Greenville-Spartanburg Airport District

PRELIMINARY PERSONAL RAPID TRANSIT FEASIBILITY STUDY

FINAL REPORT

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PRT Consulting, Inc.

In association with:

Louis Berger Group, Inc.

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1. Executive Summary

Personal rapid transit (PRT) is a form of driverless transit that offers a very high level of service characterized by frequent stations, short waiting times, and nonstop seated trips. Now that PRT is commercially available from four different suppliers and has a good record of connecting a parking lot to Terminal 5 at Heathrow International Airport, an evaluation of its ability to serve the Greenville-Spartanburg International Airport (GSP Airport) has been undertaken. This report investigates the feasibility of a PRT solution at GSP Airport and compares PRT solutions to shuttle bus solutions.

The four suppliers with commercially-available PRT systems are Ultra, with a system at Heathrow Airport, UK; 2getthere, with a system in Masdar City, UAE; Vectus, with a system in Suncheon, Korea, and Modutram, with a test track in Guadalajara and a small demonstration system near Mexico City, Mexico. When compared with transit, these systems offer a much higher level of service, more like a car than that of a bus. This analysis is based on the Ultra, 2getthere, and Modutram systems. It is recommended that the specific technology supplier be selected during a later procurement process, at which time the Vectus system could also be considered.

After evaluating a number of makes and models of shuttle buses, it was decided to base this analysis on Turtle Top's OdysseyXL which has 23 seats and wheelchair capabilities and is best suited for this application.

The projected parking space demand from 2018 to 2047 was estimated based on existing availability and use, 945,000 enplanements in 2014, and a 1.5% annual growth rate. Two alternative scenarios were developed to accommodate the projected growth. In Scenario 1, a new economy lot is constructed in the location of the disused rental car ready area followed by a new Garage C replacing the existing Daily Lot, and then a third economy lot is constructed southeast of the existing economy lot. In Scenario 2, the new Garage C construction is replaced by building the third economy lot and later adding a fourth economy lot southwest of the third one.

The price of airport parking is largely a function of connect times from car to the terminal. PRT provides better connect times, therefore enabling higher parking rates. Comparative airport parking charges and shuttle bus operations were reviewed at airports within 300 miles of GSP Airport. It was found that a connect time of five minute correlates to an average economy lot parking charge of $10 per day. Furthermore, airports with more than one shuttle lot average an extra charge for the closer lot of $0.79 per minute of time saved, close to the $0.67 per minute extra charged at GSP Airport for use of the Garage Sky Lots as opposed to the Economy Lot.

PRT connect times for the new surface lots vary from five minutes average to seven minutes maximum, while shuttle bus connect times vary from 12 minutes average to 17 minutes maximum. The shuttle bus connect times are long enough to suggest that Scenario 2 is not viable since, without the parking garage, too low a proportion of travelers will have access to a reliable short connect time. The short PRT connect times suggest a daily economy lot charge as high as $10.00 could be considered. However, because of competitive considerations, it has been decided to match the Charlotte daily rate of $5.00 in this analysis for the shuttle bus alternatives. The PRT alternatives are considered to increase the level of service sufficiently to justify a $6.00 daily rate.

PRT provides significantly shorter connect times, level boarding, and seated rides, while reducing emissions, readily accommodating wheelchairs, and not adding to surface congestion. The net present worth of the PRT solutions was found to be higher than the bus solutions. Furthermore, the net present worth of PRT Scenario 2 approximately matches the bus net present worth when a parking rate of $5.50 per day is used. This indicates that the significantly higher service level provided by PRT only costs parkers about 50c per day.

Future on- or off-airport expansions of the PRT system are possible. While these expansions could help promote development, it is likely to be some time before they are economically viable as transportation solutions.

A PRT parking lot solution could be entirely funded from economy lot revenues since the revenues are projected to exceed the capital and operating costs of the new parking facilities and the PRT system. Financing would be required to cover initial outlays. In the event insufficient parking revenues are available, a number of alternative revenue sources have been considered and addressed in the report. PRT Scenario 2 (including the construction and maintenance of the new surface lots) would make a projected net profit of $141 M over 30 years if financing was at 6% and the economy lot rate was $10 per day. PRT Scenario 2 will break even at a daily parking rate of approximately $6.40 for all economy lots.

Since PRT Scenario 1 and 2 have the identical first phase, there is no need for the Airport District to pick one or the other at this time (although Scenario 2 seems favored because it has least impact on airport cost per enplaned passenger). It is recommended that the Airport District consider implementing PRT Phase 1 in such a way that all future expansion opportunities can be readily incorporated when the time comes. Since Phase 1 may not be needed in its entirety initially, a reduced Phase 1A has been proposed. This initial system would cost about $20 M and would only serve the existing economy lot. Parking revenues at $6.00 per day would be sufficient to cover its financing, capital and operating costs.

Next steps needed to procure a PRT system involve undertaking a more detailed planning process to include determining regulatory requirements, obtaining any necessary funding/financing, and selecting a procurement model. A preliminary design process is required that would include starting the permitting process and establishing the Airport District’s project requirements. Procurement documents would be prepared and a suitable design-build team would be brought under contract.

2. Introduction

The Greenville-Spartanburg International Airport (GSP Airport) is beautifully maintained. Passengers arriving by car travel along a curving parkway surrounded by manicured gardens and trees followed by water features before the new terminal building comes into view. The airport is currently undergoing a major terminal reconstruction program that will expand and renovate the terminal facilities to meet present demand and be well-positioned to accommodate future growth, while providing a high level of service matching the beauty of the approach. Once the terminal project is complete, the lack of shuttle service from the Economy Lot will stand out as the one remaining area where the level of service still needs to be raised. This project explores ways to address this issue.

The walking distances from the Economy Lot to the Terminal are between 850 and 2,500 feet depending on which end of the Terminal needs to be accessed from which area of the parking lot. These walking distances would take three to ten minutes at a 3 MPH speed, which might be difficult to maintain going uphill, dragging bags, on a hot day. In addition, continued growth is dictating the need for additional parking facilities which could result in even longer walking distances. For these reasons, the Airport has initiated this study to investigate parking shuttle solutions, including shuttle buses and personal rapid transit (PRT).

Shuttle buses have the advantage of not requiring new infrastructure other than relatively simple bus stops. However, this advantage is also a disadvantage in that the buses run on existing roads and therefore add to congestion and road maintenance costs. At GSP Airport, this is exacerbated by the fact that the Terminal frontage road is on a single level with little extra space for buses and bus stops. Shuttle buses would not only add to congestion, but also suffer from it. Shuttle bus trips tend to be slow because of the frequent stops that must be made to pick up and drop passengers off. Trips will be even slower if they also have to contend with curbside and roadway congestion.

PRT is comprised of small driverless vehicles traveling on dedicated guideways that can be elevated or at grade (or even below grade). These dedicated guideways allow quick trips totally free from congestion. However, they also add considerably to the cost of a PRT system. On the other hand, being automated, fewer operators are required than for a bus system and, being electric, no on-site emissions are made.

In order to compare the alternatives in a meaningful way, a 30-year life cycle cost analysis is undertaken. This includes addressing the parking needs that are expected to develop during the 30-year period. The pros and cons of each solution are discussed, alternative funding sources are addressed, and recommendations made for how to proceed.

3. Attributes of Personal Rapid Transit

3.1 Attributes and Characteristics

The Advanced Transit Association (ATRA)[1] defines personal rapid transit (PRT) as having *all* of the following characteristics:

- Direct origin-to-destination service with no need to transfer or stop at intermediate stations
- Small vehicles available for the exclusive use of an individual or small group traveling together by choice
- Service available on demand by the user rather than on fixed schedules
- Fully automated vehicles (no human drivers) which can be available 24 hours a day, 7 days a week
- Vehicles captive to a guideway that is reserved for their exclusive use
- Small (narrow and light) guideways, usually elevated but also can be at or near ground level or underground
- Vehicles able to use all guideways and stations on a fully-connected network.

Any transportation system meeting all of the above characteristics will provide an exceptional level of service that, many studies indicate, will attract a high ridership level. However, exclusive use of vehicles is not considered appropriate for airport applications where travelers are accustomed to traveling together in airplanes, automated people movers, and shuttle buses. For this reason, the above PRT definition will not be strictly applied in this study in the hopes of developing a solution that provides most of the advantages of PRT at considerably lower costs. The following are the primary modifications to the above definition that will be considered in this report:

- Occasional stops at intermediate stations may be allowed (particularly during peak hours)
- Ridesharing may be required (particularly during peak periods)

Automated shuttles such as the Navia system have not been considered based on the previous finding[2] that their operating characteristics could lead to connect times up to 9 minutes from the existing economy lot. Connect times from the other proposed lots would likely be even longer. In addition, these types of systems would add to surface traffic congestion.

3.2 Comparison with Cars and Conventional Transit

In Table 3-1, PRT is compared with car and transit (light rail or bus) for a number of different attributes. For each attribute, each mode is rated Poor (red), Acceptable (yellow), or Good (green). Note that this is a generic evaluation and is not adapted to be installation-specific. It can be seen that PRT offers a level of service more like a car than a bus.

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[1] ATRA, *Personal Automated Transportation: Status and Potential of Personal Rapid Transit*, 2003

[2] Personal Rapid Transit Evaluation, An addendum to The 2010 Multimodal Transit Corridor Alternatives Feasibility Study, Greenville County Economic Development Corporation, June, 2014

Attribute	Transit		Car		PRT	
Technology Level	Mature	✔	Mature	✔	Emerging	●
Total Trip Time	Poor	✖	Acceptable	●	Acceptable	●
Operating Cost/Passenger	Poor	✖	Poor	✖	Acceptable	●
Infrastructure Capital Cost/Passenger	Poor	✖	Poor	✖	Acceptable	●
Accident Potential and Cost Savings	Acceptable	●	No	✖	Yes	✔
On-Demand 24/7	No	✖	Yes	✔	Feasible	✔
Transfers	Yes	✖	No	✔	No	✔
Seated Travel	Yes, with limits	●	Yes	✔	Yes	✔
Private	No	✖	Yes	✔	Yes	✔
Non-Stop Travel	No	✖	No	✖	Yes	✔
Vehicle Waits for passenger	No	✖	Yes	✔	Less than 1 min	✔
ADA Compliant	Acceptable	●	No	✖	Yes	✔
Safe and Secure	Acceptable	●	No	✖	Yes	✔
User Friendly	Acceptable	●	Acceptable	●	Yes	✔
Snow & Ice	Varies	●	Poor	✖	Mostly	●
Minimal Walking	Not Often	✖	Yes	✔	Mostly	●
Environmentally Friendly	Somewhat	●	No	✖	Yes	✔
Energy Efficient	Somewhat	●	Somewhat	●	Yes	✔
Visually Appealing	Acceptable	●	Acceptable	●	Acceptable	●
Operates inside buildings	No	✖	No	✖	Possible	●

Legend: Poor ✖ **Acceptable** ● **Good** ✔

Table 3-1: Benefits Comparison Table

3.3 Suppliers with Commercially-Available PRT Systems

The Ultra PRT System

Offered by Ultra Global PRT of Bristol, United Kingdom, the Ultra system[3] is rubber-tired, battery-powered, and runs on an open guideway. The front wheels are steerable, and the vehicle keeps itself on the guideway without any physical lateral guidance (using lasers), simplifying switching, which is accomplished by steering. This system has been in successful operation at London's Heathrow International Airport since April, 2011. The commitment to using off-the-shelf technology, wherever possible, coupled with a rigorous testing and development program, has allowed the Ultra system to be the first modern PRT system to win a commercial contract. Heathrow Airport has expressed its satisfaction with the system by including significant expansion in its budget[4].

Figure 3-1: Ultra vehicles operating at Heathrow

The Ultra vehicle was designed for four adults, plus luggage. However, Heathrow has opted to replace the bucket seats with bench seats, allowing the vehicle to carry a family of six.

Open guideway PRT, such as that used by Ultra and 2getthere (below), tends to be more economical, but the rubber/guideway interface can be problematic during inclement weather conditions. Ultra has plans to address this issue, by using a glass-fiber-reinforced plastic grating as the riding surface. Preliminary testing by PRT Consulting in the winters of 2006 and 2007 has shown this solution to be very successful in mitigating the effects of significant snowfall.

The 2getthere PRT System

2getthere[5], a Dutch company, has been operating an automated PRT-like shuttle bus system, in cooperation with Frog Navigation Systems in Rotterdam, Holland, since 1999. Their true PRT system went into operation in Masdar City in the United Arab Emirates in November 2010. An expansion to this system to serve the city center has recently been announced.[6]

Figure 3-2: 2getthere Pod

2gethere's PRT system is of the open guideway type, with somewhat similar attributes to those of the Ultra system.

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[3] http://www.ultraglobalprt.com/
[4] http://www.ultraglobalprt.com/heathrow-announces-plans-additional-personal-rapid-transit-prt-system-heathrow/#
[5] http://www.2getthere.eu/
[6] http://www.triplepundit.com/2014/01/interview-steve-severance-makes-business-case-masdar-city/

The Vectus PRT System

Vectus[7] is a subsidiary of POSCO, one of the world's largest steel manufacturers. Despite being a British company owned and operated by Koreans, Vectus chose to establish a full-size test track, with an off-line station, in Sweden, in order to prove operability in winter weather conditions and to meet the rigorous Swedish safety requirements. They have now accomplished both of these goals and installed a system in Suncheon, Korea.

Figure 3-3: The Vectus Pod

The Vectus system is of the captive-bogey type, where the undercarriage, or bogey, is not steerable, but has wheels which run along vertical side elements, thus, keeping the vehicle on the guideway. Switching is accomplished by movable wheels mounted on the vehicle. The test track vehicles were propelled (and braked) by linear induction motors mounted in the guideway. Mounting the motors in the guideway reduces the weight of the vehicles, but increases the cost of the guideway. This is advantageous for high-capacity systems, but expensive for low-capacity systems. Their first application in Suncheon Bay, Korea, uses conventional rotary motors which obtain wayside (third rail) power. Propulsion batteries are not required, allowing the vehicles to be lighter-weight.

The Vectus Vehicle is designed to carry four or six seated adults, plus their luggage. In an urban transportation mode the vehicle can also accommodate up to six standees for a total of 12 passengers.

The Vectus system is considered over-capable and probably too expensive for the GSP Airport application and has been excluded from consideration in this study. However, it is anticipated that any future procurement program would not eliminate them from bidding.

The ModuTram PRT System

ModuTram[8] is a consortium of Mexican companies, partially funded by the Mexican government, implementing PRT, which they call a "Lean Intelligent Transportation Network", or LINT. The vehicles are rubber-tired and battery-powered. They have a full scale test track and a ride-able but small demonstration system working near Mexico City, Mexico.

Figure 3-4: The ModuTram Vehicle

The ModuTram vehicle follows sidewalls on the track and all four wheels are steerable. The urban vehicle depicted in Figure 3-4 has six bucket seats. An option potentially more suited to the airport application has bench seats and can accommodate standees. It can accommodate four passengers plus full luggage or five passengers plus light luggage.

[7] http://www.vectusprt.com/EN/
[8] http://www.modutram.com/

4. Attributes of Airport Shuttle Buses

Airport transit from remote parking to terminals has traditionally been with shuttle buses**,** with the bus size dependent on the projected peak and average passenger volumes. Buses have evolved over the years, with added "luxury" amenities such as air conditioning, larger windows, better ingress access, luggage racks in the front of the bus near the door, reading lights, music and video screens for ads, and**,** in some locations**,** live television.

Bus fuel was originally gasoline, but has evolved to diesel, propane, natural gas, and, more recently, electric. Modern engine design innovations have migrated to buses, resulting in better performance and fuel efficiency.

Airport shuttle buses have evolved into two size ranges:

- Smaller scale shuttle buses (11-20 passenger) are more like enlarged mini-vans, and referred to as Mid-Size Buses.
- Larger scale shuttle buses (25-42 passenger) are smaller versions of typical large city buses.

School bus manufacturers, with the exceptions of BlueBird and IC, have not branched into shuttle buses, due to the smaller scale and different seating.

Mid-Size shuttle bus manufacturers include: Ameritrans, Champion, Eldorado, Elkhart, Federal, Glaval, General, IC, Sprinter, Starcraft, StarTrans, Turtle Top, and TransTech. Many of these firms are owned by larger transit corporations, such as Forest River, Inc., who owns Elkhart, Glaval, and Starcraft. Sprinter is owned by Mercedes-Benz. IC is owned by Navistar.

The larger scale shuttle bus manufacturers include: Ameritrans, BlueBird, Champion, Gillig, and Proterra.

Engines for the Mid-Size buses are typically GMC, Ford, and Mercedes-Benz, and the larger scale bus engines are typically Cummins, Freightliner, and Volvo. Proterra manufactures the only electric bus.

The airport shuttle operators who were included in this study use the following makes of buses:

Airport	Bus Make
Charlotte	ElDorado
Greensboro	Sprinter
Louisville	BlueBird
Nashville	International 2007, now marketed as IC
Raleigh	Gillig
Richmond	StarTrans

Table 4-1: Airports and Buses Used

The life expectancy of buses, as noted by the six operators, is:

- Mid-sized buses: 5-6 years: 200,000-250,000 miles
- Larger scale buses: 7-10 years: 300,000-450,000 miles

4.1 Shuttle Bus Companies

The following table shows statistical comparisons between shuttle buses, including a ranking for GSP Airport.

Manufacturers	Series	Length	Seats	Engine	MPG	Life/Miles	Price	Ranking for GSP
Ameritrans	E Series	26'	20	Diesel/Gasoline	-	6/150,000	75,000	5
Champion	Challenger	29'	20	Diesel/Gasoline	-	-	80,000	4
Turtle Top*	OdysseyXL	32'	25	Gasoline	10.0-13.5	7/200,000	110,000	1
ElDorado	Elite	29'	21	Diesel	-	7/200,000	100,000	2
Gillig	Series 29	30'	24	Diesel	5.2-5.8	12/400,000	375,000	7
IC	AC	29'	20	Diesel	5.5-6.6	7/200,000	90,000	3
Mercedes	Sprinter2500	22'	15	Diesel	14-17	5/150,000	70,000	9
Proterra	Electric 40	40'	28	Electric	16-18 E	10/300,000	825,000	8
StarTrans	Senator	26'	20	Diesel/Gasoline	-	6/150,000	75,000	6

Table 4-2: Shuttle Midsize Buses – Manufacturing Data

The Ranking for GSP Airport shows Turtle Top's OdysseyXL as #1, based on number of seats, capital, and fuel costs. The $110,000.00 price includes air ride rear suspensions and upgraded seat coverings/interiors. There is not a clear #2 choice as none of the other eight buses meet all the GSP Airport requirements. A bid specification criteria listing would need to be prepared along with a RFP, and these would need to be submitted to vendors to determine if any others bus bidders were willing to modify their models for a relatively small number of units.

Note: Equipping the preferred bus (Turtle Top's Odyssey XL) with wheelchair capabilities, as is done at most of the surveyed airports, reduces the available seats to 23 and increases the price to $127,000.00. Also note that the short routes at GSP Airport favor gasoline power over diesel, and that natural gas options for this size bus are limited and expensive to buy and maintain.

5.0 Projected Parking Space Demand

This section addresses the projected demand for parking facilities, alternative expansion solutions, and anticipated utilization rates. Based on decisions made in the Project Kickoff Meeting held on 8/14/2014, this project will assume the PRT system is implemented in 2018 and has a 30-year life. Growth is based on 945,000 enplanements for calendar year 2014 and then a 1.5% annual growth rate. This growth rate tracks most closely with the Base Case growth rate in the 2010 Terminal Area Study (TAS).

Table 5-1 shows how parking spaces are distributed among the existing facilities, the daily rates, average transaction amounts, and the average length of stay. Figure 5-1 depicts the layout of the existing parking facilities.

Facility	Current Spaces	Daily Rate ($)	Average Gross Transaction Amount ($)	Average Stay (Days)*
Garage A	720	12.00	16.93	1.4
Garage A Sky Lot	326	6.00	26.91	4.5
Garage B	1,159	12.00	23.71	2.0
Garage B Sky Lot	324	6.00	27.49	4.6
Daily	367	8.00	8.52	1.1
Economy	1,530	4.00	18.69	4.7
Total Public Spaces	4,426			

Table 5-1: Distribution of Current Public Parking Spaces by Facility

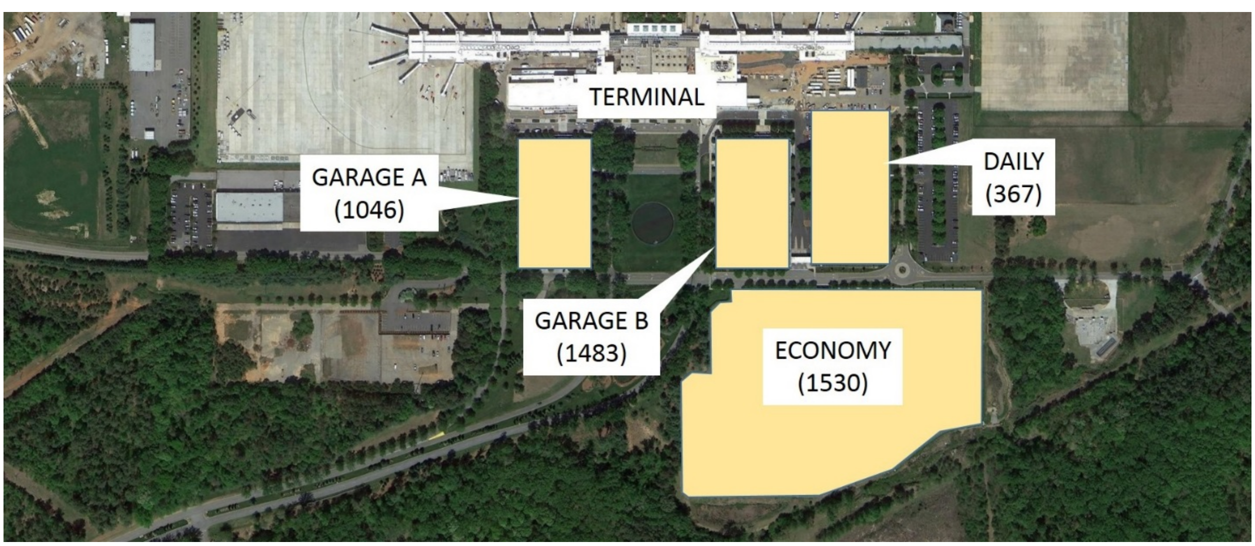

Figure 5-1: Existing Public Parking Facilities

Table 4-49 in the Terminal Area Study (TAS) has been adjusted to determine the required spaces (based on level-of-service A), and the surplus (shortfall) for the study period based on 4,426 existing total public spaces and the assumed growth rate for this study. The results are provided in Table 5-2 below and indicate parking expansion is needed before 2018. The following subsection addresses different ways to meet the demand and different solutions for providing shuttle services.

Year	Enplanements	Required Spaces	Surplus (Shortfall)
2018	1,002,989	5,009	(583)
2019	1,018,033	5,092	(666)
2020	1,033,304	5,168	(742)
2021	1,048,803	5,240	(814)
2022	1,064,535	5,310	(884)
2023	1,080,504	5,386	(960)
2024	1,096,711	5,460	(1,034)
2025	1,113,162	5,539	(1,113)
2026	1,129,859	5,612	(1,186)
2027	1,146,807	5,688	(1,262)
2028	1,164,009	5,768	(1,342)
2029	1,181,469	5,850	(1,424)
2030	1,199,191	5,929	(1,503)
2031	1,217,179	6,012	(1,586)
2032	1,235,437	6,101	(1,675)
2033	1,253,968	6,200	(1,774)
2034	1,272,778	6,305	(1,879)
2035	1,291,870	6,414	(1,988)
2036	1,311,248	6,529	(2,103)
2037	1,330,916	6,648	(2,222)
2038	1,350,880	6,774	(2,348)
2039	1,371,143	6,898	(2,472)
2040	1,391,711	7,028	(2,602)
2041	1,412,586	7,162	(2,736)
2042	1,433,775	7,298	(2,872)
2043	1,455,282	7,436	(3,010)
2044	1,477,111	7,578	(3,152)
2045	1,499,267	7,722	(3,296)
2046	1,521,756	7,868	(3,442)
2047	1,544,583	8,018	(3,592)

Table 5-2: Required Spaces and Supply Surplus (Shortfall)

5.1 Alternative Parking Expansion Solutions

Two different scenarios are examined for addressing the parking space shortfall. In the first scenario (Figure 5-2), a 1,300 space surface lot (Economy 2) is added in 2018, in the location of the disused rental car ready area, followed by a 1,500 space parking garage (Garage C) in 2028 and another 1,100 space surface lot (Economy 3), southeast of the present economy lot in 2038. The construction of this lot is accompanied by the construction of a loop road from Aviation Parkway passing southeast of the present economy lot and then turning northwest to bisect the economy lot and meet GSP Airport Drive at the present roundabout.

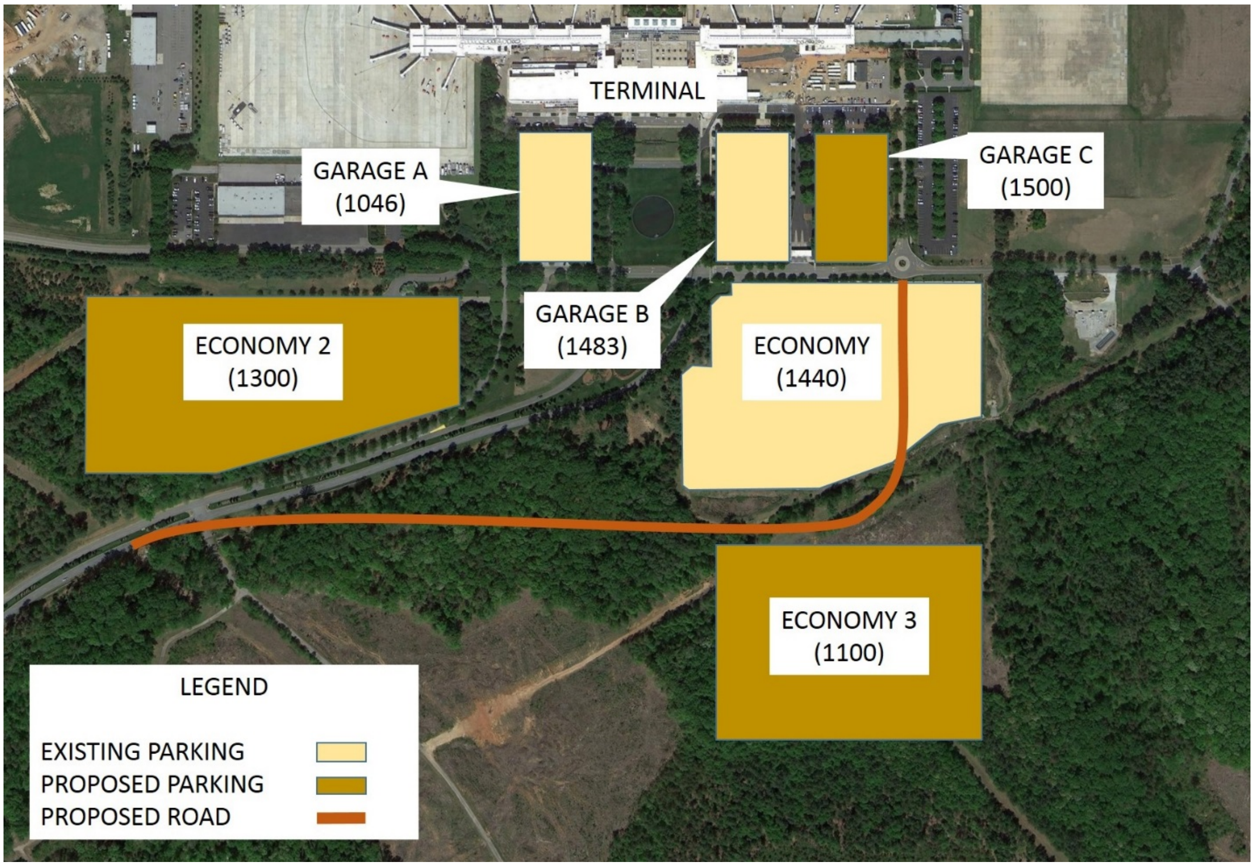

Figure 5-2: Future Public Parking Scenario 1

In the second scenario (Figure 5-3), the third parking garage is replaced by a surface lot southeast of the present economy lot (Economy 3), and the loop road construction is accelerated to serve this new lot. A fourth surface lot (Economy 4) is required in 2038.

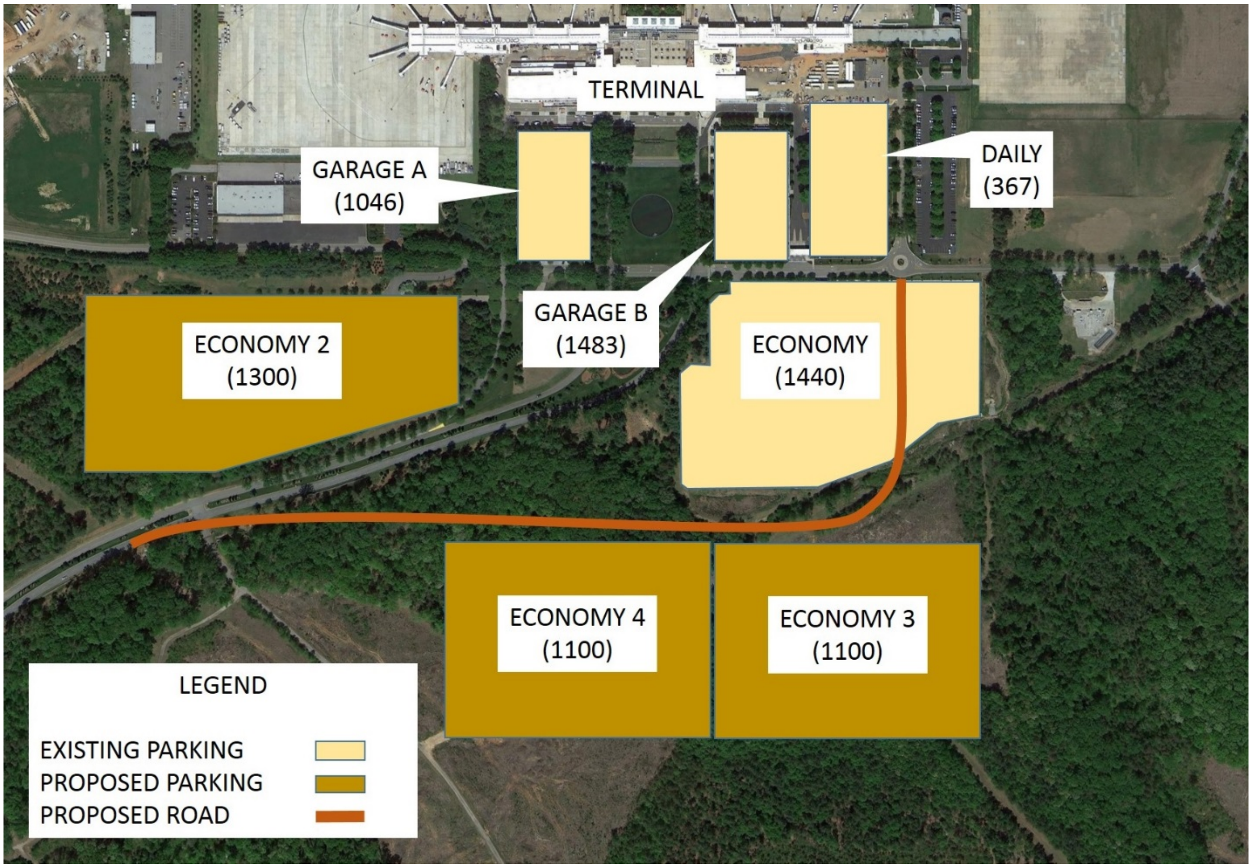

Figure 5-3: Future Public Parking Scenario 2

In the first scenario 3,900 spaces are added, but the 355 daily lot spaces are lost to the new garage, and 90 economy lot spaces are lost to the loop road, for a net gain of 3,455 spaces. In the second scenario only 90 spaces are lost (to the loop road). For this reason, the three surface lots in the second scenario are sized for 1,300, 1,100 and 1,100 spaces respectively for approximately the same net gain.

5.2 Projected Parking Utilization

Two different parking lot utilization situations need to be examined – the peak, and the average. The peak utilization (when the lot is full) drives the number of shuttle bus or PRT vehicles required (if that number is greater than the number required to meet frequency of service requirements). The average utilization determines the annual parking revenues to be anticipated.

This study addresses potential shuttle service to the existing and proposed economy lots and is thus only concerned with the peak and average utilization of these lots. It has been assumed that the average utilization of a new parking facility grows uniformly from the year it is opened to the year before another parking facility is opened. This average utilization then remains constant, and all new growth goes to the new facility.

While there are likely to be some differences in the projected demand between shuttle buses and PRT, they have been assumed to be negligible, and the demand for both shuttle systems has been determined in the same way using the same assumptions. One difference could be that the quick connect times of the PRT solution attract some cars from the parking garages. This could impact overall parking revenues. However, it is likely that there will always be sufficient drivers who are prepared to pay for covered parking to keep the garages full, and so this effect should be relatively small and short-lived.

Tables 5-3 and 5-4 show the projected average and peak parking utilization for Scenarios 1 and 2 respectively. Based on TAS Tables 4-37 and 4-39, the average utilization for all lots and garages is assumed to be 91% of the annual peak occupancy. While this seems a high rate, it has been applied equally to all options.

5. 2.1 Scenario 1

Table 5-3 shows the projected average and peak utilization assumed for the surface lots in Scenario 1

Year	Economy		Economy 2		Economy 3	
	Peak	Average	Peak	Average	Peak	Average
2018	1,530	1,392	583	531		
2019	1,530	1,392	666	606		
2020	1,530	1,392	742	676		
2021	1,530	1,392	814	740		
2022	1,530	1,392	884	805		
2023	1,530	1,392	960	873		
2024	1,530	1,392	1,034	941		
2025	1,530	1,392	1,113	1,013		
2026	1,530	1,392	1,186	1,079		
2027	1,530	1,392	1,262	1,148		
2028	1,530	1,392	1,300[9]	1,183		
2029	1,530	1,392	1,300	1,183		
2030	1,530	1,392	1,300	1,183		
2031	1,530	1,392	1,300	1,183		
2032	1,530	1,392	1,300	1,183		
2033	1,530	1,392	1,300	1,183		
2034	1,530	1,392	1,300	1,183		
2035	1,530	1,392	1,300	1,183		
2036	1,530	1,392	1,300	1,183		
2037	1,530	1,392	1,300	1,183		
2038	1,440	1,310	1,300	1,183		
2039	1,440	1,310	1,300	1,183	117	106
2040	1,440	1,310	1,300	1,183	247	225
2041	1,440	1,310	1,300	1,183	381	346
2042	1,440	1,310	1,300	1,183	517	470
2043	1,440	1,310	1,300	1,183	655	596
2044	1,440	1,310	1,300	1,183	797	725
2045	1,440	1,310	1,300	1,183	941	856
2046	1,440	1,310	1,300	1,183	1,087	990
2047	1,440	1,310	1,300	1,183	1,100	1,001

Table 5-3: Scenario 1 Projected Peak and Average Surface Lot Utilization

[9] Once Economy 2 fills up, Garage C needs to be constructed but those spaces are not included in this table.

5.2.2 Scenario 2

Table 5-4 shows the projected average and peak utilization assumed for the surface lots in Scenario 2

Year	Economy		Economy 2		Economy 3		Economy 4	
	Peak	Average	Peak	Average	Peak	Average	Peak	Average
2018	1,530	1,392	583	531				
2019	1,530	1,392	666	606				
2020	1,530	1,392	742	676				
2021	1,530	1,392	814	740				
2022	1,530	1,392	884	805				
2023	1,530	1,392	960	873				
2024	1,530	1,392	1,034	941				
2025	1,530	1,392	1,113	1,013				
2026	1,530	1,392	1,186	1,079				
2027	1,530	1,392	1,262	1,148	0	0		
2028	1,440	1,310	1,300	1,183	132	120		
2029	1,440	1,310	1,300	1,183	214	194		
2030	1,440	1,310	1,300	1,183	293	267		
2031	1,440	1,310	1,300	1,183	376	342		
2032	1,440	1,310	1,300	1,183	465	423		
2033	1,440	1,310	1,300	1,183	564	514		
2034	1,440	1,310	1,300	1,183	669	609		
2035	1,440	1,310	1,300	1,183	778	708		
2036	1,440	1,310	1,300	1,183	893	812		
2037	1,440	1,310	1,300	1,183	1,012	921		
2038	1,440	1,310	1,300	1,183	1,100	1,001	0	0
2039	1,440	1,310	1,300	1,183	1,100	1,001	72	65
2040	1,440	1,310	1,300	1,183	1,100	1,001	202	184
2041	1,440	1,310	1,300	1,183	1,100	1,001	336	305
2042	1,440	1,310	1,300	1,183	1,100	1,001	472	429
2043	1,440	1,310	1,300	1,183	1,100	1,001	610	555
2044	1,440	1,310	1,300	1,183	1,100	1,001	752	684
2045	1,440	1,310	1,300	1,183	1,100	1,001	896	815
2046	1,440	1,310	1,300	1,183	1,100	1,001	1,042	949
2047	1,440	1,310	1,300	1,183	1,100	1,001	1,100	1,001

Table 5-4: Scenario 2 Projected Peak and Average Surface Lot Utilization

5.3 Projected Parking-Related Peak-Hour Trips

In order to determine the peak hour trips from each lot, we need the average utilization from Tables 5-3 and 5-4 above, the average length of stay from Table 5-1 above, and the average vehicle occupancy for cars parked in the economy lots. Also required is the peak hour factor indicating the relationship of peak hour travel to annual travel. This has been obtained from the TAS Table 3-18 Base case for the year 2030.

Studies from other airports indicate average vehicle occupancy is 1.7. Table 6-1 indicates the average length of stay for the existing Economy lot is 4.7 days, and this value has been used for this lot. However, the airport-wide average length of stay is 3.1 days, and this value has been used for Economy 2, 3, and 4 lots. The resulting peak hour trips to the terminal from each lot (once the lot becomes full) are as shown in Table 6-5. For PRT it has been conservatively assumed that the vehicle occupancy will equal the car occupancy times 1.3 (Heathrow observations indicate peak period ridesharing will be at a higher rate – approaching a factor of 2.0).

	Economy	Economy 2	Economy 3	Economy 4	Total
Person Trips	137	176	149	149	611
PRT Vehicle Trips	62	80	67	67	276

Table 5-5: Peak Hour Trips to the Terminal

6. Comparative Airport Parking Shuttle Operations

An investigation of existing airport parking lots was undertaken to show a correlation of information useful in determining comparisons for GSP Airport. Both airports with current shuttle services as well as airports without shuttle services were studied. Airports were chosen either due to a comparative size in relation to GSP Airport (enplanements) or due to location (within 300 miles) and competitiveness with GSP Airport.

Criteria for the study:

- Airports within 300 miles of GSP Airport
- Comparatively sized airports (enplanements), as well as competitive airports
- Surface lots allowing long-term parking (with or without shuttles)
- No parking garages considered
- Combination of shuttle and non-shuttle airports (majority with shuttles)

Airports studied are listed in the table below.

Airports with Shuttles	Airports without Shuttles
BNA, Nashville, TN	MYR, Myrtle Bch, SC
SDF, Louisville, KY	CHS, Charleston, SC
GSO, Greensboro, NC	SAV, Savanah, GA
RDU, Raleigh, NC	
CLT, Charlotte, NC	
ATL, Atlanta, GA	

Table 6-1: Airports Studied

6.1 Operations

Each airport within the study operated their shuttles a bit differently as noted below.

BNA, Nashville

In Nashville, shuttle drivers must follow a specific route and schedule, and must stop at each station whether they see passengers waiting or not. There is only one terminal stop to drop passengers (Level 3) and only one stop for pick-up (Level 2). Buses loop around every 11-13 minutes.

SDF, Louisville

Although shuttle drivers have a set route, they only stop at stations if passengers are waiting there. In addition, they may be asked to deviate from the route if a call for pick-up has come in (signage advises passengers to call if waiting more than 10 minutes). Drivers are allowed to drop passengers at their specific airlines for departures, but there are only two terminal arrival picks-ups (East and West). Drivers are also allowed to deviate and drive to passenger cars for pick-up or drop-off. There is no set schedule but buses loop every 10-15 minutes.

GSO, Greensboro

In Greensboro, the shuttle drivers must maintain the actual route, but need not stop at each station. They are allowed to divert and pick-up/drop-off passengers at their cars. Departing passengers are dropped at one of four terminal locations depending on the airline. Arriving passengers have a designated area for pick-up in front of the terminal.

RDU, Raleigh-Durham

Raleigh shuttle drivers must stick to a schedule and stop at all bus stations. They drop and pick up passengers at the terminal in two locations only. The buses loop every 20 minutes.

CLT, Charlotte

Shuttles at Charlotte must follow a set schedule and route and must always stop at the bus stations. There are two terminal stops (East and West), and pick-up/drop-off are the same. The buses loop every 10-15 minutes.

ATL, Atlanta

Atlanta has many parking options, but in the surface lots chosen for this study, the drivers try to maintain a route but try to locate and pick-up/drop-off passengers at their cars. In addition, they will drop passengers off at their respective airlines in the terminal. Arriving passengers must go to the Ground Transportation Center for transport back to their cars.

6.2 Rates and Charges

Rates and Charges shown below were taken from existing 'long-term' surface lots (no garage parking). At some airports, there are multiple lots, and where there is an option for close in 'long term' parking, additional statistics were taken – hence, 1 and 2 options shown.

Note: The GSP Airport surface lot and Sky Lot rates are also included for comparison purposes only. Connect times are from the car to the terminal and are as reported or estimated based on known distances and 3 mph walking speeds or estimated shuttle speeds.

Airport	Lots Used	Parking Rate/Day	Connect Times (Min)
BNA1, Nashville, TN	Economy	$9.00	13.9
BNA2, Nashville, TN	Long Term A	$14.00	10.7
SDF1, Louisville, KY	Long Term	$9.00	9.2
SDF2, Louisville, KY	CreditCard*	$13.00	3.2
GSO, Greensboro, NC	Long Term	$8.00	23.7
RDU, Raleigh, NC	ParknRide	$6.00	18.2
CLT, Charlotte, NC	Long Term 1	$5.00	18.7
ATL1, Atlanta, GA	ParknRide	$9.00	26.0
ATL2, Atlanta, GA	Economy Lots*	$12.00	5.9
MYR, Myrtle Bch, SC	Long Term*	$9.00	2.8
CHS, Charleston, NC	Surface Lot*	$8.00	4.5
SAV, Savanah, GA	Economy E/W*	$8.00	3.0
GSP, Greer, SC	Economy*	$4.00	6.5
GSP2, Greer, SC	SkyLots*	$6.00	3.5

Table 6-2: Parking Lot Rates/Charges/Connect Times

*Indicates no shuttle service. Walking only.

When compiling statistics for the graph below, the following considerations were made:

- Shuttle Operations / Connecting Time = Wait-time, Load-Time, Travel Time, Unload Time, + Standard Add Time (.5 min)
- Non-Shuttle Operations / Connecting Time = Walk Time, + Standard Add Time (.5 min)
- Walk Time = Distance @ 3mph
- Distances = Average of Farthest/Middle/Closest distances (shuttle stations, where applicable) within selected parking lots.

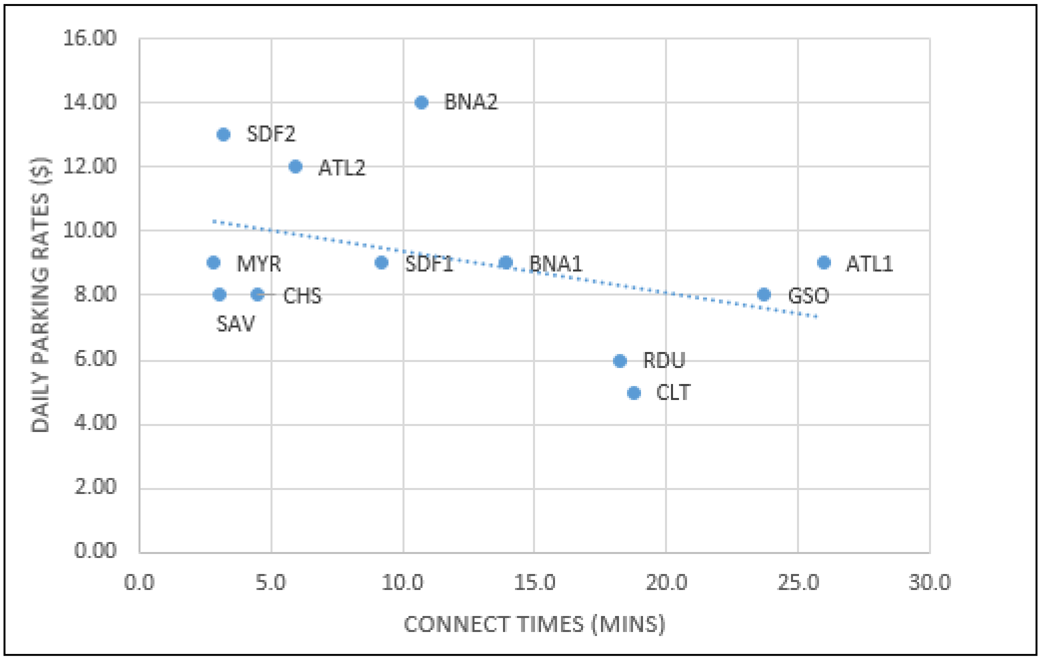

Figure 6-1: Parking Rate - Connect Time Graph

Note that, as shown in Figure 6-2, where airports have more than one surface lot, the increase in parking rate per minute saved is significant ($0.67 for Louisville (SDF1, SDF2), and $1.56 for Nashville (BNA1, BNA2) and $0.15 for Atlanta (ATL1, ATL2)). This is an average of $0.79 per minute saved.

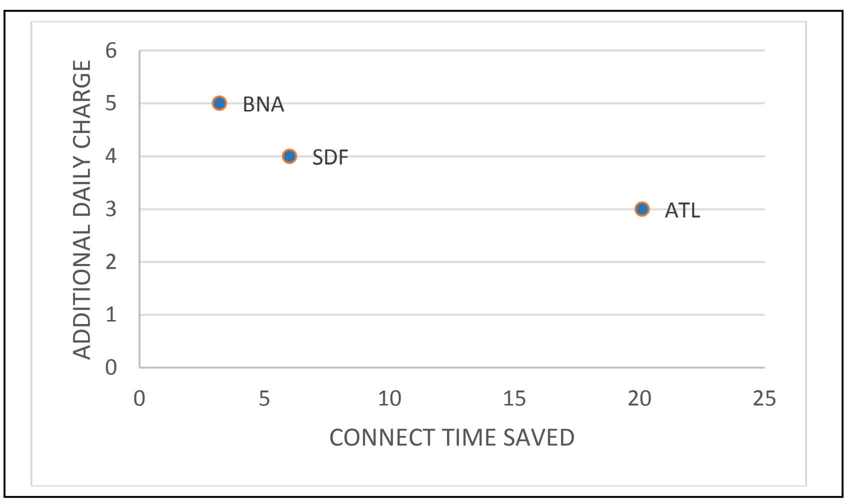

Figure 6-2: Additional Daily Charge vs. Connect Time Saved

GSP Airport rates presently reflect a similar value of time saved since the 3 minutes time savings for parking in the Garage SkyLots costs $2.00 more than the Economy Lot ($0.67 per minute).

Section 10.2 discusses potential economy lot parking rate increases at GSP Airport and concludes that, in order to remain competitive with Charlotte, $5.00 per day will be used for bus alternatives and $6.00 per day for PRT alternatives in this analysis.

7. PRT Solutions

7.1 Scenario 1

Figure 7-1 depicts the PRT layout on completion of Scenario 1. This PRT system requires 42 vehicles and has a total of 2.5 miles of one-way guideway comprising 0.50 miles one-way at grade, 0.45 miles one-way elevated, 0.35 miles two-way at grade and 0.42 miles two-way elevated (note that when adding the individual guideway lengths to reach the 2.5 mile total, two-way section lengths must be doubled). It has four elevated stations and six at-grade stations and a 3,800 square foot maintenance/storage facility[10]. The control facilities are assumed to be co-located within the airport's existing control room. About 95% of all parking stalls are within 400' (1.5 minutes) of a station. The maximum total connect time (walk plus wait plus travel) to the center of the terminal for 95% of passengers is less than seven minutes while the average is five minutes.

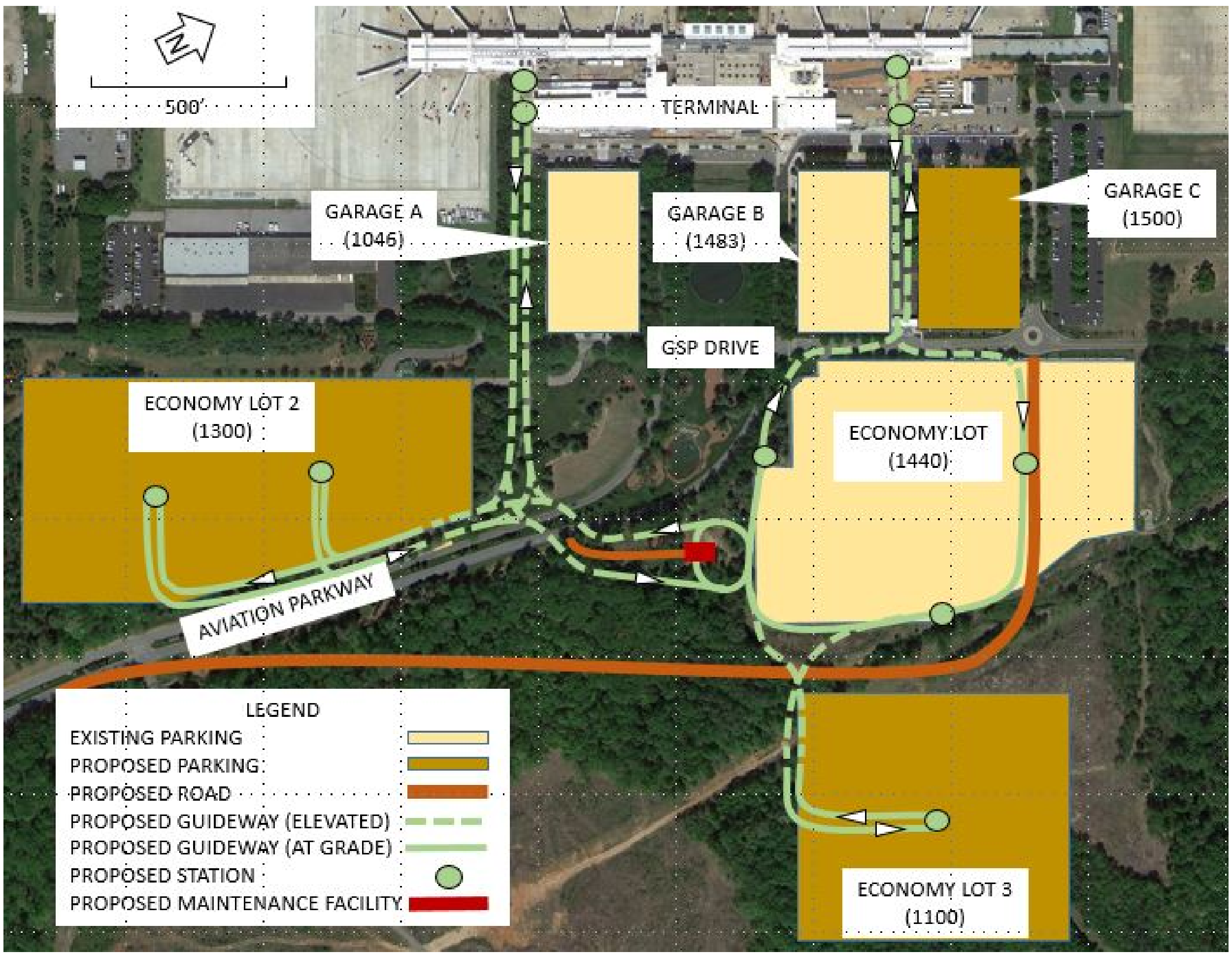

Figure 7-1: Scenario 1 PRT Layout[11]

[10] Based on 100 s. ft. per vehicle – similar to the Heathrow facility
[11] Some guideway connectors and turnarounds cannot be shown at this scale

This layout has been developed based on input received from airport management at the kickoff meeting and subsequently. An elevated station is provided at each end of the terminal building, and guideways are not routed in front of the building in order to maintain views of and from it. Elevated stations attached to each concourse allow arriving passengers not collecting checked bags to proceed directly to their cars. The system will be programmed to prevent occupied vehicles from accessing these stations and posing a security threat.

Figure 7-2: Typical PRT Elevated Station Rendering (Source: WSP)

All parking lot stations are at grade, facilitating roll-on/roll-off access by passengers with bags or in wheelchairs and obviating the need for stairs and elevators. Where possible, guideways are at grade. Elevated crossing of Aviation Parkway is located away from the terminal area and sensitive viewscapes. The maintenance/storage facility is strategically located near the center of the system and also near the initial segment serving the existing Economy Lot and Economy Lot 2. It will be accessed by a new road connecting to Aviation Parkway. Existing trees will help obscure it from view.

Figure 7-3: Typical PRT At-Grade Station (Source: Ultra/Heathrow)

7.1.1 Connect Times

PRT connect times (car to terminal) include the time taken to walk to a PRT station, wait for a vehicle, and ride the PRT system. 95% of passengers will be able to park within 400 feet of a PRT station and will wait less than one minute for a vehicle, even in peak periods. Using three MPH walking speeds, the average walking and waiting times will thus be 45 and 30 seconds respectively, while the maximums will be 90 and 60 seconds.

PRT ride times will be roughly similar for all trips between the parking lot and the terminal stations. The trip from Economy Lot 3 to the south terminal is the longest and has been analyzed in some detail. The speed profile for this trip is shown in Figure 7-1. It has been calculated using speed, acceleration rates, and speed restrictions through merges and diverges that should be achievable by all of the PRT systems considered. The maximum speed achieved is 22 MPH, and the average speed is 13.5 MPH. By comparison, the APM at San Francisco International Airport averages 9.3 MPH around the inner terminal loop and 12.5 MPH around the outer loop which connects the terminals to the rental car facility.[12] The total travel time from Economy Lot 3 to the south terminal is 147 seconds. Note that systems that can achieve higher speeds will reduce the travel times. While this will probably not be significant to passengers, it could result in fewer vehicles being needed.

The average total connect time, including walking and waiting, is thus 222 seconds (3.7 minutes), and the maximum 297 seconds (4.95 minutes). Average and maximum connect times of five and seven minutes have been used in the analysis allowing a further two minutes to walk from the PRT stations to the center of the terminal.

[12] Conley, John F., The San Francisco International Airport AirTrain Project, 2001.

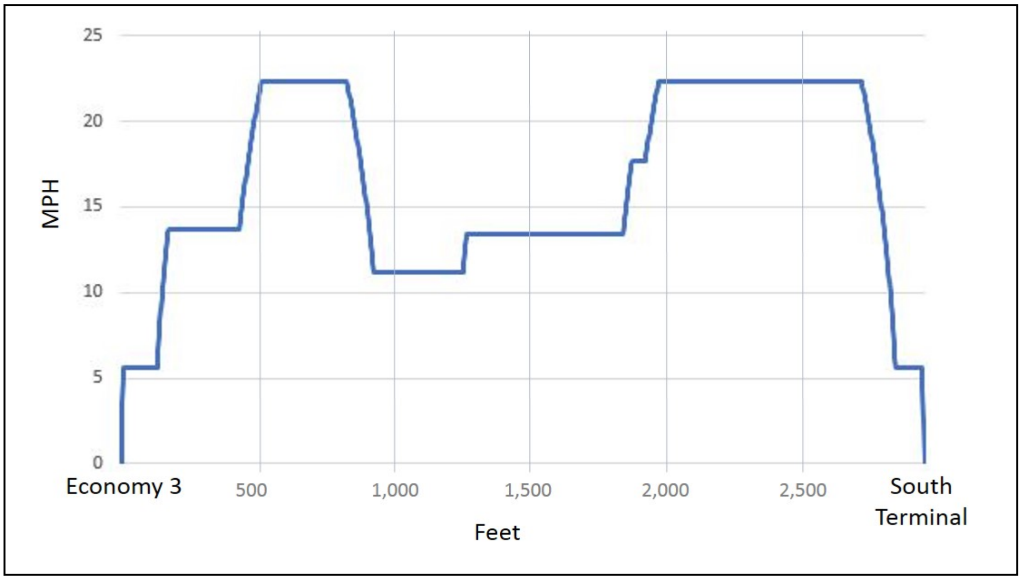

Figure 7-4: PRT Speed Profile from Economy Lot 3 to South Terminal

7.1.2 Phases for Scenario 1

The PRT system and parking lots will be constructed in phases to meet the demand. For planning purposes, the 30-year analysis period has been subdivided into three phases with each phase covering ten years. Timing for implementation of a phase should be based on actual growth in demand. The anticipated phasing is described in the following sections.

Phase 1

This phase is assumed to be complete by 2018 and will include the 1,300 space Economy Lot 2 and a PRT system connecting three at-grade stations in the existing Economy Lot and two in Economy Lot 2 to an elevated Terminal Station at the northeast end of the terminal as well an elevated station attached to the adjoining concourse. It will also include a 2,300 square foot maintenance facility and service road.

The Phase 1 layout is shown in Figure 7-5. This PRT system requires 33 vehicles and has a total of 1.7 miles of one-way guideway comprising 0.50 miles one-way at grade, 0.35 miles one-way elevated, 0.27 miles two-way at grade and 0.15 miles two-way elevated. It has two elevated stations and five at-grade stations. Road construction includes a service road to the 2,300 square feet maintenance/storage facility and an access road to the northeast side of the existing Economy Lot from the roundabout on GSP Airport Drive.

The capital cost is estimated to be $40.0 M while the annual operating and maintenance cost is estimated to be $2.5 M. This includes costs for constructing and maintaining Economy Lot 2. The annual parking revenue for this phase ranges from $4.2 M in 2018 to $5.6 M in 2027 based on $6.00 per day from the existing Economy Lot and Economy Lot 2.

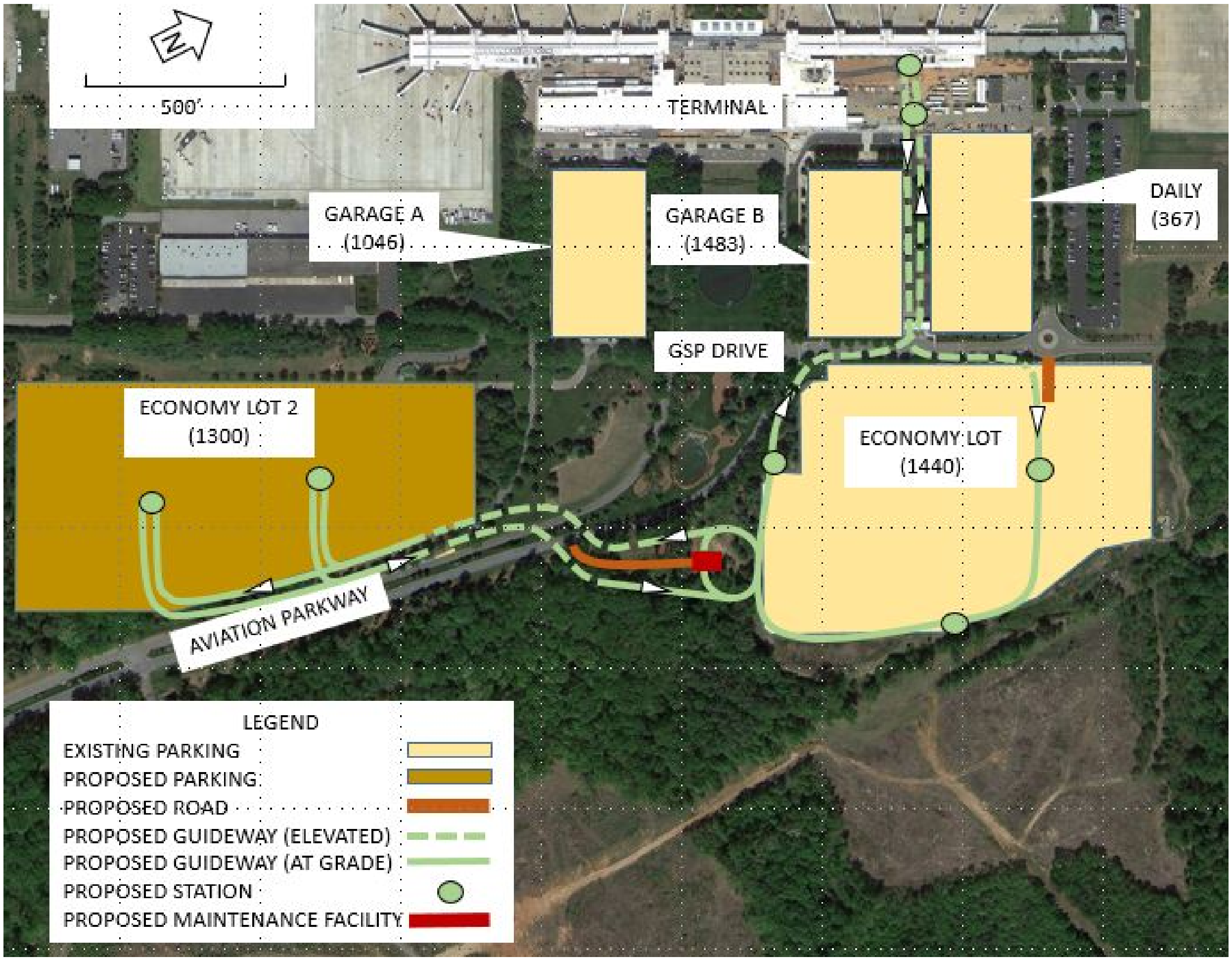

Figure 7- 5: Scenario1, Phase 1 Layout

Phase 2

During this phase the 367 space Daily Lot is converted into a 1,500 parking garage (Garage C) completed by 2028. No PRT changes are made. The capital costs associated with this phase are $45.0 M[13] and the annual maintenance costs are $1.3 M. The annual parking revenue for this phase ranges from $5.8 M in 2028 to $9.0 M in 2037 and includes revenue from Garage C based on $12.00 per day (to match the rate for the other garages and for the average at Raleigh-Durham). $6.00 per day has been used for the SkyLot on top of Garage C to match current practice for SkyLots A and B.

Phase 3

Phase 3 completes the layout shown in Figure 7-1. Economy Lot 3 is constructed in Phase 3 and is complete by 2038. The PRT system is extended to Economy Lot 3 and also to the southwest end of the terminal and the adjoining concourse during this phase. In addition, a one-way, two-lane loop road is constructed from

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[13] Parking lot and garage capital costs are based on the average of the amounts provided in ACRP Report 24 Guidebook for Evaluating Airport Parking Strategies and Supporting Technologies, 2009

Aviation Parkway to the existing roundabout on GSP Airport Drive. This road provides access to Economy Lot 3.

The PRT system is completed during this phase by the addition of 9 vehicles and 0.8 miles of one-way guideway comprising 0.10 miles one-way elevated, 0.08 miles two-way at grade, and 0.27 miles two-way elevated. Two elevated stations and one at-grade station are added. The maintenance facility is expanded by 1,500 square feet. The capital cost associated with this phase is estimated to be $28.2 M while the annual operating and maintenance cost is estimated to be $0.9 M. This includes costs for Economy Lot 3. The annual parking revenue during this phase ranges from $9.5 M in 2038 to $11.8 M in 2047 and includes $6.00 per day for Economy Lot 3.

Net Present Worth

The grand total 30-year sum of the capital and operating costs is $226 M, while the total parking revenue is $230 M. Based on a 4% discount rate[14], the net present worth of the capital, operating and maintenance costs, and revenues associated with PRT Scenario 1 is $1.7 M. Note that this is a positive cost number indicating that the facilities installed under this scenario do not generate sufficient revenue to pay for themselves (with no consideration of any financing costs). This revenue includes the revenue from the existing Economy Lot but not from any other existing parking facility.

7.2 Scenario 2

Figure 7-5 depicts the PRT layout on completion of Scenario 2. This PRT system is identical to that for Scenario 1 with the addition of at-grade guideway and a station to serve Economy Lot 4. It requires 51 vehicles and has a total of 2.7 miles of one-way guideway comprising 0.50 miles one-way at grade, 0.45 miles one-way elevated, 0.45 miles two-way at grade, and 0.42 miles two-way elevated. It has four elevated stations, seven at-grade stations, and a 4,300 square foot maintenance/storage facility. About 95% of all parking stalls are within 400’ (1.5 minutes) of a station. The maximum total connect time (walk plus wait plus travel) to the center of the terminal is less than seven minutes while the average is five minutes.

[14] As recommended in Appendix 1. Economic Analysis, FAA Advisory Circular 150/5320-6E 2009.

Figure 7-6: Scenario 2 PRT Layout

7.2.1 Phases for Scenario 2

The PRT system and parking lots will be constructed in phases to meet the demand. The anticipated phasing is described in the following sections.

Phase 1

This phase is identical to Scenario 1, Phase 1 (Figure 7-2).

Phase 2

Upon completion of this phase, the layout is identical to Scenario 1, Phase 3 (Figure 7-1) but it is completed by 2028 and does not include Garage C. The capital costs associated with this phase are $28.2 M and the annual operation and maintenance costs are $1.0 M. The annual parking revenue for this phase ranges from $5.9 M in 2028 to $7.6 M in 2037 and includes revenue from Economy Lot 3.

Phase 3

Phase 3 completes the layout shown in Figure 7-5. Economy Lot 4 and its associated PRT guideway and station are constructed in Phase 3 and completed by 2038.

The PRT system is completed during this phase by the addition of 9 vehicles, one at-grade station and 0.1 miles of one-way at-grade guideway. The additional capital cost associated with this phase is estimated to be $12.1 M while the annual operating and maintenance cost is estimated to increase by $0.5 M. The annual parking revenue for this phase ranges from $7.8 M in 2038 to $9.8 M in 2047 and includes revenue from Economy Lot 4.

Net Present Worth

The grand total 30-year sum of the capital and operating costs is $181 M while the total parking revenue is $204 M. Based on a 4% discount rate, the net present worth of the capital, operating and maintenance costs associated with PRT Scenario 2 is -$4.2 M. This is a negative cost number indicating that the facilities installed under this scenario generate sufficient revenue to pay for themselves.

7.3 Implementation

The scenarios and phases discussed above were developed in order to undertake a logical life-cycle comparison with a shuttle bus solution. They may therefore not be entirely suitable for the implementation of a PRT system should the Airport District decide that PRT is the preferred solution. This section addresses a PRT Phase 1A which comprises a practical PRT system for initial implementation.

Phase 1A

This initial phase is comprised of a PRT system connecting three at-grade stations in the existing Economy Lot to an elevated Terminal Station at the northeast end of the terminal as well an elevated station attached to the adjoining concourse. It will also include a 1,650 square foot maintenance facility and service road. Any overflow surface lot needs are assumed to be accommodated on the existing pavement in the area of the proposed future Economy Lot 2 and served by a shuttle bus when needed. Costs for two buses are included in the cost of this phase

The Phase 1A layout is shown in Figure 7-7. This PRT system requires 21 vehicles and has a total of 0.88 miles of one-way guideway comprising 0.41 miles one-way at grade, 0.17 miles one-way elevated, and 0.15 miles two-way elevated. It has two elevated stations and three at-grade stations. Road construction includes a service road to the 1,650 square feet maintenance/storage facility and an access road to the northeast side of the existing Economy Lot from the roundabout on GSP Airport Drive.

The capital cost is estimated to be $20.9 M while the annual operating and maintenance cost is estimated to be $1.81 M. The annual parking revenue for this phase is $3.05 M per year based on $6.00 per day from the existing Economy Lot.

Table A-3 in Appendix A indicates there will be an annual surplus of $33,000 if the $20.9 M capital cost is amortized over 30 years at 4%. Additional revenue could be generated from means such as advertising. Funding sources are available that could further increase the net revenue from the project. Section 10 addresses potential funding and financing alternatives in more detail.

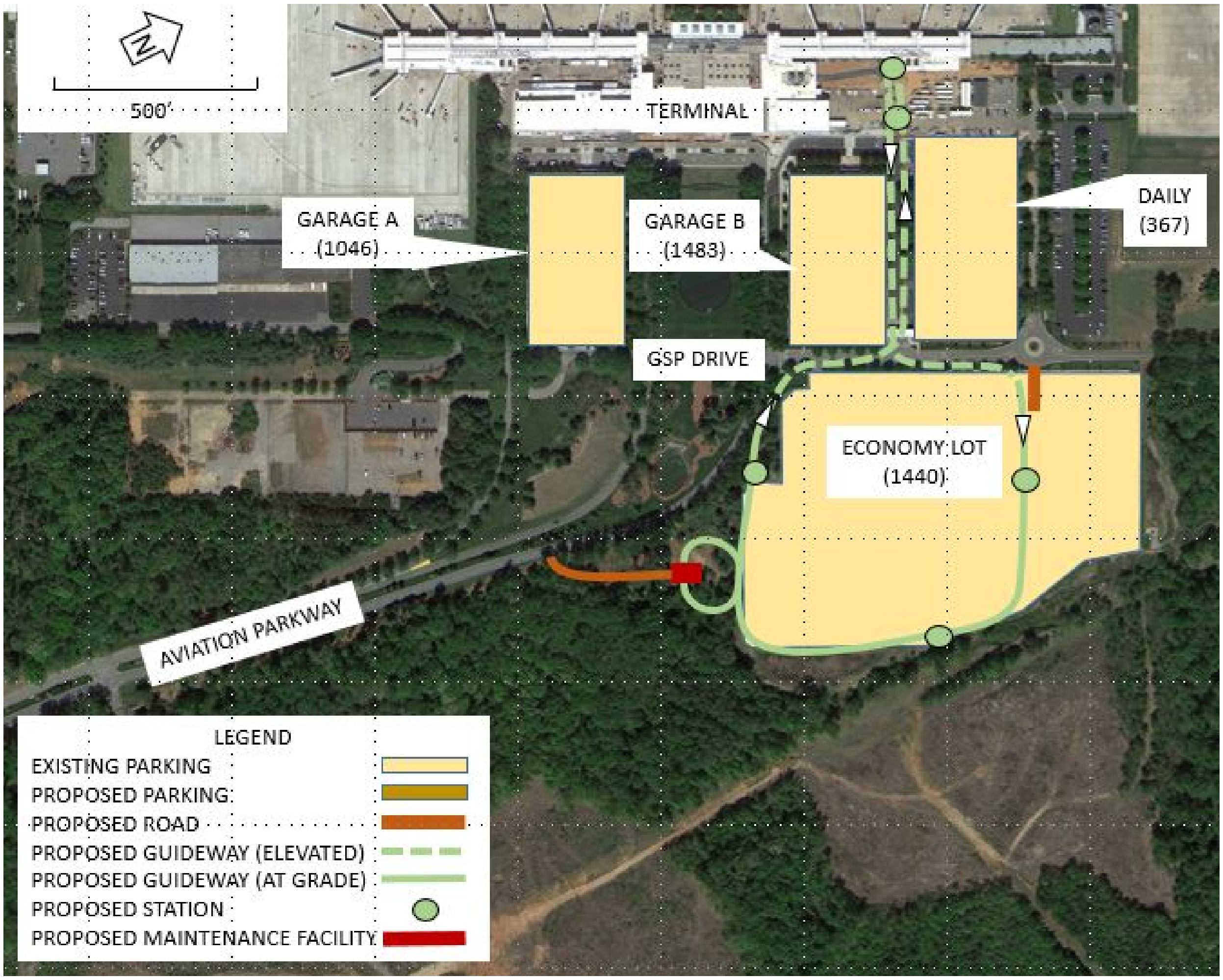

Figure 7- 7: Phase 1A Layout

8. Shuttle Bus Solutions

After reviewing the shuttle bus services of nine airports within 300 miles of GSP Airport, it was decided to model the proposed GSP Airport shuttle bus solution on those in place at Charlotte and Raleigh Durham. These airports use large buses that operate on a headway of 10 to 15 minutes and travel a fixed route including designated pickup and drop-off stops. To provide a high level of service at GSP Airport, it was decided 15 minutes between buses (as at Charlotte) is too long, and a headway of 10 minutes was targeted.

Three terminal stops are proposed, one in the middle of the terminal for passenger drop off at the ticketing area and one at each end for passenger pickup from the bag claim areas. This arrangement could lead to problematic operations when a full bus arriving at the terminal has to bypass waiting passengers at the northeast pickup point. For this reason, it was decided to locate the passenger drop-off point on the inner roadway adjacent to the terminal and the pickup points on the outer roadway away from the terminal. Buses approaching the terminal with departing passengers will be labeled “TERMINAL” and will proceed down the inner roadway to the drop-off stop. They will then loop back around Garage C, changing the label to “PARKING LOT __”, and picking passengers up from the two pickup points.

The following assumptions have been made in determining the passenger total connect times (walk + wait + ride) and shuttle bus round trip times:

- Buses average 15 mph on the roads
- Buses average 10 mph in the lots
- Each designated stop adds one minute to the trip time
- Each circuit past the terminal adds one minute to the trip time
- The maximum walking distance is 300 feet at 3 MPH.

Previous studies of ten different airport shuttle bus operations found average headways (time between buses) ranging from 3.27 to 9.69 minutes and maximum headways ranging from 9.00 to 22.00 minutes. Standard deviations ranged from 2.00 to 4.19 minutes with an average of 3.05 minutes. Since reliable connect times are important to air travelers, they must consider their worst shuttle bus experience when budgeting trip times. Assuming an average passenger makes this determination based on five trips, the worst headway experienced will be approximately 1.28 times the standard deviation (assuming a normal distribution) plus the average headway. For this reason an additional 3.9 minutes (3.05 x 1.28) has been added to the maximum bus trip times (walk + wait + ride).

8.1 Scenario 1

Figure 8-1 shows the bus routes considered under Scenario 1. Table 8-1 shows the bus round trip and passenger average and maximum connect times for each route.

Figure 8-1: Scenario 1 Shuttle Bus Routes

Since the bus round trip time is 15 to 16 minutes, two buses are needed for each route to meet the target ten-minute headway. However, in order to carry the maximum projected 176 passengers from Economy Lot 2 in an hour, three 23-passenger buses are needed. Assuming the buses are scheduled to make a round trip every 20 minutes (allowing four or five minutes for driver comfort breaks and other uncertainties) results in a bus frequency of seven minutes and a maximum capacity of 207 passengers per hour.

The buses are assumed to circulate continuously providing an average seven-minute headway. Note that the service level is quite poor since passengers could often walk to the terminal in less time. It is not physically possible to improve on these connect times much since, if the number of buses was doubled, for example, the passenger connect times would only be reduced by two minutes each.

	Route 1	Route 2	Route 3
Bus round trip time	16	16	15
Passenger average connect time (including walking and waiting)	12	12	12
Passenger maximum connect time (including walking and waiting)	16	16	17

Table 8-1: Scenario 1 Trip Times (minutes)

8.1.1. Phases

Phase 1

During Phase 1 three buses are needed to serve the existing Economy Lot and an additional three to serve the new Economy Lot 2. However, this assumes that the lots fill up uniformly which may well not be the case. For example, if all the lots are empty at the beginning of the morning peak, most of the peak traffic may choose one lot over the other. Another two buses have been added to take up fluctuations in demand of this nature. This gives us a total of eight buses. However, advice from bus operators indicates an additional two buses should be acquired to deal with service and maintenance outages. Thus ten buses are required for Phase 1.

Capital costs for this phase include bus acquisition and the construction of Economy Lot 2, a maintenance facility, and bus stops. To facilitate circulation, an allowance has also been made for ten-foot wide bus lanes through the parking lots.

Operating costs allow for operating 6 buses for 16 hours a day, reducing to four for the remaining three hours of operation.

The capital cost is estimated to be $15.5 M while the annual operating and maintenance cost is estimated to be $2.9 M. This includes costs for constructing and maintaining Economy Lot 2 and a bus maintenance facility. The annual parking revenue for this phase ranges from $3.5 M in 2018 to $4.6 M in 2027 based on $5.00 per day from the existing Economy Lot and Economy Lot 2.

Phase 2

Phase 2 of this scenario involves converting the Daily Lot into a parking garage and is assumed to have no impact on the number of buses needed. The capital costs associated with this phase are $45.0 M and the annual maintenance costs are $1.3 M. The annual parking revenue for this phase ranges from $4.9 M in 2028 to $8.1 M in 2037 and includes revenue from Garage C based on $12.00 per day. $6.00 per day has been used for the SkyLot on top of Garage C.

Phase 3

During Phase 3 Economy Lot 3 is added and an additional three buses are needed. In addition, a one-way, two-lane loop road is constructed from Aviation Parkway to the existing roundabout on GSP Airport Drive. This road provides access to Economy Lot 3.

The capital cost is estimated to be $10.8 M while the additional annual operating and maintenance cost is estimated to be $1.3 M. The annual parking revenue during this phase ranges from $8.4 M in 2038 to $10.6 M in 2047 and includes $5.00 per day for Economy Lot 3.

Net Present Worth

The grand total 30-year sum of the capital and operating costs is $198 M, while the total parking revenue is $201 M. Based on a 4% discount rate, the net present worth of the capital, operating and maintenance costs and revenues associated with Shuttle Bus Scenario 1 is $1.1 M. Note that this is a positive cost number indicating that the facilities installed under this scenario do not generate sufficient revenue to pay for themselves (with no consideration of any financing costs). This revenue includes the revenue from the existing Economy Lot but not from any other existing parking facility.

8.2 Scenario 2

Since the shuttle bus connect times are so long, Scenario 2 does not lend itself to a shuttle bus solution. It is considered that the proportion of passengers with connect times to the terminal exceeding ten minutes will be higher than desired for the airport to maintain its high level of service and construction of garage C will thus be unavoidable. However, the costs and revenues for this Scenario have been estimated and are provided in the following section for comparison purposes only.

9. PRT- Shuttle Bus Comparison

This section compares the PRT solutions to the shuttle bus solutions that were previously presented. The most significant difference between the two solutions is the much higher level of service offered by the PRT system in terms of connect times between the parked car and the terminal. The PRT times are about two-and-a-half times faster than the shuttle bus. When we consider probable maximum trip times, the PRT solution can save passengers as much as ten minutes.

The PRT level of service exceeds that of the shuttle bus in other ways, too: boarding is level, so bags roll on and off; everyone gets a seat: and, trips are smoother and nonstop. In addition, boarding by wheelchair is easier and faster. Finally, returning passengers with no checked baggage can board the PRT system at a concourse station and have a very quick ride back to their parked car.

While a shuttle bus solution will add to surface traffic, both contributing to and suffering from congestion in front of the terminal, a PRT solution will mostly be elevated above surface traffic and thus help alleviate congestion. Concerns about the appearance of overhead guideways can be addressed by ensuring they do not impact the scenic views welcoming passengers to the airport. At the same time, the vehicles using the guideway crossing the access road will provide passengers with a dynamic glimpse of the modern airport they are about to have the pleasure of seeing and using.

While PRT technology does not have the same established industry backing that shuttle buses have, it has been very successfully implemented in one of the world's busiest airports, and modern PRT implementations have all proceeded relatively smoothly. In addition, this study has used a higher contingency factor for all costs associated with the PRT solution (except for the parking garage).

All of the PRT systems considered are battery-powered, and the PRT solutions will thus have significantly lower on-site emissions. This is important in terms of local air pollution and climate change. In addition, it could help the project receive funding directed at lower emissions. In Scenario 1 the PRT system reduces on-site CO_2 emissions by a total of 7,000 tons over the 30-year analysis period while the reduction for Scenario 2 is 8,900 tons.

Considering the above factors, PRT is obviously a far superior solution for GSP Airport than shuttle buses. In addition, it has been found that the net present worth (life cycle revenues minus costs discounted for inflation) of the PRT solutions is slightly higher than the bus solutions. While the PRT capital costs are higher, the operating costs are lower and the potential for higher revenue, based on the higher level of service is better.

In summary then, the PRT solutions are superior in almost every way. However, the issue of charging more for parking because a higher level of service is provided needs to be discussed more. The PRT solutions are based on charging $6.00 per day for economy parking, while the bus solutions are based on $5.00 per day. In addition, the Scenario 1 solutions both involve a parking garage charging $12.00 per day. While the higher rates may be justifiable based on the improved level of service, they do increase the airport's cost per enplaned passenger which is an important factor in its competitiveness. The sensitivity of the PRT solutions to parking rates was explored and it was found that, for Scenario 1, a rate of $6.05

per day resulted in the PRT net present worth matching the bus net present worth. For Scenario 2 the equivalent rate was $5.50 per day. This implies that all of the benefits of a PRT system only cost an additional $0.50 in the daily economy lot parking rate.

Table 9-1 summarizes the findings, comparing the two solutions for Scenarios 1 and 2.

	Scenario 1				Scenario 2			
	PRT		Bus		PRT		Bus	
Average trip time (min)	5	✔	12	✖	5	✔	12	✖
Maximum trip time (min)	7	✔	17	✖	7	✔	17	✖
Traffic disruption	None	✔	Poor	✖	None	✔	Poor	✖
Proven technology	Acceptable	○	Good	✔	Acceptable	○	Good	✔
On site emissions	None	✔	Poor	✖	None	✔	Poor	✖
Cost per enplanement	High	✖	Medium	○	Medium	○	Low	✔
Capital cost (30 years)	$113 M	✖	$71 M	○	$80 M	○	$34 M	✔
O&M cost (30 years)	$113 M	○	$127 M	✖	$101 M	✔	$121 M	○
Revenue (30 years)	$230 M	✔	$201 M	○	$204M	○	$170 M	✖
Net present worth cost	$1.7 M	○	$1.1 M	○	-$4.2M	✔	-$5.4 M	✔

Good ✔ Acceptable ○ Poor ✖

Table 9-1: PRT Shuttle Bus Comparison

Note that the Scenario 2 Bus option is not considered viable.

10. Funding and Financing

This section addresses the probable funding sources and financing mechanisms available for the project. It begins by investigating the potential revenues generated through parking charges that could be allocated to the project. It then continues with a consideration of other funding sources and financing mechanisms that can be used to supplement these revenues to cover the large intermittent capital expenditures as well as the annual operating and maintenance costs.

As is illustrated in this study, in developing such a system, GSP Airport would join a unique group who has implemented them in both the United States and across the world. Based off of this limited implementation and the lack of rigid design criteria, the structure for establishing an innovative and creative PRT System has a high degree of flexibility, especially in the areas of planning, design, funding, and development.

GSP Airport was established as the primary component of the Greenville-Spartanburg Airport District via statute (SC Code §55-11-110). This district is empowered with many of the same powers as that of a traditional municipality including, but not limited to, right of eminent domain, annexation, and the ability to levy general obligation bonds. These powers are generally unique among like-sized airports and afford GSP Airport with abilities which may be advantageous for the development of such an innovative non-traditional transportation operation.

Understanding the legislated powers of the GSP Airport and financial structural opportunities allowed through utilizing various funding streams will afford GSP Airport the ability to determine the feasibility not just of the size and type of system which can be developed but also the specific capabilities that the system should or could have in order to qualify for needed fiscal support. While this analysis will not gauge the likelihood that such a project will receive specific types of funding, it will provide a basis for understanding the funding opportunities.

10.1 Parking Revenues

Table 5-4 shows the average surface lot utilization rates for Scenario 2. These rates have been used to determine the projected annual parking revenue. This subsection addresses the question of what parking rates should be charged and what proportion of these rates should reasonably be made available for the PRT system. The projected revenues that can be applied to the PRT system are thus determined.

Since the PRT system will provide a high level of service with a 5 minute average connect time from all surface lots, Figure 6-1 indicates that a $10.00 daily rate will match the average charged at neighboring airports for similar connect times. This seems to be a reasonable rate for GSP Airport to charge, particularly since the PRT system will provide a very reliable service with roll-on, roll-off of bags and almost no waiting. Indications from Heathrow are that people are willing to pay more for the very reliable service and short wait times provided by PRT systems. However, consideration should be given to the lowest rate charged by a neighboring airport - $5.00 at Charlotte.

An evaluation of fees and connect times at neighboring airports with multiple surface lots has been undertaken and the relationship between connect time savings and increased daily rates is discussed in

Section 6.2 and depicted in Figure 6-2. The Connect time at Charlotte is 18.7 minutes, compared with 6.0 at GSP Airport. At $0.67 per minute saved, this difference equates to an additional charge of $9.18 implying Greenville could charge much more than $10.00 and still be competitive with Charlotte.

Shuttle bus connect times are longer and Figure 6-1 indicates the average 12 minute shuttle bus connect time correlates with an average $9.00 per day parking charge at comparable airports. However, Figure 6-2 indicates the additional 7 minute connect time has a value of about $4.00 and, if $10.00 is charged for parking with PRT service, $6.00 should be charged for parking with shuttle bus service.

Based on the above, it seems reasonable that GSP Airport could charge $10.00 for economy parking served by PRT and $7.50 (average of $9.00 and $6.00) for economy parking served by shuttle bus. However, as mentioned previously, the competitive situation with Charlotte Airport must be considered and a matching rate of $5.00 has been used in the analysis for the shuttle bus solutions. The considerably higher level of service offered by the PRT solutions has been conservatively estimated at only being worth $1.00 extra per day and $6.00 has been used in the analysis for PRT solutions.

The Airport District can keep the above discussion in mind when weighing future options to increase surface lot parking rates. In addition, the very short PRT connect times should help give GSP Airport a competitive edge.

Since the system will consume all parking revenue in order to be self-financing, other sources of funds have been investigated. The remainder of this section addresses opportunities for obtaining these additional funds. It also addresses options for financing the project to spread the capital infusions required over a period of years.

10.2 Other Internal Funding Sources

Passenger Facility Charges

GSP Airport is positioned to support the development of a PRT project through independent means. In addition to reassessing parking fees discussed earlier, another funding vehicle could be the implementation of the federally-authorized Passenger Facility Charge (PFC). The PFC program, administered by the Federal Aviation Administration (FAA), allows airports to collect up to $4.50 per boarded passenger. Airports are then allowed to use them to "fund FAA-approved projects that enhance safety, security, or capacity, reduce noise, or increase air carrier competition."[15] Currently GSP Airport has not implemented a PFC and therefore does not receive any annual revenue from it. Using passenger data from 2013, the chart below estimates the possible revenues which could be generated from levying the PFC on passengers boarding through GSP Airport annually. These estimates assume that the number of enplanements stays stable. The chart shows both a full amount of the PFC, as well as half the PFC ($2.25), as well as $1.00.

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[15] "Passenger Facility Charge Program Airports" http://www.faa.gov/airports/pfc/

Amount of PFC	2013 Enplanements[1]	Total Annual Potential Revenue
$1.00	917,937	$917,937
$2.25	917,937	$2,065,358.25
$4.50	917,937	$4,130,716.50

Table 10-1: PFC/Enplanements/Revenue

Though this fee will not generate enough revenue to pay for the project at the onset, developing such a sustained source of funding would assist in the long-term costs associated with expansion, maintenance, and/or operation of the system. Additionally, there has recently been a proposal supported by the Airports Council International (ACI) and the American Association of Airport Executives (AAAE) to raise the PFC to $8.50 per passenger in order to compensate for funding shortfalls seen due to national transportation funding deficits. [16] The President's 2015 budget did include an increase in the PFC at a rate of $8.00. Neither has progressed forward significantly, and both are being met by a lack of support, especially by airlines, who believe that fees are already an impediment to passengers. In the case of GSP Airport, the increased fee could generate an additional $3.6 million[17] or roughly $7.7 million annually. Even without the possible increase, accessing the PFC would allow GSP Airport to realize significant annual revenue; but it is not the only internal avenue for funding to support the development of a PRT system.

A final internal mechanism by which GSP Airport could use to generate revenue to support the development of a PRT project would be through levying general obligation and/or revenue bonds. Pursuant to SC Code § 55-11-150[18], the District, of which GSP Airport is a constituent part, is given the ability to issue bonds derived from any of the District's revenue-generating facilities. Though it is unclear as to the exact manner in which these bonds would be levied and how much revenue they would generate, the simple ability to do so is a great flexibility which could prove valuable in the development of this project.

In general, GSP Airport and the Greenville Spartanburg Airport District possess significant means to generate revenues through internal means. While none of them independently would generate the immediate capital necessary to fully develop the proposed PRT system, a combination of the sources would provide a sustained source of revenue to support such a system's development, operation and maintenance.

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16 "U.S. Budget Would Nearly Double Airport PFC Cap" http://www.ainonline.com/aviation-news/ain-air-transport-perspective/2014-03-06/us-budget-would-nearly-double-airport-pfc-cap

17 This figure is based on a rate of 917,937 annual enplanements

18 " SC Code § 55-11-150" http://www.scstatehouse.gov/code/t55c011.php

Public Private Partnerships and Sponsorship-based Funding Opportunities

The concept of project funding through public private partnerships and outside sponsorships has recently begun to rise in usage in response to continued cuts in federal and state transportation funding. Public private partnerships allow government agencies to partner with private organizations or funding sources to give them access to larger funding capabilities.

To establish public private partnerships in a given area typically requires the approval of the state legislature. However, legislation has been presented multiple times in the South Carolina legislature but to date no significant resolution has been experienced on the issue. In 1999 the state has managed innovative design-build projects on a per-project basis, including the "27 In 7" program which focused on accelerating 27 road projects to be completed in a 7 year timeline. This was done through innovative funding structures including public private partnerships.[19] Though the project was successful, no significant projects have been completed since under this type of structure. Given the innovative nature of this project, the development of more robust and diverse legislative framework would allow for creativity in delivery and funding.

Sponsorship is another funding opportunity that many organizations are examining as a revenue generator, especially in the transit arena. Bus wraps (the marketing practice of completely or partially covering (wrapping) a vehicle in an advertisement) have been employed by agencies like Metro Transit in Minnesota to generate additional revenue, roughly $3.7 million in 2013.[20] State agencies, including the North Carolina Department of Transportation, are also exploring the possibility of allowing sponsorship on everything from rest areas to weigh stations, ferries, and driver assistance programs (IMAP).[21] While no specific program has been developed in South Carolina, other states like Massachusetts have been successful with sponsored motorist assistance programs.[22] The PRT system at Heathrow International Airport is reported to generate significant revenue through vehicle wraps.[23] Tourist destinations as well as numerous companies who possess large operations close to GSP Airport could be strong candidates for sponsorship, including Michelin, BMW, and others.

While each of these funding streams is non-traditional, all possess potential for supporting this type of project. Some could be accomplished with little to no outside involvement (i.e. sponsored vehicle wraps), others would require significant legislative modifications to allow for such a project to be funded by those means.

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19 "Utility Involvement in South Carolina Design-Build Projects" http://www.fhwa.dot.gov/programadmin/contracts/scdb.cfm
20 "Buses and trains wrapped in ads pay off big for Metro Transit" http://www.mprnews.org/story/2014/10/09/metro-transit-ads
21 "NCDOT hopes to drive in business through sponsorship" http://myfox8.com/2014/09/09/ncdot-hopes-to-drive-in-business-through-sponsorships/
22 "Emergency Roadside Assistance" http://www.massdot.state.ma.us/highway/TrafficTravelResources/EmergencyRoadsideAssistance.aspx
23 "Heathrow Announces Unique Sponsorship Opportunity" www.ultraglobalprt.com/wp-content/.../press-release_sponsorship.pdf

10.3 External Funding Sources

Though GSP Airport possesses the ability to raise capital through internal means, utilizing external funding sources to offset internal impacts might be necessary to develop and support long range project growth and development. However, since PRT systems are unique, traditional funding mechanisms have yet to fully adapt to explicitly recognize them as eligible for existing sources of transportation funding. Many of these mechanisms are presented as opportunities for funding but with the significant caveat that there may need to be further discussion to reach external agency acceptance of such a project. Keep in mind, the use of external funding sources brings with it the potential for increased scrutiny and regulation. The external oversight that accompanies the money can also be a burden to project delivery. Additionally, continual analysis needs to be undertaken as it relates to the longevity of funding sources, especially from those relying solely or in part from federal funds.

The accompanying chart examines multiple grant processes managed by the United States Department of Transportation. Each are presented and analyzed based on their potential application to the PRT project, even though none specifically address that type of system in their funding processes.

US Department of Transportation Grants			
Grant Name	**Explanation of Grant**	**Funding Cycle**	**Application to Project**
Clean Fuels Grant Program (5308)	The program has a "two-fold purpose. First, the program was developed to assist nonattainment and maintenance areas in achieving or maintaining the National Ambient Air Quality Standards for ozone and carbon monoxide (CO). Second, the program supports emerging clean fuel and advanced propulsion technologies for transit buses and markets for those technologies."[24]	Funds are allocated on a discretionary basis and are available the year appropriated plus two years. The funding match shall not exceed 90 percent.	Though these grants have typically only applied to the purchase and support of clean diesel, electric or hybrid buses, an argument could be made that electric PRT vehicles would have a similar impact on maintaining clean air standards. Additionally GSP Airport would reduce the need for buses by building a PRT system connecting parking lots which would negate the need for additional energy-efficient vehicles for passenger movement.
National Research and Technology Program (5312)	This is a statute-authorized program which funds projects seeking to "improve public transportation by funding research, development, demonstration, and deployment projects."[25]	Funding for this program is allocated on a discretionary basis through advertised grants. Currently the program is advertising a grant for a "Transit Oriented Development Pilot Program" (closing 11/3/2014).	Due to its innovation the GSP Airport PRT system would be a strong candidate for this program if the appropriate grant was advertised. However, because of the timeline, the GSP Airport project would not qualify for the current advertisement.

[24] "Clean Fuels Grant Program" http://www.fta.dot.gov/grants/13094_3560.html
[25] "National Research and Technology Program" http://www.fta.dot.gov/grants/13094_3551.html

US Department of Transportation Grants			
Grant Name	**Explanation of Grant**	**Funding Cycle**	**Application to Project**
Transportation Investment Generating Economic Recovery (TIGER) Grant Program	Founded in 2009, TIGER grants were designed to allow "DOT to examine a broad array of projects on their merits, to help ensure that taxpayers are getting the highest value for every dollar invested."[26] Over the past 5 years, the program has allocated $4.1 billion to projects across the country.	Funding for this program is allocated based on an application process. Availability is set at the beginning of the process and completely allocated over a multi-year timeline. In FY 2014, $600 million was allocated for disbursement under the program.	To date, 7 projects in South Carolina have received TIGER funds, including one in Greenville for transit-oriented development planning. While this project would be well equipped for competition in the application process, there remains significant uncertainty regarding future application rounds.
Voluntary Airport Low Emission(VALE) Program [FAA]	The VALE program was created in 2004 to "help airport sponsors meet their state-related air quality responsibilities under the Clean Air Act."[27] Funded through Airport Improvement and PFC funds, the program is available to airports in EPA-designated compromised air quality areas.	Grants vary in amount but are based on the airport's PFC and AIP capabilities. In 2014, $2.8 million was allocated to two projects through the program.[28]	Based on the EPA's standards, GSP Airport qualifies for inclusion in the program. It is unclear as to the other qualifications for the program, especially given that GSP Airport does not currently collect PFCs. Additionally the amount of available funds through the program is significantly lower than that required to develop a full system. However, monies could be used for planning or component implementation.

[26] "TIGER Grant Program-About" http://www.dot.gov/tiger/about
[27] "Voluntary Airport Low Emission Program" http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=15235
[28] *Ibid*

US Department of Transportation Grants			
Grant Name	**Explanation of Grant**	**Funding Cycle**	**Application to Project**
Congestion Mitigation and Air Quality Improvement (CMAQ) Program	The CMAQ program was created in 1991 in response to the Clean Air Act Amendments of 1990. It was designed to support surface transportation projects that contribute to air quality improvements.[29]	Funding for CMAQ projects are allocated through the Surface Transportation legislation. For FY 2014, MAP-21 allocated $2.2 billion for use in projects.	Given that a PRT system is not a traditional surface transportation project (based on current definitions), it is unclear if the GSP Airport project would qualify for CMAQ monies. The development of such a system would allow GSP Airport to avoid using other forms of passenger movement (i.e. shuttle buses) which would reduce the airport's carbon emissions.
FHWA Special Experimental Projects No. 14 - Alternative Contracting	Begun in 1990, SEP 14 was developed to allow for "nontraditional contracting techniques" to be used in project development. These techniques include "cost-plus-time bidding, lane rental, design-build contracting, and warranty clauses."[30]	The program is not a funding stream but rather allows the acceleration of contracting processes, thereby reducing project costs. Program has been employed by numerous states including North Carolina and Florida.	This program typically applies to state DOT projects and has historically only applied to roadway/highway projects. However, guidance was released in 2006 which discussed ITS projects which may apply to this project.[31] Regardless of application, the project would need to engage SCDOT as a partner in order to qualify.

[29] "CMAQ Program" http://www.fhwa.dot.gov/environment/air_quality/cmaq/
[30] "Special Experimental Projects No. 14 - Alternative Contracting" http://www.fhwa.dot.gov/programadmin/contracts/sep_a.cfm
[31] "NCHRP Report 560 -"Guide to Contracting ITS Projects" http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_560.pdf

US Department of Transportation Grants			
Grant Name	**Explanation of Grant**	**Funding Cycle**	**Application to Project**
FTA New Starts, Small Starts, and Core Capacity Improvements Capital Investment Program	This program serves as FTA's "primary grant program for funding major transit capital investments."[32] Investments are allowed for any type of public transportation system.	The project was restructured in FY 2013 under MAP-21 and provided $1.907 billion for FY13 and FY14. It also created a new project area for core capacity projects.[33]	The basic structure of this funding program seems to fit the general spirit of the proposed project. However additional research and partnership may be needed to qualify under FTA guidelines. Additionally the program's structure as a multi-year process may prove difficult for funding in the development stages.[34]

While additional grants exist through other agencies of the federal government (i.e. US Department of Energy (DOE) and Environmental Protection Agency (EPA)), it is unclear as to whether or not this type of project would comply under their existing standard processes. Many of these grants relate specifically to carbon emissions and/or diesel abatement so any project being developed would have to meet those standards to qualify, though PRT systems typically have a dramatic carbon emission impact, especially in low-carbon electrical grids like South Carolina's.

Additionally, many of these grants have state-level matching programs that could be utilized once a concept is more fully developed. The DOE also manages numerous incentive processes through its Office of Energy Efficiency and Renewable Energy (EERE) which could be used to defray the costs of many of the components used to develop this project. Each of these programs present a significant amount of opportunity to this project, however, it will be necessary to develop more understanding of the benefits of a PRT system to transit. Finally the project may have access to the roughly $1.2 million in American

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32 "FTA New Starts, Small Starts, and Core Capacity Improvements Capital Investment Program" http://www.fta.dot.gov/12347_5221.html

33 Fact Sheet: FIXED GUIDEWAY CAPITAL INVESTMENT GRANTS ("NEW STARTS") SECTION 5309" http://www.fta.dot.gov/documents/MAP-21_Fact_Sheet_-_Fixed_Guideway_Capital_Investment_Grants.pdf

34 "How do I obtain Capital Investment Grant Program funding for my project? http://www.fta.dot.gov/12304_15522.html

Recovery and Reinvestment Act funds which were found by a 2013 audit to be unexpended in South Carolina.[35]

The Mineta Transportation Institute's report on PRT titled Automated Transit Networks (ATN): A Review of the State of the Industry and Prospects for the Future[36] recommends that a PRT or ATN demonstration project should be built in the USA. Federal funding for this project may be available on the basis that the project provides a demonstration of PRT and could be used for further research on the topic.

In addition to these federal funding sources, there is a potential state funding source outside of traditional transportation funding structures. The South Carolina Infrastructure Bank is a fund which was established by statute in 1997 [37] and provides funding for large projects. The purpose of the bank is defined as "to select and assist in financing major qualified projects (exceeding $100 M) by providing loans and other financial assistance…for constructing and improving highway and transportation facilities necessary for public purposes including economic development."[38] Examples of some of the projects which have been funded by the bank include the Palmetto Parkway in Aiken County and the Intercoastal Waterway Bridges in Horry County. To qualify, the project would need to complete an application and demonstrate that the project enhances mobility and safety, promotes economic development, and increases the quality of life and general welfare of the public. This project would need to be better defined in order to understand if it qualifies but it certainly has the potential to compete.

Finally, there may be funding opportunities available through the South Carolina State Energy Office, and funding which was made available through Federal Qualified Energy Conservation Bonds (QECB). These funds are allocated to states by the US Department of Energy and are used for projects of all shapes and sizes. In South Carolina these funds are allocated in two different ways; a certain percentage is allocated to each county with the remainder being reserved by the Energy Office.[39] The Energy Office currently possesses a reserve and is in the process of communicating with counties about their unexpended balances. While it is unclear how much funding may be available through this program, there may be unique opportunities to support this project. These options would appear to require partnerships with the county and/or the state. Additionally, the Energy Office has the opportunity to serve as a valuable resource as the project is developed given its knowledge of unique energy grants (i.e. carbon reduction, clean energy, etc.) and tax credits for innovative projects such as this.

While there are numerous external means by which this project could be funded, much investigation is needed to understand how this project compares to others which have come before it or is innovative

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[35] "FHWA IS MONITORING UNEXPENDED RECOVERY ACT HIGHWAY FUNDS, BUT SOME FUNDS MAY REMAIN UNUSED" https://www.oig.dot.gov/library-item/28741

[36] http://transweb.sjsu.edu/project/1227.html

[37] "SIB Legislation" http://sctib.sc.gov/Documents/SIB%20Legislation%20Section%2011%20Title%2043.docx

[38] "South Carolina Transportation Infrastructure Bank: Purpose of Bank" http://sctib.sc.gov/Pages/default.aspx

[39] Email conversation with Jones Herring, SC State Energy Office, 10/30/14

and therefore outside of what has previously been considered a transportation system. In considering these options, GSP should remember there will also be the added effort and cost of developing proposals and applications for any funds outside the control of the airport.

11. Potential System Alternatives and Expansions

11.1 Initial PRT Layout

The PRT parking lot solutions shown earlier in this report were derived after an analysis of alternative solutions. The chosen solutions were found to provide a high level of service at a reasonable cost. However, this is not to say that better solutions cannot be found with a more thorough investigation. One possibility would be to replace the double guideways adjacent to Garages A and B with single guideways, one leading to and the other from the Terminal. These guideways could then be linked by a guideway passing between the concourses and the bag claim areas and over the heart of the Terminal building as shown in Figure 11-1. This solution would require less guideway but crossing such extensive existing infrastructure may prove not to be practical.

Figure 11-1: Alternative PRT Layout at the Terminal

Other layout options that should be investigated include replacing flyovers with roundabouts, and adding short segments of double guideway (e.g. from the Maintenance Facility to Economy Lots 3 and 4) to reduce trip length and the number of vehicles required. In many cases, the best solution may depend in which specific PRT technology is selected.

Another alternative worthy of consideration and involving the initial layouts previously discussed, is the addition of a bus transfer station. Such a station could be located along Aviation Parkway south of where the PRT guideways cross. All off-airport shuttle buses could be intercepted at this point and their passengers transferred to the PRT system which would then take them on to the terminal.

This solution would remove all shuttle buses from the terminal area. It would also greatly facilitate way finding for arriving passengers since the two Terminal PRT stations could be simply labeled “All Shuttles”. The bus transfer station could then be called “All Hotel Shuttles”, while the parking lot stations would each be given memorable names. Off-airport shuttle bus users would have to use the PRT system to get to and from their buses. The additional hassle of doing this would be somewhat like having to take an elevator to a different floor. In addition, they would have to wait for shuttle buses in an area away from the terminal building. However, they could always return to the building in a matter of minutes via the PRT system.

11.2 Future Expansion

This section addresses potential PRT system expansions not previously addressed. Despite the section title, these expansions could take place before the initial system is fully built out.

On-airport expansion opportunities consist primarily of connecting the terminal building to other facilities such as the rental car service center and a future development area adjacent to Interstate 85, with the latter opportunity appearing to be more promising. Expanding the PRT system to the future development area will require approximately two miles of two-way guideway which could mostly be at grade. The capital cost of such an extension would be roughly $38.5 M while the annual O&M costs would amount to approximately $1.2 M. The total annual cost including amortizing the capital at 6% would be about $4.0 M. Its potential value is discussed below.

The future development area is anticipated to include a mix of uses including hotels. While a PRT connection to the airport may be of some value to mixed-use businesses, it is likely to be of most value to hotels. Hotels in this area would have the double advantage of being adjacent to the freeway and, simultaneously, effectively also adjacent to the terminal, with a ten-minute connect time including waiting. This double advantage should result in an increased room rate and/or occupancy for these hotels. In addition, they would have savings resulting from not having to operate shuttle buses. A conceptual comparison of PRT to shuttle bus costs indicates about 12 hotels would be needed in order to justify a PRT system on the basis of shuttle bus cost savings alone. If each hotel is assumed to have 120 rooms with a 65% occupancy rate[40] and the PRT system is assumed to allow the room rate to increase by $10.00 a night, the number of hotels needed to break even reduces to about six.

In order to initiate development, it may be desirable to build roads and install utilities in an attempt to “build it and they will come”. Building the PRT connector could be considered as part of the strategy to get the development started.

[40] Size and occupancy suggested by Hotel Development Associates

Off-airport expansion opportunities include connecting to nearby facilities/businesses such as BMW, Michelin and the shopping center at The Parkway and Pelham Road. In order to get an idea of the potential trip demand, representatives at Michelin and BMW were contacted. These conversations indicated a potential for 44 daily trips to/from the airport from Michelin. However, these are for all Michelin facilities and the proportion for their headquarters building close to the airport is unknown although probably less than half. BMW did not provide hard data in response to requests for information.

If a PRT connector were provided to Michelin and BMW facilities, the proportion of airport users that would use the system is uncertain. Discussions with these companies indicated many of the trips may originate or end at home rather than at work and people would only be inclined to use the system for those trips originating and ending at work.

Connecting the BMW facilities to the airport will take three or more miles of two-way guideway, or somewhat less if the connection is made to the future development area discussed above. Additional guideway and stations will probably be required in order to provide access to and from the various BMW facilities. These guideways and stations will likely prove useful to BMW to the extent that they have needs for people to move around their campus from facility to facility.

Given that there is probably a low demand for trips between BMW and the airport, the likely course of PRT development would be for networks serving the airport and the BMW campus to be developed separately and then ultimately connected if justified. The PRT manufacturer selected by the airport might therefore approach BMW concerning a campus network.

Connecting the Michelin facilities will also take about three or more miles of two-way guideway. While Michelin's potential for daily trips to and from the airport is only about 20 at most, they have the advantage of being located close to other potential trip generators such as the Greenville Marriott and the Best Western Greenville Airport Inn as well as the shopping center at Pelham Road and The Parkway. Connecting all of these facilities with each other and the airport would have some value. However, many more connections would probably be required to make this a viable endeavor. Outside of an airport-like situation, a transportation network needs to be quite large before it becomes truly useful.

13. Conclusions & Recommendations

Since both PRT solutions provide significantly higher levels of service than the shuttle bus alternatives while also providing higher net revenue, PRT seems to be the clearly-favored solution. Of the two PRT scenarios evaluated, PRT Scenario 2 seems favored because it generates a higher net present worth. In addition, it does not include Parking Garage C, helping keep costs per enplaned passenger down and freeing up this area to remain as a surface lot and/or to be put to a higher use in the future. Finally, the PRT solutions reduce surface traffic and will not add to curbside congestion.

Based on the assumptions made here, PRT Scenario 2, including the costs of the new economy lots and associated roadways, will break even at a daily parking rate of approximately $6.40 for all economy lots. The higher level of service provided by the PRT system only costs passengers parking in economy lots an extra $0.50 per day. Indications are that, based on reduced connect times alone, the perceived value will be significantly higher than this.

Since Phase 1 is identical for both PRT scenarios, the final decision as to which scenario to choose need not be made at this time. It is therefore recommended that the Airport District gives serious consideration to undertaking PRT Phase 1 (beginning with Phase 1A) by following the steps outlined in the next section.

PRT Phase 1 should be implemented in such a way as to protect for accommodating either PRT Scenario 1 or 2 as well as for the expansion options previously discussed.

14. Next Steps

This section outlines the steps to be taken to advance the project through the completion of the procurement phase, should the Airport District decide to proceed with PRT implementation.

14.1 Detailed Planning for Initial Implementation

Initial System Definition

The proposed initial system (probably the one depicted in Figure 7-7) will be analyzed in more detail to define station locations and layouts as well as guideway routing and system operations. Alternative layouts and operational methodologies will be explored in order to ensure the optimal solution is selected. Interfaces with existing and proposed infrastructure and utilities will be investigated and planned for. Animations and renderings will be prepared to facilitate visualization and understanding of how the system will operate and integrate with existing viewscapes and airport facilities. Capital and O&M costs will be refined as will revenue projections. The optimal solution will preferably be such that it can be implemented by more than one supplier (with small adjustments if needed). However, it is possible the potential supplier list will be reduced (only for the purposes of optimizing the layout and the operations) if certain suppliers are found to be significantly more suited to the application than others.

Regulatory Requirements

Thorough research is needed to determine which agencies will have jurisdiction over the PRT system installation and operations. Since the results will depend in part on the funding sources used, this step will need to be undertaken concurrently with the next one. Where appropriate, permitting processes will commence.

Obtain Funding/Financing

The Airport District will need to decide how it would like to fund/finance the project and then undertake the necessary work to obtain the funding/financing. This step could include applying for grants/loans/financing and/or establishing a passenger facility charge. It could also include a detailed investigation of revenues from parking charges and advertising. Depending on the procurement model selected, this step may be limited to obtaining funding/financing for the procurement phase only.

Select the Preferred Procurement Model

This study has included roads and parking facilities in the scenarios/alternatives that were analyzed. However, the Airport District may want to procure these elements separately from the PRT system since they involve conventional and relatively common construction procedures and could be procured under conventional design-bid-build methodologies. On the other hand, there may be merit in selecting a Master Builder that would take overall responsibility for the entire parking and transportation package.

Since each PRT system has its own unique vehicle to guideway and station interface, it is important that the PRT suppliers be involved in the details of the infrastructure design. Providing a PRT supplier with completed infrastructure for them to install their system on is likely to lead to inefficiencies and/or integration problems. For this reason a design-build procurement model is recommended (and assumed in the following discussions). Under this model the client prepares bridging documents that explain the client's needs in some detail. The design-build team then prepares the detailed plans and specifications (the "design") while it constructs and implements the project (the "build"). Because the design and construction are undertaken somewhat concurrently, this model usually results in quicker project implementation.

Since PRT systems have unique operating and maintenance requirements, it makes sense for the supplier to be required to operate and maintain the system for some period of time.

The Airport District could choose to have the design-build team finance all or part of the project. Under this model the design-build team provides the capital for the project and is paid availability payments on an annual or monthly basis, providing the system meets pre-established availability criteria.

If all of the above options are implemented the project is known as design-build-finance-operate-maintain (DBFOM).

The Airport District absorbs the risk involved with projected parking revenues not being met, no matter which financing option/procurement model is used.

14.2 Preliminary Design

The major decisions for the project will be finalized under this step. The permitting process will be started and station locations and guideway routes will be finalized along with operating protocols – subject to minor adjustments after a supplier team is procured. This work will include a more detailed site investigation, including engineering surveys and geotechnical investigations, and the preparation of guideway plan and profile drawings. Layouts will be fine-tuned to help ensure the optimum solution is chosen. End-result (as opposed to "method") specifications will be prepared as will procurement documents.

The plans and specifications will be detailed enough to allow the bidders to know what the Airport District is looking for and expects to receive, thus facilitating comparison of the bids received while helping ensure the supplied system will meet the Airport District's needs. At the same time, the documents will allow flexibility, so that different suppliers can meet the requirements in different ways.

14.3 Procurement

The procurement process used will have to consider the requirements of any agencies involved in funding the project and/or having jurisdiction over it. It will be desirable to encourage competitive bids and it is anticipated that this project should attract two to four bids from established providers.

It is considered unlikely that the procurement process can be completed based on only one bid submittal from each bidder. A more likely scenario is that the bidders are screened through a pre-qualification process. This would be followed by a pre-proposal meeting where qualified bidders are given the opportunity to review and comment on the plans and specifications. After appropriate revisions, the contract documents would be issued for bidding and the bids received. Meetings would be held with the best-qualified bidders and adjustments to the requirements would be made as appropriate. Best and final offers will be made, and the team best meeting the Airport District's needs would be selected. Final negotiations would then result in an executed contract to implement the project.

APPENDIX A. Cost Estimating Methodology

PRT

Three PRT suppliers, 2getthere, Modutram, and Ultra Global were approached for assistance with PRT capital and operating costs. All were provided with a description of the phased scenarios and a straw-man capital and operating cost breakdown. They were asked to revise the quantities and unit prices to match what would be required for their system to be successfully installed and operated. Knowing the sensitivity of the suppliers to closely held commercial information, the request was made on the basis that the information provided would not be divulged and only representative total numbers would be published. Nonetheless, most suppliers chose not to provide individual unit prices but only provided aggregated prices and/or generalized remarks as to the suitability or otherwise of the straw-man numbers provided. The resulting bottom-line capital and operating costs vary quite considerably.

Since cost is by no means the only criterion that will be used to select a PRT system, it was not possible to base this study on the lowest estimate received. By the same token, using the highest estimate seems too conservative and unit prices used are typically between the average and the highest with due account being given to local infrastructure costs.

Infrastructure costs were increased by 25% to account for soft costs (engineering, administration, and legal).

Manpower requirements were subjected to similar comparisons with some consideration being given to airport staff being available to assist with incident response. Labor costs were based on local wage rates increased by 50% to allow for overhead burden.

Costs included building new parking facilities and parking/PRT-specific roadways. Annual operations and maintenance costs included an allowance of 3% of capital costs for infrastructure maintenance. All capital and operating costs were increased by a 40% contingency factor (except for the parking garage where a 30% factor was used). This is 10% higher than the contingency used for buses primarily to account for unknown regulatory requirements.

Shuttle Bus

Shuttle bus manufacturers provided capital costs and estimated lives of their different products as well as the anticipated gas mileage. This enabled selection of the best-suited bus for the application and costs estimates were based on this bus (the 32’ Turtle Top OdysseyXL equipped for handicap access).

Bus stops and maintenance/storage facility were estimated at similar rates to those for the PRT system. Labor costs were based on local wage rates increased by 50% to allow for overhead burden.

The study also considered the impacts of a shuttle bus system on existing roadways. These impacts apply to both capital and operating costs. On the capital side buses will require bus stops and additional roadway width in some places. An allowance of 10’ was made for extra width for buses for the length of the bus route through each new parking lot. No extra width was allowed for anywhere else, and no account was taken of additional curbside or roadway congestion that may result from shuttle buses.

According to the American Association of State Highway and Transit Officials (AASHTO, 1993), the passage of one shuttle bus over an asphalt roadway does the equivalent damage to the passage of about 1,300 cars. Thus roads supporting cars and buses need thicker pavement than roads supporting cars alone. In addition, a large proportion of the maintenance requirements will be due to the bus traffic.

Since most of the roads to be used by a shuttle bus system already exist, no account has been taken of the contribution of the buses to the capital costs. However, adding significant bus traffic to these roads, which was probably not accounted for in the pavement design, will undoubtedly increase maintenance requirements. The additional maintenance cost due to shuttle bus traffic has been conservatively assumed at 25% of the estimated maintenance costs for 12’ of road the length of the shuttle bus route.

Costs included building and maintaining new parking facilities, bus stops, and parking/shuttle bus-specific roadways. All capital and operating costs were increased by a 30% contingency factor.

Life Cycle and Financing Costs

The following tables show the analysis of present worth life-cycle costs for the PRT and shuttle bus options. The analysis of financing costs is shown for the PRT Phase 1A option only.

Discount rate = 4%

		PRT Scenario 1					PRT Scenario 2				
Year	PW Factor	Item	Capital Cost	Operating Cost	Parking Revenue	Total PW Cost	Item	Capital Cost	Operating Cost	Parking Revenue	Total PW Cost
2018	1.0000	Phase 1	39,974,541	2,548,290	-4,211,278	38,311,553	Phase 1	39,974,541	2,548,290	-4,211,278	38,311,553
2019	0.9615			2,548,290	-4,377,213	-1,758,580			2,548,290	-4,377,213	-1,758,580
2020	0.9246			2,548,290	-4,528,531	-1,830,843			2,548,290	-4,528,531	-1,830,843
2021	0.8890			2,548,290	-4,670,765	-1,886,872			2,548,290	-4,670,765	-1,886,872
2022	0.8548			2,548,290	-4,811,800	-1,934,858			2,548,290	-4,811,800	-1,934,858
2023	0.8219			2,548,290	-4,961,750	-1,983,688			2,548,290	-4,961,750	-1,983,688
2024	0.7903			2,548,290	-5,110,274	-2,024,773			2,548,290	-5,110,274	-2,024,773
2025	0.7599			2,548,290	-5,267,293	-2,066,219			2,548,290	-5,267,293	-2,066,219
2026	0.7307			2,548,290	-5,412,836	-2,093,096			2,548,290	-5,412,836	-2,093,096
2027	0.7026			2,548,290	-5,564,227	-2,118,957			2,548,290	-5,564,227	-2,118,957
2028	0.6756	Phase 2	45,093,750	3,901,103	-5,793,444	29,185,324	Phase 2	28,186,375	3,528,225	-5,903,015	17,437,382
2029	0.6496			3,901,103	-6,091,176	-1,422,630			3,528,225	-6,065,415	-1,648,110
2030	0.6246			3,901,103	-6,381,093	-1,548,995			3,528,225	-6,223,551	-1,683,493
2031	0.6006			3,901,103	-6,684,778	-1,671,803			3,528,225	-6,389,198	-1,718,226
2032	0.5775			3,901,103	-7,010,226	-1,795,441			3,528,225	-6,566,715	-1,754,652
2033	0.5553			3,901,103	-7,373,526	-1,928,114			3,528,225	-6,764,879	-1,797,199
2034	0.5339			3,901,103	-7,756,788	-2,058,582			3,528,225	-6,973,931	-1,839,690
2035	0.5134			3,901,103	-8,155,177	-2,183,928			3,528,225	-7,191,233	-1,880,490
2036	0.4936			3,901,103	-8,572,204	-2,305,787			3,528,225	-7,418,703	-1,920,449
2037	0.4746			3,901,103	-9,007,191	-2,423,566			3,528,225	-7,655,968	-1,959,202
2038	0.4564	Phase 3	28,186,375	4,838,814	-9,466,827	10,751,729	Phase 3	12,094,250	4,019,797	-7,831,440	3,780,074
2039	0.4388			4,838,814	-9,876,309	-2,210,622			4,019,797	-7,795,389	-1,656,857
2040	0.4220			4,838,814	-10,136,566	-2,235,415			4,019,797	-8,055,647	-1,702,948
2041	0.4057			4,838,814	-10,402,689	-2,257,411			4,019,797	-8,321,769	-1,745,423
2042	0.3901			4,838,814	-10,673,868	-2,276,380			4,019,797	-8,592,948	-1,784,084
2043	0.3751			4,838,814	-10,950,199	-2,292,483			4,019,797	-8,869,279	-1,819,122
2044	0.3607			4,838,814	-11,231,780	-2,305,874			4,019,797	-9,150,860	-1,850,719
2045	0.3468			4,838,814	-11,518,712	-2,316,699			4,019,797	-9,437,792	-1,879,050
2046	0.3335			4,838,814	-11,811,095	-2,325,099			4,019,797	-9,730,175	-1,904,283
2047	0.3207			4,838,814	-11,836,165	-2,243,711			4,019,797	-9,844,926	-1,867,836
Salvage Value			(65,595,166.50)			-21,033,183		(42,577,041.50)			-13,652,389
	TOTALS		**113,254,666**	**112,882,070**	**-229,645,782**	**1,714,998**		**80,255,166**	**100,963,127**	**-203,698,801**	**-4,233,099**
		Capex + Opex =		**226,136,736**			**Capex + Opex =**		**181,218,293**		

Note: Salvage value based on 50 year life for all capital items. Salvage value is excluded from all totals except for PW Cost.

Table A-1: PRT Present Worth Life-Cycle Costs

Discount rate =		4%										
		Bus Scenario 1					Bus Scenario 2					
Year	PW Factor	Item	Capital Cost	Operating Cost	Parking Revenue	Total PW Cost	Item	Capital Cost	Operating Cost	Parking Revenue	Total PW Cost
2018	1.0000	Phase 1	15,495,342	2,910,881	-3,509,398	14,896,825	Phase 1	15,495,342	2,910,881	-3,509,398	14,896,825
2019	0.9615			2,910,881	-3,647,678	-708,458			2,910,881	-3,647,678	-708,458
2020	0.9246			2,910,881	-3,773,775	-797,794			2,910,881	-3,773,775	-797,794
2021	0.8890			2,910,881	-3,892,304	-872,481			2,910,881	-3,892,304	-872,481
2022	0.8548			2,910,881	-4,009,834	-939,389			2,910,881	-4,009,834	-939,389
2023	0.8219			2,910,881	-4,134,792	-1,005,965			2,910,881	-4,134,792	-1,005,965
2024	0.7903			2,910,881	-4,258,562	-1,065,092			2,910,881	-4,258,562	-1,065,092
2025	0.7599			2,910,881	-4,389,411	-1,123,561			2,910,881	-4,389,411	-1,123,561
2026	0.7307			2,910,881	-4,510,697	-1,168,969			2,910,881	-4,510,697	-1,168,969
2027	0.7026			2,910,881	-4,636,856	-1,212,647			2,910,881	-4,636,856	-1,212,647
2028	0.6756	Phase 2	45,093,750	4,263,694	-4,853,459	30,065,297	Phase 2	10,825,856	4,173,870	-4,919,179	6,810,056
2029	0.6496			4,263,694	-5,151,192	-576,502			4,173,870	-5,054,512	-572,049
2030	0.6246			4,263,694	-5,441,109	-735,410			4,173,870	-5,186,293	-632,357
2031	0.6006			4,263,694	-5,744,794	-889,510			4,173,870	-5,324,332	-690,938
2032	0.5775			4,263,694	-6,070,242	-1,043,236			4,173,870	-5,472,262	-749,789
2033	0.5553			4,263,694	-6,433,542	-1,204,840			4,173,870	-5,637,399	-812,646
2034	0.5339			4,263,694	-6,816,804	-1,363,126			4,173,870	-5,811,609	-874,402
2035	0.5134			4,263,694	-7,215,192	-1,515,220			4,173,870	-5,992,694	-933,736
2036	0.4936			4,263,694	-7,632,220	-1,662,799			4,173,870	-6,182,252	-991,394
2037	0.4746			4,263,694	-8,067,206	-1,805,308			4,173,870	-6,379,974	-1,047,111
2038	0.4564	Phase 3	10,825,856	5,526,683	-8,378,032	3,639,460	Phase 3	8,175,318	5,022,137	-6,377,280	3,112,639
2039	0.4388			5,526,683	-8,927,496	-1,492,391			5,022,137	-6,496,158	-646,850
2040	0.4220			5,526,683	-9,144,377	-1,526,506			5,022,137	-6,713,039	-713,485
2041	0.4057			5,526,683	-9,366,145	-1,557,771			5,022,137	-6,934,807	-776,021
2042	0.3901			5,526,683	-9,592,128	-1,586,018			5,022,137	-7,160,790	-834,334
2043	0.3751			5,526,683	-9,822,404	-1,611,397			5,022,137	-7,391,066	-888,625
2044	0.3607			5,526,683	-10,057,055	-1,634,057			5,022,137	-7,625,717	-939,083
2045	0.3468			5,526,683	-10,296,165	-1,654,135			5,022,137	-7,864,827	-985,892
2046	0.3335			5,526,683	-10,539,817	-1,671,768			5,022,137	-8,108,479	-1,029,226
2047	0.3207			5,526,683	-10,560,709	-1,614,168			5,022,137	-8,204,105	-1,020,302
Salvage Value			(41,915,071.25)			-13,440,127		(19,233,904.63)			-6,167,379
	TOTALS		**71,414,948**	**127,012,578**	**-200,873,394**	**1,122,938**		**34,496,516**	**121,068,884**	**-169,600,081**	**-5,380,454**
Capex + Opex				**198,427,525**					**155,565,400**		

Note: Salvage value based on 50 year life for all capital items. Salvage value is excluded from all totals except for PW Cost.

Table A-2: Shuttle Bus Present Worth Life-Cycle Costs

	Interest Rate =		4%	Period =		30 years	
	Daily Parking Rate =		$ 6.00				
	PRT Scenario 1 or 2, Phase 1A						
	Capital		Annual	Operating	Total	Parking	Annual
Year	Item	Cost	Amortization	Cost	Annual Cost	Revenue	Surplus
2018	Phase 1A	20,855,266	1,206,062	1,810,352	3,016,414	3,049,137	32,723
2019			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2020			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2021			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2022			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2023			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2024			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2025			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2026			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2027			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2028			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2029			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2030			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2031			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2032			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2033			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2034			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2035			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2036			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2037			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2038			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2039			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2040			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2041			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2042			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2043			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2044			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2045			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2046			1,206,062	1,810,352	3,016,414	3,049,137	32,723
2047			1,206,062	1,810,352	3,016,414	3,049,137	32,723
TOTALS		**20,855,266**	**36,181,863**	**54,310,560**	**90,492,423**	**91,474,110**	**981,687**

Table A-3: PRT Phase 1A Costs and Parking Revenues

APPENDIX B. Case Studies of Commercially-Available PRT Systems[41]

Heathrow Pod[42]

Ultra is a modern PRT system that became reality when it was implemented by BAA as a pilot network at Heathrow International Airport to help shuttle passengers to and from a distant car parking lot to Airport Terminal 5. The system was implemented at a capital cost of $50 M. Passengers pay for parking and ride for free. There have been no known incidents or accidents and the availability is currently reported to be 99.7%.

With a nod to the history and success of other efforts in Automated People Movers (APM), GRT, and PRT design around the world, this BAA/Ultra mobility initiative proudly claims itself as the first traditional, super light-weight, personal rapid transit system designed to be commercialized for passenger use. It entered limited passenger service in late 2010 and full service on April 11, 2011. Since then, it has achieved over 99% reliability to rave passenger reviews. Today, the system provides 900 passengers a day with a link between Terminal 5 (T5) and the remote parking lots.

from the parking lots on the left to Terminal 5 on the right.

The Heathrow track from T5 to the parking lots exits the airport below the access road, tracks above the roadways, back under the runway approach, up again over the access road, river, wetlands, and then back down to the parking lots.

The Ultra system uses a fleet of low power, battery-powered vehicles on a dedicated guideway. The operation of the system and movement of the vehicles on the network is managed by software and systems developed by Ultra Global, the maker of Ultra, which work to direct and distribute the independent vehicles on a network of direct routes and offline stations to help provide non-stop travel.

The track is passive and switching is achieved by in-vehicle steering using an electronic guidance system. Stations can have spacing similar to bus stops and the basic network form allows the guideway to be one-way, providing important benefits in cost and visual intrusion.

Figure B-2: Vehicle running under Access Road.

Ultra can operate at-grade or elevated either within or external to buildings, offering the opportunity for more convenience to the passenger. Low loading footprint means that the system can be carried by conventional building structure with no need for structural strengthening. The vehicle has a small (16 foot) turning radius and readily copes with grades of 20%, yet operating routes are limited to 10% to ensure passenger comfort.

[41] Heathrow, Masdar and Suncheon sections adapted from: C&S Companies, Feasibility of PRT in Ithaca, New York, September, 2010

[42] http://www.ultraglobalprt.com/wheres-it-used/heathrow-t5/

Most Reports commenting on Ultra's overall performance have suggested that the design, engineering and technology have indeed proven viable. Because the Ultra model mostly utilizes modern, yet mature, off-the-shelf, computing and information technologies from the automotive industry, they provide their product with a foundation of reliable systems and components.

Some basic features of the Ultra PRT:

- Principal parameters - scale overhead or at-grade:
    - Width: 6.5 feet
    - Depth: 1.5 feet
    - Height above roadway: 18.7 feet
    - Column spacing: 59 feet

- Basic vehicle characteristics:
    - 4 - 6 seats
    - 1,000 lbs. payload
    - 25 mph

- Simplified analysis of theoretical capacity:
    - 50 seat bus every 5 minutes provides 600 seats/hour
    - 200 seat light-rail every 10 minutes provides 1200 seats/hour
    - 4 seat Ultra every 3 seconds provides 4800 seats/hour

Vehicles

The vehicles are controlled autonomously. Once the vehicle has received its instructions from central control it will continue to its destination without any need for further input.

Figure B-3: Inclement weather operations.

Extensive tests have been done on various forms of vehicle control. Ultra Global has performed full scale system evaluations tests to examine control methods based on wire guidance, optical and radar sensing, embedded guideway magnets and local sensors based on Ultrasonics or lasers. They found the last two of these approaches to be significantly more reliable and robust, so a combination of these is used in the final system.

Each pod is electrically powered with four rubber wheels. Battery pack weight is 64 kg and is only 8% of the vehicle's gross weight, compared to many electric cars which require up to 50% of gross weight for batteries. In testing, it has shown that it can recharge a 5 minute trip in 1 minute.

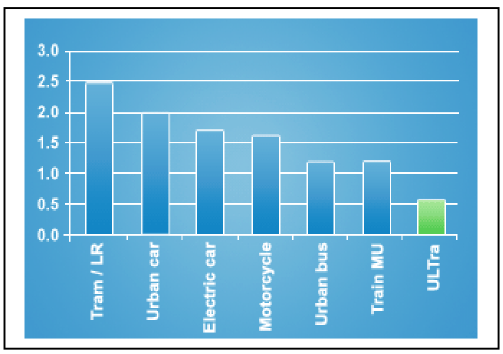
The vehicle is equipped with two bench seats facing each other and has a level entry from the station, allowing plenty of barrier-free access for wheelchairs, shopping or pushchairs. Individual vehicles feature heating and air conditioning for hot or cold climates, as well.

Ultra vehicle - Principal parameters:

Gross weight	800 kg
Empty weight	400 kg
Maximum speed	40 km/h
Length	3.7m
Width	1.45 m
Height	1.6 m
Passengers	4
Payload (kg.)	450
Minimum Turn Radius to center-line of front track (m.)	5
Maximum Climb Gradient	20
Maximum Planned Climb Gradient	10
Maximum Planned Decline Gradient	6.25
Maximum Vehicle Speed on level (m/s.)	11

Emissions and Energy Use

Because Ultra is electrically powered, zero emissions are released at the point of use, while it also boasts significantly reduced energy usage overall; over 70% more efficient when compared with cars, rising to 90% in peak periods when cars are restricted by congestion. The average system energy usage is 0.55 megajoules (MJ) per passenger kilometer. This can be compared with figures between 1.2 and 2.4 shown for conventional forms of transport in the table below.



This energy saving translates directly into reduced CO_2 emissions. Documentation shows that Ultra meets the recommendation of the Royal Commission on Environmental Pollution (RCEP), following the Intergovernmental Panel on Climate Change, that CO_2 emission should be reduced by at least 60%. The RCEP target is set for 2050, and Ultra is able to exceed this target in the present decade - 35 years early.

Figure B-4: Average System Energy Usage (MJ per passenger km)

Ultra also boasts an emission saving of a factor of 3 or 4 over current car or public transport, meeting Kyoto sustainability targets, providing the required 60% reduction in carbon emissions over the car today, rather than in 2050, which is the target date set by the Kyoto agreement.

Guideway

Like traditional PRT, Ultra runs on its own guideway network with offline stations. Typically, the pods are guided electronically with sensors embedded in the vehicle and the guideway network is arranged in a series of loops, combined by merge/diverge sections, serving key locations in the city. However, most of the Heathrow track consists of two-way guideways in a more conventional corridor alignment. The total length of one-way track is 2.4 miles.

The vehicles run at ground level or on elevated guideways in the form of a concrete trough, supported on a lightweight steel structure; columns are designed to be truck impact proof.

Control Systems

Figure B-5: Heathrow Control Room.

Technically, the operating system is managed by software developed by Ultra Global. It utilizes synchronous controls, similar to that used at Morgantown, and ensures that vehicles are only launched from their berth when it is known that there is a safe free route to their destination. This allows the central control system to respond to the passenger's request by allocating a vehicle for the journey and instructing the vehicle on the required path and precise timing.

Basically, the system manages fixed 'slots' for each vehicle at the prescribed headways and requires free routes to be identified from start to destination, including all merges before the launch of a trip from the station. Each slot is unique, ensuring there is no interaction between vehicles and includes empty vehicle management, which sends available vehicles to where they are needed, when needed, including to maintenance. Ultra Global suggests that this reduces overall waiting times and ensures lower environmental impact due to not having to take unnecessary journeys.

The central control function, including development of effective empty vehicle-management algorithms, has been the subject of extensive simulations by Ultra Global since the start of the project, and the functionality has been well developed and tested. Average waiting times at Heathrow are under 30 seconds and 75% of passengers immediately board a vehicle with no wait at all.

Stations[43]

The Ultra pod system station at T5 Heathrow Airport comprises the following main elements:

1. Berth – vehicle docking point, interfaces, buffer and charging equipment
2. Passenger interface – each berth features a destination selection console, communications, and automatic doors
3. Plinth – a raised floor for passenger-level access to vehicles
4. Envelope – the overall station building
5. Canopy – passenger area roof and vehicle solar shading

Figure B-6: Station with Canopy

The two remote stations (parking lots) at Heathrow comprise a 200 square feet passenger weather-protected concourse and two berths.

Approved by disability groups, the stations always offer at least minimal shelter above the bays.

[43] http://www.Ultraglobalprt.com/wp-content/uploads/2011/09/PDF_Infastructure.pdf

Maintenance

Ultra's system is highly reliable and minimizes the possibility of breakdown. Each pod has an on-board computer that automatically detects maintenance issues so that the unit can be taken out of service before a problem develops. The Heathrow maintenance facility is similar to an automobile repair shop.

Figure B-7: Maintenance Facility at Heathrow

Figure B-8: Service Vehicle

In the extremely unlikely event that a vehicle does break down, a service vehicle can be sent to retrieve it. The vehicles also have emergency exits, the guideway does have escape routes; however, passengers should stay in the pods at all times where possible.

Masdar City PRT System[44]

On November 28, 2010, the Masdar City PRT application was the world's first podcar system to open to the general public. 2getthere was selected as the supplier for the first phase of Masdar City, providing the link to the Masdar Institute of Science and Technology (MIST) by means of eight PRT, two VIP (leather interior) and three freight vehicles. In this phase, the network is approximately 1.2 kilometers long and features five stations (two for passengers, three for freight). The installation costs are unknown and passengers travel for free.

Figure B-9: FRT for delivery of small goods and removal of waste (not yet in service).

The PRT vehicles travel at speeds up to 40 kmh, with the longest routes in the city taking around 10 minutes. The system was planned for 3,000 PRT vehicles serving 130,000 trips/day over the 85 stations. The dedicated guideway in the undercroft, an artificial basement created by raising the pedestrian level, will also accommodate the Freight Rapid Transit system (FRT). The FRT system will be capable of making 5,000 trips per day carrying the loads and deliveries for residents, stores and

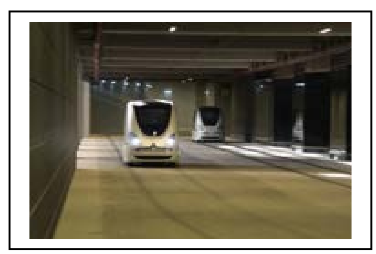


Figure B-10: Undercroft view with visible tracks

44 http://www.2getthere.eu/

hotels. The flatbed vehicles can carry two pallets, with a maximum total payload of 1,600kg.

As viewable in the Figure B-10, the vehicle tires have marked the precise track where they follow magnets embedded within the pavement.

2getthere PRT System Summary:

System Capacity (4 second headway):	3,200 – 4,800 passengers per hour
Economically viable from:	Approx. 300 pax/hour or 1500 pax/day
Supervisory System (Network Controls):	TOMS (Transit Operations Monitoring and Supervision)
Vehicles:	6 passenger CyberCab
Infrastructure:	Asphalt, at grade or elevated
Status:	2nd generation
Configuration:	Network
Operations:	On-demand / On-schedule
Connections:	Direct / Ride-sharing (Single Origin, Multiple Destinations)
Stations:	Off-line
Propulsion:	Central AC motor, differential rear axle
Energy supply:	Electric or Hybrid
Maximum speed:	40 km/hour [25m/hour]
Guidance:	FROG-technology
Track Length:	1200 meters (one-way)
Number of Stations:	2 offline (+3 freight stations)
Berths per station:	6
Crossings for Traffic/Pedestrians:	On podium level

History

2getthere was established in 2001. Formerly it was a business unit within Frog Navigation Systems. It was established as an independent company to capitalize on the people mover market opportunity and split off in 2007.

Masdar City itself was established in 2006 to be the world's first carbon neutral, zero-waste to landfill, car-free city powered entirely by alternative energy sources. Masdar City is being built on six and a half square kilometers and will eventually grow to house 1,500 businesses, 40,000 residents and 50,000 commuters. There will be no fossil fuel cars within Masdar City. The city will be a pedestrian-friendly environment, with a Personal Rapid Transit system available for longer journeys. The PRT vehicles will travel at speeds up to 40km/h, with the longest routes in the city taking around 10 minutes. Ultimately there will be 3,000 PRT vehicles serving 130,000 trips/day over the 85 stations.

Figure B-11: Masdar station level platform with 4 passenger vehicles, seated across.

Vehicles

2getthere's personal rapid transit system features a number of automated taxis (CyberCabs). The CyberCab accommodates a 6-person family (4 adults, 2 children) and additionally has space available for either a wheelchair or luggage. The vehicle features an automated sliding door, optionally a second door can be installed allowing (dis)embarking on both sides of the vehicle.

Performance

In 2013, the Masdar City system celebrated the completion of its third year of operation, having transported over 819,000 passengers during that time. Since its opening, the system has carried more than three times the expected number of passengers and operates consistently with a system availability exceeding 99.4%.[45]. In May, 2014 the system carried its millionth rider after being in operation for three and a half years.

Benefits include:[46]

- Passenger transfer time between the car park and MIST is reduced to approximately two minutes.
- There is a minimal waiting time as the vehicles are generally waiting in the stations for passengers and only travel on demand. If no vehicles are present the distributor function ensures empty vehicles are on their way.
- Each vehicle has 4 seats and enough room for accompanying luggage. Passengers travel in their own passenger groups or on their own.
- There are no emissions at the point of use. The system uses lithium ion batteries which provide a 60+km range.
- The vehicle features a flat floor which aligns accurately with stations to allow safe and easy access for push chairs, wheelchairs, luggage and people, meeting the access requirements for disabled passengers.

Control

2getthere's ability to provide a PRT system is based on the well-proven (20+ years) FROG network and vehicle controls, fully customized for Automated People Mover requirements. 2getthere's personal rapid transit system features the supervisory control system TOMS (Transit Operations Monitoring and Supervision). The guideway can be constructed at grade, but also elevated, embedded in buildings or underground. The system is configurable as 'true' PRT – providing direct connections, on-demand operations and personal transportation – but

Figure B-12: Masdar Control Room.

45 http://electricvehicle.ieee.org/vehicles/masdar-podcar-2getthere/

46 http://www.advancedtransit.org/advanced-transit/applications/masdar-prt/

alternatively 'ride sharing' (single origin, multiple destinations) and scheduled operations (to optimize capacity) can also be implemented.

Safety

2getthere was granted certification by the Abu Dhabi Department of Transportation for the Masdar PRT System on November 23, 2010, based on the Letters of No Objection as issued by the Independent Safety Assessor (Lloyd's Rail Register) and Independent Health Assessor (Bureau Veritas).

Figure B-13: Rescue Vehicle

One distinct feature of 2getthere's systems is the advanced obstacle detection sensors applied on the vehicles. The sensors are capable of scanning up to 200 meters in front of the vehicle -- the actual area taken into account being dependent on the speed of the vehicle. The area is always scanned empty, a failsafe approach.

Suncheon Bay PRT System[47]

Following a successful four year period of testing and demonstration at the test track, Vectus has now moved forward very rapidly with building its first fully commercial system in South Korea. This is essentially a visitor transit between a park-and-ride location on the outskirts of Suncheon city, in the southernmost part of the country, linking to a world famous wetlands and bird reserve in the Suncheon bay estuary. The main station, 'Station One', is located at the entrance to the 2013 International Garden Exposition. From here, Vectus operates 40 vehicles initially (and one maintenance vehicle) running down to a second station, along 3 miles (end to end) of elevated, double track. The track has a full loop at either end with four on-line berths at each. The capital costs are uncertain.

Figure B-14: Suncheon Bay Layout - following the river.

An average of three million visitors per year are expected to visit the Suncheon Wetland Park, and daily ridership is forecast at around 5,000 passengers per day. The system entered limited service in August 2013 and full service on April 19, 2014. Passengers travel for free.

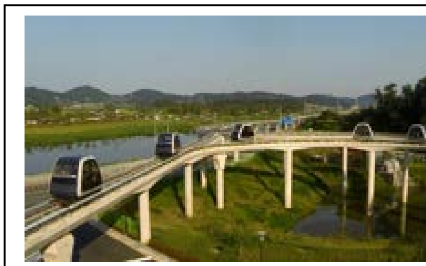


Figure B-15: Pre-cast concrete to withstand earthquakes and severe weather, and secured over marshland; hence, structure is larger than normal.

Guideway

The guideway itself is predominately concrete using site-cast columns and pre-fabricated, pre-stressed beams of typically 30 meter spans – although there is also one 50 meter steel box-girder section over a river. Because the entire area is an earthquake zone and is also prone to occasional cyclones, the construction has

[47] http://www.vectusprt.com/EN/media/documents/

been very carefully engineered, with most of the column piling buried some 30 meters into the marshy terrain. Since, in most cases, the foundations are laid far under the top soil on top of the pilings, this has the effect of placing the bending moment from wind loading deep underground.

Track

The track-work itself is manufactured from rolled steel profiles, mounted along the concrete structure and the entire railway is powered through a 500VDC system of continuous current collection located on both sides of the guideway. For this application, where there is no issue of track adhesion (in comparison with Uppsala, for example, which is prone to very icy winters), there is no necessity for using in-track linear motors at all.

Vehicles

The 4.6 km line runs parallel to the Suncheon-dong Stream, mud flats and reed fields of the bay. Twelve hundred people an hour will be able to use the system which consists of 40 vehicles — each vehicle capable of transporting a maximum of nine persons. The vehicles or “podcars” can travel at a maximum speed of 50 km/hour and are fully automated. One major difference with the PRT system is that vehicles only operate when there are passengers, the opposite to other transport systems where the passenger usually has to wait for the service to arrive.

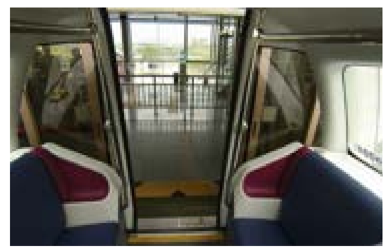


Figure B-16: Inside bench seating with grab bars for standees.

Control

Where Vectus starts to add value beyond the notion of simply running point-to-point, is the way that each vehicle controls its speed, position and direction, relative to all other vehicles on the system, as a method of optimizing overall system capacity and efficiency. The methodology behind the Vectus control system, which is being deployed at Suncheon, can be divided into four key components: distributed and scalable control, asynchronous control, dynamic moving block and optimal control.

A distributed system means that the control is carried out locally, in pre-designated zones. If there is a fault, it only effects a small part of the system. The rest of the system will continue to work. With the distributed system there is no increase in the load for each individual control segment when the system is expanded.

With asynchronous control the flow of vehicles is handled as they each travel along their paths to their respective destinations. Merging of vehicles is managed as required on a local basis. Occasionally there may be a need to slow down to facilitate merging in switches; there may even be short queues along the route at times. Travel time may be prolonged by a few seconds, but the overall capacity of the system is maintained, which is essential to the overall ability to transport passengers during periods of high system loads.

A dynamic, moving-block vehicle protection system is superior to any fixed-block system, even if the fixed blocks are very short. It continuously updates each vehicle with information on the position of the one in front of it. With this information, each car can run, by varying its speed relative to the others, with the shortest allowed spacing based on the worst case braking performance. At lower speeds the vehicles run closer to each other; at higher speeds the distance is increased. These systems, in combination, are the building blocks in providing both safety and capacity within the Vectus system.

Stations

Currently, there are only two stations. Station One includes passenger facilities such as the elevators, turnstiles, platform screen doors, information displays and waiting areas. Station Two is similar to Station One and houses the same facilities.



Figure B-16: Four-bay Station

Figures B-17/18: Turnstile entry and level platform with station doors

Maintenance

The Operations and Maintenance building is located adjacent to Station One (the Suncheon City end). This houses the control room, vehicle storage (on the lower levels) a five berth daily maintenance area and a five berth, off-line, heavy maintenance facility. The maintenance building houses the control room, all vehicle lifts, garaging facilities and maintenance bays within the depot facility below.

Figure B-19: Maintenance Facility

ModuTram

ModuTram's AutoTren is a complete transportation system based on group rapid transit (GRT) technology that combines the convenience and comfort of the car with the efficiency, timeliness, and safety of modern trains. This system, whose technological integration is performed by ModuTram, offers trips with less wait, more comfort, and more direct service than conventional systems. It can be installed in less time and in places where other systems do not fit, and was specifically developed to be affordable to customers in Latin America.

Vehicles

The automated guided vehicles (without human drivers) are light, efficient, can accommodate up to 6 passengers seated, and can be coupled to form a mini-train capacity of 12 seated passengers. In addition to the 6-passenger urban vehicle, ModuTram has a 6-passenger site-seeing vehicle (depicted in Figure B-20), and an airport vehicle which accommodates standees. The airport vehicle holds 4 passengers plus luggage or five passengers plus light luggage. Each vehicle has four steerable wheels that are steered by side wheels that run against the side walls of the guideway. A centrally-mounted bi-stable switch located on the vehicle is used to switch at diverge points.

Figure B-20:
ModuTram vehicle

Stations

Prefabricated passenger stations based on a unique modular construction system (with which you can make different sizes and types of stations), are located on side rails. This allows for non-stop flow of traffic on the main lanes.

Figure B-21:
Prefab Station

Control System

Electronic devices and software that control the operation of the system adjust routes and schedules automatically depending on the demand, and coordinate the movement of all vehicles on the network.

Guideway Structure

ModuTram structure consists of a slender structure with prefabricated rails which can be interconnected in various ways to form any network.

Figure B-22:
Interior of Urban Vehicle

System Comparisons

The following table shows statistical comparisons between the four systems:

	Masdar	Heathrow	Suncheon	ModuTram Test Track/Demo
In service date	11/28/2010	4/28/2011	4/20/2014	10/2013
Number of vehicles	13	21	20-40	3
Miles of one-way track	.75	2.4	5.8	0.4
Number of stations	2(+3 freight)	3	2	2
Maximum speed (mph)	25	25	40	33
Availability (%)	99.5	99.5	N/A[1]	N/A
Vehicle power principle	Battery	Battery	Wayside Electric	Battery
Range (miles)	37	12	Unlimited	24
Vehicle/guideway interface	Rubber tires	Rubber tires	Polymer on steel	Rubber on steel
Lateral guidance	Magnets in pavement	Laser sensing of sidewalls	Side rails	Side rails
Switching	Steered	Steered	On-board side wheels	On-board switch wheels
Vehicle capacity	4 + 2 children	4 + 2 children	6 seated, 3 standing	5
Maximum headway (sec)	5	6	3-4	4
Max theoretical capacity	2,880	2,400	8,100	4,500
Max track gradient (5)	10	10	10	10
Min centerline radius (feet)	18	16.5	16.5	9.9
Clearance envelope (feet wxh)	6.1 x 7.5	6.9 x 6.6	6.9 x 8.2	6.2 x 11 (incl. truss)
Max berth throughput per hour	120	120	160-200	375
Emergency recovery	Manual + tow vehicle	Reduced speed + tow vehicle	Reverse operation + push/tow with other vehicles	Reverse operation + push/tow with other vehicles
CCTV/Intercom/Operator	Yes	Yes	Yes	Yes
Energy consumption (kWh/mile)	0.30	0.21	0.38	0.21 (prelim)

Table B-1: Systems Comparisons

[1] NA = Information not available