

PRT System Requirements

Level of development of existing system

Dr. Anderson initiated the design of a new PRT system in 1981 following 13 years of activity in the field of PRT as a Professor of Mechanical Engineering at the University of Minnesota, where he coordinated a 15-professor interdisciplinary task force on new concepts in Urban Transportation, chaired three international conferences on PRT, studied the work on automated transit systems underway in eight industrialized countries, consulted for governments and industry, and developed a textbook¹ that laid out engineering science needed to guide the development of PRT systems. See the list of 122 of his papers related to PRT included in the biography section, 24 of which can be found on www.prtnz.com. With this background he developed comprehensive lists of criteria for PRT design and analyzed 48 trade-off issues before initiating his design work.² While with Taxi 2000 Corporation, his design was worked on and reviewed successively by five engineering companies including a \$1,500,000 design study sponsored by the Northeastern Illinois Regional Transportation Authority. Before any hardware was built, his design won international competitions in Chicago, SeaTac, and Cincinnati. Subsequently he lead the design and construction supervision of the automatically controlled, linear-induction-motor propelled PRT vehicle shown in Figure 1 and the 60-ft (18.3 m) piece of guideway on which it operated flawlessly for thousands of rides as an exhibit at the 2003 Minnesota State Fair. Since leaving Taxi 2000 Corporation in January 2005, based on public-domain information and his basic engineering knowledge, he has specified his system in terms of a series of requests for proposals for systems engineering, safety and reliability, control, guideway final design, chassis final design, cabin final design, power and propulsion final design, station and maintenance system design all in sufficient detail so that, when funded, we will be able to build, operate, and complete testing on a test system in less than two years. The process he used to design his system is described in a Power Point presentation that can be viewed on www.prtinternational.com.



Figure 1. PRT Vehicle and Guideway.

Status of regulatory submittals, review, testing or approvals.

In the above-mentioned \$1,500,000 design study the prime contractor, Stone & Webster Engineering Corporation, reviewed and showed that the system met over 80 specifications. The RTA selected the system that resulted from the design study for full-scale testing. Raytheon Company was selected as the prime contractor on the test program. Determined to use only their own engineers, who had no experience in PRT and were accustomed to receiving contracts from the De-

¹ J. E. Anderson, *Transit Systems Theory*, Lexington Books, D. C. Heath and Company, 1978. www.advancedtransit.org.

² J. E. Anderson, "The Future of High-Capacity Personal Rapid Transit," www.prtnz.com.

fense Department, they over-designed the system to the point that it was too expensive for the RTA to accept; however their version of PRT was tested extensively.

Financial plan and capabilities

We have developed a program of tasks, schedules, and costs that indicate that we will be able to complete a test program on a half-mile test guideway, with one station, a maintenance facility, and three vehicles plus planning for the first small application for \$20 million and in two years. Further details will depend on negotiations with the funding source. We are in contact with several possible funding sources. Launching of the above-named web page has been important for us to establish our position as a PRT system supplier, under the name *ITNS (Intelligent Transportation Network System.)*

Energy use and environmental impact of proposed system. Viability of solar or alternative energy use.

Dr. Anderson has discussed the energy use of his PRT system in Section 15, page 20, of the paper ITNS³, which is included with this submittal. The environmental impacts are discussed in Sections 14 and 17 of the same paper. Section 15 of this paper discusses the viability of use of solar, wind, geothermal, biomass, or other forms of renewable energy for system operation.

Design and operational considerations specific to Santa Cruz

The main consideration specific to Santa Cruz is the fact that the Beach Boardwalk and Downtown are tourist destinations, particularly in the summer. People desire to move from downtown or large parking areas near Highway 1 and 9 to local tourist destinations. In the summer the roads to the beach are in gridlock. The PRT feasibility study⁴ identifies this route as option 1. Also, Santa Cruz is a university town and has the typical controversy of a State-funded University impacting City resources. The feasibility study mentions the University link; however, the topography will be a major factor. The University is on a hill above the City with limited traffic corridors that currently exist on primarily residential streets. Previous transportation studies have considered a gondola type system to access the University from Harvey West Park industrial area. The PRT technology is ideal to provide direct access to the University over steep terrain with minimal impact to the adjacent public greenbelts. The Santa Cruz Master Transportation Study identifies the University - Harvey West – Downtown – Beach communities as a desirable high frequency link for a Fixed Guide Way System (PRT). Utilization of a PRT system combined with intercept parking lots and off season Boardwalk parking would significantly improve local traffic flow. A properly designed PRT system will enable Santa Cruz to achieve the Sustainability Principles articulated in its year 2003 Master Transportation Study far better than any conventional transit system.

The Recommended Network.

Figure 2 shows a map of the PRT network emailed to potential PRT suppliers. We drew it in more detail to show that the route to UCSC and to the beach would have to be two way, and also to show the direction of the curves at the intersections, drawn in a way that causes merges and diverges to alternate, thus

³ J. E. Anderson, "An Intelligent Transportation Network System," November 2008, www.prtinz.com.

⁴ da Vinci Global Services, "Report on the Feasibility of Personal Rapid Transit in Santa Cruz, California, 3.2007.

reducing the chance of bottlenecks. To meet the ride-comfort criterion at 20 mph, the curve radii needs to be 60 ft for flat curves and 40 ft for superelevated curves. By measuring on the map, the one-way length of guideway is about 6.34 miles, and the longest travel distance (from USCS to the beach) is 2.71 miles. With a system of this length we can assume at least 12 passenger stations and one storage station. Assume a typical generic system cost of \$15 million per mile, a number that will vary with system and with inflation or deflation of some of the costs. Then the capital cost of the system would be about $6.34(15) = \$95$ million.

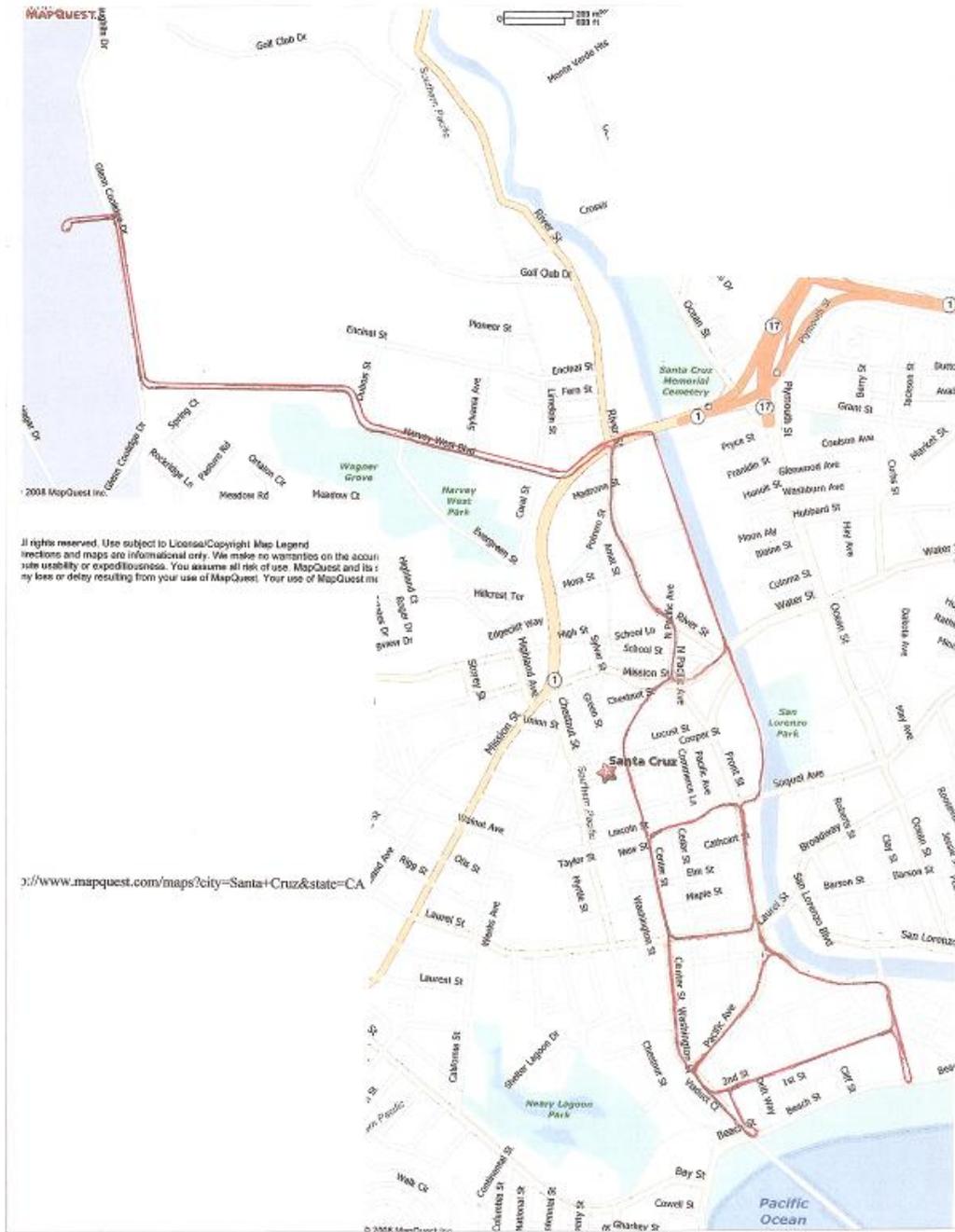


Figure 2. The Recommended Santa Cruz PRT Network.

We note a significant asymmetry of the network of Figure 2. At the beach end the turn-around guideway is placed on 2nd St., about 430 feet from the beach, evidently to prevent the guideway from blocking the view of the ocean. A pair of spurs would take passengers right to the Beach. At the UCSC end, unlike the alignment recommended in Reference 4, the guideway stops a considerable distance from the main campus, a map of which reproduced here as Figure 3.

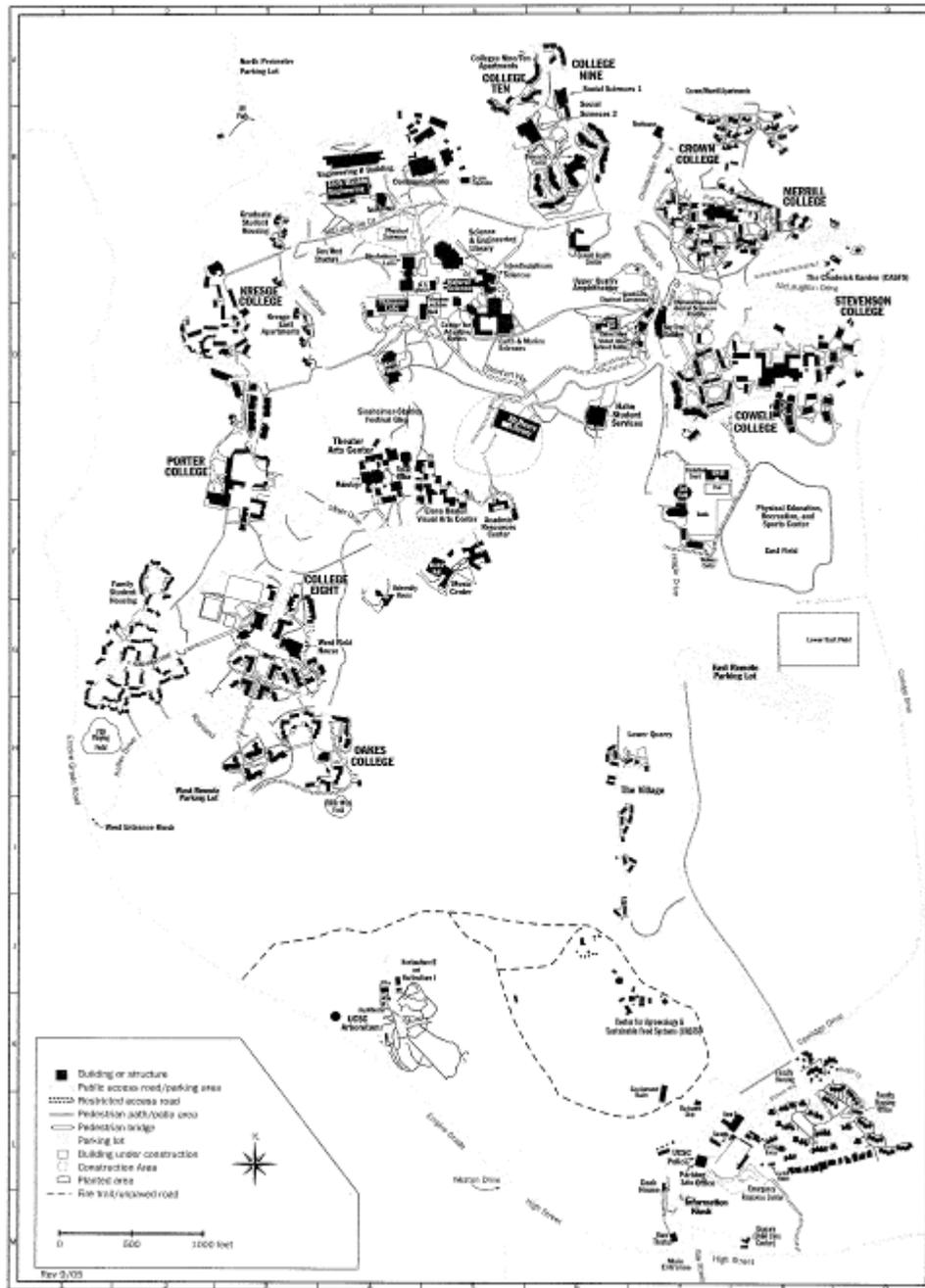


Figure 3. Map of UCSC Campus.

From Figure 3 we find that the main campus buildings are up to about 3680 feet from the end of the PRT line. According to Fruin⁵ the average walk speed is about 240 feet per minute or 22 minutes per mile, which means that at the beach end, the spur guideways are extended to Beach Street from 2nd Street to avoid an average walk time of only 1.8 minutes, whereas at the UCSC end a typical walk to one of the Colleges is about 15 minutes. From observations of human behavior reported in many transit studies, such a long walk is likely to inhibit ridership from the UCSC Campus to the beach quite substantially.

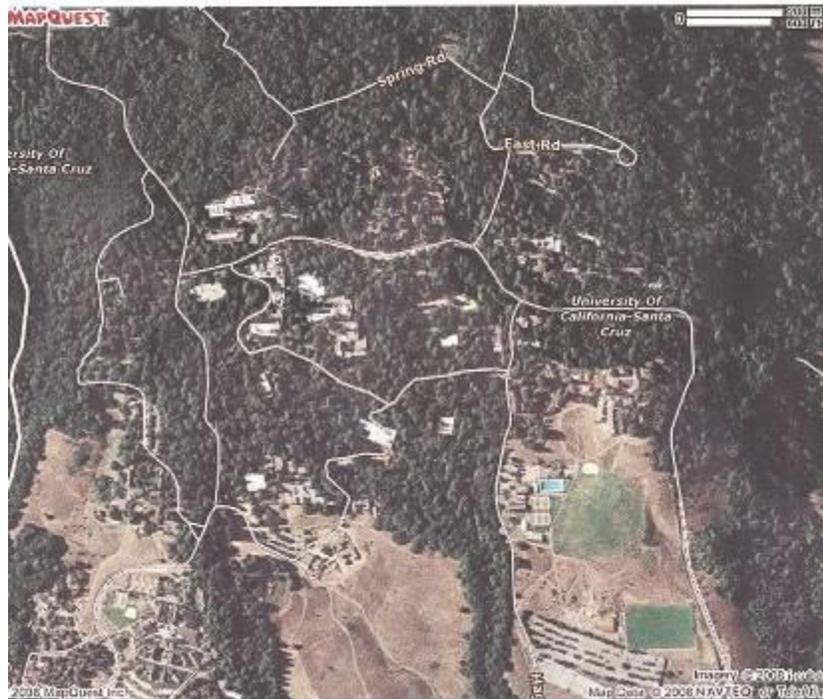


Figure 4. Aerial Photo of the UCSC Campus.

The tacit recommendation to not penetrate the Campus as recommended in Reference 4 is likely due to the number of trees on the Campus, as shown in Figure 4. This is certainly an important problem and one that requires a balance between the environmental advantages of causing more people to use the PRT system and the environmental advantages of maintaining the tree-scape as it is. The University Community must indeed want the PRT system very badly if it is to penetrate the Campus.

Let's try to estimate the ridership on the network of Figure 2. According to the UCSC web site, in the fall of 2007 there were 15,820 students on the UCSC campus. Thus counting faculty, staff, and visitors, there are likely to be perhaps 30,000 to 40,000 people on the campus every school day. We need to recognize that there will be two other major sources of revenue as a result of

⁵ John J. Fruin, *Pedestrian Planning and Design*, 1971, Elevator World, Inc., Mobile, AL 36606.

deploying the PRT system: goods movement and advertising. These sources may result in revenue at least equal to revenue from passenger fares. An important question now is this: How many trips per person can be expected to be taken on the PRT system per day? Since many students live on campus, that number is likely to be smaller than found in a typical community. I have tabulated⁶ data taken from studies by Zahavi in the early 1970s on Mobility, i.e, the vehicle trips per resident per day, in various U. S. cities. Based on this data, which is old, but considering the character of future Santa Cruz in an age of declining oil, the mobility in Santa Cruz may not be much more than two, and for people at UCSC likely fewer, but the potential for goods movement between the Campus and the city might be substantial if the network penetrated the Campus. Assuming that about a half of the vehicle trips would be taken on the PRT system if it penetrated the Campus, the total number of PRT trips, including both passenger and goods movement, might be in the range from 30,000 to 40,000 per weekday. If the PRT system stops as indicated in Figure 2, the ridership will be reduced by an amount that can be estimated only by a detailed site-specific ridership study.

The annual cost for operations, maintenance, and debt amortization for an automated transit system is typically about 10% of the capital cost, so total the annual cost will be about \$9.5 million. The total cost per trip is then

$$Cost\ per\ Trip = \frac{\$9.5(10)^6}{Trips\ per\ weekday \times Weekdays\ per\ year}$$

in which we mean the busy weekdays, in this case when school is in session. Counting vacation and breaks between terms, assume school will be in session for five days a week for 45 weeks per year or 225 weekdays per year. Then

$$Cost\ per\ Trip = \frac{\$42,200}{Trips\ per\ weekday}$$

The cost per trip or break-even fare is plotted in Figure 5 as a function of the number of trips per weekday. There will of course be other trips by people not connected with UCSC. Estimation of the total number of trips per year requires a detailed ridership study, but a rough guess is useful.

Compare the possible cost per trip from Figure 5 with the cost per trip on a conventional transit system. In conventional surface-level rail all of the capital costs and typically two thirds of the operating costs are paid through federal and local taxes. For example, as shown in Reference 3, page 17, the total cost per trip or break-even fare on the Minneapolis light rail line is about \$9.63 per trip, and such a system has little potential for goods movement. Compared to this cost, the cost per trip obtained from Figure 5 appears eminently reasonable.

⁶ *Transit Systems Theory*, op. cit., Table 6-1, page 135.

Cost per Trip on Santa Cruz PRT Network

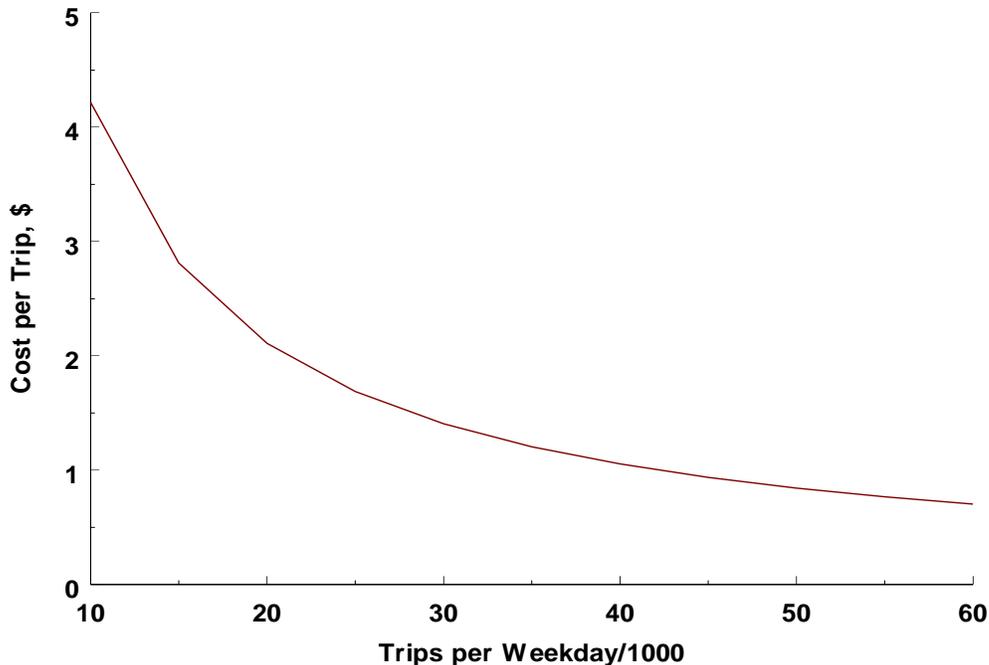


Figure 5. Rough estimate of the cost per trip on the proposed Santa Cruz PRT Network

A Generic Network.

Another way to think about PRT for Santa Cruz is to consider that, from the official Santa Cruz web page, the City has a population of about 56,300 people and occupies an area of about 12 square miles, giving a population density of about 4700 people per square mile. From maps of Santa Cruz, it can be seen that the city occupies a strip roughly two miles wide between ocean and mountains. Thus consider a city of two miles by six miles.

From the Santa Cruz Master Transportation Plan, Section III, 2.5, the access goal is to place every person in the city within 5 to 10 minutes of a transit stop. With this goal in mind, consider the PRT network shown in Figure 6. This network follows the design principle that merges and diverges should alternate to minimize possible bottlenecks. It has 28 miles of guideway and 48 stations. To cover the real city, consider the lines to be elastic so that they can stretch or shrink to fit.

The longest walk distance from any point within the 2 x 6 mile service area along east-west or north-south streets occurs only in the four corners of the service area and is 3/4ths of a mile, whereas for the rest of the residents the maximum walk distance is 1/2th a mile. Thus for almost all residents the maximum walk to a station is 11 minutes, with the average being about 5.5 minutes.

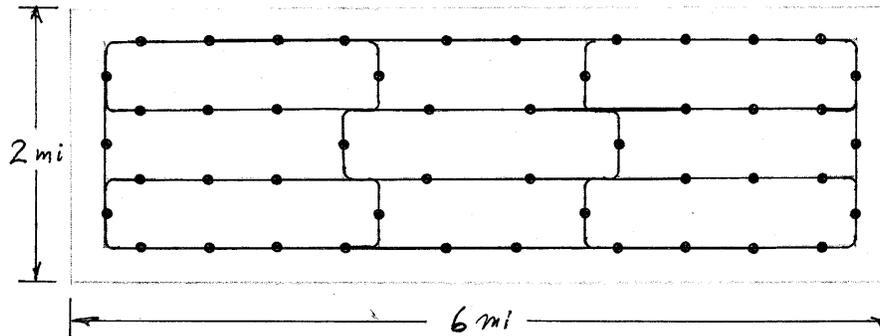


Figure 6. A Generic PRT Network.

Assuming as before that the cost of the system is \$15 million per mile, the cost of this network would be \$420 million. The daily ridership is given by the equation

$$\text{Trips per day} = m_i \tau P$$

in which m_i is the mode split to the PRT system, τ is the mobility, and P is the population. With the short walking distance to a station in the network of Figure 6, $m_i = 0.5$ is reasonable.⁷ From Reference 1, Table 6.1, page 135, assume $\tau = 2$. Then $\text{Trips per day} = 0.5(2)(56,300) = 56,300$. For a city, it is reasonable to assume for a PRT system that the ratio of passenger trips per year to passenger trips per weekday is about 320. Thus, we estimate that $\text{Passenger trips per year} = (320)(56,300) = 18$ million. On a network such as shown in Figure 6, we can assume that about as many freight trips as passenger trips will be attracted.⁸ Thus we estimate the total number trips per year at about 36 million.

Assume again that the annual cost is 10% of the capital cost or \$42 million. Thus we estimate that the cost per trip would be $42/36 = \$1.17$. In a system the size required to serve Santa Cruz, the average trip length could be expected to be about 2.5 miles, in which case the cost per passenger-mile would be 47¢. Counting advertising revenue, the cost chargeable to the passenger would be less. In comparison, the total cost per mile of an automobile ranges from 32.2 cents for a subcompact to 52.9 cents for a full-size utility vehicle.⁹ These numbers are, as implied, rough estimates. A detailed economic study will be needed to produce reliable data. Such a study must include detailed layout of lines and stations, visual-impact studies, ridership analysis, simulation of the operation,¹⁰ and detailed estimation of capital and operating costs.

⁷ Francis P. D. Navin, "Time Costs in Personal Rapid Transit." *Personal Rapid Transit II*, University of Minnesota, 1974, pp. 589-602.

⁸ J. E. Anderson, "An Overview of the field of Personal Rapid Transit," *PRT II*, pp. 1-9.

⁹ www.fhwa.dot.gov/ohim/onh00/onh2p3.htm

¹⁰ J. E. Anderson, "Simulation of the Operation of Personal Rapid Transit Systems." *Computers in Railways VI*, Lisbon, Portugal, WIT Press, Boston, Southampton, 1998, 523-532. (available on www.prtinz.com)

Construction, Maintenance, Operation, and Safety

Problems of construction of our PRT system, which we call ITNS, were studied while Dr. Anderson led its development for two decades. During that period we consulted with large engineering firms (in the most detail with Stone & Webster Engineering Corporation), steel fabricators, and other component suppliers. For construction of the curved guideway, we need to develop computerized jigs and fixtures and robotic welding, all of which are common today. This work is similar to the construction of the curved guideway of amusement-park rides. We have identified firms experienced in this work. We have obtained detailed estimates for design and construction of the foundations for the posts. We have found that there are several specialty steel fabricators in the USA that can construct the posts reliably and inexpensively. We have gone through the process of building a chassis and a vehicle cabin, and are aware of a number of companies to whom we can contract the final design of the cabins to Santa Cruz specifications.

During the above-mentioned PRT design study for the Northeastern Illinois Regional Transportation Authority (RTA), we developed detailed designs of the maintenance facilities and estimated the operational cost of maintenance.

Accurate study of the operation of a PRT system requires detailed computer simulation, which has been done by every group that has been serious about PRT development.¹¹ This work was done in detail during the above-mentioned RTA study under Dr. Anderson's supervision and can be done for Santa Cruz by our software engineering staff.

Safe design of PRT systems is and has been fundamental to our design.¹² During the detailed design and test program and beyond PRT International will have a team of engineers devoted 100% to all questions of system safety and reliability. This team will be led by Joseph Ward, whose biography is included with this submittal.

Detailed time line that addresses each phase of development, implementation and operation.

We have developed detailed plans and can explain them during private conversations with the selection team.

¹¹ J. E. Anderson, "Some History of PRT Simulation Programs," PRT International, 2008. (A discussion of 32 PRT simulation programs available on www.prtinz.com)

¹² J. E. Anderson, "Safe Design of Personal Rapid Transit Systems," *JAT*, 28:1(1994):1-15, www.prtinz.com.

J. E. Anderson, "Failure Modes and Effects Analysis," Sky Loop Committee, Cincinnati, 2001, www.prtinz.com.