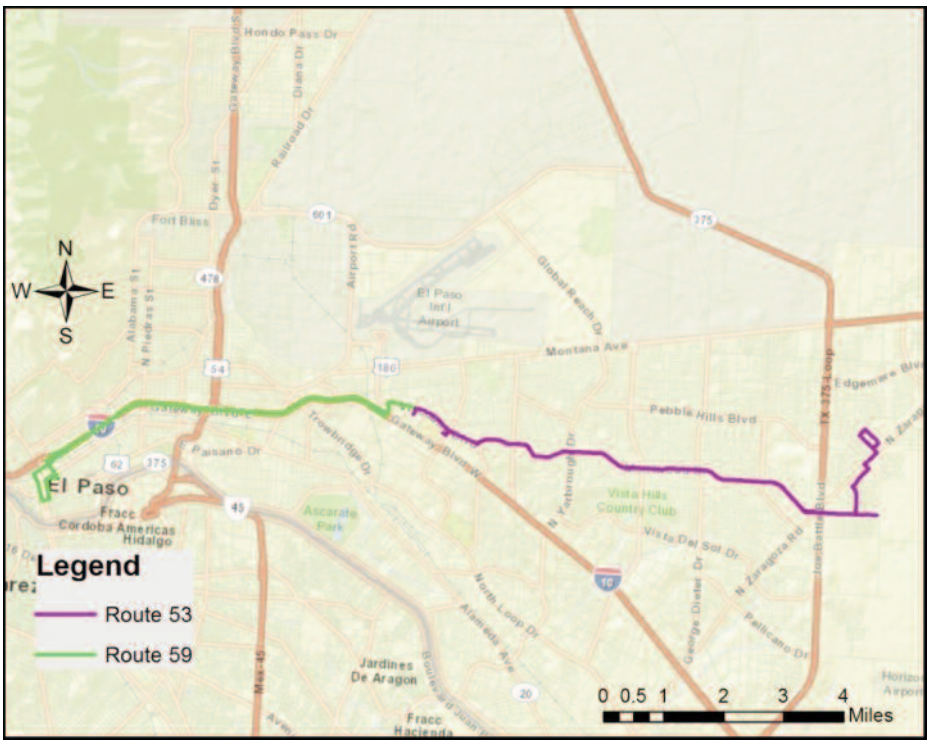

Figure 4. Existing bus routes connecting the proposed P&R lot and downtown

several trips in the morning peak hour along the regular commuting route via the major arterials and the freeways to the downtown transit terminal. It was found that P&R users would take an average of 77 minutes to travel from the proposed P&R lot to the downtown terminal. On the other hand, driving from the same origin-destination pair would require an average of 51 minutes. The difference in travel time is equivalent to 26 minutes, or LOS C. To make P&R more attractive to users, the bus operator may consider running Route 53 more frequently, and/or making Route 59 an express service. This will improve the transit-auto travel time LOS.

In consultation with the bus operator (Sun Metro), a projected re-routing for Route 53 is suggested so that buses can better serve the P&R users. The project route include having the bus make a detour from Montwood Drive to turn into the shopping mall to pick up and drop off P&R customers. Obviously, bus schedule would need to be adjusted if Route 53 is detoured to pass by the P&R facility.

4.3. Parking Supply and Usage Analysis

The parking study consists of a series of steps that examine the capacity and usage of an existing parking facility.

The projected P&R site has an approximate floor area of 54,758 ft^2. The portion of the parking lot highlighted by a green rectangle in Figure 3 contains 168 parking stalls

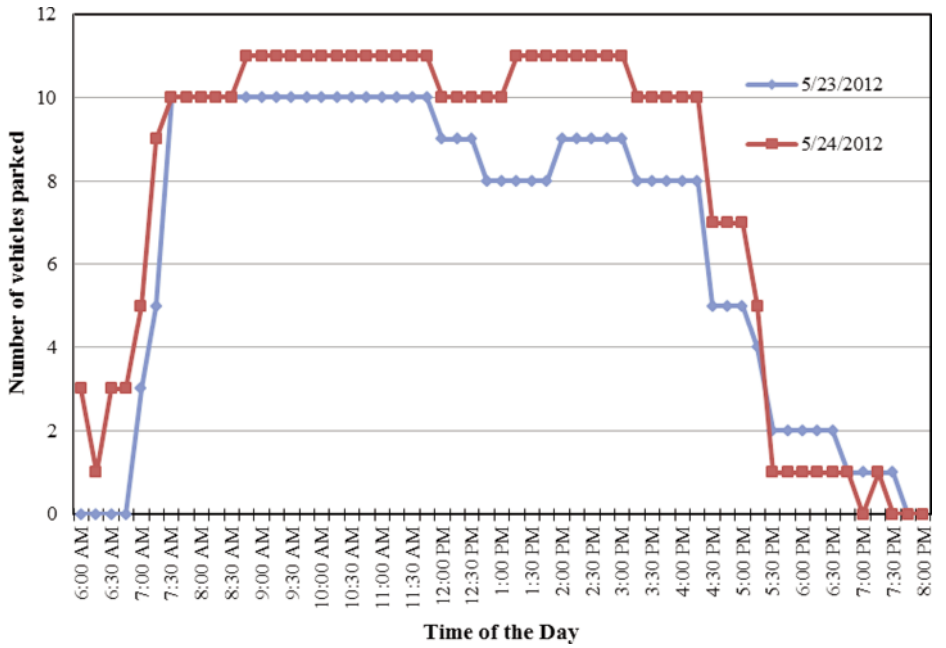

Figure 5. Parking accumulation curves

for potential P&R use. They are divided into a set of 8 rows each containing 21 parking stalls. This area selected is a distance away from the retail stores so that the P&R operations will not affect regular store customers. In compliance with the Americans with Disabilities Act of 1990 (ADA) a minimum of six handicapped parking stalls must be provided within the P&R facility, based on the projected total number of stalls. Taking into consideration the size of the handicapped stalls, the 168 existing stalls may be converted into 156 regular P&R stalls and six handicapped P&R stalls.

To collect information on the site's parking accumulation and duration, a two day survey was conducted from 6:00 a.m. to 8:00 p.m. to (i) count the total number of vehicles parked in the potential P&R designated area at 15-minute intervals; and (ii) record the length of time each vehicle remains parked. The parking accumulation curves are plotted in Figure 5. During the observed days, the maximum number of cars parked was 11 cars while the longest parked duration was 4 hours and 45 minutes. This implies that, converting the existing 168 regular parking stalls into 162 P&R stalls (including six handicapped stalls) will not cause much inconvenience to the existing parkers.

4.4. Mode Choice Model

Prior to estimating P&R user demand and transit ridership, a mode choice model was developed. A questionnaire survey was conducted among 447 El Paso residents. The sample consisted of 73% respondents who commute by driving car alone, 22% by bus, 3% by carpool and 2% by motorcycle. The survey consisted of 15 questions and was divided into four parts: demographic profile, characteristics of commute (including

mode and travel time), specific questions for car users, and specific questions for transit users. Details of the survey have been described in [16].

The date gathered from the survey was used to develop a binary logit model by means of LIMDEP [17]. The response variable is the probabilities that an individual n who will use mode i (i = 1 for P&R; i = 2 for other modes). The binary logit probability of individual n using mode i is:

$$P_{in} = \frac{e^{V_{ij}}}{e^{V_{1_n}} + e^{V_{2n}}} \tag{1}$$

where V_{in} is the deterministic components of the utility function of mode i for individual n, which may be expressed as

$$V_{in} = \beta_i X_{in} \tag{2}$$

in which β_i is a row vector of the coefficients associated with a specific mode i and X_{in} is the individual n's attribute values of using mode i.

The result of using the maximum likelihood estimation in LIMDEP is shown in Table 2. This table lists the attributes used and their explanations. During model development, effort has been made to keep the model as simple and as portable as possible so that (i) planners in other cities who do not have time and budget to conduct surveys and develop their own models can use this model; and (ii) its attribute can be

Table 2. Estimation results for binary logit model

Variables	Coefficient	*t*-statistics	*p*-value	Marginal Effects
Constant	0.8606	1.763	0.0782	0.1886
Age and Household Income (1 if 1 – 24 or younger & less than $24,999 / year, 0 otherwise)	0.5896	2.105	0.0353	0.1231
Household Size (1 if 2 persons, 0 otherwise)	–0.4472	–1.354	0.1759	–0.1024
Car Ownership (0 if 0 cars, 1 if 1 car,…, 5 if 5 cars or more)	–0.2453	–2.356	0.0185	–0.0538
Commute Travel Time (1 if 0 to 9 minutes, 2 if 10 to 19 minutes, 3 if 20 to 34 minutes, 4 if 35 minutes or more)	0.1680	1.212	0.2256	0.0368
Number of variables used			4	
Log-likelihood at zero,			–207.0385	
Log-likelihood at convergence			–200.8678	
χ^2value			12.3413	
p-value			0.0224	
Number of observations			326	

found in commonly used Geographical Information Systems or similar demographic databases and no additional massive data collection is necessary.

4.5. User Demand and Ridership Estimation

Having developed the binary logit model, the next step in the analysis was to apply this model to the demographic and trip characteristics data in the area of interest to estimate the P&R user demand and transit ridership. The estimation was performed with the following steps:

1. Identify the catchment area;
2. Gather demographic and trip characteristics data from the catchment area;
3. Estimate the total number of trips (using all modes) between the catchment area and downtown;
4. Apply the binary logit model;

The first step in users and ridership estimation is to identify the catchment area where residents would consider P&R as a mode of travel. Researchers have suggested different geometric shapes that can be used to demarcate the catchment area, for examples, circular, semi-circular and parabolic shape [2, 12, 13]. In reality, most of the P&R users prefer the P&R facility to be in the same direction between their origins and destinations. Few of them would drive in the reverse direction (i.e., backtracking) for more than 2.5 miles to access the P&R facility. Ultimately, the determination of the catchment area is based on the data that each planner has collected the on site's location and its attractiveness to the potential users. Other factors such as congestion within the region, extent of the transit network, future land development could also contribute to the determination of the catchment.

In this case study, the catchment area was decided after consultation with El Paso MPO. The catchment area covers several Traffic Analysis Zones (TAZs). The area west and north of the potential P&R facility was not included because (i) travelers would not want to cross the busy Loop 375 Freeway to access the P&R facility; (ii) these areas are in the reverse direction of the bus routes; (iii) commuters in the north would prefer to access the transit system by a transit terminal in that area. Part of the catchment is currently empty land that has been zoned for future residential development.

After identifying the catchment area, the demographic and trip characteristic data was gathered from the ArcGIS Business Analyst database [18]. The important attributes necessary for the application of the binary logit model are household size, household income, age, car ownership and travel time (see Table 4). Aggregated information in the catchment area such as age distribution, household income distribution, household size distribution, car ownership distribution and travel time distribution were then extracted from ArcGIS Business Analysis. The P&R users and ridership demands in 2010 and 2035 are of interest in this case study. However, ArcGIS Business Analyst only provided the discrete probability distributions of household size, car ownership and commuter travel time in year 2000. Assuming that the distributions of household size, car ownership and commuter travel time remain unchanged from 2000, these distributions, with the household income distributions and age distributions in 2010 and 2035 (projected) were used as inputs into the binary logit model.

To apply the binary logit model, the number of commuting trips from the catchment area to downtown in 2010 and 2035 must be determined. This population pools (or trip pools) were estimated from the El Paso MPO's regional travel demand model [19]. The number of commuters traveling from the TAZs that formed the catchment area to the TAZs in downtown was estimated to be 69 trips/day in 2010 and 131 trips/day in 2035, respectively.

The binary logit model was applied by means of Monte-Carlo simulation, with the following steps:

1. Identify an individual n in the population pool in the target year;
2. Use random numbers to generate this individual's age, household income, household size, car ownership and travel time according to their respectively probability distributions;
3. Enter the individual's age, household income, household size, car ownership and travel time into the binary logit model to calculate the probability that this individual will use P&R, i.e., P_{1n} in (1);
4. Repeat from Step 1 for all the individuals in the population pool. When this is completed, the sum of P_{1n} from the population pool is the estimate of P&R users and transit ridership.

For 2010, the model estimated a total of 46 P&R users (out of 69 commuting trips/day). The number of P&R users for year 2035 was estimated to be 87 (out of 131 commuting trips/day). Comparing to the total number of 162 P&R parking stalls available at the proposed facility, the space set aside would be able to meet the expected demand. It should be noted that not all the P&R users will use the facility every day or at the same time. On the other hand, there could be latent demand, for example, P&R users who travel to destinations other than downtown who are not captured by the population pool used in the estimation.

4.6. Cost Estimation and Economic Impacts Analysis

Towards the end of the P&R feasibility analysis, estimations were performed on the costs of different transportation improvements proposed at the P&R site, and the associated financial impacts of the P&R facility have on stake holders.

The necessary infrastructure modifications to implement P&R at the proposed site include widening of entrance and exit of the parking lot to accommodate buses, erect a bus shelter, installing traffic signs, re-striping of parking stalls and constructing handicapped access ramps. The total amount was estimated to be $50,100.00 (2012 dollar).

A fraction of P&R users may purchase items at nearby stores while transferring between car and bus modes. Applying the fraction of users who will make a purchase and for those who make a purchase an average spending of $21.13/person/day (2004 dollar) [15], after adjusting for inflation, the 46 users/day are expected to spend $462.60/day (2012 dollar). The same analysis for year 2035 gives an equivalent of $874.48/day (2012 dollar). The extra income due to the implementation of P&R may be used as an incentive for the public officials to convince the store owners to locate the P&R facility at the proposed site.

Currently, Sun Metro, the El Paso bus operator offers monthly passes for unlimited bus trips at $30.00 for students and $48.00 for standard adult users. Assuming that most of the P&R users will pay a standard monthly fee, for the year 2010, Sun Metro will receive additional fare revenue of $2,208/month (2012 dollar). The P&R demand in 2035 will generate fare revenue of $4,146/month (2012 dollar).

Arrangements between the property owners and transit agencies can take on many forms. Each party could take responsibility for such thing as maintenance, cleaning, insurance, installations of amenities, or providing incentives to bus users [15]. The City of El Paso may consider leasing the P&R parking space from the property owners. This will be an added cost but was not estimated during this research. The congestion impact of removing vehicles driven by the P&R users from the network, and its associated emission reduction is also not estimated.

4.7. Summary of Case Study

Based on the site location analysis, bus reliability analysis, parking supply and usage analysis, user demand and ridership estimation, cost estimation and economic impact analysis, the following recommendations specific to the potential P&R site have been made:

- The proposed site has sufficient capacity to designate 162 P&R stalls (including six handicapped stalls) and will not cause much inconvenience to the existing parkers.
- Some infrastructure modifications are necessary for the implementation of P&R at the selected site. The total amount was estimated to be approximately $50,100.00 (2012 dollar).
- Overall, bus service of Routes 53 and 59 that take P&R users to El Paso downtown is reliable. However, the printed arrival times of Route 53 at certain bus stops need to be updated. The bus operator may need to increase Route 53's service frequency or even provide an express service to make P&R more attractive.
- For the two target years of 2010 and 2035, the P&R demands are estimated to be 46 trips/day and 87 trips/day respectively.
- The P&R users will bring revenue of $462.60/day in 2010 and $874.48/day in 2035, expressed in 2012 dollar. The revenue for the bus operator will be $2,208.00/month and $4146.00/month, both in 2012 dollar.

5. CONCLUSION

In this paper, a comprehensive analysis approach has been proposed to evaluate the feasibility of a proposed P&R facility. The analysis approach covers site location analysis, bus system reliability analysis, parking supply and usage analysis, mode choice model, user demand and ridership estimation, cost estimation and economic impact analysis.

A case study has been conducted to demonstrate the application of the proposed analysis approach. Based on the analysis performed, the necessary infrastructure improvements have been identified, and the related costs estimated. The improvements to make the bus service more attractive have also been identified. The analysis has also estimated the P&R user demand in 2010 and in 2035; and determined that the site has

enough parking stalls to accommodate P&R user in 2010 and in 2035. The economic benefits to the stores adjacent to the P&R facility, and to the bus operator are also estimated. The successful implementation of the P&R facility eventually will depend on the business model agreed between the transportation agency (in this case the City of El Paso), the property owner and the bus operator. Arrangements between the property owners and transit agencies can take on many forms.

The proposed analysis approach may be used by P&R planners in other cities to evaluate the merit of a proposed site, or the relative merits of several potential sites. The binary logit model may also be used in other sites, with the local demographic and travel time data to estimate P&R demand.

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The case study reported in this article is for demonstration purpose only. It does not represent the policy or endorsement by the El Paso Metropolitan Planning Organization (MPO) or the City of El Paso.

REFERENCES

[1] AASHTO, *Geometric Design Guide for Transit Facilities on Highways and Streets*, American Association of State Highway Highway Transportation Officials, 2002.

[2] R. J. Spillar, *Park-and-Ride Planning and Design Guidelines*, Parsons Brinckerhoff Quade & Douglas, Inc., NY, 1997.

[3] F. H. Harris Inc., *State Park and Ride Lot Program*, Office of Public Transportation, Florida Department of Transportation, 1996.

[4] A. Faghri, A. Lang, K. Hamad, and H. Henck, Integrated knowledge-based geographic information system for determining optimal location of park-and-ride facilities, *Journal of Urban Planning and Development*, 128(1), 2002, 18–41.

[5] B. Farhan, and A. T. Murray, Siting Park-and-Ride Facilities using a Multi-Objective Spatial Optimization Model, *Computers & Operations Research*, 35, 2008, 445–456.

[6] R. Liu, and S. Sinha, Modelling urban bus service and passenger reliability, Paper presented at the 3rd International Symposium on Transportation Network Reliability, July 19–20, 2007, The Netherlands, 2007.

[7] J. Lin, M. L. Wang, and D. T. Barnum, *A Quality Control Framework for Bus Schedule Reliability*, Great Cities Institute, Chicago, IL, 2008.

[8] M. N. Milkovits, *Simulating Service Reliability of a High Frequency Bus Route Using Automatically Collected Data*, Master of Science Thesis, Dept. of Civil & Environmental Engineering, Massachusetts Institute of Technology, 2008.

[9] TRB, *Transit Capacity and Quality of Service Manual*, 2nd edition, Transportation Research Board, Washington, D.C., 2004.

[10] W. S. Homburger, J. H. Kell, and D. D. Perkins, *Fundamentals of Traffic Engineering*, 13th edition. Institute of Transportation Studies, University of California at Berkeley, 1992.

[11] R. P. Roess, E. S. Prassas, and W. R. McShane, *Traffic Engineering*, 3rd. Pearson Prentice Hall, Upper Saddle River, NJ, 2004.

[12] J. Holguín-Veras, J. Reilly, and F. Aros-Vera, *New York City Park and Ride Study*, Final Report, Project C-07-66. Rensselaer Polytechnic Instititute, NY, 2012.

[13] B. Farhan, and A. T. Murray, A GIS-based approach for delineating market area for park and ride facilities, *Transactions in GIS*, 9(2), 2005, 91–108.

[14] Z-C. Li, W. H. K. Lam, S. C. Wong, D. Zhu, and H. Huang, Modeling park-and-ride services in a multimodal transport network with elastic demand, Paper presented at the 86th Annual Meeting of the Transportation Research Board, 2007

[15] F. Wambalaba, and J. Goodwill, *Public Transportation Research Study Evaluation of Shared Use Park & Ride Impact on Properties*, National Center for Transportation Research, University of South Florida, 2004.

[16] L. E. Cornejo, *Systematic Approach to Evaluate Potential Park and Ride Facilities*, Master of Science in Civil Engineering Thesis, Dept. of Civil Engineering, The University of Texas at El Paso, 2012.

[17] W. H. Greene, *Econometric Modeling Guide. Vol. 1*, Econometric Software Inc, Plainview, NY, 2006.

[18] ESRI, *ArcGIS Business Analyst Desktop*, Environmental Science Research Institute, Redlands, CA, 2012.

[19] El Paso MPO, *Mission 2035 Metropolitan Transportation Plan*, El Paso Metropolitan Planning Organization, 2012.