Personal Rapid Transit for
The University of Texas

January 14, 2011
FOR LIMITED DISTRIBUTION

A special report commissioned by AustinPRT
and created by ULTra PRT

(v1.3)
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ULTra PRT founder Martin Lowson (rocket scientist), Austin PRT’s Richard Garriott (entrepreneur / astronaut).

Picture taken inside an ULTra vehicle at London Heathrow Airport.

This photo was taken during the early part of testing stage when construction safety gear was required.

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PRT4UT Report (v1.3)
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To the Readers of this Study,

I first began to imagine what it would be like to travel around Austin using small, driverless, private vehicles back in the 1990s. Fifteen years ago I liked to refer to my idea as computerized gondolas, which would transport passengers to their destinations inside the same sort of gondolas you see at ski resorts or amusement parks. It was only an idea at the time, but one I communicated often to friends and family as I continued working in the interactive entertainment industry.

Now here we are in 2010, and the idea of a transit system using small, private cars on raised guideways has come a long way. There is even a name for it now; Personal Rapid Transit, or PRT. And there are commercial PRT systems in place in other parts of the world as you are reading this.

When I traveled to space nearly two years ago, I came back to Earth with a new appreciation for our planet. From 250 miles up, you begin to better appreciate the world we live in and how fragile it is. I wanted to do my part to protect Earth. Austin’s traffic problems seemed to be a great place to start. And PRT seemed like the perfect answer. PRT is private, it’s point-to-point and it’s on demand. It’s also less expensive to build and operate than other mass transit alternatives. And, it uses “green” sustainable energy.

When I first discussed the idea of PRT in a Texas Monthly article in the spring of 2009, the positive response from citizens, community leaders and politicians left me pleasantly surprised. I clearly wasn’t alone in my thinking that PRT had some real merit. I began meeting with local officials and leaders to gauge that interest. Then I decided to put my money where my mouth was and pay for an initial study into the viability of PRT in my hometown of Austin, Texas.
What follows is that study. It is commissioned by Austin PRT, a company I’ve formed to help determine PRT’s viability in the Austin community. The study was completed by the leading PRT company in the world, ULTra PRT, headquartered in the United Kingdom and with offices in the United States. ULTra PRT is the only company that has a modern PRT system currently in operation, at London’s Heathrow Airport.

And the subject of our study is the University of Texas campus in Austin. With more than 70,000 students, faculty and staff, the UT campus is literally a city within a city. There is limited parking and an abundance of people to move around a very large campus. All issues that PRT is perfectly geared to help resolve.

One fiscal requirement that I established early on in this process was that our group would only endorse a PRT option that did not require taxpayer money to build or operate. I believe that the public sector and private industry should be able to build and operate an energy efficient, comfortable, environmentally conscious transit system – like PRT – without putting taxpayers at risk.

This study is just the first step in determining if Personal Rapid Transit is a viable option under those conditions. And I believe that we have enough evidence to move forward with the next step. Based on the findings in this report, Austin PRT recommends moving to that next step, a full engineering study on the proposed PRT system for the University of Texas found in this report.

We hope you enjoy the contents and it helps you gain a better understanding of PRT, mass transit for the 21st century in Austin, Texas.

Sincerely,

Richard Garriott
President, Austin PRT
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Acknowledgements

The following people participated in an important way in the PRT4UT study. With exception, these professionals are generically referred to as “stakeholders” or “power stakeholders” in the study text below.

Stakeholders / Participants:

• Austin PRT: Richard Garriott, David Swofford, Hull Youngblood, Victor Meinert, Cathy Conley,
• UT School of Architecture Professors: Kent Butler, Dean Almy, Talia McCray, Ming Zhang, Matt Fajkus, Ulrich Dangel
• UT Civil Engineering Professor: Michael Walton
• University of Texas: Patricia Clubb – VP for University Operations; Frederick Steiner, Dean School of Architecture; Bob Harkins, Assoc. VP for Campus Safety and Security; Bobby Stone, Director, Parking and Transportation Services; Jeri Baker, Asst Dir Parking and Transportation
• Capital Metro: James Gamez, Meredith Highsmith
• Mayor Lee Leffingwell & Chief of Staff Mark Nathan
• City of Austin Transportation Dept: Assistant Director Gordon Derr
• TxDOT: Robert Stuard
• Sierra Club Central Region’s Ian Davis
• State Senator Kirk Watson’s office: Legislative Analyst Sandy Hentges.
• CAMPO: Joe Cantalupo (now with PB World)
• W. W. Webber LLC: Business Development Director Bill Hasbrook
• PBS&J: Program Director Kay McKinley
• Austin Chamber of Commerce: Director of Economic Development Tony Schum
• Austin Energy: Sr. Strategic Engineer Mark Kapner

Major contributions to the study were provided by following ULTra PRT staff: Steve Raney (Principal Investigator), Phil Smith, Martin Lowson, Ken Mitchell, Mark Griffiths, Bernadette Fielden, Nicholas Davenport, Tim Thorne, Nathan Koren, Adam Ruddle, Zara Sinclair, John Hammersley, Torquil Ross-Martin, Richard Teychenne, Chris Cook
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** “PRT4UT” is a shorthand acronym for “personal rapid transit for University of Texas.” This PRT4UT notation will be used throughout this report.**
Chapter 1. ULTra System Introduction

1.1 What is PRT?

PRT is the most energy efficient urban mass transit system that has been devised so far. PRT consists of small, light-weight, four-passenger vehicles. The vehicles run on elevated or ground level guideways under computer control. PRT vehicles are electric cars that are extremely quiet and run either on batteries or they take power from electric contacts on the guideway. PRT systems do not use schedules; service is demand responsive, rather than on fixed schedules and is available 24 hours a day and it takes you from your origination to your destination with no stops in between.

1.1.1 Why PRT?

Energy efficient
- Lightweight Electric Vehicles
- Sustainable Energy Solution

Highly efficient travel
- Point to point – non-stop travel
- No schedules or fixed routes, vehicles run on your schedule
- Vehicles wait for passengers, passengers don’t wait for vehicles
- Traffic is computer controlled, no possibility of traffic jams

Affordable infrastructure
- Lightweight modular components, simple and fast construction
- Minimal street level impact, elevated installation will not conflict with or destroy existing roadways

Private vehicles offer comfortable and desirable travel experience
- Little or no waiting
- Riders will never be forced to share a vehicle with anyone if they don’t desire
- No stops to let others on, the vehicle is yours for the duration of the trip

Safe
- Segregated from all other urban traffic
- Flow segregation, no opportunity for head-on collisions
- Constant flow with off-line access/egress with no stop starts and no traffic pile-ups. PRT won’t have rear-end collisions

Quiet operation
- Lightweight, electric vehicles
- No noise pollution regardless of traffic density

Can also be used to automate transport of cargo, mail and waste

Capital costs are low compared to other forms of mass transit

Reduces auto congestion
1.2 Executive Summary

ULTra is a battery-driven, 200-mpg-equivalent, elevated personal rapid transit (PRT) system with many four-person vehicles. First deployment is scheduled for London Heathrow Airport in early summer 2010 (revenue service commences in June), to serve Heathrow’s new Terminal 5. Working as circulator transit for office parks, airports, universities, and other major activity centers, ULTra is faster than a car. In these applications, ULTra makes carpooling, Capital MetroRail, Austin Urban Rail, Capital MetroBus (express, circulator, cross-town, rapid bus, etc) more effective, by solving the “last mile problem.” PRT also enables longer bike commutes and shopping trips.

Proposed is a 7.2 mile, 180-vehicle, 20-station PRT4UT system, replacing three Capital Metro MetroBus routes: 642 WC (West Campus), 640 FA (main campus or Forty Acres), and 641 EC (East Campus). This system provides four major benefits:

- Improves parking management
- Creates national cleantech leadership
- Accelerates UT’s strategy to have more students live closer to campus
- Increases the perceived size of main campus by shortening distances

Figure 1.1: Alignment Option #3

ULTra easily accommodates 13,800 or more passenger trips per day, at an operating cost per passenger mile of $0.47, one-third the cost of the Dallas Fort Worth Airport Skylink automated people mover system.
The report develops a 21-year PRT4UT business model, based on $104M capital costs, $3.6M annual operations and maintenance budget, vetted revenue sources, and a debt/equity PPP finance package featuring 49.5% Local Government Corporation low-interest debt. The business model is an excellent starting point for scenario analysis and further discussion, and does not provide a “single correct answer” because many feasible solutions exist.

This report is the result of a five-month research effort, featuring numerous in-person meetings. The report would not have been possible without important contributions from major stakeholders such as Austin PRT, University of Texas, Capital Metro, The Mayor’s Office, City of Austin Transportation Department, TxDOT, Sierra Club, Senator Watson’s office, W.W. Webber LLC, PBS&J, Austin Chamber of Commerce, and Austin Energy.

Independent peer-review is provided by UT School of Architecture and UT Civil Engineering professors: Kent Butler, Dean Almy, Talia McCray, Ming Zhang, and Michael Walton.

1.3 The ULTra System

ULTra is a battery-driven, 200-mpg-equivalent, elevated personal rapid transit (PRT) system with many four-person vehicles. First deployment is at London Heathrow Airport, serving Terminal 5. Heathrow passenger operations commenced in October of 2010. Working as circulator transit for office parks, airports, universities, and other major activity centers, ULTra is faster than a car. In these applications, ULTra makes carpooling, Capital MetroRail, Austin Urban Rail, Capital MetroBus (express, circulator, cross-town, rapid bus, etc) more effective, by solving the “last mile problem.” PRT also enables longer bike commutes and shopping trips.
1.3.1 Self-Driving Electric Vehicles

ULTra is significantly more software, sensor, and communications intensive than traditional transit. An ULTra system may have 180 computer-driven vehicles driving with a precision better than +/- one inch laterally and longitudinally, with 100 position updates per vehicle per second.

The U.S. Department of Transportation (DOT) has developed a long-term vision of self-driving cars on U.S. roads called Automated Highway Systems (AHS). Automation will increase capacity (because cars will follow more closely) while improving gas mileage and safety. The current early DOT technology development project in this arena is called “Vehicle Infrastructure Integration” (link) and this effort is being complemented by automaker advances such as “stop and go adaptive cruise control.” All automobile manufacturers agree that it will be impractical to remove ultimate responsibility from the driver in a conventional road situation for many decades. In contrast, ULTra offers fully self-driving vehicles now.

The ULTra system uses a lithium-ion battery-powered electric vehicle (EV) and will exploit future advances in EV propulsion over the coming years. The system design provides opportunities for recharge when stopped at stations. Required battery pack size is low, under 10% of vehicle empty weight.

1.4 Perspectives on PRT

PRT systems are being pursued for San Jose Airport, Silicon Valley, Alameda Point, Portland suburbs, Minnesota, Virginia, Suncheon (South Korea), Sweden, and Masdar EcoCity in Abu Dhabi in the United Arab Emirates. One of the advantages of a PRT network “is that it offers a lot of flexibility. It's much less expensive than traditional transit. It doesn't serve the same needs as high-speed rail or BART. It's a complement to those systems,” Laura Stuchinsky, Sustainability Officer, City of San Jose Department of Transportation.

"We've concocted a system where local trips take an auto. That's our biggest tragedy. Streetcars, such as those used in Portland's Pearl District, and elevated people movers, like those in downtown Miami, are moving people from rail stations to their final destinations. But a new concept, PRT, may help revolutionize urban transportation, providing a cost-effective way to get people from train stations to where they need to go.” - Peter Calthorpe, Berkeley-based Calthorpe Associates (Alameda Point, etc).

"The social perception of public transportation depends on the quality of the transportation. I think we may be looking to technological advances in public transportation to create new kinds of personal rapid transit. If this is as successful as I think it will be, this could be a big breakthrough which could transform our cities in ways that we can't yet see." - Sir Peter Hall, author: Cities of Tomorrow: An Intellectual History of Urban Planning and Design in the Twentieth Century.

"When I was here at Michigan, I wanted to build a personal rapid transit system on campus to replace the buses. It was a futuristic way of solving our transportation problem.” - Google Co-founder Larry Page, from a University of Michigan commencement speech.

"This innovative system forms part of BAA's plan to transform Heathrow, improve the passenger experience and reduce the environmental impact of our operation through the development of cutting edge, green transport solutions. It offers a completely new form of public transport - one that will deliver a fast, efficient service to passengers and bring considerable environmental benefits, saving more than half of the fuel used by existing forms of public or private transport.” - David Holdcroft, BAA's PRT Manager

"PRT fits perfectly with public transit and high-speed rail. It is a brilliant solution to the first and last mile of travel, connecting people to the primary transportation lines. They also allow many people to have greater mobility, such as seniors, disabled people, and anyone else who cannot easily walk to transit.” - Rod Diridon, Executive Director of the Mineta Transportation Institute and a California High Speed Rail Authority board member.
1.5 ULTra PRT (the company) and ULTra the product

ULTra PRT is the 40-person company responsible for the ULTra system: ULTra PRT Ltd is the UK corporation and ULTra PRT Inc is the US corporation. Both the US and UK companies were previously known as Advanced Transport Systems, but name recognition for ULTra became much greater, so our corporate name changed accordingly. ULTra PRT (the company) is larger than the rest of the worldwide PRT industry combined.

As far as the transit “product,” this is the “ULTra system.” The term “ULTra” was formerly an acronym for “urban light transit,” but is now more of a standalone brand name for our ULTra system.

BAA is the privatized company that was formerly known as British Airports Authority. BAA owns or operates a number of airports, including London Heathrow. BAA is the majority shareholder in ULTra PRT Ltd. BAA has operating or concession contracts at number of US airports.

In turn, BAA is owned by Grupo Ferrovial. Grupo Ferrovial owns WW Webber, the eighth largest construction firm in Texas and Cintra, a financier of Texas toll roads.
Chapter 2: Main Campus Alignments

Topics covered within this chapter include: route alternatives, expansion options, benefits, and implementation. Chapter 4, Current Conditions, establishes the context for UT transportation and should be read first by those unfamiliar with UT and Austin.

2.1 Route Alternatives

Five of many possible PRT route alignments are shown in this section. The first (Alignment #1) traces the route of the current UT circulator bus system consisting of Metro Bus 642 WC (West Campus), 640 FA (main campus or Forty Acres), and 641 EC (East Campus) routes. The second utilizes a series of six alternative clockwise and counter-clockwise PRT loops. The third is a shorter version of the second, with different routing west-of-campus. The fourth avoids crossing east of I-35 and serves stations along East Martin Luther King Jr. Blvd. The fifth adds service to UTA (near the State Capitol) as adding back service east of I-35.

Laying out PRT systems is an iterative process that is optimized with brainstorming among stakeholders, transportation analysis, driving/walking of areas where the guideway may go, and viewing satellite imagery and maps.

Estimated capital costs for each of the first four alignments is roughly $104M. Annual operating costs are roughly $3.6M.

2.1.1 Alignment 1
Figure 2.1: Alignment 1

The first alignment follows the current WC, FA, and EC circulator bus routes. The PRT equivalent alignment has 7.2 miles of one-way guideway and 21 stations.

The table below presents comparison trip times for a trip from west-of-campus housing to the eastern UT campus border. The addresses used to calculate travel time via Google maps were:
- 910 W 26th St. to
- 1401 East Dean Keeton St.

Resultant trip times:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Trip Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRT</td>
<td>5 minutes</td>
<td>PRT takes a more serpentine route (2.4 miles) than driving, but avoids traffic &amp; stop lights. Trip length is 1.7 miles</td>
</tr>
<tr>
<td>Car</td>
<td>5 minutes plus parking</td>
<td>Considerable time spent parking at both ends. Trip length is 1.7 miles.</td>
</tr>
<tr>
<td>MetroBus</td>
<td>30 minutes</td>
<td>14 min 642 WC trip. 9 min transfer. 7 min 641 EC trip. Trip times calculated with Google Maps Directions by public transit</td>
</tr>
<tr>
<td>Walking</td>
<td>33 minutes</td>
<td>Trip time calculated with Google Maps Directions by Walking</td>
</tr>
</tbody>
</table>

Table 2.2a
PRT stations are positioned around the alignment with very short walking radii between stations. Most stations may be easily accessed with no more than a 300m walk from anywhere in the area.

### 2.1.2 Alignment 2

![Alignment 2 Diagram](image)

Input from stakeholders suggested a refinement of Alignment 1 into Alignment 2. PRT has a small 5m turning radius compared to the larger turning radius of 35-foot-long buses, so the PRT alignment was better able to serve the west campus, along a different route. This alignment has 8.0 miles of one-way guideway and 21 stations.

An alternating series of clockwise and counterclockwise PRT loops was developed for Alignment 2. This PRT layout style efficiently manages PRT merges and diverges (where two guideway segments either join or diverge from each other). This style was first seen in University of Washington Professor Jerry Schneider's six-loop downtown Bellevue PRT sketch concept created in 1994.
2.1.3 Alignment 3

Alignment 3 begins with Alignment 2, but then follows different north/south streets west-of-campus. This alignment has 7.2 miles of guideway and 20 stations.
2.1.4 Alignment 4

Alignment 4 avoids crossing east of I-35 and serves stations along East Martin Luther King Jr. Blvd. By serving East Martin Luther King Jr. Blvd., this alignment provides better access to the campus-owned iSchool block at 17th and San Antonio.

Capitol Metro previously studied a “loop the campus” LRT system. According to one power stakeholder, “Alignment 4 will be much superior to the previous LRT campus loop proposal.”

Figure 2.4.1: Alignment 4
2.1.5. Alignment 5

Further meetings with stakeholders resulted in Alignment 5. Alignment 5 adds service to UTA near the State Capitol as well as adding back in service east of I-35. There are also shorter ways to service these 25 stations, but this particular sketch alignment encompasses 9.3 miles of one way guideway:

![Figure 2.4.2: Alignment 5](image)

Figure 2.4.2: Alignment 5
2.1.6 Examples of where PRT will run at the edges of area streets

Multiple site visits (by car and foot) by the team have led to the conclusion that much of the civil engineering for the alignments is straightforward. The west-of-campus area features narrow streets and guideway will pass within close proximity of apartment windows. Chapter 8, Visual Impact, will explore aesthetic solutions for this area in depth.

Generally, PRT is well-suited for application within the existing UT streetscape. Some example street scenes follow, with explanations of where PRT will likely pass:

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**Figure 2.5: E Dean Keeton at Townes Hall, looking west. Run guideway on left hand side (LHS), on edge of grass. Red arrow shows possible route for column foundations.**

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**Figure 2.6: E Dean Keeton near Speedway, looking west: Plenty of room for guideway on either side. For pedestrian bridge, run above sidewalk & tuck under the bridge (or rise up over the ped bridge). Red arrow shows possible route for column foundations.**
Figure 2.7: 21st at University, looking east. Run guideway RHS, edge of parking. Red arrow shows possible route for column foundations.

Figure 2.8: MLK at I35. Run guideway adjacent to L or R edge of MLK. Red arrow shows possible route for column foundations.

Figure 2.9: E Dean Keeton crossing under I35, looking west.
2.2 Expansion Options

While the proposed Urban Rail system is expected to connect easily to PRT4UT, connecting to MetroRail Red Line at the MLK Jr station will require some additional guideway. One possible extension to MetroRail is shown below with new guideway shown with magenta color:

Such an extension to MetroRail would provide a significant benefit to neighborhoods east of Leona, providing low-cost, fast access to jobs, downtown shopping via the MetroRail Red Line, and enjoyable activities.

Figure 2.10: Magenta colored extension of third PRT4UT alignment to MetroRail MLK Jr station, adding 2.0 miles of one-way guideway and three stations. This is one of many possibilities for such an extension.

Stakeholder input regarding running PRT east of I-35:

- “In an attempt to run this system East of I-35, there is a need to include at several levels, individuals/leaders (more than one) from the African American community. UT has a mixed history engaging with the African American community east of I-35. There should be an intentional effort to include African American leaders early, possibly in the form of focus groups in neighborhoods affected by the PRT4UT.”

PRT4UT could also eventually be expanded south to the nearby State Capitol Complex and the series of parking structures on San Jacinto.
2.3 Benefits

2.3.1 PRT replaces WC, FA, EC circulator buses

PRT will eliminate the need for the MetroBus WC, FA, and EC circulator buses. However, PRT is not a conceptually simple replacement. WC, FA, and EC circulator buses represent very cost-effective buses with high daily ridership. PRT provides different benefits than the current bus system.

Unfortunately, for traditional transportation planning purposes, student value-of-time is calculated to be very low. A high level-of-service PRT system with significant capital costs cannot cost-effectively replace a high-ridership, moderate level-of-service circulator bus system with low capital costs. PRT is not a simple circulator bus replacement. The PRT business case must be made beyond transportation analysis, based on unearthing unique long-range planning or real-estate benefits that circulator buses cannot create. (In situations with high transit value-of-time, such as in moving surgeons between hospitals, PRT may be able to replace circulator buses, based solely on a transportation analysis.)

2.3.2 Benefits

“While PRT isn’t the only answer to Austin’s transportation challenges, it’s part of the solution. I only wish that UT had a PRT system when I was an undergrad.” – power stakeholder.

“A very attractive way to tile UT together.” – power stakeholder.

- Improves parking management
- Creates national cleantech leadership
- Accelerates UT’s strategy to have more students live closer to campus
- Increases the perceived size of main campus by shortening distances

*Improves Parking Management*

Parking is a huge challenge for main campus, and PRT provides much-needed flexibility. PRT facilitates staff/students parking on one side of campus when their main business is on the other side.

“PRT makes the parking garage system way more efficient. It enhances the value of the garage permit.” – power stakeholder.

“Austin is Number One:” Cleantech Leadership

PRT4UT will be an iconic, landmark development bringing worldwide attention to Austin/UT’s cleantech leadership. PRT4UT will be the first PRT system in the US and the world’s first University PRT system. Austin and UT thrive on innovation and leadership: “Silicon Valley is the Austin of the West Coast.” Stakeholders repeatedly connected PRT innovation with Austin innovation leadership.

PRT4UT will provide a recruiting advantage, riding on green concerns of undergrads, graduate students, staff, and professors. Given a choice between UT and another top school, the “coolness factor” of a PRT-enabled UT can tip the scales. The recent passage of the student green fee shows a willingness to “put their money where their mouth is,” and a more-than-superficial student interest in protecting the planet.
“Attractively, PRT4UT is designed and promoted as a clean technology. If implemented soon, PRT4UT would become the first PRT on university campus in the world, strengthening UT’s innovation leadership image.” – power stakeholder.

**PRT4UT is part of UT’s strategy of having more students live closer to campus**

PRT4UT supports a lower cost-of-living, car-free lifestyle close to campus, for existing and new housing developed in all directions around main campus. Students living closer to campus have more opportunity to spend time on campus, interacting with professors, staff, and classmates. UT studies have shown that such students have higher GPAs than students living farther away.

**Increases Perceived Campus Size**

PRT increases perceived main campus size by pulling campus areas on the edges inwards. Main campus is characterized as “built out,” because the campus is densely developed with few developable parcels. However, many UT departments would like to expand and modernize facilities to better serve their students. These departments are faced with challenging long-range master planning problems. PRT facilitates such long-range plans by providing added flexibility.

A student can participate in a class close to I35, finish that class, take PRT, and arrive in time for a class on main campus, *all in a clock time of less than 5 minutes*. Says one stakeholder, “PRT could enable dual degree students to make tight connections between classes.”

**Still More Benefits:**

- PRT reduces auto-dependence, energizing the continuing pedestrian-ization of campus.
- PRT makes MetroBus, MetroRail, Urban Rail, and carpooling more effective. PRT is the best “last mile” solution for other transit modes. While UT students and staff will be system PRT4UT “VIPs,” other Austin citizens will enjoy a very high quality PRT system experience as well, including during special events.
- Greenery-laden west-of-campus guideway will bring about aesthetic enhancement, creating a unique-in-the-world streetscape.
- PRT can be inexpensively and rapidly reconfigured over the years, in the modular style of Lego, accommodating changes in plans. Because of this flexibility, PRT is less risky than inflexible traditional capital-intensive transportation projects.
- PRT infrastructure construction is faster and less disruptive than typical transportation infrastructure projects. Once column piles are in place, then a four-person crew can erect a mile of pre-fabricated guideway in one week.
- PRT improves ADA access. The challenges of serving UT’s disabled population are growing, and PRT provides stigma-free premium service.
- The system is easily extended beyond UT. Inexpensive extensions can be easily made to MetroRail and the State Capitol Complex. As the system grows, new passenger synergies arise.
- PRT is a non-destructive implementation. UT’s roads, vehicular parking and pedestrian pathways are unaffected. PRT vehicles do not add to local congestion and do not consume road real-estate.
- PRT provides more reliable service than bus. Bus performance is sensitive to roadway conditions and therefore has large variations in travel time between peak and non-peak hours and under different weather conditions. PRT, which is grade-separated from other traffic, offers more consistent and reliable service.
- PRT4UT follows CAMPO’s 2035 “activity center” concept.
2.4 Implementation Highlights

While this PRT4UT Study Report provides a feasible project package with design considerations, travel demand forecast, and working business model, many more steps are required to move to an implementation. These steps include political, environmental, transportation, and civil engineering tasks.

A brief summary of PRT4UT implementation highlights follows:

To implement a PRT4UT system, a corporate Special Purpose Entity (SPE) will be formed to design, build, operate, and maintain the system. SPE member companies may include ULTra PRT Inc (a US company), Austin PRT, equity partners, and a large Texas constructor.

It is expected that Austin City Council will negotiate and grant right of way (ROW) / air rights for PRT guideway and stations on City of Austin land, similar to the granting of parking spaces for the car2go car sharing service.

We expect that UT students will win the Architecture Design Competition (detailed in Chapter 8, Visual Impact) and will design an aesthetically pleasing west-of-campus solution that most probably includes hanging plants and greenery intertwined with the guideway and stations.
Chapter 3. Pickle Research Center

UT’s Pickle Research Campus (PRC) is a very large parcel located about 7.2 miles northwest of main campus. UT’s Dr. Bob Harkins states that “…if reliable transit trip times of 20 minutes or less can be achieved, PRC may appear to have been pulled close enough to be part of main campus.” A PRC PRT connection to main campus meets the 20-minute test, so represents a compelling long-term opportunity.

If desired, it is possible to consider long-term increases in ULTra maximum vehicle speed, with the possibility to lower the trip time to 16, 14, or even 12 minutes. Speed increases require new engineering, testing, and safety clearances.

The PRT4UT system simulation (See Chapter 6, System Sizing) demonstrates significant transit capacity and a PRC PRT connection would also have very sizable capacity (for capacity explanation, please see Chapter 5, Capacity). As of now, only a few UT students take the bus between PRC and main campus, hence long-range planners contemplating a PRT-enabled PRC should envision a much larger student/staff back and forth flow to/from main campus.

Comparison of PRC to main campus transit trip times:

<table>
<thead>
<tr>
<th>Transit mode</th>
<th>Door-to-door trip time</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRT</td>
<td>Less than 20 minutes</td>
</tr>
<tr>
<td>PRC bus (Mopac)</td>
<td>24 mins + headway + first/last mi</td>
</tr>
<tr>
<td>Burnet-Guadalupe MetroBus Rt 3</td>
<td>35 mins + headway + first/last mi. BRT will help a bit</td>
</tr>
</tbody>
</table>

Table 3.1: PRC to main campus

A 7.2-mile, bi-directional PRC-to-main-campus PRT system might run primarily on Burnet Road, connecting to Guadalupe:
Figure 3.2: One concept to connect PRC to Main Campus with PRT
Such a system would utilize bi-directional guideway, similar to the bi-directional guideway segments used at London Heathrow ULTra:

An approximate capital cost for such a PRC to Main Campus system would be in the range of $120M.

“$120M to open up PRC is not unreasonable. We are land-locked. Opening up this land is worth a lot. $120M is the price of a building. It’s not out of the question. We build a lot cheaper at PRC than on main campus.” – power stakeholder.
3.1 PRC – Domain Circulator

Once PRT comes to PRC, then it can easily expand to serve MCC, The Domain, and IBM. A system sketch concept is shown in Figure 3.3. This PRC – Domain circulator connects jobs, shopping, housing, recreation, and academics. In addition, wider connectivity is enabled:

- A PRC – Domain PRT system provides a huge catchment area of potential riders for the MetroRail Red Line Kramer station.
- A PRC – Domain PRT system provides a huge catchment area of potential riders for the proposed Lone Star regional rail system, connecting Georgetown to San Antonio.

![Figure 3.4: PRC – Domain PRT Circulator sketch. MetroRail LRT shown in red, Lonestar rail in purple.](image)

The Figure 3.4 PRT sketch concept above encompasses 33 stations and 13 miles of one-way guideway, with a PRT station at MetroRail Red Line Kramer Station and a PRT station at Lone Star regional Rail Braker Lane / Domain Station. While ULTra used for purposes of circulation has a speed limit of 25 mph, a higher vehicle speed could be implemented for the PRC connection, reducing PRC to main campus travel time further.

A MetroRail red line LRT connection could be created between PRC and main campus. This red line trip would use the PRC – Domain PRT Circulator in the north and main campus PRT extended east to MLK Jr. Red Line station in the south. “Best case” trip times would be 25 minutes: 4 minute PRC PRT, 17 minute red line from Kramer to MLK Jr, 4 minute main campus PRT.
Chapter 4: Current Conditions

Topic areas covered within this chapter include: weather, the UT campus setting, special events, line-haul transit, and circulator transit.

4.1 Austin Weather

Austin has hot summers. In 2009, there were 70 days in a row with temperatures above 100 degrees Fahrenheit. PRT4UT system design must keep vehicles and passengers cool, with canopies for all vehicle berths providing proper shading. When vehicles are parked in berths they are electrically connected so that A/C can be maximized. The ULTra system is designed for hotter conditions in the Middle East, thus should meet Austin's hot weather requirements. ULTra guideway may also be modified to provide shade for pedestrians passing underneath on hot days.

Destructive hailstorms occur regularly, with some storms dropping golf-ball sized hailstones that break car windshields and dent vehicles. PRT4UT system design must include sturdy canopies to provide safe haven for all vehicles in the system during severe hailstorms.

Ice events occur once or twice per year. The ULTra “open grid GRP” guideway system has been designed for robust operation during such events, with most ice passing through the grid and any ice that affixes flaking off as vehicles go by. (Glass-reinforced plastic or GRP is a composite material made of a plastic matrix reinforced by fine fibers made of glass.) ULTra vehicle tires deform around the GRP grid, increasing traction under icy conditions.

4.2 UT Campus Setting

University of Texas has approximately 55,000 students and 15,000 university staff. No population growth is expected for the main campus over the next 21 years.

There are 15,000 parking spaces on campus for student/staff use. In the future, some surface parking spaces may be converted to structured parking, but the total number of spaces is expected to remain constant.

Ian Davis, Senior Regional Organizer, Sierra Club Central Region, and former UT student government President related the following about UT student attitudes (March 29, 2010 meeting):

- The students just passed a “green fee,” indicating a sincere green sentiment
- "UT is Number One with PRT" will be appealing to students, the students like the idea of UT being a leading university.
- PRT guideway as a rain shield for bikers/pedestrians would be appreciated.
- Feedback on the current circulator bus system: A) safety is an issue: buses are so full that students have fallen down. B) over-full buses cause waiting-at-bus-stop students to be late for class. C) Students want lower cost of living. PRT lowers the need for car ownership and therefore the cost of living. PRT provides better access to more affordable housing east-of-campus.
- Students who live closer to campus have a higher GPA, and PRT pulls students closer to campus.

Capital Metro’s James Gamez explains further that campus circulator bus ridership is not always balanced. “Some counterclockwise routes with hills have heavier demand in the AM than in PM (and vice versa). This is because some trips are slow and roundabout, so the walking alternative is preferred in one
direction. Likewise some trips require walking up hill, and the terrain motivates folks to prefer the bus over walking.” It is expected that PRT will generate a more balanced flow profile.

Under a 2004 Comprehensive Plan update, west-of-campus was re-zoned for higher density. This enabled a number of new apartments for student housing, most under the brand known as The Block. 40% of UT students now reside in this area.

East-of-campus has a strong neighborhood. UT has plans to possibly expand by acquiring parcels between I35 and Leona. UT has agreed to not grow east of Leona.

Figure 4.1: Home location plot of 18,000 close-to-campus students. Courtesy Capital Metro.
Figure 4.2: Home location plot for most UT students (48,000 out of 55,000). Source: Capital Metro.
4.3 Line-haul transit

A substantial line-haul transit system serves student/staff commutes to UT, including MetroBus, MetroRail, and proposed urban rail.

MetroBus

Average weekday commuter MetroBus ridership (not including WC, FA, and EC circulator bus) totals 31,000 passenger trips. The extensive MetroBus system is detailed in the following map:

Figure 4.3: Line-haul MetroBus service to UT campus. Courtesy UT Parking and Transportation.
To expand MetroBus service, federal FTA funding for Burnet Road MetroBRT (connecting Pickle Research Campus to UT main campus) has been approved.

**MetroRail**

MetroRail's 32-mile, 9-station Red Line is shown in the following map:
As the crow flies, MetroRail MLK Jr. station is 0.8 miles away from the envisioned PRT4UT system. One potential future connection would loop on Manor in one direction and circle back on MLK in the other direction, for a 2.0 miles of one-way guideway PRT extension. In the future, Red Line frequency and hours-of-service may expand, further motivating the need for a last-mile connection to UT.

**Planned Urban Rail**

City of Austin is in the process of developing a future urban rail / streetcar proposal, potentially brought to a vote via a 2011 ballot measure. One variation of the system is shown in blue in the image below:

![Figure 4.5: Urban Rail: Central Austin Circulator Exec Summary, 11/20/06. Courtesy Capital Metro.](Image)

*Figure 4.5: Urban Rail: Central Austin Circulator Exec Summary, 11/20/06. Courtesy Capital Metro.*
A second image of urban rail shows two north/south streetcar lines running along the east and west edges of UT campus:

![An expanded rail plan](image)

**Figure 4.6:** Statesman.com, 2/24/10, “Expanded ‘urban rail’ would run through downtown on both sides of Capital”

**Planned Lonestar Georgetown to San Antonio Regional Rail**

A portion of the proposed Lonestar regional rail system is shown below. Austin stations would include #6 – downtown Austin, #5 – 35th St. / MOPAC, and #4 Braker Lane / Domain.

This proposed regional system features:
- “Modern, safe, clean and comfortable passenger cars with amenities including wireless Internet access.”
- “90-minute express service from downtown Austin to downtown San Antonio, with stops in San Marcos and New Braunfels.”
4.4 Special events

Special events require transportation and promise to generate significant revenue for premium PRT service.

Darrell K. Royal Texas Memorial Stadium has been expanded by 4,525 permanent bleacher seats, raising home attendance to more than 100,000. There are about six Longhorn football games per year.
plus the well-attended state high school football championships. For Longhorn football games, a Park & Ride service including shuttle bus is provided for $8 per person. One popular parking lot is at 51st and the intramural fields. Another is at the Barton Creek Mall. “A PRT Park & Ride premium service could easily charge $10 or $15.”

The Frank Erwin Center has a flexible, two level layout of 16,000 for events, with a maximum configuration of 16,755 spectators. The center holds diverse events including concerts, Longhorn basketball, high school graduations, WWF wrestling, and private banquets. The Erwin Center also hosts the semifinals and finals of the University Interscholastic League boys’ and girls’ basketball playoffs in all five classifications. From 1977-2010, over 23 million attendees attended Erwin Center events, for an average of about 700,000 attendees per year. There are roughly 17 home Longhorn basketball games per year and roughly three concerts / special events per month.

Disch-Falk Field is the home of Longhorn baseball, with a capacity of 6,500. There are 37 home games on the 2010 Longhorn baseball schedule.

Between the three event facilities, more than 80 special events are held per year.

### 4.5 Circulation: WC, FA, EC

The campus bus circulation system consists of three popular MetroBus routes: 642 WC (West Campus), 641 EC (East Campus), and 640 FA (Forty Acres). Average daily ridership for 145 within-semester weekdays is 13,800.

The following four Capital Metro board/alighting charts help explain route ridership flows that were used to develop the PRT4UT origination/destination matrix. The first chart shows 642 WC:

![Figure 4.7: MetroRail 642 WC boardings/alightings. Courtesy Capital Metro.](image-url)
Route 642 is primarily used for travel to/from class from west-of-campus apartments. A secondary flow is travel between classes. Many line-haul commute buses terminate at the central campus transit hub on the chart’s RHS station shown with 1,380 daily boardings/alightings, where the aforementioned secondary flow may begin. A tertiary flow is for crossing campus, for example from north-of-campus apartments to classrooms on the southern side of main campus. These tertiary flows include trips from the southern Jester Center bus stop with both classrooms and apartments/dorms (with 2,428 boardings/alightings) to classrooms and apartments/dorms near northern bus stops on Dean Keeton (with 774 and 556 boardings/alightings). With the recent sharp increase in housing west-of-campus, west-of-campus to main campus transit ridership is expected to grow.

The MetoBus Route 640 FA boarding/alighting chart follows:

![Figure 4.8 MetroRail 640 FA boardings/alightings](image)

The primary role of 640 FA is transport students between classroom locations during the day. The secondary role is to transport students between apartments/dorms and classrooms.
MetroRail 641 EC boarding/alighting flows are shown via a pair of charts, the first showing the eastbound version of the route, and the second showing the westbound version of the route:
Figure 4.10: 641 EC westbound boardings/alightings

641 EC flows are primarily between parking by the baseball stadium and the main campus transit hub, shown with 793 westbound alightings and 628 eastbound boardings. A secondary use for 641 is for travel between classes.

MetroBus Circulator Peak Ridership

Annually, there are 215 days of WC, FA, and EC bus service:
- 115 full-service weekdays, Mon-Thurs
- 30 reduced-service Fridays
- 55 reduced-service summer semester days
- 15 reduced-service finals days

Full service weekday operation runs from 6AM to midnight.

The highest three-hour full-service weekday ridership period is 12 noon to 3PM:

<table>
<thead>
<tr>
<th></th>
<th>642 WC pax/day</th>
<th>640 FA pax/day</th>
<th>641 EC pax/day</th>
<th>totals</th>
<th>pax/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Peak: 6:00AM to 9:00AM</td>
<td>533</td>
<td>416</td>
<td>337</td>
<td>1,286</td>
<td>428.7</td>
</tr>
<tr>
<td>Midday AM: 9AM to 12 noon</td>
<td>1,831</td>
<td>1,804</td>
<td>656</td>
<td>4,292</td>
<td>1430.6</td>
</tr>
<tr>
<td>Midday PM: 12 noon to 3PM</td>
<td>1,828</td>
<td>2,155</td>
<td>641</td>
<td>4,624</td>
<td>1541.4</td>
</tr>
<tr>
<td>PM Peak: 3PM to 6PM</td>
<td>1,147</td>
<td>1,241</td>
<td>521</td>
<td>2,910</td>
<td>970.1</td>
</tr>
<tr>
<td>Evening: 6PM - midnight</td>
<td>204</td>
<td>268</td>
<td>229</td>
<td>702</td>
<td>116.9</td>
</tr>
<tr>
<td>Total</td>
<td>5,544</td>
<td>5,885</td>
<td>2,385</td>
<td>13,814</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.11: Representative weekday ridership data courtesy Capital Metro
From Capital Metro boarding/alighting counts from a week of service, for Wednesday, the highest ridership individual hour is 10AM to 11AM:

<table>
<thead>
<tr>
<th>Hour</th>
<th>Combined</th>
<th>Peak Horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>374</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>1,063</td>
<td></td>
</tr>
<tr>
<td>900</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>1,618</td>
<td>1,618</td>
</tr>
<tr>
<td>1100</td>
<td>1,296</td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td>1,450</td>
<td></td>
</tr>
<tr>
<td>1300</td>
<td>1,417</td>
<td></td>
</tr>
<tr>
<td>1400</td>
<td>1,139</td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td>1,028</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>968</td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td>669</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>745</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.12: Representative weekday ridership data courtesy Capital Metro

Within the Wednesday 10AM highest ridership hour, the peak 15 minute period is at 10:30AM, with 555 passenger boardings:

<table>
<thead>
<tr>
<th>Hour</th>
<th>Boardings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>262</td>
</tr>
<tr>
<td>1015</td>
<td>375</td>
</tr>
<tr>
<td>1030</td>
<td>555</td>
</tr>
<tr>
<td>1045</td>
<td>425</td>
</tr>
</tbody>
</table>

Table 4.13: Boarding/alighting data courtesy Capital Metro

Hence, PRT simulations that match WC, FA, and EC bus ridership should have capacity to service this peak quarter-hour flow.

MetroBus Circulator Costs

Capital Metro contracts to First Group for WC, FA, and EC. (“First Group is the world's leading transport operator, moving more than 2.5 billion passengers every year.” One of ULTra PRT's board members, Trevor Smallwood, was the CEO of First Group.) MetroBus WC, FA, and EC circulator annual costs are provided in the separate, confidential PRT4UT business model spreadsheet.
Chapter 5: Capacity

PRT capacity consists of multiple dimensions: vehicle capacity, loop capacity, and station capacity, with various technologies and operational techniques that impact loop and station capacity. In comparison to bus and light rail transit (LRT) systems, PRT capacity is surprisingly high.

5.1 Capacity per PRT vehicle

Each spacious ULTra vehicle holds 1,100 pounds of travelers, backpacks, duffle bags, and brief cases. For UT, this translates into three offensive linemen and a placekicker:

Figure 5.1: Three offensive linemen and a placekicker total to less than 1,100 pounds

When children are involved, more than four people can fit into ULTra vehicles:
5.2 Capacity per PRT “loop”

A PRT system may have multiple interconnected loops, increasing system capacity. For UT, one loop could connect students west-of-campus to main campus and a second loop could connect east campus to main campus. This set of two interconnected loops would have roughly double the capacity of a single PRT loop.

Typical PRT capacity calculations are provided below. 20% of vehicle movements are predicted as empty vehicles moving to stations where passenger demand is located. PRT headways will begin by being “large” (6 seconds) at Heathrow and will progressively be lowered.

<table>
<thead>
<tr>
<th>Headway (seconds)</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>vehicles per hour (20% are empty)</td>
<td>720</td>
<td>960</td>
<td>1140</td>
<td>2880</td>
</tr>
<tr>
<td>4 passengers per vehicle</td>
<td>2880</td>
<td>3840</td>
<td>5760</td>
<td>11520</td>
</tr>
</tbody>
</table>

Table 5.3: PRT capacity per loop per hour

5.3 PRT Headway Influences Loop Capacity

Headway is a measurement of the distance between vehicles in a transit system. Headway is measured as the distance from the tip of one vehicle to the tip of the next one behind it, expressed as the time it will take for the trailing vehicle to cover that distance. A shorter headway signifies a more frequent service. Freight trains might have 15-minute headways. Metro rail systems operate with headways on the order of 1 to 5 minutes. Cars on a freeway have smaller headway, as little as 0.6 seconds.

For a low-capacity PRT system such as ULTra London Heathrow Phase I (2.2 miles of guideway, 21 vehicles, 3 stations) 6.4 seconds headway is sufficient. The current ULTra traditional fixed block fail-safe system (such as is used in many rail systems) accommodates lowering of headways to 3.0 seconds. The ULTra fixed block fail-safe system is called Automatic Vehicle Protection or AVP. For 2.0 second headways, ULTra will use forward-facing, scanned, multi-layer LIDAR distance-keeping, using the same automotive sensor system found in luxury sedans providing stop and go adaptive cruise control with obstacle detection. (LIDAR - Light Detection And Ranging - is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target.) LIDAR sensing provides both distance and velocity information about obstacles in the forward path, allowing for modulation of emergency braking rate to the minimum required to prevent collision, to further reduce the risk of passenger unseating during emergency braking. ULTra 2.0 second emergency braking works in both dry and wet conditions.

In railroad practice, the minimum headway between trains is determined by the condition that, if one train stopped instantaneously, the train behind can stop before a collision occurs. This is called a “brick-wall stop.” Current American Society of Civil Engineers (ASCE) Automated People Mover (APM) Safety Standards require sufficient PRT headway to meet the brick wall stop condition. In the case of the technologically-advanced but commercially-unlucky Cabinentaxi PRT system developed in Germany in
the 1970’s, headways were set to 1.9 seconds because the developers adhered to the brick-wall criterion. The ASCE APM standards are expected to relax the brick wall criteria over time as proof of PRT safety is demonstrated. For 2.0 second headways, a 0.5g emergency stop is used for the trailing vehicle to stop before hitting an instantaneously stopped vehicle. The ULTra system can achieve this emergency stop under wet or dry conditions.

Cars traveling on freeways do not follow the brick wall stopping criteria, following more closely than the brick wall stopping distance. Young drivers are comfortable at 0.7 second headways (62 feet nose to nose at 60 mph – more than three cars fit in between vehicle pairs), older drivers are comfortable with 0.9 second headways. When the headway between a pair of cars goes beyond 1.1 seconds, other drivers are likely to cut in between the vehicle pair. The freeway driving “safety concept” is that leading vehicles do not instantaneously stop, but instead apply brakes for more gradual stops, allowing sufficient time for the trailing vehicle to safely stop.

Relaxation of the ASCE APM Safety Standards brick wall stop criteria is envisioned over time, as reliable PRT operation is proven in revenue service. The ASCE APM Safety Standard will progress in measured, thorough, conservative, gradual steps. To further reduce ULTra headways, vehicle-to-vehicle radio communication will be combined with forward-facing LiDAR.

### 5.4 PRT Capacity per Origination Station Berth

In March of 2010, ULTra PRT (the company) demonstrated 48 passengers departing from the 4-berth London Heathrow Terminal 5 station in 5 minutes, for an hourly capacity of 576 passengers. This is the current PRT world record outbound-from-a-station. Because of expected low demand, the Heathrow Terminal 5 ULTra station is unoptimized for high outbound capacity.

The general rule for outbound ULTra station capacity is:

<table>
<thead>
<tr>
<th>Capacity per berth, 30 second load/unload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle reservoir just upstream of station</td>
</tr>
<tr>
<td>berths</td>
</tr>
<tr>
<td>trips/hour</td>
</tr>
<tr>
<td>passengers/hour</td>
</tr>
</tbody>
</table>

*Table 5.4: PRT outbound capacity per vehicle berth*

Full-optimized stations may be required with vehicle storage just upstream from station berths as well as with waypoints for vehicles within the station configuration. Under these conditions, a new vehicle may arrive at a berth every 22 seconds:

<table>
<thead>
<tr>
<th>Capacity per berth, 22 second load/unload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full optimized station configuration</td>
</tr>
<tr>
<td>berths</td>
</tr>
<tr>
<td>trips/hour</td>
</tr>
<tr>
<td>passengers/hour</td>
</tr>
</tbody>
</table>

*Table 5.5: Optimized PRT outbound station capacity per vehicle berth*

User research conducted by leading human factors consultant Davis Associates has shown that familiarity with the ULTra system brings boarding times down significantly. Boarding time includes the destination selection process, which can be minimized through a well-designed fare gate interface. Also,
UT students will carry minimal luggage, further reducing boarding time compared to airport PRT applications.

### 5.5 PRT Capacity Compared to a 48-seat Bus

If we compare a 4-berth PRT station (with 30 second vehicle cycle) with a bus stop for a 48-seat bus, 48 PRT seats go through the PRT station every 90 seconds. Hence a 4-berth PRT station is similar to a bus stop with another bus every 90 seconds.

Comparing PRT main guideway capacity at 2 second headways with a bus system with 48-seat buses, 48 PRT seats (padded for 20% empty vehicles) go by on the main guideway every 30 seconds, for the equivalent of one bus every 30 seconds on a route.

It is important to note that the social expectation to share rides increases with the length of PRT station queues, so delivered PRT capacity increases with passenger demand.

### 5.6 PRT Capacity Compared to a two-car (100 seats per car) LRT train

If we compare a 4-berth PRT station (with 30-second vehicle cycle) with an LRT station for an LRT system with two-vehicle trains consisting of 100-passenger vehicles, 200 PRT seats go through the PRT station about every six minutes. Hence a 4-berth PRT station is similar to an LRT station operating with 6-minute headways (e.g. an LRT train stops at the station every six minutes).

Comparing PRT main guideway capacity at 2-second headways with the two-vehicle LRT system with 200 seats per train, 200 PRT seats (padded for 20% empty vehicles) go by on the main guideway every one minute forty seconds (1:40). Hence, for main guideway, a PRT system with 2-second headways provides more capacity than a two-vehicle train LRT system operating at 2-minute headways.
5.7 Operational Techniques to Increase Station Outbound Effective Capacity

During peak hours, increasing the average occupancy of vehicles is helpful. Various operational techniques exist to increase occupancy by encouraging ridesharing. In bustling ski chair lift lines, “singles lines” are used to fill up unused seats on chairs to increase occupancy.

![Figure 5.6: Ski chair lift lines move faster when singles lines increase average occupancy](image)

The same singles line technique may be utilized for PRT. For a special event exit from Texas Memorial Stadium to parking at Disch-Falk Baseball Stadium, an outbound station berth might be dedicated to the baseball stadium. A family queuing line and a separate singles line may be deployed for this berth, with a social expectation that each vehicle will have four passengers.

Outbound station human factors are important to ensure that singles lines function smoothly. Electronic signage/displays and queuing shoe/footprints on the floor are important to guide passengers and to create the ridesharing expectation.

![Figure 5.7: Foot/shoe prints on the station floor guide queues to maximize vehicle occupancy](image)

Displays may also be helpful in setting expectations for average waiting time before boarding and in providing diverting content for impatient football fans. Examples from resort operators such as Disney and airport operators such as BAA provide ample examples of well-designed queue management processes. Such processes must be designed, tested with simulated passenger trials, and then refined.

No transit system can whisk away the Texas Memorial Stadium crowd in one minute, but a well-designed PRT system can provide a very pleasant end-of-game travel experience and can be an important part of a world-class, multi-faceted football game transportation solution.
Chapter 6: System Sizing and Capacity Analysis

ULTra is a computer-controlled system that automatically adapts to – and even predicts – passenger demand. The program which ULTra PRT (the company) uses to operate the system can be also used to design the system, functioning as a high-fidelity simulator. ULTra PRT is thus able to simulate and accurately predict system behavior before construction begins. This allows the customer to understand how the system will be operated; what level of service this will give PRT users, and at what cost; and what demand levels can be accommodated in the future. Simulation also allows ULTra PRT to determine sensitivity to design risks, especially those concerning demand prediction accuracy.

ULTra PRT currently regards key design targets as being the average time users spend waiting at a PRT station, the maximum waiting time assured for 90% of journey requests, and the maximum overall demand level for which these waiting time targets can still be met. These design targets are applied for peak or special demand conditions to ensure that the system provides a high level of service at all times. The ULTra simulators provide the necessary feedback with respect to network topology and vehicle fleet size to ensure that these targets can be met. The ULTra simulator is highly detailed – accounting for everything from individual passengers once they enter the station to the charge state of the batteries on-board the vehicle – ensuring no hidden factors will hinder system performance.

ULTra PRT has produced an initial PRT4UT network layout, including guideway alignment and station locations. ULTra PRT has modeled the initial PRT network on a combination of the three UT MetroBus circulator routes – 640 FA, 641 EC and 642 WC. This guideway layout may change slightly through subsequent design studies, however is expected to remain similar in terms of guideway length, number of stations, and station locations. Using the three UT MetroBus circulator routes as a basis for the PRT network will allow for more accurate station and fleet sizing, and thus more accurate costing based on the current demand for transit in and around the UT campus.

ULTra PRT designs PRT networks to ensure high service levels (low waits) for passengers traveling in the busiest hours, and so have simulated PRT operations under worst-case expected demand conditions in order to determine required station sizes and vehicle fleet size. Simulations have also been used to understand the effects of increased demand levels, accounting for potential latent demand and general upward trends in transit around the UT campus area. ULTra PRT plans to ensure that the PRT network provides sufficient capacity to accommodate transit demand in the long term.

ULTra also understands that the use of parts of the campus will change over time, and that transit patterns and behavior will adapt to new developments and transit services into and out of the main campus area. The routing of the network and use of stations must be flexible, providing sufficient capacity overhead to allow for variation in transit behavior.

Sizing estimates have been used to provide initial estimates on capital and operating costs for the PRT4UT system.
640 FA - Forty Acres: Circulates traveling clockwise around campus on San Jacinto, 21st, Guadalupe, Dean Keeton, Robert Dedman and 23rd.

641 EC - East Campus: Circulates between UFCU Disch-Falk Field, the parking lots east of IH-35, and main campus. Stops at Disch-Falk, Red River/MLK, Clyde Littlefield/Red River, Robert Dedman/23rd, and San Jacinto/23rd, San Jacinto/Dean Keeton, Dean Keeton (School of Law), Dean Keeton/east of IH-35, Lafayette/Manor, Comal/Manor.

642 WC - West Campus: Circulates traveling counter clockwise, stopping at San Jacinto/23rd, Dean Keeton/Speedway, 27th/Whitis, 26th, San Gabriel, 22nd, and 21st.
6.1 System Sizing for Daily Peaks

The system has been simulated with Origination/Destination (O/D) demand figures produced using Capital Metro ridership data and population density data obtained from Capital Metro. With no direct O/D demand data, ULTra PRT has worked collaboratively and iteratively with Capital Metro to develop O/D matrices. ULTra PRT regards this approach as suitable for initial system sizing. In later studies, overall demand conditions should be determined via an Origin-Destination survey of the affected area, establishing overall demand patterns/levels and their sensitivity to walk distance, waiting time, transit time, and fare price. This data would then be fed into a transit-planning tool for determining the ridership for the PRT network.

ULTra PRT has inputted the initially proposed PRT network into their simulation design tool. This simulates everything from individual passengers once they enter a station to the charge state of the batteries on-board each PRT vehicle. Simulations feedback passenger waiting time statistics, which are used to rate a particular system configuration. ULTra PRT has developed an O/D demand matrix with Capital Metro which specifies mean demand rates between all PRT station pairs during the worst-case peak hour. ULTra PRT has then iterated the system design – including station sizes, vehicle fleet size, and vehicle buffers and holding lanes – using simulations of the worst-case peak demand to ensure that target passenger services levels are met.

ULTra PRT has sized the vehicle fleet and stations so that mean passenger waiting times remain under 30 seconds, and 90% of passengers are served in less than one minute. This target represents a very high level of service, relative to existing modes, with passengers rarely having to wait for service. Subsequent studies should determine whether there is economic justification for relaxing these service level targets.
The ULTra PRT simulator provides feedback on recommended power requirements (assuming battery-powered vehicles for this study). Having undertaken simulation studies on a number of similarly sized networks, it is expected that the PRT4UT system will work best with LiIon batteries.

ULTra PRT has assessed the impact of increased demand levels for the worst-case peak hour, indicating that the network is capable of accommodating peak demand well above projected levels.

### 6.1.1 Demand Analysis

Capital Metro has provided averaged demand profiles for each day of the week during full service (see Figures 6.4, 6.5, and 6.6). This data suggests that the busiest hour along all three routes is typically 10:00-11:00AM on a Wednesday. We also see peaks-within-peaks, mostly due to hourly class schedules. Note that Mon/Wed/Fri schedules are hourly; Tue/Thur classes are 90 minutes.

Overall ridership for 640 FA and 642 WC routes are similar, however demand on the 642 WC route is likely to be heavily tidal in the morning peak hour, with the majority of students travelling from WC residences (see Figure 6.7) to the main campus area. Demand is expected to become less tidal throughout the rest of the day as students commuting from WC residences mix with students travelling around campus and students returning from the main campus area to WC. While the mid-day demand levels are as significant as the morning peaks in terms of peak-within-peak demand level, it is expected that the flow would be relatively balanced, and is therefore less of a concern for PRT planning purposes. The morning peaks are expected to place the heaviest load on PRT vehicle movements; here, the vehicle fleet must be large enough to transport students travelling in a particular direction and have enough spare vehicles to continually resupply the origin stations.
640 FA sees the largest spikes in demand during the morning peak, with demand averaging out at 1600 passengers per hour over the hour, and with 15-minute peaks hitting 2200 passengers per hour. The demand distribution would be most likely dominated by student movements from the Jester Center, and other dormitories such as Roberts Hall, Goodall Wooten, Dobie Center, Castilian, and Scottish Rite, to the rest of the main campus area (see Figure 6.7). There will most likely be a level of demand from students based north of campus, who may walk, or come in on FW, IF or PRC bus services, and then use the 640 FA. Given the clockwise direction of travel, and the relative population densities shown in Figure 6.7, the trip bias during a typical morning peak is likely to be from south to north and from west to east during the morning peaks. Later on, demand is expected to distribute more evenly around the FA loop, as students commute both to and from classes. It is expected that the lunch-time rush will create a bias towards PRT stations near refectories such as the Campus Café in the north, and to the west side of the main campus, where the majority of restaurants and shops are situated. However, there is little data to support these demand scenarios, so ULTra PRT has focused on the morning peak, where demand is likely to be dominated by population spread.

641 EC has relatively low demand. This service is thought to link EC residences across I-35 to the main campus area. Morning peaks are likely to exhibit tidal flow, with most trips from east of campus to the main campus area.
Figure 6.6: 641 EC – Wednesday Ridership Average by Trip - Fall 2008

Figure 6.7: UT close-to-campus student residential location overlaid with PRT4UT Alignment 1.
6.1.2 Origin-Destination Demand Model

In collaboration with Capital Metro, ULTra PRT has used UT MetroBus circulator ridership data, UT student population data, and boarding/alighting data to develop a typical worst-case morning peak hour O/D matrix. The 10:00-11:00AM peak hour has been simulated with an overall demand level of 2070 passengers per hour. This has been set higher than the average demand for this peak to better represent those passengers arriving during the peaks within peaks; however, is set just short of the localized spike in demand to avoid over-designing the system. The O/D demand model used to produce this O/D matrix apportions the 2070 passengers per hour between particular groups of O/D station pairs. Within each group, demand is distributed evenly between the specified O/D station pairs.

The apportionment of demand between key O/D station groupings is shown in Figure 6.7. These key demand groups are expected to account for roughly 70% of the worst-case morning peak demand, with the remaining 30% split between remaining logical O/D pairs – mostly those found east of campus.

![Figure 6.7: Key WC and FA demand trends during the worst-case morning peak (courtesy of James Gamez, Capital Metro).]
In subsequent studies to finalize the system design, further refinement of the demand profiles (via the use of an Origin-Destination surveys) will provide added robustness to the predicted demand conditions. In subsequent studies, peaks-within-peaks will be modeled explicitly, and the distribution of demand within each group of O/D station pairs will be appropriately fine-tuned.

<table>
<thead>
<tr>
<th>From</th>
<th>WC1</th>
<th>WC2</th>
<th>WC3</th>
<th>WC4</th>
<th>Castilian</th>
<th>FA1</th>
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<th>Jester</th>
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Figure 6.8: O/D matrix, showing the average number of passenger trips per hour between all O/D station pairs.

6.1.3 Static Analysis

The network layout and peak hour O/D matrix have been fed into the ULTra PRT simulation tool and analyzed for station throughput, average trip time, and peak guideway loading.

Station throughput

The resulting O/D matrix has been used to suggest initial station sizes as a starting point for subsequent iterations of development and simulation. With relatively low throughput at WC stations, 2-berth, serial-berth design may be appropriate; whereas FA stations will require 4-berth, saw tooth configurations for handling higher throughput. (Serial berth stations are first in, first out. Sawtooth stations provide random departure order.) EC stations can use 2-berth, serial-berth stations. These suggested sizes do not account for the needs of special events, which would inevitably require more berths at Stadium, Stadium2, Erwin Center and Baseball stations.
Average trip time

Table 6.1 indicates that the average trip time during the morning peak hour will be approximately 4.5 minutes, with the furthest trip lasting approximately 11 minutes. Here, we see that empty vehicle flow is relatively high during the peak hour to accommodate tidal flow conditions.

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</thead>
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<th>All</th>
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</thead>
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Table 6.1: Static analysis summary

Capacity analysis

The ULTra PRT simulation tool has been used to assess guideway capacity utilization. Examining one of the simulation runs with a 3-second headway, the maximum load on a section of guideway is 731 veh/hr, using 60% of the guideway capacity. This provides some headroom for increased demand levels; however as guideway utilization reaches 100%, passenger service levels suffer; ULTra PRT would not recommend guideway utilization of above 80% except during short periods of extreme tidal flow.

With a 2-sec minimum headway, the guideway is only at 41% utilization, providing significant headroom for up to a 100% increase in overall demand level.
This estimate on capacity is conservative as it relates to the worst-case morning peak demand scenario. This network allows for considerable increases in demand around the EC loop, and between EC loop and FA loops. This capacity overhead will become important for managing special events at the Memorial Stadium, baseball ground, and Erwin Center.

![Image of the ULTraPRT system]

**Figure 6.10: Peak hour guideway loading**

### 6.1.4 Simulation

The ULTra PRT simulator has been used to analyze network designs as they iterate towards a desirable solution. This section details the simulation method and assumptions.

**Ridesharing**

ULTra PRT simulations assume a mean of 2 passengers per ride. ULTra PRT simulations offer the opportunity to include ridesharing when passengers arrive at the same station intending to travel to the same destination. This is found to provide a valuable benefit in some situations, for example during peak periods at airports. Here, strangers meet at the stop and discover that they wish to travel to the same destination. Ridesharing in a university campus will reflect a different social dynamic. Here, it is likely to result from friends or colleagues discussing the possibility of ridesharing when they plan their trip and then forming a group prior to arriving at a stop. It is also believed that the ULTra system will encourage additional ridesharing through the well-designed fare gate interfaces.

The present results have not simulated ridesharing explicitly; other than by scaling the average demand matrix according to the average of 2 passengers per ride. Further information on passengers’ ridesharing habits would be needed for a more detailed approach.

If queues develop at peak times there is a natural tendency to ride share. This means that the PRT system automatically provides a higher capacity under peak conditions. This can be encouraged by active measures such as signage. These will be the subject of separate recommendations during full system design.
**Vehicle headway**

Simulations have been run with a 6-second, 3-second and 2-second minimum vehicle headway. Please refer to Section 5.3 in Chapter 5 on headway for further details.

**Empty vehicle buffers**

For stations with high outbound demand, holding a number of empty vehicles just upstream of the station berths allows for rapid response to spikes in demand.

Besides Operations and Maintenance Facility vehicle storage, empty vehicle storage buffers are either stand-alone upstream buffers which may serve multiple downstream stations or in-station storage in larger stations.

Further study will be required to accurately determine empty vehicle buffer sizes and locations. This will require a more refined assessment of the demand patterns and scenarios expected for the PRT4UT system.

**Power usage**

For assessment of vehicle power requirements, simulations have assumed a travel cost of 0.003 Ah/m and an idle cost of 10 Amps. Idle cost accounts for power consumption for systems other than for vehicle propulsion (e.g. heating, air-conditioning, and onboard computer).

This idle power consumption considers the intermittent use of heating and air-conditioning units as a result of the vehicles' power management and temperature control algorithms.

**Battery charging**

Simulations assume that all berths and empty vehicle storage buffers have battery chargers.

### 6.1.5 Peak Hour Sizing Results

**For 2070 passengers per hour**

Simulations of the Option 1 network suggest that, for 2070 passengers per hour during the worst-case morning peak, a fleet size of 180 vehicles is necessary to provide a high level of service to passengers traveling during this time. This includes a 10% (18 vehicle) overhead for planned maintenance and inspection.

The required number of berths at each station is shown in Table 6.2. The number of berths for a particular station has taken into account the predicted occupied vehicle throughput and the desired pattern of empty vehicle movements in accordance with Empty Vehicle Management (EVM). The relatively low throughput at these stations requires relatively few berths. With the need for only 2 berths at each WC station, ULTRA PRT would suggest a serial-berth configuration to minimize station footprint, visual intrusion, and cost.

<table>
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<tr>
<th># BERTHS (2070 PAX/HR)</th>
<th># BERTHS (3300 PAX/HR)</th>
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<td>WC2</td>
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<td>WC3</td>
<td>2 serial</td>
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<tr>
<td>WC4</td>
<td>2 serial</td>
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</table>
Table 6.2: PRT station berth sizes for expected level and increased level of demand during the worst-case morning peak hour. Stations are “parallel” berth stations unless otherwise stated.

### For 3300 passengers per hour

The system can easily accommodate 3300 passengers per hour with the worst-case morning peak demand pattern. Simulations of 3300 passengers per hour with the same trip distribution require a fleet of 240 vehicles (including 10% maintenance overhead) to ensure high service levels. This has shown the initial network design to easily accommodate current worst-case demand scenarios, with enough headroom to accommodate demand levels over 50% higher than currently expected levels.

For this higher level of demand, WC and FA stations become marginally bigger, however EC stations can remain small. Serial-berth stations would be an option for EC stations.

### Power requirements

ULTra PRT has conducted a preliminary analysis of the 2070 passengers/hr and 3300 passengers/hr demand scenarios to suggest the minimum battery specification required to maintain vehicle charge and ensure high vehicle availability during the peak periods. From the analysis, we conclude that ULTra lithium-ion battery propulsion is well suited for PRT4UT.

### Stadium, Baseball and Erwin Center Stations

These station sizes have not been specified here since they are driven by demand during special events. With the requirement for handling large pulses in demand, empty vehicle buffers in and around these stations will be necessary for providing a high level of service.
6.2 Sizing for Special Events

The Darrell K Royal-Texas Memorial Stadium, Frank Erwin Center and Disch-Falk Field together host more than 80 special events per year. Much of the parking on game days is done in the garages all over campus (see Figure 6.11), and many take the bus to the stadium. In addition to student access, the proposed PRT network could play an important role in connecting general off-site parking with the stadium; particularly those parts of the system which follow the 641 EC and 640 FA routes. These special events would create large pulses in demand before and after an event with strong tidal flow conditions; that is, where all passengers originate or terminate at a single station (or zone). The ULTra system can move up to 5,760 passengers per hour along a single PRT loop. With multiple loops serving car parks both east and south of the stadium, ULTra would be capable of providing an efficient park-and-ride service, replacing some special event bus routes.

As a park-and-ride system for special events, PRT stations around the Memorial Stadium, Erwin Center and Disch-Falk Field sites would have to be expanded to allow for high throughput and accommodating crowds. While the initially proposed PRT network does not explicitly suggest, there is huge potential in integrating PRT stations and guideway with the parking structures, allowing PRT vehicles to infiltrate car parks and avoid crowd congestion.

Figure 6.11: Football parking
6.2.1 Capacity for Memorial Stadium Demand

ULTra PRT (the company) has simulated tidal flow from the stadium PRT stations (Stadium and Stadium2) to stations thought to serve the surrounding car parks. Demand has been apportioned using relative car park capacity figures. Simulations have been used to understand what portion of the Stadium’s capacity could be served in an hour by the vehicle fleet size currently envisaged for normal daily service (180 vehicles). An analysis of station throughput has been used to suggest stadium PRT station sizes.

With 180 vehicles in the fleet, the network can capacitiate just over 4,000 passengers leaving Memorial Stadium per hour. The capacity for demand into the Stadium stations is slightly higher, due to the topology of the network. ULTra PRT has assumed an average of 4 passengers per vehicle, where passengers are encouraged to ride share with others travelling to the same destination. This should certainly be possible for trips to Memorial Stadium, where all passengers share the same destination, however trips from Memorial Stadium will require enhanced station designs to promote ridesharing and ride-share group formation. Here, the system requires 5 berths at each stadium station (Stadium and Stadium2) to process this many passengers.

With 240 vehicles in the fleet, the network can serve 5,760 passengers per hour under these tidal flow conditions. The same assumptions on ridesharing apply. Here, 6 berths are required at each stadium station (Stadium and Stadium2).

6.2.2 Erwin Center and Disch-Falk Field

The Memorial Stadium event scenario has been used to project the likely capacity of the system under tidal flow conditions. The Frank Erwin Center and Disch-Falk Field will produce similar tidal demand scenarios, and will require PRT stations of a similar size to Stadium and Stadium2. Further work should evaluate capacity limits relating to each anticipated special event scenario. The decision to expand these stations, or even add additional stations to manage high throughput and crowd congestion, should be considered with respect to overall requirements for the PRT4UT system.
Chapter 7: Infrastructure

ULTra infrastructure encompasses guideway, stations, an operations/maintenance facility, and vehicles. A PRT4UT system costing is provided. Implementation responsibilities are explained.

All guideway, station, and maintenance facility construction materials will be sourced locally.

7.1 Guideway

7.1.1 Guideway Description

For PRT4UT, all guideway is expected to be elevated and made of precast concrete. Expected elevated guideway headroom is 16’, although City of Austin might allow 14’ in some locations.

![Figure 7.1: Typical one-way elevated guideway cross section](image)

One-way guideway is roughly a two-meter-wide trough, comprising a flat floor with a central cable tray and 18” high “kerbs.” The guideway is unpowered. For London Heathrow, elevated ULTra guideway structure is made of steel, with a precast concrete running surface for the rubber-tired vehicles. The standard Heathrow span length was 18m, with some spans reaching 36m long.

The guideway is of lightweight construction due to the low overall loading (British Standard for floor loading is 5kN/m2, ULTras loading is 2.2kN/m2). This low overall loading also allows the vehicles to run on existing building floors without significant strengthening or modification. Cantilevering off the sides of new buildings is also enabled. For London Heathrow, at-grade guideway has an asphalt running surface with concrete kerbs.

Various other guideway solutions are available, including “cut and cover with glass” in a culvert, shown below. With this treatment, station guideway may be brought up to grade for simplified pedestrian access. As far as the passenger experience, elevated guideway may provide a better view, providing more of a “transportainment” experience.
7.1.2 One-way Guideway Dimensional Requirements:

The guideway consists of a flat running surface, a minimum of 1.7-m wide, with 25-cm kerbs on either side. It can be built from any material. The kerbs must be constructed to within ± 2 mm of their intended locations.

The profile shown above, if constructed of precast concrete, should be sufficient to span 20 meters. Longer spans can be achieved by creating outer beams deeper than the standard 0.45m.

7.1.3 Structural Requirements

In station areas, the structural live load on the guideway is 3.5 kN/m (distributed as 13 kN loads at 3.7-m intervals). On guideway spans, the design load is 2.2 kN/m (typically distributed as 13 kN loads at 10-m intervals, with an allowance for 21 kN loads in the event of a vehicle-recovery scenario).
Deflections under maximum live loading shall not exceed the span length / 200.

### 7.1.4 Standardized Curves

The guideway must be widened on curves, according to the specifications below.

<table>
<thead>
<tr>
<th>Vehicle Path Alignment Radius VPA (m)</th>
<th>Inner Kerb Face Radius Ri (m)</th>
<th>Outer Kerb Face Radius Ro (m)</th>
<th>Guideway Width (m)</th>
<th>Front Axle Centre Radius LRA (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>24.177</td>
<td>25.888</td>
<td>1.711</td>
<td>25.069</td>
</tr>
<tr>
<td>20</td>
<td>19.171</td>
<td>20.909</td>
<td>1.738</td>
<td>20.086</td>
</tr>
<tr>
<td>12.5</td>
<td>11.654</td>
<td>13.469</td>
<td>1.816</td>
<td>12.638</td>
</tr>
<tr>
<td>10</td>
<td>9.142</td>
<td>11.007</td>
<td>1.885</td>
<td>10.172</td>
</tr>
<tr>
<td>5</td>
<td>4.083</td>
<td>6.169</td>
<td>2.086</td>
<td>5.335</td>
</tr>
</tbody>
</table>

*Table 7.4*

### 7.1.5 Junctions

Junctions are characterized by one or both guideway paths being a non-circular arc (typically a cornu spiral). Although there will be a number of different junction configurations, each configuration should be replicated enough to order in bulk quantities.

### 7.1.6 Vertical Transitions

Vertical transitions occur at stations and grade changes. These are circular arcs with radii ranging from 40 to 440 meters.
7.1.7 Dual Guideway

The dual guideway is used for bi-directional traffic:

![Figure 7.6](image)

7.1.8 Safety Railing

Emergency safety railing is required for safety of maintenance personnel and for emergency evacuation. A visually minimized safety rail is desirable – a simple pipe column welded to the guideway beam, with tensioned wire cables and a top handrail. The railing must be able to withstand a horizontal force of 0.74 kN/m.

![Figure 7.7](image)

The safety railing used for ULTra London Heathrow is not visually appropriate for Austin as the visual impact is too large:
7.1.9 Type ‘B’ – Precast Concrete w/ GRP Open Grid

This guideway type consists of monolithic precast spans, with concrete joists spanning between the two primary beams, approximately every 2 meters on-centre. These joists are then covered by a structural polycarbonate mesh panel (glass reinforced plastic or GRP). The dimensions of the grid: interior opening square dimension is 1 3/16”; the GRP is 1/4” wide; depth is 15/16.” The guideway is fully permeable, so no gutters are required. Robust tie downs are required for each polycarbonate panel.
Figure 7.10

Figure 7.11

Figure 7.12: Guideway: 20% sunlight occluding GRP full grid running surface

Cable tray: Running down the middle of the guideway, tucked just below the GRP running surface, is a 2” high x 12” wide cable tray that houses communications and utility cables.

The open grid GRP guideway lets rain through without requiring gutters. This guideway also robustly handles the infrequent Austin ice events that occur: A) It is difficult for ice to form and attach to the pebbly GRP surface. B) Movement of vehicles on the guideway acts to flake off any ice that sticks.
7.1.10 Outfitting

The guideway is outfitted with:
- All-weather fixed-position CCTV cameras
- Control system communications equipment

Street lights may be affixed to either side of the guideway, negating the need for separate street light poles. Likewise, above-ground utilities such as power lines, fiber optic cables, and telephone lines may be hidden within the guideway cable tray.

7.2 Columns

7.2.1 General Column Info

Columns should be modular elements, each of which is capable of meeting the requirements of the most demanding conditions. Therefore, Column footings and caps may be varied depending on local soil conditions and guideway support requirements, however the main column body should be a standardized element, varying only in height. Except for the pilings and footings, the column elements are assumed to be reinforced precast concrete.

7.2.2 Column Dimensions
Columns are comprised of several elements:

- **Column Head**: typically 2.10m in width (for a single guideway), this must be expandable to 4.95m in width (for a dual guideway), or even 7.65m for a dual guideway with a junction. The column head should include weld plates to attach the guideway spans. On rare occasions, the column head may support a cantilevered guideway, although this would also have ramifications for the footing and piling design.

- **Column**: This should be a standardized circular-profile column, approximately 0.50m in diameter, varying in height according to the requirements of the site and guideway.

- **Plinth**: This is an impact-resistant base, 1.00m x 1.00m x 1.60m.

- **Pile Cap**: Typically 2.00m x 2.00m x 0.5m., although this will vary depending on local site conditions.

- **Piles**: approximately 0.40m-diameter piles, with varying depth depending on the soil conditions. The piling locations can be varied as necessary, to avoid intersecting in-ground infrastructure (if necessary, the pile cap can be enlarged to accommodate this).

### 7.2.3 Structural Requirements

Each column must be capable of supporting the weight of up to four 36-meter spans, in addition to the live loading of 2.2 kN/m per span.
7.2.4 Construction Disruption and Moving Underground Utilities

PRT infrastructure construction is faster and less disruptive than typical transportation infrastructure projects. Once column piles are in place, then a four-person crew can erect a mile of pre-fabricated guideway in one week. Construction of piles and pile caps can be scheduled to impact only a small portion of campus at any one time. Underground utilities such as water, electric, gas, or communications may run under some streets in the location where ULTra columns will be placed, hence movement of underground utilities may be required. During London Heathrow Airport ULTra system construction, no utilities were moved. Once pile caps and piles are in place, then a four-person crew can erect a mile of pre-fabricated guideway and columns in one week.

7.3. Stations

Envisioned is a “traditional” PRT open-canopy elevated station design, providing shelter for passengers and vehicles from thunderstorms and golf-ball sized hail storms, while providing full shade protection from hot days. Station features include: stairs, an ADA-compliant elevator, and safety railing. A number of renderings of such stations have been created over the years for slightly different PRT technologies:

![Figure 7.14: Images courtesy Cities21](image1)

![Figure 7.15: Images courtesy Jerry Schneider, ULTra PRT](image2)

The open-canopy must not only provide shade for passengers, but must also provide shade at appropriate sun angles for PRT vehicles parked at station berths. This reduces air conditioning operations costs.
It is worth comparing open-canopy PRT stations to the inexpensive fabric canopies provided for surface parking lots by Austin-Bergstrom Airport and for some Austin swimming pools:

![Figure 7.16: Popular Austin fabric canopy](image)

Station design will be modular, so that additional vehicle berths may be added in the future at minimal incremental cost. The modular design is envisioned to include standardized components that are manufactured off-site for rapid on-site assembly/erection.

For relatively lower-demand two-berth stations, we will utilize “serial” vehicle berths, where the first vehicle must exit before the second vehicle may exit. UT provides a somewhat homogenous, agile population, providing faster vehicle load/unload behavior than found in other environments such as airports. In higher demand instances we will use saw tooth berths, as utilized for London Heathrow ULTra.

Some stations could potentially span across a street from sidewalk to sidewalk, with stairs running down to both sidewalks. This could be attractive for some pedestrian situations.
7.3.1 Station Dimensions

Shown below is a 20’ x 13.5’ elevated station platform for a 2-berth serial station, using an Oyster Card swipe and DSP (Destination Selection Panel). Elevated serial berth stations have the following elevated platform area space requirement: 135 square feet per vehicle berth. ADA elevator and stairs are in addition to this space requirement.

Figure 7.17: Floor plan for elevated two-berth serial station

Sawtooth station configurations are also used:

Figure 7.18: Floorplan for two-berth sawtooth station
Sawtooth stations allow vehicles to depart as soon as they are full of passengers, rather than having to wait for the vehicles in front to clear, as is the case with serial berth stations. Compared to serial stations, sawtooth station platform area requirements are doubled, 270 square feet per berth.

Examples of ULTra Destination Selection Panels (DSP) can be found in the ULTra Heathrow Terminal 5 four-berth sawtooth station:

![Figure 7.19: Destination Selection Panel (DSP)](image)

Station square footage requirements for costing purposes are provided in the separate, confidential PRT4UT business model spreadsheet.

One of the top references for station design is: Building Type Basics for Transit Facilities, by Kenneth Griffin, 2004, John Wiley & Sons. “Provides guidelines, cautionary advice, and lessons learned from a variety of actual transit design projects--such as facilities serving heavy- and light-rail trains (including subways), airports, buses, and ships--to steer everyone on a project toward making sound decisions early in the planning cycle. Descriptive illustrations and need-to-know information offer valuable coverage on such essential topics as ridership analysis, station-area development, vertical circulation, and safety and security issues.” Sub-topics covered include: ADA, materials/finishes, lighting, acoustics/vibration, wayfinding, ticketing, queuing space, station platforms, sizing, fire safety, elevators, and stairs.

### 7.4 Operations and Maintenance Facility (OMF)

This section provides details for a PRT Operations and Maintenance Facility (OMF) or depot. The OMF will be used to perform scheduled and routine inspections, vehicle maintenance, on-car repairs, and exterior cleaning of the PRT vehicles. The OMF will also be the base for PRT Facilities Maintenance (station and guideway cleaning and maintenance crews), and serve as the base for field service technicians and PRT recovery vehicles. The facility will also serve as component storage and change-out location.

Major items such as large-scale component rebuild, major body repairs, vehicle painting, major machine shop work and body/sheet metal work will all be performed at another location. This will be accomplished...
by contracting out to local shops with space, manpower and equipment to perform this work. Minor machining and electronic repair work, however, will be performed at the OMF.

OMF interior materials shall be chosen for durability and low maintenance. Finishes should be as follows: a) sealed concrete floors in shop areas and the roof storage area, b) wall areas in shops shall have a minimum 8’ high concrete or concrete block wainscoting, c) office areas shall be metal stud and 5/8” gypsum-board construction. Floor and ceiling materials appropriate with use. Sound insulation shall be provided between adjacent office spaces, d) toilet/shower areas shall have ceramic tile floor and wall finishes.

A 0.5 acre site for the OMF might possibly be found east of I35.

7.4.1 OMF Building Features:

The OMF houses the control room, office space, vehicle maintenance bays, parts storage, electrical room, and vehicle storage.
Building features include:

- A hydraulic freight elevator shall be installed that can accommodate complete PRT vehicles and pallets of heavy components (such as batteries).
- A loading dock will be provided on ground level. This dock will face into the site area (not the roadway) and have an adjustable dock height to accommodate a variety of truck floor heights. The dock will either be immediately adjacent to the freight elevator or open directly into the freight elevator.
- A minimum 13 feet of interior vertical clearance is required in the hydraulic lift areas.
- A 3 ton overhead crane shall be provided in the Service and Inspection Bay area and shall also be accessible at the freight elevator door.
- An emergency battery backup UPS system and automatically-activated standby diesel generator will be provided to ensure uninterrupted power to operate the Control Center and all communications systems related to PRT operation.
- A shop DC power supply.
- Provision for shop compressed air outlets
- Car wash water recycling system
- A small electronics lab within the maintenance area
- Building access shall be secured via the use of ID card readers

Site access shall be secured via fencing

Maintenance / inspection tasks conducted in the facility include:

- Service, remove and replace PRT battery modules.
- Replacement of brake shoes
- Service, remove and replace PRT heating, ventilation and air-conditioning units.
- Exchange of defective components with new or rebuilt parts.
- Repair of miscellaneous system equipment and components.
- Periodic inspection and maintenance.
- Steering system inspection and maintenance
- Door system inspection and maintenance
- Communications system inspection, test and maintenance
- Replacement of modules and/or PC boards in PRT vehicles (sent off-site for repair)
- In-house repair of selected components
- Air-conditioning unit secondary maintenance and overhaul.
- Safety inspections.
- Thorough interior cleaning (light interior cleaning will be done by station cleaning staff)
- Automated exterior cleaning using the test-track-mounted wash rack
- Loading/off-loading equipment to/from vendors
- Wheel and component replacement on axles.
- Tire replacement.
- Motor replacement

### 7.4.2 System vehicle storage

Vehicle storage is distributed throughout the system. The OMF would not be designed to hold all of the vehicles. During system shutdown, vehicles are stored under canopies in stations, under canopies in adjacent-to-guideway storage just upstream of high-demand stations, as well as within the OMF.
7.4.3 OMF size: square footage

Calculation of required OMF square footage is calculated via an extrapolation of London Heathrow’s Depot as well as two previous studies for other “medium-sized” PRT systems. The calculation worksheet is provided in the separate, confidential PRT4UT business model spreadsheet.

7.5 Vehicles

ULTra vehicles are four wheeled with rubber pneumatic tires. The vehicles are front wheel steered and have conventional damped spring suspension. The vehicles comprise an aluminum ladder rack chassis on which the majority of the vehicle propulsion and guidance equipment is mounted. Sitting on top of the chassis is an aluminum honeycomb floor. The above floor level is constructed of a steel frame and an ABS panel body that can be fitted with single side or double side electric doors. The vehicle interior and exterior bodywork design can be made to suit individual client demands. The vehicles are air-conditioned, have internal destination and information screens, CCTV internal surveillance and audio controller contact. 

Vehicles use a laser sensor system to guide the vehicles on the guideway and in the stations. Vehicles use lithium-ion batteries optimized for rapid charging. The vehicles are designed to be adaptable for future battery developments and for other power sources such as hydrogen fuel cells, ultracapacitors, and new advances emanating from the fast-moving electric vehicle industry (Tesla Motors, etc). Batteries are charged via electrical contacts at station berths, or at waiting points. ULTra vehicles have a very low energy usage of 0.15Kwh/vehicle km at 25mph.

Each standard car has carrying capacity of five adults + luggage (Total 500kg); it has a turning radius of 5 meters and has a top speed of 25mph. The standard car has four contoured seats although other arrangements for example bench seating is available.

The cars can be modified to carry freight. PRT freight might relieve some central campus congestion by eliminating the need for delivery trucks, recycling trucks, food/vending machine deliveries, etc. Recycling materials could be ferried to a central campus perimeter drop site for city pick up.
7.5.1 Vehicle dimensions

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Length</td>
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</tr>
<tr>
<td>Width</td>
<td>1.47m</td>
</tr>
<tr>
<td>Height</td>
<td>1.8m</td>
</tr>
<tr>
<td>Empty weight</td>
<td>820kg</td>
</tr>
<tr>
<td>Door opening</td>
<td>&gt; 1.5m x 0.9m (h x w) (ADA compliant)</td>
</tr>
<tr>
<td>Flat floor area</td>
<td>1.44m x 1.2m</td>
</tr>
<tr>
<td>Turning radius</td>
<td>5m</td>
</tr>
<tr>
<td>Max climb angle</td>
<td>&gt; 20%</td>
</tr>
<tr>
<td>Planned climb angle</td>
<td>10%</td>
</tr>
<tr>
<td>Planned descent angle</td>
<td>6.25%</td>
</tr>
</tbody>
</table>

Table 7.25
7.5.2 Vehicle performance

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Max speed</td>
<td>25 mph</td>
</tr>
<tr>
<td>Emergency deceleration</td>
<td>3 m/s²</td>
</tr>
<tr>
<td>Maximum range on a battery charge</td>
<td>63 miles</td>
</tr>
<tr>
<td>Maximum payload</td>
<td>500 kg</td>
</tr>
</tbody>
</table>

*Table 7.27*

7.5.3 Vehicle configuration and features

Powertrain, and Energy Systems

- ‘7kW’ Synchronous AC Drive Motor (Typical average motive power use < 2kW)
- Solid State Drive Controller / Inverter
- Lithium Ion Batteries (rear mounted) 48V nominal
- Automatic Charging Connection System
- Fixed ratio transaxle assembly
- Front Wheel Drive

Braking Systems

- Drive motor regenerative braking
- Fail Safe Electromagnetic ‘hold off’ Motor Brake (1)
- Fail Safe Electromagnetic ‘hold off’ Rear Wheel Brakes (2)
- Safety interlocks between brakes, motor and doors

Chassis, Suspension and Steering Systems

- Fabricated Aluminum ‘Ladder Frame’ lower chassis with structural Aluminum Honeycomb floor and bulkhead Panels
- Separate Front and Rear Aluminum fabricated subframes with mountings for suspension, steering, motor/ transmission and batteries
- Bumper structure designed to progressively absorb impact energy and limit passenger deceleration
- Welded Steel tubular upper frame to support exterior and interior bodywork, side doors and front / rear hatches
- Double Wishbone suspension Front and Rear using predominantly aluminum machined wishbones, coil over damper units and standard automotive joints, bearings and bushes
- Rack and Pinion steering gear operated by Automotive Electric Power Steering unit
- 13” Wheels with automotive tubeless radial (135x70R13) tires
Exterior Body, Doors and Glazing
- Body panels constructed in self colored ABS with high gloss Acrylic capping
- Vacuum formed exterior panels bonded to vehicle structure
- Twin leaf plug and slide doors
- Doors actuated by dc motors through reduction gearbox and locking linkage system
- Microprocessor controlled door operation
- Door leaves constructed of ABS panel, steel reinforcement and bonded laminated (tinted) glass
- Flashing door header rail warning
- Vacuum formed tinted Acrylic ‘Quarter Window’ glazing
- External vehicle operating lights (Front White and Amber, Rear Red and Amber)

Interior and Passenger Controls
- Interior panels vacuum formed from grey, grained ABS
- Seats facing front and rear providing flexible accommodation for 4 adults
• Illuminating Door / Control switches
• Illuminating Communication / Alarm switches at both ends of vehicle (diagonal pair front right and rear left)
• Cabin speakers (one with each communication panel), ceiling mounted inductive loop and microphone for passenger communication
• Internal and externally releasable emergency exit (locked while vehicle in motion)
• Passenger information LCD screen
• Internal lighting sufficient for reading
• Vehicle signs / symbols and information labels
• Non-slip easy clean floor covering
• Cabin heating, ventilation and air conditioning
• Cabin smoke detector, emergency fire extinguisher and two internal CCTV monitoring cameras mounted in ceiling to monitor all of cabin
• Weight sensors to monitor vehicle loading and prevent operation if overloaded
• Wireless communication system for 2-way data, passenger comms and command exchange between vehicle and system central control

7.6 PRT4UT System Costing

PRT4UT system costing is provided in the separate, confidential PRT4UT business model spreadsheet. For costing, two estimates were received from major local firms.

7.7 Construction Responsibilities

A major Texas infrastructure construction company (called a “constructor”) will be responsible for guideway, OMF, and stations. Constructor responsibilities include:
• Fabricating guideway and columns off-site
• Foundation site work (pile cap and piles)
• Erecting columns and guideway with a small crane and 4-person crew
• Implementing the Arborist plan
• Installing safety rail
• Installing the GRP vehicle running surface
• Moving any underground utilities to accommodate column foundations
• Hiding above-ground utilities in the guideway as specified by UT and City of Austin
• Constructing the Operations and Maintenance Facility Shell
• Construction of Stations: elevators, stairs, ADA finishes, power, lights, safety rail, etc

ULTra PRT (the company) finishes the guideway: CCTV, lays control system cabling in the guideway cable tray, prepares the kerbs for location sensing.

ULTra guideway is fabricated off-site. On site, a four-person crew with a crane can assemble one mile of guideway per week.
ULTra guideway is somewhat like Lego. It is easy to modify existing PRT system alignments and move guideway segments to different locations to accommodate new buildings.

ULTra PRT (the company) as part of the SPE will fit out the guideway for the PRT control system, stringing PRT cables in the guideway cable tray, applying finishes to the kerbs to enable location sensing, and hanging fixed position CCTV cameras.
For the Operations and Maintenance Facility, the constructor provides a “functional building shell” with HVAC, electrical, lighting, plumbing, working restrooms, and lockers. ULTra PRT (the company) finishes off the building for use as a PRT depot. This finishing encompasses control room equipment, maintenance equipment, office furniture, equipment storage racks, hydraulic vehicle lifts.

For stations, the constructor is responsible for the structure, stairs, electrical hookup/wiring, lighting, ADA elevator, and safety rail. There is a relatively small chance that new utility substations will be required for a station, because station electricity usage is low. ULTra PRT (the company) is responsible for signage, fare gate, destination selection panel, station/vehicle interface, and station control equipment installation. ULTra PRT provides the vehicles.

### 7.8 Minimal Infrastructure Vandalism Risk

The ULTra system is grade-separated. The guideway is fenced off from access so that boisterous, thrill-seeking students may not endanger themselves. In addition, closed circuit TV monitoring of the guideway by operations personnel should catch thrill-seekers well before they endanger themselves. Vandalism is not expected to be a large issue. Graffiti is typically spray-painted on large rectangular areas that can be read by by-passers from significant distance. The ULTra system presents few large target areas.

Vandalism is minimized in the following ways: (thanks to J. Edward Anderson)

**By Surveillance.** The stations will be CCTV television monitored with two-way voice communication. They are small areas that can be surveyed easily, and infrared detectors will be used to detect the presence of people so that the operator, in slack times, need not constantly view the screen.

**By Identification.** A means will be provided to permit a boarding passenger to reject a vandalized vehicle. An alarm signal will then be sent to the nearest control room where a human operator is alerted to roll back a video memory unit and make a permanent record of the last passenger to egress from the vandalized vehicle, and to command the vehicle to the nearest maintenance shop. Normal police methods will then be used to apprehend the vandal. Experience at the Morgantown automated people mover system has shown that knowledge of such a procedure, not possible in conventional transit, will by itself deter most vandalism.

**By Psychology.** In public places, vandalism has been greatly reduced by the application of human psychology (see *Psychology Today*, September 1982). Plain walls that look like writing tablets invite being written on. Textured walls and walls with diagonal lines or protrusions markedly reduce graffiti. Appropriate colors, music, architectural design, and plants reduce vandalism. Frequently cleaned public places are not as subject to vandalism as dirty ones.
Chapter 8. Visual Impact

Threading PRT: the challenge, visual impact research, aesthetic guideway, proposed architecture competition, native plants for the guideway, protecting nearby apartments.

8.1 Threading PRT: the challenge

It is challenging to “thread” PRT through the west-of-campus area on north-south running streets such as San Gabriel, Rio Grande, San Antonio, and Guadalupe. There are numerous protected Oak trees with sensitive root systems. PRT guideway must avoid these trees, to such an extent that the PRT alignment may be dictated by the trees. On a few streets, PRT might begin on one side of the street and then cross to the other side in an effort to protect key trees.

Stakeholders requested a visual solution that provides aesthetic improvement with consideration given to guideway with features such as: lattice design, multi-purpose, greenery to add natural beauty, shade, weather protection, utility-hiding, street lighting, and street furniture. An Architecture Design Competition, with UT School of Architecture student participation, is proposed to develop the best solution for this challenge.

8.1.1 Live Oak Trees

First, it should be noted that ULTra PRT staff members have participated as activists in protecting Oak and other trees. We “get it.”

Oak trees present challenges for PRT. Major Oak trees have special legal protection. Oak trees are long-lived and develop neighborhood constituencies. Oak tree root systems are sensitive and Oak tree pruning must be carefully undertaken by an experienced tree service.

There are many challenges with the oak trees on the east side of Guadalupe:

- Oak trees are slow-growing and can live for hundreds of years. There are many activists dedicated to the preservation of these trees. The City of Austin has a significant urban forestry
program. The City recently considered a motion to strengthen oak tree protections. The legislative idea was to characterize smaller oak trees as protected "heritage trees."

- It may be difficult to put underground column footings next to oak trees as the root systems are sensitive inside the drip line of the tree's canopy.
- It is non-trivial to prune oak trees to accommodate PRT guideway at 16' high, because pruning should be symmetric and can lead to beetle infestations. That said, there are some cases where light pruning may be viable, with careful consideration.
- Oak trees like to spread horizontally, so they just are not the ideal trees to be next to PRT guideway.

Details

- The southern live oak (Q. Virginiana) is a massive (50 ft, or 15 m, tall), durable evergreen tree. The trunk divides near the ground into several limbs that extend horizontally as much as two to three times the height of the tree. The elliptical leaves are dark green and glossy above, whitish and hairy below. A valuable timber tree, the southern live oak is also planted as a shade and avenue tree in the southern U.S. The oldest trees are 200 – 300 years old.
- City of Austin citizens are strong tree advocates and City Council considered a motion to reduce tree size for qualification as a protected heritage tree. Heritage trees require permits for pruning. The city is haunted by the 1989 partially-successful poisoning of the 500-year-old Treaty Oak, a once-majestic Southern live oak.
- The City of Austin Parks and Recreation Department’s Urban Forestry Program mission: “To provide, protect and preserve the highest quality care of Austin’s urban forest through planting, maintenance and replacement of trees in parks, along streets and in other public areas, thereby contributing to positive recreational, cultural and outdoor experiences for the Austin community. Austin citizens greatly value trees in their city, as does the Parks and Recreation Department Forestry staff.”
- Oak Tree pruning recommendations are as follows: a) The late dormant season is best for most pruning. Pruning in late winter, just before spring growth starts, leaves fresh wounds exposed for only a short length of time before new growth begins the wound sealing process. Pruning at the proper time can avoid certain disease and physiological problems. B) To avoid oak wilt disease DO NOT prune oaks during April, May, or June. If oaks are wounded or must be pruned during these months, apply wound dressing to mask the odor of freshly cut wood so the beetles that spread oak wilt will not be attracted to the trees.
8.1.2 The narrow west-of-campus streets

A series of west-of-campus street-level images follow, with suggestions about where to run ULTra guideway.

Figure 8.2: San Antonio & 21st, looking north. Run guideway down the RHS, above the small trees.

Figure 8.3: San Antonio & 23rd, looking north. At 23rd, run by LHS gutter (with pruning), then RHS near 24th.
Figure 8.4: 24th near Pearl, looking west. Hide LHS poles, run guideway instead. Red arrow shows possible route for column foundations.

Figure 8.5: Guadalupe near Dean Keeton, looking south. Run guideway on RHS, at edge of parking

Figure 8.6: Guadalupe south of 24th, looking south. Run guideway on RHS, at edge of parking
8.1.3 24th near Pearl: Composite before and after showing PRT implementation

24th today

PRT on 24th (note power/utility lines & telephone poles removed)
8.1.3 Dean Keeton: Composite before and after showing PRT implementation

Dean Keaton today

PRT on Dean Keaton
8.2 Visual Impact Research

Three PRT visual impact studies have found that the public is ready to embrace context-sensitive PRT implementations:

1) ULTra PRT’s (the company’s) rider research tested the visual impact of ULTra guideway in two historic UK cities: “No respondent felt that the vehicle appearance was poor, indeed the majority thought the vehicles would look excellent. The visual appearance of the elevated structure was regarded generally as good, with 40.4% rating it excellent. It is especially noteworthy that the response to the elevated track gave a notably positive response, with no definitely negative responses and only 2.6% feeling that it could be difficult.”

2) In the paper entitled, “The Impact of PRT on Army Base Sustainability,” Peter Muller studied PRT for new mixed-use development at the large Fort Carson military base in Colorado. A “community impact focus group” was held as part of the study. A survey weighed the value of different transit system characteristics. Respondents were advised, “Please vote on which of the following transportation characteristics are most important to you. You have a total of 100 votes. You may not use more than 25 votes on any one characteristic.” The results showed that respondents cared much more about the level-of-service of a transit system than the visual impact, by roughly a 73.0 vote to 2.67 vote ratio:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable</td>
<td>13.22</td>
</tr>
<tr>
<td>Flexible Departure and Arrival</td>
<td>10.22</td>
</tr>
<tr>
<td>Low Cost</td>
<td>9.50</td>
</tr>
<tr>
<td>Easy to Use</td>
<td>9.22</td>
</tr>
<tr>
<td>Short Walking Distance</td>
<td>7.72</td>
</tr>
<tr>
<td>Short Waiting Time</td>
<td>7.61</td>
</tr>
<tr>
<td>Energy Efficient</td>
<td>6.72</td>
</tr>
<tr>
<td>Short Travel Time</td>
<td>6.39</td>
</tr>
<tr>
<td>Low Emissions</td>
<td>4.56</td>
</tr>
<tr>
<td>No Transfers</td>
<td>4.39</td>
</tr>
<tr>
<td>Consistent Travel Time</td>
<td>4.17</td>
</tr>
<tr>
<td>Safe</td>
<td>3.72</td>
</tr>
<tr>
<td>Comfortable</td>
<td>3.44</td>
</tr>
<tr>
<td>Visually Appealing</td>
<td>2.67</td>
</tr>
<tr>
<td>Seated Travel</td>
<td>2.28</td>
</tr>
<tr>
<td>ADA Compliant (disabled persons access)</td>
<td>1.94</td>
</tr>
<tr>
<td>Personally Secure</td>
<td>1.94</td>
</tr>
<tr>
<td>Private</td>
<td>0.28</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

3) In a 2009 paper entitled “Assessing public preferences for design and environmental attributes of an urban automated transportation system,” researchers from West Virginia University attempted to quantify the public perception of the 21-person-vehicle Group Rapid Transit system on their Morgantown, WV campus. This system, dating from the 1970s, involves infrastructure which is far bulkier and visually intrusive than that of modern PRT systems, but is somewhat similar to PRT systems in function. By conducting visual preference surveys of 190 Morgantown residents – including both users and non-users of the GRT system – the researchers were able to establish which infrastructure characteristics most influenced the negative or positive perceptions of the guideway. Among the conclusions of this study:
• “We found that the view of tracks from a higher vantage point was preferred. This suggests that the direct view of tracks from buildings or high vantage points should not be considered as a negative element in the planning of routes for the tracks. On the contrary lowering tracks could be a means toward increasing visual quality of scenes.”

• “Results also indicated preferences for scenes that included vegetation. This finding confirms preference for a greater amount of vegetation or for a greater naturalness of scenes which is consistent with other studies … and also confirms the importance of natural elements in the perception of transportation systems and urban environments.”

• “…We found that at-street level tracks were perceived negatively while overpasses or elevated tracks did not emerge as negative elements… This result implies that visual intrusion… is not primarily relevant to elevated tracks. These considerations confirm the critical role the street level environment plays in the case of both elevated and at street level tracks.”

The conclusion of this Morgantown study was that the context of the urban environment had more to do with the perceived visual impact of the guideway than did design of the guideway itself. This lends support to the objective of preserving the existing urban vegetation and streetscaping – or even improving upon it – while perhaps alleviating concerns about the perceived obtrusiveness of elevated infrastructure.

### 8.3 Aesthetic guideway and visual solutions

PRT has created a brand new architectural arena of invention and innovation. Our recent Bath Architecture Design Competition explored theoretical options for placing PRT within a historically sensitive city that dates back to the Roman Era. PRT’s svelte, elevated form enables low-impact threading where other modes cannot pass. PRT guideway can be easily tailored to blend in with many architecturally challenging backdrops. As evidenced by the many competition submissions, architects enjoy working with PRT. Many of the submissions presented first-of-its-kind concepts:

![Figure 8.8: Lattice guideway by Bath Architecture Design Competition winner ARUP](image)

(ARUP helped design ULTra LHR guideway)
8.3.1 Other novel, aesthetically-pleasing PRT guideway concepts:

Cantilever guideway off the sides of buildings:

Figure 8.9:

Cut and Cover with walk-on-top structural glass in a culvert. With this treatment, station guideway may be brought up to grade for simplified pedestrian access. As far as the rider’s experience, elevated guideway may provide a better view, providing more of a “transportainment” experience.

Figure 8.10: “Cut and cover” dimensions are 7’ wide by 6’ high

The 1994 PRT Visual Intrusion Study in Gävle, Sweden, created innovative visual solutions. The PRT system alignment showed that PRT would lead to a significant visual encroachment within the city. “However, this visual impact can be countered by careful architectural design of columns, guideway, vehicles and stations with a view towards blending the system into the existing street environment and building facades. A PRT system’s visual encroachment upon narrow streets may be countered by adjusting the street environment to the street’s new function. Reduction of vehicular traffic allows for a reduction in the size and number of car lanes and increased space for pedestrians, cyclists and tree plantings.” Two figures from the study are shown below.
1) multipurpose guideway column designs provide homes for benches, street lights, stop lights, and bike racks. PRT cast iron finishes are used to blend in with the city’s traditional architecture:

2) Guideway serves as a partial roof for a lengthy pedestrian mall. For west-of-campus, the use of dual columns could allow columns to span a street while running the guideway above the street.

In addition, the shade of columns may be verified under specific demands. To run columns in a street’s centerline or center median, long, narrow columns could be created (for example: 9” x 36”).

I’d go with an ARUP-style latticework for the guideway, but then I’d take it a step further: run planters and evergreen creeping vines along the guideway, so that the whole thing becomes a green canopy. This would be a genuine aesthetic enhancement to the public realm.

- Nathan Koren, ULTra PRT
8.4 Proposed architecture competition

A rough concept for a PRT design competition arose from stakeholder meetings. It is detailed below to provide a sense of the idea, but actual implementation will be different. Austin PRT offered significant funding for the competition.

**Timeline**
- Create street data for entrants by end of June, 2011. Provide digital photos of streetscapes, etc. Provide stock 3D trees. Possibly create 3D models of the streets.
- Launch the competition in July of 2011.
- For Spring Semester, the School of Architecture (SOA) advanced design studio (about 15 students) should participate. SOA students would undertake this project early in the semester. Grades, cash prizes, and portfolio highlights will motivate students.
- UT planning and civil engineering students should also be encouraged to participate in the competition.
- Announce winners in October, 2011.

**Design goals:**
- Thread PRT through west-of-UT-campus in a manner that provides an aesthetic enhancement.
- PRT architectural elements represent an opportunity to enhance the drama of certain common gathering areas by defining a new sense of place.
- Consider multi-purpose guideway integration of vines, hanging plants, shade, weather protection, utility-hiding, street lighting, street furniture, and fiber optic cable.
- New UT architecture often yields a modern update to the traditional Spanish Colonial campus architecture. The Alumni Center’s trellis is suggestive of the UT mascot’s longhorns. Burnt orange PRT guideway with embossed longhorns might be taking things too far, but there might be a reason to make some visual references to UT “branding.”
- PRT columns and trellis’ represent significant opportunities to create new meeting places for students and faculty. Columns could be personalized for different ‘Austin’ or ‘UT’ themes like music, history, or sports “…Hey let’s meet at the Stevie Ray Vaughn ULTra Kiosk” or I saw Adrien over near the BEVO Kiosk yesterday….”

**Competition Submission Guidelines:**
- Provide digital images of your architectural solution.
- Model two city blocks of west-of-campus with one-way PRT guideway.
- West of campus has many Live Oak trees with sensitive root systems. The City of Austin honors urban forestry and recently passed stronger protections for medium-sized Live Oaks. PRT guideway, columns, and footings should blend with and protect these trees. “20% pruning” of individual trees is allowable. A few trees may be removed provided there are equivalent new tree plantings on other portions of the street.
- Within a single block, PRT guideway may “zig-zag” across the street no more than once (for cost containment purpose). It will be possible for guideway to begin on the edge of right side on-street parking, veer to the center median, and then veer to the sidewalk edge of the left side. .
- The competition will be well supported. Four high-quality photos of each street will be provided. (Entrants will be required to composite their design onto these photos, to facilitate direct comparison between competing entries.) A web chat forum will support entrants in their endeavors. Non-jurist professionals will be available to confidentially critique interim work. 3D SketchUp models of ULTra guideway, vehicle, and simple station will be provided.
**Competition Prizes**
- Professional category: $2,000 first prize, $1,000 second, $500 third
- Student category: $2,000 first prize, $1,000 second, $500 third

**Competition Sponsors might include:**
- UT SOA
- Funding by Austin PRT
- ULI

**Jurists might include:**
- Jurists are independent from Austin PRT and ULTra PRT, in a manner similar to the SOA PRT4UT study review team led by Kent Butler.
- Local architecture firms: Anderson Moore
- Local architects that also teach at the School of Architecture (SOA):
  - Larry Speck has played an important role at the school and also the local architecture scene.
  - Sinclair Black has been instrumental in the revitalization of downtown and the creation of Austin's pedestrian-friendly street environment.
  - Elizabeth Danze and John Blood worked as associate architects on the UT master plan with Pelli Clark Pelli Architects out of New Haven in the 1990s.
- Other SOA Faculty
- Neighborhood Group representatives: University Area Partners - Mike McCone; Blackland Neighborhood Association - Bo McCarver (he’s a designer); Reverend Joseph C. Parker of the David Chapel Missionary Baptist Church on MLK & Chestnut.
- Student body representative
- Elected official / community leader
- ULI, AIA
- Big names: Peter Calthorpe, Nan Ellin

**Non-Jurist Professionals might include:**
- Victor Meinert, Austin PRT
- ULTra PRT staff
- SOA: Ulrich Dangel, Matt Fajkus, Dean Almy
- UT campus architect David Ray
- Larry Maginnis, Urban Forester for the University of Texas (Arborist of the Year, 2008)
- City of Austin Arborist Michael Embesi
- PBS&J and TxDOT architects

**Stakeholder Comment:**
The overall PRT system visual design will be a complex, multi-party process, relying on input from buildings and owners, occupants, and neighborhood leaders. UT administration will have the final decision on the visual and design solutions within the campus. Outside of UT campus, the City Council and the entities that they will ask to review and comment (Planning and Zoning Commission, Urban Design Commission, organized neighborhood associations, and Urban Transportation Commission) will all weigh in on visual impact and the compatibility issues of the design as it winds through public right of way. Austin’s decision-making process is admirably decentralized when it comes to deciding on development approvals that have impacts on neighborhoods and public spaces.
8.5 Native plants and vines for the guideway

Plants from the Austin Grow Green plant list (see: http://www.ci.austin.tx.us/growgreen/) may be intertwined with stations and guideway to ensure that an aesthetic enhancement is achieved. The Grow Green list includes beautiful, native “earthwise plant choices which are naturally drought-tolerant, require minimal care, and are resistant to pests and diseases. The less watering, fertilizing, and chemical control required, the more we contribute to the conservation and preservation of our precious water resources - our streams, lakes, and aquifers.”

Vine selections include:

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Botanical Name</th>
<th>Native</th>
<th>Light</th>
<th>Height</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolina Jessamine</td>
<td>Gelsemium sempervirens</td>
<td>Texas</td>
<td>Sunny/Part Shady</td>
<td>0 ft to 0 ft</td>
<td></td>
</tr>
<tr>
<td>Confederate Jasmine</td>
<td>Trachelospermum jasminoides</td>
<td>Non-Native Adapted</td>
<td>Sunny/Part Shady</td>
<td>15.0 ft to 15.0 ft</td>
<td></td>
</tr>
<tr>
<td>Coral Honeysuckle</td>
<td>Lonicera sempervirens</td>
<td>Texas</td>
<td>Sunny/Part Shady</td>
<td>0 ft to 0 ft</td>
<td></td>
</tr>
<tr>
<td>Coral Vine</td>
<td>Antigonon leptopus</td>
<td>Non-Native Adapted</td>
<td>Sunny/Part Shady</td>
<td>0 ft to 0 ft</td>
<td></td>
</tr>
<tr>
<td>Crossvine</td>
<td>Bignonia capreolata</td>
<td>Texas</td>
<td>Sunny/Part Shady</td>
<td>0 ft to 0 ft</td>
<td></td>
</tr>
</tbody>
</table>
### Table 8.13: Austin-appropriate vines

Perennials that thrive in Sunny/Part Shady conditions (such as hanging underneath a PRT lattice guideway) include:

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Botanical Name</th>
<th>Central Texas Native</th>
<th>Light</th>
<th>Height</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batface Cuphea</td>
<td>Cuphea llavea</td>
<td>Non-Native Adapted</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 1.0 ft</td>
<td></td>
</tr>
<tr>
<td>Bicolor Iris (African)</td>
<td>Dietes bicolor (Morea bicolor)</td>
<td>Non-Native Adapted</td>
<td>Sunny/Part Shady</td>
<td>3.0 ft to 5.0 ft</td>
<td></td>
</tr>
<tr>
<td>Black-eyed Susan, Goldstrum</td>
<td>Rudbeckia fulgida var. sullivantii 'Goldstrum'</td>
<td>Both Blackland Prairie &amp; Edwards Plateau</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 3.0 ft</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------</td>
<td>------------------------------------------</td>
<td>------------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>Calylophus (Square Bud Primrose)</td>
<td>Calylophus berlandieri</td>
<td>Edwards Plateau</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 3.0 ft</td>
<td></td>
</tr>
<tr>
<td>Chile Pequin (Chile Petin)</td>
<td>Capsicum annuum</td>
<td>Edwards Plateau</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 5.0 ft</td>
<td></td>
</tr>
<tr>
<td>Coralbean</td>
<td>Erythrina herbacea</td>
<td>Texas</td>
<td>Sunny/Part Shady</td>
<td>5.0 ft to 5.0 ft</td>
<td></td>
</tr>
<tr>
<td>Coreopsis</td>
<td>Coreopsis lanceolata</td>
<td>Texas</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 3.0 ft</td>
<td></td>
</tr>
<tr>
<td>Fall Aster</td>
<td>Aster oblongifolium</td>
<td>Edwards Plateau</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 3.0 ft</td>
<td></td>
</tr>
<tr>
<td>Fall Obedient Plant</td>
<td>Physostegia virginiana</td>
<td>Blackland Prairie</td>
<td>Sunny/Part Shady</td>
<td>1.0 ft to 5.0 ft</td>
<td></td>
</tr>
<tr>
<td>Firecracker Fern</td>
<td>Russelia equisetiformis</td>
<td>Non-Native Adapted</td>
<td>Sunny/Part Shady</td>
<td>3.0 ft to 3.0 ft</td>
<td></td>
</tr>
</tbody>
</table>

*Table 8.14: Austin-appropriate perennials*
8.6 Protecting nearby apartments

Interaction between the PRT4UT system and apartments located very near the guideway could create viewing concerns or problems with glare. At an apartment’s request, visual protection/occlusion may be provided between PRT passengers/vehicles and apartment residents.

There are a lot of different ways of occluding the guideway, and I’d say that this is something which the design competition could address. You can create occlusion with foliage, occlusion with flat screens, and occlusion with slatted screens that have some depth (which allows you to select the “directionality” of the occlusion, and also means that the “degree” of occlusion changes with viewing distance). There are two general guidelines that I can suggest:

1. The degree of screening depends on the distance between the viewer and the guideway. The more of the visual field the vehicles would occupy – and the faster that they would move across the visual field – then the more screening will be needed. From a distance, only light screening should be required, if any. So it makes sense to have either several different screening designs, or a design that was “tunable” to specific conditions (ie by increasing the slat spacing or grill aperture).

2. Regarding the potential issue of glare from direct light-bouncing off of vehicles near apartment windows. Strobing might also arise. So you might have a situation, for example, where vertical slats provide a much greater degree of visual occlusion, but still allow light-flashes through, whereas horizontal slats wouldn’t. In some cases, it may be necessary to also provide glare-baffles “above” the vehicles, where there’s the chance that they could cast glare into windows immediately above the track. This level of concern is probably only appropriate in the rare situations where vehicles are passing within a few feet of a window – eg., closer than a car on the street would ever pass.

   - Nathan Koren, ULTra PRT
Chapter 9. Operations and Safety

ULTra System operations and safety encompasses operations approach, station user interface, safety procedures/certification, annual costs, and smartphone futures.

9.1 Operations approach

The design of PRT is focused upon world-class levels of reliability. However, excellence in service delivery is wider than mere reliability and is a reflection of the full spectrum of interactions between customers and the service from first to last. How customers perceive those points of interaction will determine their perception of the system.

The operational success of a PRT system can be judged by a series of critical success factors. These may include aspects such as reliability and wait times and also encompass elements such as passenger perception. A series of secondary targets on items such as cleanliness, presentation, and quality of information provision can also be used to gauge the operational success of the scheme.

9.1.1 Passenger Support Services

ULTra control room staff (Controllers) will provide a factual, customer-focused interpretation of a passenger query/situation. Controllers are chosen for outgoing personalities, as a significant portion of their responsibility is friendly interaction with passengers. They will provide timely, accurate information and be able to answer further questions via the passenger call-points as a customer support situation develops.

Every vehicle will have a Passenger Call Point (PCP) for use by passengers to talk directly with the Controller. All Controllers will be trained in how to respond to PCP activations. The Controller will be trained to assess the circumstances and, depending upon the nature of the call, deal directly with any matters or summon other assistance. The vehicles have two call buttons, one for general inquiries and a second for use in an emergency. The emergency call would take priority in the control room.

The CCTV system is critical to creating a safe and secure environment for passengers so it is crucial that the system performance and support is of the highest standard. The operation of CCTV on the system and in vehicles will be done in accordance with state/federal legislation and international / industry guidance ensuring that the sensitivity of image monitoring is recognized.

Our CCTV system operates in both standard mode and infrared mode. The infrared mode allows for viewing in low-light, nighttime operation without requiring a lighted guideway.

9.1.2 Maintenance Timing

All intrusive system maintenance can be achieved outside busy operating hours. This will include all routine inspection and maintenance of infrastructure, systems and vehicles. In addition, vehicles will receive their “deep” battery condition charging at night. At Heathrow we have analyzed the demand figures for the system and have set up maintenance procedures that give maximum vehicle availability.
during highest demand periods. By scheduling maintenance around the busy periods, we ensure maximum capacity

### 9.1.3 Presentation

Cleanliness of a system is immediately apparent to all who use it. Much of the mistrust and low modal shift associated with some public transport systems (outside of Austin) is associated with failed standards of cleanliness. ULTra vehicles and stations will be kept clean. To assist with the volume of cleaning activity an automated vehicle wash will be provided at the Operations and Maintenance Facility (OMF), with a water recirculation system to reduce the environmental impact.

Standards will be maintained by unifying cleaning and preparation for service under the care of a team, led by the Cleaning Team Leader. During the day, it will be ensured that vehicles stay clean in service by positioning cleaning staff at critical locations to collect litter and sweep through to remove newspapers and other items discarded by passengers. The cleaning staff provides rapid response for urgent cleaning of vehicles in case of spills or worse.

On a regular, scheduled basis, vehicles and stations will receive a deep clean, conducted during system shutdowns. These will involve a much more intensive cleaning effort to ensure that all the facilities on the system remain bright and fresh. At Heathrow we have agreed standards of cleanliness with recognized measures and inspections.

### 9.1.4 Operations staffing

Three main grades of staff will be used. Key to the most cost effective solution is to seek multi-skilling to allow effective utilization of staff. Staffing levels accommodate someone reporting sick or arriving late. Description of the three staff positions follow below. In addition, there are the management positions of control manager and technical manager.

**Duty Controllers**

The Duty Controller provides shift leadership, owning the system during the shift. The individual will make final decisions on priorities and incident management (other than engineering judgments). Staff on duty for that shift will take operational instruction from the Duty Controller e.g. releasing vehicles for cleaning. The Duty Controller will be competent on all Control System equipment. Duty Controllers will report to the Contract Manager.

**Technicians & Controller Technicians**

Technicians are competent to faulting and maintenance level on virtually the full range of assets on the system (except for specialist skills such as air conditioning maintenance). A technician presence is required during operating hours to allow immediate attendance to a vehicle or system failure.

Controller technicians usually work alongside the controller in the control room but also have a technical background allowing them to assist the technician if required. They do not have the in-depth skills of the technician but are able to undertake basic faulting and repairs.

**Cleaners**

Cleaners move from task to task dependent upon asset availability. They are also a visible staff presence on the system. They also aid with daily visual checks of the vehicles, checking that all buttons and in-vehicle media are working correctly.
9.1.5 Staff training

Substantial staff training takes place during system commissioning. Before revenue service, staff will also train at the London Heathrow ULTra system. The ULTra Heathrow team has developed a series of specialized training courses and documents that will be extremely helpful for PRT4UT training. Hence staff will have a more rounded understanding of not just the technical aspects of the system but the context and standards of performance that can be expected. Staff will be actively involved in designing, reviewing and testing operation and maintenance plans, ensuring not only that staff are familiar with the plans and that they are fit for purpose, but also that there is strong buy-in and ownership from the staff right at the outset.

Training and incident drills continue throughout each staffer’s career.

9.2 Station user interface

9.2.1 Preamble: Oyster Card ticketing / fare payment

It is envisioned that within a few years after PRT4UT is built, a convenient single fare payment mechanism will work seamlessly on all Austin-area transit including CapMetro, urban rail, and the ULTra system. The system will provide unique traveler identification, rapid fare gate processing, and cloud credit card payment. Transport for London’s Oyster Card is an example of such a mechanism:

![Oyster Card being read at a fare gate with a touch to the "yellow card reader"](image)

The ULTra system user interface software (both the user-facing Destination Selection Panel as well as the back end) was designed to process smart cards and automatic payments. The Heathrow user interface implementation is somewhat pedestrian compared to the capability that has been designed in.

9.2.2 Station user interface

Described below is the station user interface for a simple, two-berth, serial, elevated station with canopy, safety rail, an ADA elevator, and stairs.

A 20’ x 13.5’ station platform for a two-berth serial station, using an Oyster Card swipe and Destination Selection Panel (DSP):
Figure 9.2

Each standing, queuing passenger takes up a 24" x 18" box, shown via a 10 x 9 grid of these boxes above.

The station platform area is split in half. A 20’ x 6’ waiting area connects to DSP / Oyster Card reader / fare gate and then opens to a 20’ x 6’ “ready” area. Passengers may not enter the ready area without telling the DSP where the one- to four- person party is going. The ready area holds up to two parties per berth. The ready area has “shoe prints” to help get folks to line up away from the exit lane that starts where the doors open. The DSP / fare gate doesn’t let the next party into the ready area until the next vehicle leaves. This time-tested queuing process should be easily recognizable to people who have experienced Disney theme park ride loading.

The waiting area may back up down the stairs. A portion of the queuing area and stairs will be delimited as “exit lane” to indicate that departing passengers should allow arriving passengers to exit the station.

The station also supports wheelchair access and large parties with small children.

Within the station, audio/visual communication with the ULTra control room is also provided.
Larger sawtooth stations with more berths have different configurations of DSP and may have special queue management to encourage ridesharing.

### 9.3 Safety narrative/certification

Worldwide, there are 144 automated fixed guideway transit systems operating. These carry more than 4.6 million passengers per day (source: Planners Guide to Automated People Movers, 2006/7), operating with 100 times fewer accidents per passenger mile compared to both a) non-grade separated transit such as Commuter Rail and LRT and b) private automobile travel.

Interestingly, legacy transportation systems such as “automobiles traveling on roads” and non-grade-separated rail transit could NOT achieve safety certification under the spirit of the current automated transit safety law. Under this spirit, fatalities are not allowed. In contrast, there were 500 fatal collisions between non-grade-separated trains and pedestrians in the US in 2006 and there were 37,261 US highway fatalities in 2008.

ULTra is compatible with federal and state PRT safety standards as well as national fire escape code. There will be approximately 361 different “safety cases” for any PRT implementation, covering: earthquake, truck crashes into column, falling debris, fire, bad people, extreme weather, vehicle fails on guideway, slipping on stairs, etc.

Safety in all aspects of the design, construction and operation of PRT is ULTra PRT’s (the company’s) first priority. So far as practicable we have designed out risks so as to minimize human error. The wide range of experience held within the team at ULTra PRT, combined with the expertise of members of the independent Safety Verification Team (SVT), means that a culture of positive but direct challenge to the detail of the proposal is embedded within the project team.

The process by which UK ULTra safety approvals were obtained is similar to that employed within the US. A Preliminary Hazard Analysis (PHA) was undertaken and mitigating features identified. The residual risks were classified in terms of frequency with which an accident may occur and the worst-case harm that could be caused by the accident. A frequency and severity score, agreed with the UK Rail Authority, was applied to each possible accident. A risk ranking score was then obtained by multiplying the frequency and severity scores. These risk-ranking scores were then applied to a risk classification matrix that identifies a set of risk acceptability criteria, again agreed by the UK Rail Authority. The residual risks from the PHA were deemed by the Rail Authority to be acceptable.

In the U.S., Code of Federal Regulations (CFR) 659 delegates fixed guideway (PRT, APM, monorail, LRT, heavy rail, cable car, and heritage trolley) public transit safety certification to the states, with a series of minimum requirements placed on each state’s regulatory agency. CFR 659 envisions mature transit systems and, accordingly, is less rigorous about “designing safety in” in comparison to the UK Rail Authority safety regime. There are 44 regulated fixed guideway systems in 27 states.

There are four important CFR 659 definitions, which ULTra PRT will employ:

- **Safety** means freedom from harm resulting from unintentional acts or circumstances.
- **Security** means freedom from harm resulting from intentional acts or circumstances.
- **System Safety Program Plan** (or SSPP) means a document developed and adopted by the rail transit agency, describing its safety policies, objectives, responsibilities, and procedures.
- **System Security Plan** (or SSP) means a document developed and adopted by the rail transit agency describing its security policies, objectives, responsibilities, and procedures.

The CFR 659 process follows the same generic steps for any state, with a few customizations expected within each state implementation:
A Rail Transit Agency (RTA) is formed to operate an ULTra system

- The RTA informs the state fixed guideway safety regulator of intent to operate a fixed guideway system.
- A competent, independent safety team is formed to certify the ULTra system. The state regulator is required to analyze the qualifications of the safety team and approve the team.
- A Safety Certification Plan is written and reviewed at least 12 months before approval to operate is given.
- The SSPP and SSP are written, following applicable standards. For PRT certification, the ASCE (American Society of Civil Engineers) APM Standards, Parts I-IV should be followed.
- Once documentation is in order and commissioning has completed, a public hearing is held to grant safety certification, allowing the ULTra system to begin operation.
- Once a system begins operation, the RTA is expected to conduct internal safety audits.

This CFR 659 process can be closely matched to existing Heathrow ULTra Safety Certification documentation, with implementation-specific modifications. Many of the 361 Heathrow “hazard cases” can be copied over directly. The current Heathrow ULTra documentation is closely matched to the ASCE APM Standards and an ASCE compliance matrix was developed for BAA at Heathrow.

BAA and ULTra PRT have had representation on the ASCE APM Committee for a number of years and are active in evolving the APM standard to better comprehend PRT. Under the brick wall stop criteria, the current ASCE Standard allows ULTra to run at 2.0 second headways. These standards are excellent and the brick wall stop criterion is expected to be relaxed over time, in a measured, prudent, and conservative manner.

### 9.3.1 TxDOT PRT/APM Safety Regulation

CFR 659 PRT/APM safety is implemented by TxDOT in Texas, covering DFW Skylink and Houston George Bush Intercontinental Airport TerminaLink APMs. Within the TxDOT Rail Safety Section of the Rail Division, Susan Hausmann is responsible. The previous DFW Airtrans APM operated for more than 31 years with very few safety events, so there is broad public acceptance to automated system safety in Texas. Texas PRT/APM fixed guideway transit system regulation and state safety oversight program are outlined in Texas Administrative Code Title 43, Part I, Chapter 31, Subchapter F, Rule 31.60. The rule is implemented by Texas Transportation code, Chapter 455. The relevant chapter of the Transportation code: [http://caselaw.lp.findlaw.com/txcodes/tr045500.html](http://caselaw.lp.findlaw.com/txcodes/tr045500.html). TxDOT regulates APM safety with a light hand. TxDOT also oversees rail freight, DART, and Houston MetroRail safety.

Because of the relative newness of PRT technology, the first Texas PRT system should proactively seek TxDOT safety oversight, by forming an RTA and making contact with TxDOT Rail Safety Section and the local TxDOT Austin Field Office. A “low-burden-on-TxDOT” process would meet state legal requirements and might entail the following:

- The RTA might consist of staff from City of Austin, University of Texas, and Capital Metro.
- The RTA could oversee the independent safety verification team, safety certification case, SSPP, SSP, and periodic audits.
- Documentation of this RTA effort could be forwarded to a designated TxDOT staff member for oversight.

It would be preferable to have more involvement from TxDOT, especially via the staff who oversee DART and Houston MetroRail safety.

ULTra PRT has found that engagement with the relevant safety authorities at an early stage provides the surest route to successful approval.
9.3.2 NFPA130 Evacuation

ULTRA’s non-electrified passive guideway meets U.S. National Fire Protection Association (NFPA) 130: Standard for Fixed Guideway Transit and Passenger Rail Systems. For NFPA evacuation requirements, ULTRA passengers may exit the front of the vehicle and safely walk on the guideway. Safety rails are attached to the guideway, primarily for safety of maintenance personnel, but the rails also serve to ensure safety of evacuating passengers.

Safety References

  - Safety-critical employees are drug-tested.
  - The audit made 10 recommendations for improvements.
  - Bombardier designed, built, and operates AirTrain. Primus Industries supplies operating and maintenance personnel.
  - AirTrain holds annual emergency drills involving first responders (IE fire, police, and emergency medical.)
  - Formal Emergency Evacuation Procedures are in place.
  - An Operation and Maintenance Rulebook, easily readable by mildly skilled operations and maintenance personnel, should be created, with source control. When new operating rules are issued, each employee is required to sign a form acknowledging receipt. Instructions for calibration of tools and test equipment should be provided. For vehicle, station, and guideway inspection, tolerances and other quantifiable metrics should be provided to determine if an item conforms.
  - A vehicle history preventative maintenance database must be kept.
  - Pages 11 thru 35 provide California PUC’s Audit Checklist.
- ASCE Automated People Mover Standards Committee: http://www.apmstandards.org/
- NFPA 130: http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=130&canvas%5Ftest=1

9.3.3 PRT4UT safety implementation and first response

An initial conference call was held on the topic of PRT safety implementation and first response, with the following results:

April 21 Conference Call with UT re: Safety and First Response

Attendees:
- Dr. Bob Harkins - Associate Vice President for Campus Safety and Security
- Chief of Police Robert Dahlstrom
- Bobby Stone - Director, Parking & Transportation
- Mark Griffiths, ULTRA PRT London Heathrow Operations Manager
- Steve Raney

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UT and LHR first response would operate similarly. For example, both systems are served by two police departments with partial jurisdiction of the PRT alignment area. ULTra control room staff would identify an incident requiring intervention on the CCTV monitor and then contact a central point of first response dispatch. LHR uses the Star central dispatch system; PRT4UT would go through UT Police Central Dispatch. PRT4UT responder would include: (City of Austin, UT Police, City of Austin Police, City of Austin EMS (Emergency Medical Service). When a UT incident occurs, an “incident command post” is established.

Dr. Harkins concluded, “We’re comfortable that we can put together a safety program to keep passengers safe.”

Situations discussed included:

- Identification of a suspicious package left in a vehicle. ULTra control room staff identify the parcel as requiring investigation by first responders and a specialist team responds. Both UT and LHR have quick-response teams.
- Evacuation of a stopped vehicle on elevated guideway. Vehicles ahead travel to their destination station. Vehicles behind may be stopped and routed to the nearest station, or may simply be stopped. Keeping passengers inside the stopped vehicle may be the safest course of action. To keep passengers calm, ULTra control room personnel immediately initiate two-way dialog with stopped passengers. First responders are not allowed on the guideway until the control room verifies that the system is stopped with zero vehicle movement and the control system has been put in safety stop state.
- Evacuation of disabled passengers from a stopped vehicle on elevated track is accomplished as follows. First, remove the passenger from the vehicle through the front-of-vehicle escape hatch. Next, the passenger is either wheeled away to a station via a one-wheeled trolley or carried to a station by a strong.
- Murphy’s Law. LHR police “broke procedure” and scaled a grade-separation fence to walk on active ULTra LHR guideway. The officers were not hurt and no vehicles were running at that time.
- It would be extremely unlikely to find a trespasser underneath an ULTra vehicle after having had the extremely unlikely occurrence of being run over by the 800 kg vehicle. First response training was held at LHR for this scenario. First responders have special equipment to lift a vehicle, either by a jack or by an inflatable airbag. By bringing about such lift, a trapped-under-vehicle trespasser may be extricated. The staging of this small kit of special equipment in secure storage in three or more locations for a PRT4UT system was contemplated as well as the use of a mobile van to store the equipment.
- Guideway trespassers are detected by ULTra control room staff via CCTV. Scenarios for environmental protestors are contemplated, even though ULTra is an environmentally beneficial technology.
- The process to develop a PRT4UT safety plan was discussed. First, UT staff should visit LHR to develop “strong memory” of operational details. Second, building on the 361 LHR safety cases, extensive safety procedure documentation should be developed with teamwork. Control room staff and first responder training was discussed, both with desktop seminar training as well as via drilling certain scenarios.
- If a vehicle runs over a small animal such as squirrel, system operation is not impacted. If a vehicle hits a larger animal such as a German Shepherd, the vehicle bumper detects the collision and the vehicle stops.
- Vehicle tires are selected to enable the vehicle to reach a safe stopping location when a tire is damaged.
- To deter incidents between mixed gender passengers within a vehicle, control room staff says a cheery hello, communicating that passenger behavior is being monitored. The safety of females late at night was discussed, as these passengers may feel more uneasy at this time of day. The extremely low waiting time of the PRT system provides safety. The airy, open design of station does not provide any hiding places and loitering is readily detectable.
9.3.4 Guideway Emergency Evacuation

Note on Guideway Emergency Evacuation

UK strategy for emergency evacuation of the PRT guideway uses the guideway as the pathway for passenger evacuation on elevated and at grade sections of the guideway. The case for this approach considers the following:

- PRT stations are typically 500m to 1000m apart and provide good controlled emergency access to the guideway and egress for passengers.
- The guideways are ‘one way’ so a failure of a vehicle on the guideway will result in vehicles ahead completing their journey unhindered and those behind stopping behind the failed vehicle. All new journey requests are automatically held. Within a short time there will be no vehicle movements on the guideway.
- All the guideways are fenced and provide a good walking surface.
- Normal emergency procedures are to request that passengers remain in the failed vehicle until the emergency services arrive to escort them to the nearest exit from the system, normally a station.
- Only in the event of an emergency that demands evacuation of the vehicle (eg a fire or smoke within the vehicle) would the passengers be instructed to exit via the emergency exit hatch at the front of the vehicle:

![Figure 9.3: Front of Vehicle Escape Hatch](image)

- Operation of the emergency escape hatch automatically triggers the vehicle’s safety relay cutting all power to the traction system (the vehicle cannot restart without a technician resetting the relay) and automatically flags the open emergency hatch to the Controller.
- Controllers have CCTV images of the interior of the vehicle and are in audio contact with the
passengers as soon as the vehicle starts to slow (i.e. starts to fall behind schedule). They are therefore in a position to provide instruction, dependent upon the nature of the emergency.

- Should it be essential for the passengers to vacate the vehicle they will be instructed to disembark through the emergency exit and wait on the guideway until ULTra control room staff or emergency rescue services arrive to escort passengers off the guideway. In the case of mechanical failure, ULTra staff will handle the situation directly without calling emergency services.
- CCTV coverage of the guideway allows the Controller to monitor the situation and if required to advise the emergency/rescue services on the developing incident.

- Chris Cook, ULTra PRT

9.3.5 Example of typical first responder live training exercises

Heathrow Emergency Services Development Trial, 20\textsuperscript{th} February 2010

Summary

Members of the Heathrow emergency services attended a development trial at the ULTra PRT site to progress the capability to deal with the scenario of recovering a trapped casualty from under the vehicle on the guideway.

Participants

Attending were:
- Heathrow Fire & Rescue Service
- London Fire Service
- London Ambulance Service
- Metropolitan Police Liaison
- ULTra PRT Vehicle Engineering
- ULTra PRT Operations Team

Activities

The ULTra vehicle was taken to three locations representing worse case conditions:

1) Tight bend
2) Adjacent to a Guideway Electrical Equipment (GEE) box
3) On a span with double height kerbs

Observations

A number of different lifting adaptors were available and the Fire and Rescue services trialled these with their own lifting equipment (air bags and hydraulic jacks).

In the case of locations 1) and 2) it was shown that with minor modifications to the lifting adaptors, the vehicle could be successfully raised off a casualty using the hydraulic jacks.
In the case of location 3), access to insert the lifting adaptors was impaired / marginal. It was however shown that if necessary, a combination of using air bags initially to lift the vehicle sufficient to insert the adaptors and then the hydraulic jacks should provide a workable solution.

**Actions**

ULTra PRT will have modified version of the lifting adaptors made in time for the formal Emergency Services trials to be undertaken as part of the Operational readiness activities. In service, three sets will be held; one set in each recovery vehicle and one in the Operations Support Vehicle (van).

During the trials, ULTra PRT and the Emergency Services will document the process and subsequently create quick reference sheets for ULTra PRT to attend with at any incident.

Consideration will be given to having part of the trials conducted at night to establish any lighting issues.

**Photographs taken during the trial are shown below:**

![Figure 9.4, Location 1](image-url)
Figure 9.5. Location 1 at left, Location 2 at right

Figure 9.6, Location 3
9.4 Annual costs

Projected PRT4UT annual O&M costs are $3.55M per year. Details are provided in the separate, confidential PRT4UT business model spreadsheet. Costs were based on the London Heathrow ULTra system cost base, translated to US dollars and scaled to PRT4UT size.

9.4.4 Power

Electrical quote from Austin Energy: A PRT system would represent important infrastructure, so would need somewhat high reliability electricity, although this is somewhat mitigated by the fact that the vehicles are battery operated, so store energy and can robustly accommodate short power outages. The “medium-sized” PRT4UT system would need roughly 3 to 5 million kWh per year. The exact rate schedule that would be applied depends on whether the maximum demand exceeds 20 kW. If it does, then the large commercial rate would be applied: A) To figure the monthly electric bill, multiply maximum demand (measured in kW) by $13 and B) add that number to monthly kWh multiplied by $0.054 per kWh.

9.4.5 Labor

A breakdown of annual labor costs by position is provided in the separate, confidential PRT4UT business model spreadsheet. Labor costs dominate overall O&M costs.

9.4.6 O&M Comparison with DFW Skylink APM

ULTRA provides a lower operating cost per passenger mile than the Bombardier Innovia Automated People Mover (APM) system implemented as DFW Skylink. DFW Skylink 2009 O&M is $22.5M; $30M, including associated airport services and debt service. 2010 O&M is projected to rise to more than $25M, due to contractually scheduled increases. With 18M ppa (passengers per annum - based on DFW projection of 50,000 passenger trips/day) and an average trip length of 1.0 miles, the DFW Skylink APM yields about ~$1.4 per passenger mile.

At $3.55M/year O&M, PRT4UT is expected to move over five million passengers over an average distance of 1.5 miles; this yields $0.47 cost per passenger mile. PRT4UT is three times more cost-effective than Bombardier, and provides a much higher level-of-service, with waiting times measured in seconds rather than minutes.

Smaller vehicles allow for smaller maintenance facilities and reduced spares storage space. Regular inspection and maintenance of a few vehicles at a time allows for fewer technicians and better utilization of personnel. Off-the-shelf automotive components are cheaper to replace and require less specialized maintenance equipment.

Because of low column loadings, ULTRA guideway is simple and slender. Heavy APMs require massive guideway and columns. Therefore ULTRA guideway maintenance requires less time, fewer personnel, and cheaper materials and maintenance equipment.
The level of automation provided by the ULTra system allows for a reduced operator workload, resulting in the need for fewer operators. Automatic control and management of vehicle operations with respect to demand levels ensures that the system uses energy to move passengers in the most economical way. Computerized demand management systems ensure that operational planning is matched with expected demand levels, feeding performance data back into the system to provide continual improvements to service levels and customer experience. These factors all contribute to significant savings in O&M compared to APMs.

9.5 Smartphone Futures

9.5.1 Intro to smartphone apps

The intent of Section 9.5 is to paint a broad picture of “smartphone-enabled” transportation that we expect will arise in 5 to 10 years. Smartphones such as Droid and iPhone provide robust software development platforms with location-tracking capability (via GPS). We expect such smartphone handsets will be ubiquitous in the Austin market within a few years. The larger the PRT network, the more value provided by smartphone travel support.

A number of helpful applets will arise, including: effortless ticketing, line-haul transit to/from PRT coordination, etc.

9.5.2 Effortless PRT ticketing and destination selection

For many PRT trips, smartphones with short-range ID broadcast can eliminate ticketing and destination selection effort. Smartphones with keypad data entry and graphical displays provide richer capabilities than Oyster Cards.

Because it provides direct point-to-point service, PRT requires the specification of destination station before a vehicle departs a station. The 20 PRT4UT stations may evoke images of a "pick 1 of 20 stations from a large touch screen map" user interface.

As an alternative, a traveler’s smartphone may identify a traveler to a fare gate, and the control system can retrieve that traveler’s trip-making context, suggesting the likely destination station. If no changes are required, this can all occur with no physical effort by the traveler. Thus this very personalized fare gate system reduces transaction time and effort.

The typical fare gate interaction is as follows:

- A traveler walks up to an entrance gate at a PRT station with smartphone in brief case or pocket. The gate is constantly polling for traveler IDs provided by smartphones.
- The traveler’s smartphone announces that a traveler with a unique ID has arrived.
- The gate retrieves trip making patterns, selects the most likely destination, and displays the information on a flat panel monitor that is visible to the traveler.
- In most cases, the traveler agrees with the suggested destination station and boards the appropriate vehicle. When the traveler prefers another destination, they select it from the display.
- Once the vehicle is on-route, cloud payment is made.
Individual Trip Making Patterns

Most travelers will only use a few of the 20 stations on a regular basis. For example, one west-of-campus resident might have the following historic travel patterns (using Alignments 1, 2 or 3, from Section 2.1.3):
- Early AM: travel to FA3
- Mid-day: travel to FA7
- Late afternoon: travel to WC2.
- If the traveler appears in the proximity of a PRT4UT station between 8AM and 10AM, then he is going to go to FA3.
- If he appears in the proximity of a station between 11AM and 2PM, then he will go to FA7.
- If he appears in the proximity of a station between 2PM and 4PM, then he is traveling to WC2.

9.5.2 NextTrain

NextTrain tracks a “race” between the front car of an LRT or streetcar “train” (MetroRail or Urban Rail) and a traveler to a meeting point at a train station. In this race, the traveler will use PRT as the “first mile” solution to access the train station. The traveler should always win the race with some time to spare.

Example

Consider, for example, a traveler attempting to catch a 6:35PM Urban Rail streetcar to downtown. The streetcar is on time. The traveler is studying near the Castillian PRT4UT station and will take ULTra to the PRT4UT “Urban Rail” station. Her desk is a one-minute walk from the Castillian PRT station.

Once per minute, the traveler’s NextTrain handset application queries the NextTrain application server for the streetcar’s predicted arrival time at the “Urban Rail” PRT4UT station. This parameter is called “TR” for Train. The NextTrain application server in turn receives frequent updates from the streetcar’s train location server. For purposes of this example, TR is 6:35 PM, meaning the train is on schedule.

The time for the traveler to travel from desk to the train station is called “TTAT” for Time To Access Train. This parameter varies for travelers at different locations throughout the research park, in this example the time is calculated as the sum of:
- 1 minute to walk from desk to Castillian PRT station
- 1 minute wait at the PRT station to wait for and enter a vehicle
- 4 minute ULTra trip from the Castillian station to the Urban Rail PRT station.
- 1 minute to exit the PRT vehicle, walk to the streetcar, and enter the streetcar
- 2 minutes of “slack” in anticipation that something might take longer,

for a TTAT of 9 minutes. The one-minute PRT wait above will actually be a dynamic calculation based on current and anticipated PRT demand around the time of departure.

The time for a traveler to leave from their current location is called "LV", for Leave. LV is calculated as TR – TTAT. In this example, we have 6:35 – 9 minutes = 6:26.

For this example, the traveler will have set up NextTrain to cause her cellular handset to play a single tone at five and then two minutes to LV. NextTrain will check whether sufficient PRT vehicles are available at the origination station at time [LV minus four minutes], understanding current status of demand at that station. Should there be a vehicle deficit, NextTrain will order a PRT vehicle to be sent to that station.

In the unlikely case where the traveler leaves as directed, but still misses her train, NextTrain will ensure that she gets downtown as conveniently as possible, and will provide compensation, such as a free lunch or a few free PRT trips. Before switching to transit from driving, a traveler never even had a connection to miss. But missed trains could cause a from-car-to-transit switcher to revert back to driving alone, so
customer support should take such incidents very seriously. Traveler tracking can evolve to instantly identify customers missing connections.

For the morning connection to LRT or Streetcar, one prospective user also has a race against the train to the train station, "If I got notifications that the train was late, this would allow me to stay inside my house. I don't need a reminder when things are going well, but I do need to know when things are out of sync."

### 9.5.3 Future All-encompassing Wireless Traveler Assistant

Over time, all software applications should merge into an all-encompassing smartphone traveler assistant. Such a Traveler Assistant would have the following features:

- **Be a "smart alarm clock."** Rail and bus travelers fear falling asleep and missing their stop. The Commute Assistant can wake travelers when they are three minutes from their train station / bus stop, regardless of the time. This is preferable to travelers manually setting their watch alarms to beep in a certain number of minutes, as the transit system might be delayed on-route, and their watch would wake them earlier than is desirable.

- **As part of preventing nightmare commutes, proactively detect when travelers miss connections**, then take corrective steps. Don't wait for a call.

- **"HomeSafe"** verifies that a carpooler arrives home safely via geolocation cross-checked against scheduled arrival time. HomeSafe may also be optionally configured to ask the traveler for a password upon arrival, providing a second level of protection. When a traveler has not reached home within a certain number of minutes after scheduled arrival, HomeSafe gets into action: a) sends text message query, "are you OK?", b) eventually calls police. HomeSafe's unnecessary nagging of late travelers who get stuck in traffic is a reassuring feature; the system's concern for travelers in non-threatening situations increases confidence that the system will be there vigilantly when danger lurks. Berkeley's Susan Shaheen held carpool focus groups that revealed that safety concerns reign supreme for carpooling amongst strangers. HomeSafe lessens this safety objection.

- **Trip planning** using a traveler's current location and the Traveler Assistant back end preference data to make smarter selections with less traveler data entry.

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**Section 9.5 Reference:**


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### 9.6 Disabled Travelers

Wheelchair traveler system use has been previously mentioned in Sections 2.3.2, 7.3, 7.7, 8.4, and 9.2.2, as well as in Figure 7.26.

Hearing-impaired travelers will navigate the ULTra system via signage and Destination Selection Panels.

#### 9.6.1 Accommodating Visually-Impaired Travelers

At UT, there are several visually impaired students. Station and vehicle design will accommodate such travelers. Early in the implementation of PRT4UT, live human factors exercises will be undertaken to
verify that the human interface accommodates visually impaired travelers without introducing excess fear and anxiety. Station design will feature tactile floor strips to guide in-station vehicle access and from-vehicle station egress. Two-way audio communication between Controllers and travelers will facilitate destination station selection. Live passenger training with Orientation and Mobility Specialists will familiarize visually impaired student travelers with the system.

Historically, the Morgantown (West Virginia) group rapid transit system (21-person vehicles) provides an example of serving visually impaired passengers with two-way audio communication between Controllers and travelers. For PRT4UT, the envisioned fare card system will allow for immediate Controller notification that a visually-impaired traveler is at a station, allowing the controller to better monitor and assist such travelers.

While two-way audio communication should suffice for visually impaired traveler destination station selection, the Destination Selection Panel (DSP) could also be designed to allow for automated voice response interaction whereby travelers could speak their destination station selection to the DSP.

The European Union’s 2002-2005 EDICT (Evaluation and Demonstration of Innovative City Transport) PRT study surveyed potential visually impaired PRT users and found:

"Initially, many people were a bit suspicious of the idea, especially the question of personal safety in unstaffed stations and vehicles, but once they knew the details, the response was very positive. We spoke to blind people and wheelchair users, and most of them thought ULTra would be easier to use than taxis or existing public transport."

PRT human factors for visually impaired travelers will provide a relaxing, low-stress travel experience. In contrast, noisy, crowded rapid mass transit systems with open platform pits often provide a high-anxiety travel experience:

- Fear and anxiety can reduce blind and visually impaired willingness to use rapid transit (especially when switching over from bus). Hence design should minimize fear and anxiety.
- Complex rapid transit station designs, noise, and crowdedness are a major cause of fearfulness. Compared to large mass transit stations, the simple PRT4UT stations envisioned minimize these fear sources.
- Mass transit station platforms have a “pit” where the train runs, introducing fear of falling into the pit. The London Heathrow ULTra system is fully grade-separated and double glass doors prevent the ability to come into contact with moving vehicles on the guideway. In addition, ULTra has no pit and vehicles run at low speeds within station areas.

Section 9.6 Reference:

Solutions for problems for visually impaired users of rapid rail transit, B.L. Bentzen, US Department of Transportation/UMTA, August, 1981.

Chapter 10: Business Model

Analysis of the economics of the proposed PRT system shows that there is a positive business case that allows the system to be built and operated over a 21-year period.

Described below, in summary and by component, is a 21-year PRT4UT business model, based on $104M capital costs, $3.6M annual operations and maintenance budget, vetted revenue sources, and a debt/equity PPP finance package featuring 49.5% Local Government Corporation low-interest debt. Net Present Value (NPV) analysis is provided for both Special Purpose Entity (SPE) and UT economic perspectives. The electronic Microsoft Excel business model spreadsheet flexibly allows changing variables and amounts, and then seeing such “what-ifs” ripple through the model back to NPV. The business model is an excellent starting point for scenario analysis and further discussion, and does not provide a “single correct answer” because many feasible solutions exist.

As previously stated in Section 2.4, Main Campus: Implementation, to implement a PRT4UT system, a corporate SPE will be formed to design, build, operate, and maintain the system. SPE member companies may include ULTra PRT Inc (a US company), Austin PRT, equity partners, and a large Texas constructor.

10.1 Potential Revenue Sources

Potential revenue sources for the PRT4UT business model are described in the separate, confidential PRT4UT business model spreadsheet.

There are additional sources of tangible and intangible value, such as:

- Favorable clean tech public relations boost from bringing about the first US PRT system
- PRT enabled staff/student recruiting advantage over non-PRT-enabled universities, for example increasing the attractiveness of UT to prospective students
- Value to UT in enabling farther-away parking
- Value to UT of “park on north side when you work on south side” (and variations)
- PRT-enabled reduction in special event bus service costs.

These values have not been quantified within the model as presented.
10.2 Capital Costs

System capital cost is currently estimated at $104M, including $9M in expected finance and legal transactions costs.

For $95M of non-finance, core capital costs, an approximate percentage breakdown by major component is:

<table>
<thead>
<tr>
<th>Rough Capital Cost Breakdown</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Guideway</td>
<td>46%</td>
</tr>
<tr>
<td>Vehicles</td>
<td>24%</td>
</tr>
<tr>
<td>Stations</td>
<td>12%</td>
</tr>
<tr>
<td>Guideway systems</td>
<td>5%</td>
</tr>
<tr>
<td>OMF</td>
<td>5%</td>
</tr>
<tr>
<td>Other capex</td>
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</tr>
<tr>
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<td>4%</td>
</tr>
<tr>
<td>total</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 10.2: Capex Breakdown

The equivalent cost per mile is $13M. This is obtained from a number of sources to generate a value that is appropriate to Austin:

1. The emerging cost of Heathrow allowing for the value engineering that has been identified from the first deployment of an ULTra system.
2. Budget costings provided by two Texas-based construction companies.
3. A separate costing exercise undertaken for a similar-sized system by a UK-based Quantity Surveying company.

Chapter 7, Infrastructure, details major capital components and provides more cost detail.

10.3 Annual Operations and Maintenance Budget

In Chapter 9, Operations and Safety, Section 9.4 details the $3.6M annual Operations and Maintenance budget. ULTra operates at a small fraction of the operating cost per passenger mile compared with the DFW Skylink automated people mover.

10.4 21-year business model narrative

Distribution of the 21-year business model spreadsheet is necessarily tightly controlled, with a limited distribution list. Such business models represent unique intellectually property in the nascent PRT industry, and ULTra PRT’s fiduciary responsibility precludes the inclusion of the spreadsheet within this report.
10.4.1 Goals

The goal of the business model is a “win/win/win/win/win/win” for UT, students, the Special Purpose Entity (SPE), City of Austin, taxpayers, and the environment. More specific goals are:

- Provide UT with a state-of-the-art $104M PRT system at a fraction of that cost, with small initial and annual contributions.
- The SPE should show proportionate financial commitment by having “skin in the game.”
- Avoid general taxpayer obligation.
- Provide the City of Austin with a state-of-the-art $104M PRT system at minimal cost.
- Create a thriving SPE with the ability to enhance Austin further by bringing future ULTra expansion/systems to Austin and Texas.

10.4.2 Details

As previously stated, there are many feasible sets of values within the business model spreadsheet that can provide a win/win/win/win/win/win. There is no single correct answer. The current set of values in the business model spreadsheet is only a starting point for scenario analysis and optimization.

The spreadsheet allows for “what-if” exercises, where values such as interest rates, inflation, revenue sources detailed above in section 10.1, etc., can be varied. The “shape” of the agreement and percentage of various debt and equity financing tiers in themselves have many different possibilities.

*Transacting “residual value” after 21 years*

At end of 21 years, the residual value of the system is the straight-line depreciated value of guideway, stations, and OMF building. For 50-year lifespan assets, the residual value is calculated as 60% of this infrastructure, which in turn represents about 70% of capital costs.