A Rebuttal

to the

Central Area Loop Study Draft Final Report

By

The Sky Loop Committee

and

Taxi 2000 Corporation

September 2001

Prepared by

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SLC & Taxi 2000 Rebuttal Report
Executive Summary

This rebuttal is necessary because of numerous errors and incorrect assumptions in the CALS Draft Final Report (DFR) made by Parsons Brinckerhoff (PB) and their PRT sub-contractor, JKH Mobility.

These errors and incorrect assumptions likely have arisen from:

- the consultants' limited experience with PRT;
- limited information received by them on Taxi 2000 system design and engineering, which they did not ask for;
- the major mistake of acting beyond the scope of the Study by attempting to re-engineer the Taxi 2000 design (especially without informing Taxi 2000 and the SLC prior to their release of the CALS Draft Final Report that they were doing this).

This rebuttal will demonstrate the following key points:

- Vehicle weight will indeed be 1,013 lbs, not 1,900 lbs.
- Vehicle size will be as Taxi 2000 designed it, and will not be impacted negatively by ADA requirements.
- Guideway structure analysis, including curved truss sections, has been done for Taxi 2000 by Stone & Webster Engineering Corp., demonstrating that it will in theory work as designed.
- Stations will not need to be as large or costly as PB assumes.
- PB's proposed 68,000 SF storage facility is unnecessary. Taxi 2000's 7,000 SF maintenance and control facility (MCF) is adequate for the Sky Loop. Vehicles will be safely stored elsewhere.
- Right–of-way costs will be a fraction of what PB estimates.
- Engineering, construction management and project contingency costs will be a fraction of what PB estimates.
- Total capital costs should be about $109,000,000, up from our original $70,000,000 estimate, but far less than the $448,000,000 PB estimates.
- Annual operating costs will depend upon how many people are needed to operate and maintain the Sky Loop. PB's staff of 119 is 230% more than Taxi 2000's staff of 36 and based upon a misunderstanding of Taxi 2000's design and reliability standards.
- PB's travel demand model produced about 20,000 riders per day for PRT. While this is significantly lower than the SLC and Taxi 2000's estimate of 30,000 riders per day, it is encouraging. However, because PB's demand model is inadequate to properly consider PRT and because of erroneous assumption about PRT used by PB, flawed in several respects, their results likely represent less than the real demand for PRT and more for the other alternatives.
- The various safety concerns raised by PB are based upon incomplete understanding of how Taxi 2000 PRT will work.

The Rebuttal is designed to cover all these points in concise text, then refer the reader to relevant attachments for further details, data and explanations.

Our objective with this rebuttal is simple: to demonstrate that the Sky Loop is a reasonable choice as the long-term Locally Preferred Alternative for the CAL.

TABLE OF CONTENTS

Rebuttal to Central Area Loop Study Draft Final Report

by

The Sky Loop Committee and Taxi 2000 Corporation

1a. Why this rebuttal is necessary

The Sky Loop Committee (SLC) and Taxi 2000 Corporation very much regret the need to submit this rebuttal. However, as drafted, the Central Area Loop Study Draft Final Report (DFR) is so negative in so many respects that, as presently worded, it will kill any chance of PRT being built in Cincinnati if it is left unanswered. One of the more frustrating aspects is that the DFR seems to adopt the "worst-case scenario" in nearly every case when discussing PRT, while treating some major problems, such as use of the three bridges, in the most favorable light for alternatives like the Trolley. This negative perspective conveyed in the DFR along with the incorrect information presented about PRT has already had negative impact on the image of PRT in the community at large (see 7/18/01 *Cincinnati Post* article and 8/21/01 *Cincinnati Post* editorial in Attachments 1 and at http://www.cincypost.com/2001/jul/18/oki071801.html and http://www.cincypost.com/2001/aug/21/edita082101.html)

The Sky Loop Committee and Taxi 2000 had no chance to review the DFR before it was presented to the CALSC on July 17th. In light of the many changes made by Parsons Brinckerhoff (PB) to Taxi 2000's design and costs and the many assumptions made in other areas that clearly differ from Taxi 2000's, it would have been appropriate for PB to give us a draft version for comment at least 15-30 days in advance. We then would have been able to provide guidance on where we felt PB was incorrect. As it is, we didn't have that opportunity, so now this rebuttal is necessary.

This Rebuttal Report is submitted to all CALSC members, PB and OKI simultaneously, so all will have time to review it prior to the September 25th CALSC meeting.

1b. About the experts

Taxi 2000 Corporation is experienced in the theory and design of PRT. PRT is their only interest. Dr. J. Edward Anderson, the CEO of Taxi 2000 Corporation, has published many articles on theory and design, has organized international conferences on PRT, taught courses on PRT and directed the securing of funds for PRT projects, one of those being the $1.5M study of PRT for the Chicago RTA. Documentation of this expertise can be seen at the Taxi 2000 website, http://www.taxi2000.com/. It is important to dispel the notion that Taxi 2000 Corporation is only one person. Lists of 75 people currently involved with the Taxi 2000 Corporation and 16 companies that have been involved with the development of the Taxi 2000 system can be found in Attachments 1. There you will also find a log of the efforts for PRT over the last 33 years by Dr. Anderson and colleagues at the University of Minnesota and elsewhere, along with a record of the more than $32 million invested in Taxi 2000 to date.

⦿ Attachments 1

Note: Some people at PB have privately asked, “Has Ed Anderson built anything?” We passed this on to Dr. Anderson for comment. His reply is included in Attachments 1. We believe it serves to document Dr. Anderson’s capability in leading Taxi 2000 Corporation in the design and implementation of its PRT system.

1c. PB attempted to re-design PRT

Taxi 2000 and the SLC assumed that PB would accept the performance specifications set forth by Taxi 2000 and then compare them with the other technologies. After all, this design had already been approved by the Chicago RTA for its Rosemont PRT project. PB was aware of its limited knowledge of PRT design, and thus brought in JKH Mobility (JKH), a division of Kimley-Horn & Associates, to be the PRT consultant on their team. Given the limited budget and time available to PB and JKH in this study, we never dreamt they would attempt to evaluate the Taxi 2000 design, developed over a period of 25 years, and then create their own design as a substitute.

This is like a heart surgeon attempting to do brain surgery. The heart surgeon is an expert in his/her field of expertise but wouldn’t attempt to act like an expert out of his/her field by operating on someone’s brain. So it should be with transportation consultants. The experience of PB and JKH with large vehicle transit systems such as commuter rail, light rail, vintage and modern trolley, and APM systems does not transfer well to PRT.

This is especially true considering PB was not working with all, or even a small part, of the information available on the Taxi 2000 PRT system. Taxi 2000 PRT has volumes of engineering data, calculations, etc. that PB never used. One such item is a $1.5 million study of the Taxi 2000 PRT design done in 1991 by Stone & Webster Engineering for the Chicago RTA – a 15” thick four-volume set. The S&W study contains, among other information, complete data on the guideway design and tests, including both straight and curved truss sections. Moreover, since this study was done, Taxi 2000 PRT has further improved the design studied in the S&W report.

Because PB did not fully communicate its intentions and needs to Taxi 2000 PRT or the SLC, nor give any indication they wanted more information, they based much of their PRT analysis that appears in the DFR on faulty or incomplete data.

More important, however, is that PB erred in redesigning Taxi 2000 PRT because doing so was *clearly outside the scope of this study*.

The following sections of this rebuttal report show where PB went wrong.

1d. PB's projected costs for PRT are based upon their PRT system, not the one proposed by Taxi 2000; PB also assumes the worst-case scenario for every cost element

Our costs comparison for the Sky Loop is in Attachments 2. There we show our original cost estimate, derived from Taxi2000's estimates done in 2/00, then PB's cost estimate from the DFR, and then our revised cost estimate. In preparing our revised cost estimate, we carefully reviewed all assumptions made by the DFR, on some of which we agree or partially agree. We also asked Taxi2000 for revised figures in some areas and incorporated these as well.

⦿ Attachments 2

The result is a higher cost estimate for the Sky Loop than our first one, but nowhere near as high as the figures given by PB. A capsule summary of why we differ is contained in "Notes to Cost Comparisons for Sky Loop" in Attachments 2. More detail will be provided below.

⦿ Attachments 3

2. Vehicle Weight

JKH received a detailed breakdown of the vehicle cabin and chassis components along with Taxi 2000's weight estimate for each component. These totaled 1,000 lbs. JKH then increased the size of the vehicle so that a wheelchair patron could turn around inside (see Section 3 on vehicle size and ADA requirements below), without any consultation with Taxi 2000. The consultant then proceeded to recalculate the weight for each component of the now much heavier vehicle and concluded that the PRT vehicle would weigh 1,900 lbs. (DFR, Appendix F) See Attachments 3.

⦿ Attachments 3

The DFR provides no justification for the sub-consultants action other than the erroneous application of ADA regulations. The Taxi 2000 vehicle design that should have been properly considered is based on a careful analysis of vehicle components over a period of 25 years, an analysis of ADA requirements and consideration of the principle of minimization essential to PRT if it is to work well.

Vehicle weight is the lynchpin for the rest of the PRT system. Without knowing the vehicle weight, one cannot design the guideway. And without minimizing the weight of the vehicle, one cannot minimize the weight of the guideway and the subsequent cost of both. Taxi 2000 knew this and has done its weight calculations very carefully and with minimization in mind.

DFR, Appendix F, Section F.1.3 states the Taxi 2000 auxiliary mechanical brake with a holding capacity of 100 lbs. to be used as a parking brake will also need to be used as an emergency brake and, consequently, would need at least 200 lbs. (and possibly 500-

800 lbs.) for emergency duty. JKH thus doubled the weight of these components, not realizing that they had already been substantially over-designed. Indeed, Taxi 2000 has found that, because of advances in the design of the Duff-Norton linear actuator, one that has a capacity of half a ton, which is adequate for the purpose, now weighs only 2.75 lb., and the entire auxiliary brake weighs only 5.75 lb. instead of the 24 lb. tabulated in the DFR. The 1991 S&W Report, p. 5-74, Section 5.4.2.5, notes that the batteries on-board the Taxi 2000 vehicle can be used to energize the LIMs (Linear Induction Motors) to effect an emergency stop. Using the auxiliary brake for an emergency brake, as PB has done, is a belt-and-suspenders solution.

DFR p. 2-13 states Taxi 2000 would use regenerative braking and goes on to suggest that dynamic braking be used as an option. Regenerative braking uses the LIMs as a power plant to put power back into the power system, thus slowing the vehicle in the process. However, if the line is not receptive, regenerative braking does not work. Therefore it is not recommended for emergency stops. Dynamic braking uses up that same power by generating waste heat and requires some on-board resistance heaters. In a PRT system, because there are no intermediate stops, the fraction of input energy that can be recovered by regeneration is too small to be of interest. Therefore the Taxi 2000 design has from its beginning used on-board resistors to absorb the heat of braking. Because of the light-weight of the Taxi 2000 vehicle, the required dynamic braking resistor bank weighs less than one lb., which is the reason it was not specifically called out. The DFR, Appendix F, Section F.2 “Vehicle Estimated Weight” allows a 10% (174 lbs.) contingency for various items and parts not itemized which would include dynamic brake resistors, and which reflects their experience with large-vehicle transit systems. JKH should have studied the actual design of the Taxi 2000 vehicle before advising PB on its braking system.

Vehicle weight is very important for PRT. A major premise for Taxi 2000 or any other PRT system is that the weight of all components be minimized. This is how costs are kept down. This is one of the major reasons the PB’s cost estimates are so much higher than the SLC/ Taxi 2000’s. (See

The true weights of components for the Taxi 2000 vehicle as designed have been re-checked by Taxi 2000 in the past two months. They are listed in a table in3, which also includes a text review of the current component weights.

⦿ Attachments 3

3. Vehicle Size and ADA Requirements

In addition to revising all the component weights, JKH also attempted to determine what the Americans With Disabilities Act (ADA) would require for PRT. The U. S. Access Board, the federal agency which develops the vehicle guidelines adopted by the Department of Transportation as standards, has advised that it considers PRT to be covered under Subpart H of the vehicle guidelines (49 CFR part 38) which states that specific standards are to be determined on a case-by-case basis by the DOT, in consultation with the Access Board. The PB report makes the following errors:

60-Inch Accessibility Envelope: The DFR incorrectly states that a 60-inch minimum diameter envelope (circle) is required in the vehicle cabin for wheelchair accessibility based on the "Accessibility Handbook for Transit Facilities". Unfortunately, JKH and PB used the incorrect source, since that handbook provides guidelines solely for transit stations and stops and interior elements thereof. It does not address transit vehicles. The document which applies is the "Code of Federal Regulations: Title 49-Transportation, Part 38-Americans With Disabilities Act (ADA) Accessibility Specifications For Transportation Vehicles" (49CFR38). Per 49CFR38, wheelchairs or mobility aids must be positioned in areas having a minimum clear space of 48 inches by 30 inches – see Attachments 4. The Taxi 2000 vehicle design satisfies this requirement with a 50-inch by 32-inch space. We have corresponded with Dennis Cannon, Accessibility Specialist with the Access Board and primary author of the ADA regulations applicable to public transit vehicles. He confirmed our understanding that there is no requirement in the CFR for wheelchairs to face forward, except in buses and vans, or to be able to execute a 360-degree turn.

⦿ Attachments 4

Vehicle Cabin Size: The DFR is incorrect in stating that the Taxi 2000 vehicle cabin size will need to be increased because the ADA regulations they cite as reason do not apply. Thus PB's increase of the floor size by a foot in width and at least three feet in length and of the frame weight by 40% is not necessary.

48-Inch Wide Bench Seat: The DFR is incorrect in stating that the bench seat is 48 inches wide. The Taxi 2000 design specifies a 50-inch wide bench seat.

CALSC members should be aware that the ADA regulation 49CFR38 also says, "Departures from particular technical and scoping requirements of these guidelines by use of other designs and technologies are permitted where the alternative designs and technologies used will provide substantially equivalent or greater access to and usability of the vehicle. Departures are to be considered on a case-by-case basis by the Department of Transportation under the procedure set forth in 49 CFR 37.7." What this means is that ADA regulations are flexible, especially with new transit system designs.

4. Guideway Design; Curved Truss Guideway Sections

In the DFR, pp. 4-4 and 4-5, PB chose to modify the Taxi 2000 guideway in significant ways. PB states it "recommends a plate girder design with lateral bracing to account for vibration and curves", then concludes, "the guideway would be approximately six feet in width" and incorporate "aluminum covers."

These are all major design changes that add significantly to guideway weight, size and cost. As noted on page 2 above, PB did not use the 1991 S&W report that had analyzed the Taxi 2000 curved truss guideway. Also, PB came up with a weight of 1,900 lb. for its larger vehicle, and for unknown reasons, assumed aluminum covers rather than composite.

The reasons stated for these changes are not valid. Sections and attachments from the 1991 Stone & Webster (S&W) Subsystems Design Report dealing with guideway design, referred to earlier, demonstrate that both straight and curved sections of the Taxi 2000 guideway have been thoroughly studied and tested (see references in Attachments 5). All of this information was available from Taxi 2000, if PB had only asked for the information.

⦿ Attachments 5

As noted earlier, JKH and PB were given a copy of Dr. Anderson's 500 page plus *Transit Systems Theory* in early November of 2000. One section of this book, Chapter 10 on Guideway Structures, is designed to provide insights into the principles of cost minimization as relates to guideway structure. On pp. 266-267 of this chapter, Dr. Anderson compares the two-I-beams girder design (the design proposed by PB) with a single-box beam (Taxi 2000) design and demonstrates that a guideway cost penalty is paid if the girder design is used. Having studied PB's girder guideway design, a drawing of which had $700 per linear foot written on it, Taxi 2000 pointed out it will only cost $280 per linear foot for the truss-type Taxi 2000 guideway. Here again PB has demonstrated its ignorance of the principles of minimization as applied to PRT. PRT has not been built to date not because it is "unproven" technology but rather in good part because large national consulting firms, accustomed to designing large and heavy transit systems, rule out the design of PRT because they don't understand it, recommending larger, heavier and much more costly systems instead.

In his paper "The Design of Guideways for PRT Systems", also included in his *Transit Systems Theory* (and included in Attachments 5), Dr. Anderson develops the relationship between acceptable guideway weight, depth, weight of the load carried, and other parameters of interest for a range of span lengths and speed.

⦿Attachments 5

Had the engineering staff at PB read either of these above papers, which PB has had in its possession since November of 2000, they would likely not have spent project time and money to redesign the Taxi 2000 guideway.

DFR p. 4-4 Section 4.3 states that Taxi 2000 uses aluminum covers. The S&W Subsystem Design Report, pp. 4-22, lists covers as being made of FRP (fiberglass reinforced plastic) with embedded wire mesh for electromagnetic shielding and with an UV resistant coating. Such construction is 30% lighter, more resistant to corrosion & denting, and is less expensive than aluminum.

DFR p. 4-4 Section 4.3 claims Taxi 2000 design uses a 4'x4' concrete foundation. This is incorrect. For ease of installation, Taxi 2000 plans the use of post-hole drilling rigs to sink holes of appropriate diameter and depth for steel reinforced concrete post foundations.

PB also refers to “trackwork problems” as one of the major maintenance headaches and common causes of failures in automated transit systems (DFR, p. 4-5). This leads PB to conclude that Taxi 2000 will require a large number of maintenance vehicles and personnel to deal with trackwork problems. Taxi 2000 solved this problem in 1984 by designing a seamless guideway track that prevents deflections and other irregularities normally associated with “trackwork.” The Taxi 2000 design interfaces the rails so that there is no step or slope discontinuity, and so that there is no chance of a running surface interfering with the motion of a vehicle. How this is done is explained in detail in the Taxi 2000 guideway patents, which can be downloaded from http://www.taxi2000.com/readiness.htm. The patent numbers are listed on the webpage and in Attachments 5. With the Taxi 2000 design neither step nor slope discontinuities are possible at the joints. These are keys factors in ride comfort. It also does away with the need for a vertical suspension system, which cuts down on the vehicle weight and costs.

⦿Attachments 5

DFR p. 8-23 states, “The PRT guideway structure must maintain a clearance of 19 feet above street level to allow vehicles to pass underneath. The minimum height requirement for overpasses crossing over non-collector roads in the State of Ohio is *16 feet*. In the State of Kentucky the same requirement is *14 feet 6 inches*. The Taxi 2000 PRT will cross streets at a height that meets the local code. The reason why PB required a minimum clearance of *19 feet*, in contrast to Taxi 2000’s basic design of 16-ft. clearance, was not given in the DFR.

Curved truss guideways are in use today as the guideways for some roller coasters, e.g. the Millennium Force roller coaster at Cedar Point Amusement Park in Sandusky, Ohio (see home page photo at http://www.cedarpoint.com/). The reason curved truss guideway are used there is because they are relatively lightweight and low cost. Just imagine using steel I-beam girders such as those proposed for PRT by PB on a roller coaster. The other advantage of using curved truss guideways on roller coasters is that the steel tubing which serves as the stringers can be curved to allow for the many turns and loops found on roller coasters (see “Millennium Force” at http://badnitrus.coasterbuzz.com/). The 4-inch by 4-inch square tubes that will constitute the horizontal stringers for the corners of the Taxi 2000 guideway can be bent similarly. Evidence for this can be seen at the website of BendTec, a steel-bending company that is prepared to fabricate the Taxi 2000 guideways (see photo below, and also in middle of page at http://www.bendtec.com/induct.html). (BendTec was the fabricator that bent the steel for the Chicago RTA/Raytheon test track guideways). For the Taxi 2000 guideway fabrication, after the corner stringers are bent, they will be mounted in a welding jig where the cross members will be welded to the stringers.

Roller coaster curved truss guideways have the strength to safely handle a 20,000 lb. rollercoaster load at 3.5 g's, or 70,000 lb. of force. Taxi 2000 guideways will sustain mere 1,650 lb. per vehicle at .25 g. The Taxi 2000 guideway is not quite the same structure as that used on the Millennium Force roller coaster, since it is open on top, and so lacks a left-right truss structure there. This is overcome by using square tube stringers, which provide greater torsional rigidity, but more importantly by the method of clamping the guideway to the posts. As described above, the Taxi 2000 design has already been subject to and has passed thorough structural analysis and evaluation as reported in the 1991 S&W Report.

Bending square tube at BendTec

5. Headways

There has been a dispute since 6/15/01 between Taxi 2000 and JKH over the minimum safe "headway" for PRT, when JKH first informed Taxi 2000 about its position on this and other issues. The DFR Appendix G represents JKH's recommendation that the minimum safe headway be set at 5 seconds. Taxi 2000 has stated many times that its goal is to achieve a minimum safe headway of 0.5 second, but plans to start with perhaps 2 seconds as reasonable, assuming a maximum speed of 45 mph or less. The dialogue on this issue, as well as various related safety and reliability issues, can be found in Attachments 6.

⦿ Attachments 6

What is headway and why is it important? Headway is a measure of the distance between vehicles traveling on the guideway. It is the nose-to-nose distance between two vehicles divided by the speed, and its unit of measure is time – in the case of PRT, seconds. Headways for other transit systems, such as the SouthBank Shuttle and the Trolley, are in minutes (the time between vehicles passing any given stations). Headway determines how many vehicles travel past a point in one hour which, in turn, is generally used to determine the capacity of a transportation system. The capacity of a transportation system is the maximum number of passengers it can handle at any one time. Headway is very important for PRT because what the minimum headway is for the system determines the capacity of the system, or the maximum number of passengers that can use the system at one time.

DFR Section 2.4.1 (p, 2-11) and Section 2.4.2 (p. 2-14,15) deal with PRT headways.

PRT Headways Constrained to 5 Seconds: DFR p. 2-14 states headways should be limited to 5 seconds until Taxi 2000 has demonstrated safe operations below this level. This limitation is needless at this point in the overall process and one wonders why a minimum headway was imposed *without properly allowing for the designed half-second headway of Taxi 2000*. Indeed, the SLC has proposed to the CALSC a strategy of successive phases of study and engineering dependent on development and test of a full-scale operating Taxi 2000 prototype that demonstrates safe operation at headways small enough to satisfy Sky Loop demand, with the ultimate goal of headways as short as 0.5 seconds.

While the DFR states that PRT headways "should be limited to 5-seconds until the Taxi 2000 system has demonstrated safe operations below this level" (DFR, p. 2-4), it then goes on to say a sensitivity analysis was performed using projected ridership numbers from the travel demand model to evaluate the effects of a decrease in PRT headways to 0.5 seconds. Doing such an analysis is irrelevant to whether a vehicle can run safely at fractional-second headway. *Because ridership is not the determining factor in the headway capability of the PRT system!* The safe headway capability is determined by the engineering of the vehicle and the computer control system, not by ridership.

The shorter the headway, the greater is the ridership capacity of the system. And that is why the ability to run at short headways is so important. Long headways mean that the PRT system won't be able to transport as many people and this will seriously affect ridership and the profit-making potential of PRT.

> Note: Simple calculations of the arbitrary 5-second headway limitation at various speeds illustrate its absurdity: 147 feet between vehicles at 20 mph; 293 feet at 40 mph; 440 feet at 60 mph. Compare these distances to those between automobiles traveling 40 mph (293 feet = *19.5 car lengths*).

This 5-second limitation imposed by JKH is likely the result of:

1. Misapplication of brickwall stop, collision impact absorption and other criteria from APM standards that apply to trains, owing to the lack of due diligence in understanding the systemic application of failure modes analysis in the design of the Taxi 2000 system.

   The major results of Taxi 2000 analysis of failure modes and effects that result from interpretation of the APM standards for "brickwall" stops and from other materials including AHS literature are shown I the following table:

Speed, mph	Minimum headway per APM Standard, sec	Minimum headway using best current AHS technology, sec
15	1.06	0.49
30	1.43	0.29
45`	1.94	0.23

See the following in Attachments 6:

- “Automated People Mover Standards-Part 1, Chapter 5; 5.1.2 Separation assurance”; 1 page.
- "Readiness of the Taxi 2000 System”; 3 pages.
- "Failure Modes and Minimum Safe Headway in the Taxi 2000 System”; 3 pages.
- “Failure Modes and Effects Analysis and Minimum Headway in Taxi 2000”; 26 pages.
- "Calculation of Minimum Headway"; 1 page.

⦿ Attachments 6

2. Misunderstanding the goals and results of prior PRT studies and engineering efforts. Taxi 2000 was told by JKH that the 5-second minimum came from the Chicago RTA/Raytheon PRT 2000 study. But JKH may have misinterpreted the headway specifications for that study. The 1991 Stone & Webster Subsystem Design Report (in section 5.3.4. *Service Levels*) states that the initial headway for the prototype test system for the Chicago RTA PRT is to be 5 seconds. But it also states that the system capacity headway for the operation system will be 0.5 seconds. See the following in Attachments 7:

- "Chicago RTA: Phase I Scope Of Services", 1 page.
- Page 24 of Report No. UMTA-WA-06-0011-84-3, “Advanced Group Rapid Transit Vehicle Control Unit Design Summary, Boeing Aerospace Company”; 1 page.
- From the Summary Conclusions of Report No. UMTA-WA-06-0011-84-3, “Advanced Group Rapid Transit Vehicle Control Unit Design Summary, Boeing Aerospace Company”; 1 page.
- Stone & Webster Subsystem Design Report, Vol. 1, 1991, 5.3.4 Service Levels [Headway]
- "Additional Headway Citations"; 3 pages.

⦿ Attachments 6

Dr. Anderson relates, “Sam Lott’s insistence on the 5-second minimum headway was, per his own statement at the APM Conference, based on his knowledge that the Chicago RTA PRT specification mentioned 5 seconds. He apparently did not read far enough to realize that that specification listed 5 seconds as a headway that would have to be proven at start up but that the system would in time have to show a headway small enough to handle a large PRT system. I asked Sam for a calculation of this headway based on the APM Standard. He provided none saying it was what the Chicago RTA specified and he did not feel he needed to go farther; indeed his said he had run out of money and could not do any more work. He did not even try to apply the means of calculating minimum headway given in the APM Standard, which if applied to Taxi 2000 results in a minimum headway less than 2 seconds [see table in 1 above].”

3. Ignoring proven technology developments in fractional-second headways, vehicle steering, braking, and response times in other transportation fields more related to PRT, such as in the Automated Highway Systems (AHS) field. In a July, 1997, test of automated highway controls, the National Automated Highway Consortium (NAHSC) ran a platoon of eight Buick LeSabres on Interstate 15 just north of San Diego driving 60 mph at a nose-to-tail spacing of 6 feet, which corresponds to a nose-to-nose spacing of 21 feet, totally on automatic computer control. 21 feet at 60 mph represents a headway of less than one-quarter of a second. Operating PRT vehicles at one-half second headways will be much easier and safer than with these automobiles, since the PRT vehicles have much simpler systems, many fewer parts that can break down, and are captive to a guideway. The short headways achievable by PRT represent another instance of why APM standards don't apply to PRT, which shares much more in common with automated highway systems (AHS) than APM's. See the following in Attachments 6:
    - "On the Road to the Future; Global Consortium Test-Drives Automated Highway, Cars", *The Washington Post,* August 9, 1997.
    - "Hands-free driving debuts", *The Cincinnati Enquirer*, July 23, 1997.
    - See video of NAHSC 1997 test of eight Buicks platooning at one-quarter second headways at: http://www.gigascale.org/pubs/talks/1997/path/path/

⦿ Attachments 6

Marsden Burger, the CEO of CabinTaxi Corp. in Detroit, has informed us that CabinTaxi PRT, which ran on a test track in Hagen, Germany, used extensively during the period 1973 to 1979, was operated at 0.5-second headways on occasion. We can provide videotape documentation of this. CabinTaxi in Germany proved over twenty years ago that vehicles more complicated in design than those of Taxi 2000 can run at fractional second headways. We wonder why JKH and PB have made an issue out of something that has already been demonstrated possible to do.

One of the several purposes of the Taxi 2000 program of testing in advance of moving people will be to demonstrate safe, reliable operation down to half-second headways. Taxi 2000 will not operate a system at a headway lower than proven to be safe.

6. Computer Control System

The DFR refers to the computer control system for the Taxi 2000 PRT as an automated train control (ATC) type system. As evidence, on p. 2-14 it requires that this control system "will meet the functional requirements of the automated train protection (ATP), automated train operations (ATO) and automated train supervision (ATS) subsystems, as defined in Chapter 5 of the ASCE APM Standard – Part 1 (ASCE 21-96)." But the computer control system for Taxi 2000 PRT is not an ATC-type system. For the close headway of at least 0.5 seconds required for PRT, the control philosophy is different from and more rigorous than that of railroad practice. Where did PB get the "Systems Operations" for Taxi 2000 PRT that they subjected to analysis? (One thing is certain; they did not get it from Taxi 2000). Here we see another instance of PB applying APM standards to a non-APM technology. The Taxi 2000 control system is closer in many respects to automated highway systems (AHS) than to APMs. (See discussion of AHS headway demonstration in Section 5–Headways).

DFR p. 2-14 states that: "high capacity stations would platoon inbound and outbound vehicles to and from boarding positions during heavy passenger flows. There is no platooning of vehicles in the Taxi 2000 control system. PB probably got this idea from using JKH's computer simulation, which is an ATC-type control system (See Attachments 7)
.

⦿ Attachments 7

DFR p. 8-27 states "The control system for Taxi 2000 has not been demonstrated in a system as complex as the current proposal or in a similar operational environment." This is not true. The Morgantown (W. Va.) PRT (M-PRT) Computer and Communication System (C&CS) is similar in operation to the one designed for Taxi 2000 PRT. And JKH and PB should know that. Because this system has been in existence and operating successfully for over 25 years!

The original M-PRT computer control system (C&CS) was installed in the early 1970's. This system consisted of dual redundancy central supervisory computers and dual redundancy station control computers, as well as guideway and onboard vehicle control and communication equipment. In 1998, Boeing upgraded this control system with new computers, modems, etc. and new operating software. This upgrade included adding a third central control computer as a backup.

But how would PB know the ways in which the computer controls of a functioning (during non-peak hours) PRT system compare to that of Taxi 2000's when they never discussed the control system with Taxi 2000?

Computer control systems for PRT have also been demonstrated to work successfully in several prototype PRT systems that have been built over the years. In the mid-1970, CabinTaxi PRT ran on a one-mile test track during the period 1973-1979 (see discussion of CabinTaxi in Section 5–Headways). And in the mid-1970's, The Aerospace Corporation built and successfully operated a one-eighth scale prototype for a PRT system planned for Los Angeles – the Aerospace system was controlled by mainframe computers. Imagine how much easier and better the PC technology of today makes this task.

Lastly, and known to PB, in 1998, the Raytheon Corporation built and successfully demonstrated the operation of a computer-controlled prototype for a PRT system planned for Rosemont, Illinois. (See Section 17–Raytheon PRT 2000; see also Attachments 7 on a demonstration run for this system).

⦿ Attachments 7

The problem here is that once again we see PB applying a “worst-case scenario” to Taxi 2000 PRT, by implying that significant hurdles will have to be crossed by Taxi 2000’s computer control system. How could they assume this when they never consulted with Taxi 2000 about its control system?

7. Safety

Throughout the DFR, PB assumes a “worst-case scenario” for PRT when it comes to safety and reliability. It is very easy to take this position for a system that has not yet been built. However, based upon design, Taxi 2000’s PRT will be the safest and most reliable public transit system ever devised. For those who wish to delve into this subject, please read “Failure Modes and Effects Analysis and Minimum Headway in Taxi 2000” in Attachments 6.

⦿ Attachments 6

Based on years spent designing the Taxi 2000 vehicle and on analysis of the component systems, the mean times to failure for these components are listed below.

Table 1. Component Mean Times to Failure

Component	Single-Component	Redundant System
	MTBF, hrs	MTBF, hrs
Switch Actuator	4800	69 million
Auxiliary Brake	4600	
Power Pickups	10,000	300 million
Push-Mode Actuator	50,000	
Door Actuator	4600	
Hydraulic Bumper	5000	
Wheels	45,000	
Air Conditioning Unit	1900	
Ventilation Fan	5000	
Heater	5000	

(From J.E. Anderson, “Failure Modes and Effects Analysis and Minimum Headway in Taxi 2000”, 08/26/01).

This paper also gives a summary of design features required for minimum safe headway:

- Checked dual redundancy in vehicle and wayside controllers using fault-tolerant computers.
- Bi-stable, in-vehicle, conservatively designed switch mechanism.
- Switch torquer shielded against stray voltage pulses.

- Virtually instantaneous back-up power for propulsion and braking.
- Carefully designed, non-breakable power-pickup shoes.
- Frictionless propulsion and primary braking, i.e., linear electric motors.
- No-power-on, no-power-off auxiliary braking against the primary running surface.

The key to design of any vehicle for safety is to insure that no one major failure can cause injury to the passengers, whether by action of the system or by the passengers or by anyone near the system. In the case of simultaneous occurrence of two major failures, no system can insure that no one will be injured. For example, in railroad practice, safety depends on a vital relay working when needed. If its contacts were to stick, for example, a crash could result, but the chance is small enough that it is accepted. In the above list "anyone near the system" is included. Designers of surface-level light rail vehicles – which are well known to kill people, essentially ignore people “near the system”. These designers and consultants working on light rail wrap themselves in the mantle of great concern for safety and at the same time recommend surface-level light rail running down city streets with no barriers to prevent people from crossing the tracks. Why do safety concerns with those systems not apply to “anyone near the system”?

To understand why Taxi 2000 PRT will be much safer than any other mode of transit, public or private consider the mean time between failures (MTBF) for various components and parameters listed below:

MTBF in one on-board dual redundant computer system: > 10^{17} years.

MTBF in one LIM propulsion system: > $12(10)^8$ hours.

MT between pushing incidents in a fleet of 500 vehicles: > 150 years.

MTBF in one dual redundant zone-control computer system: > 10^{16} years.

MT between vehicle-to-vehicle collisions in 1000 km network: > $66(10)^{10}$ years.

MT between merge collisions in 1000 km network: > $400(10)^{10}$ years.

Lifetime of the known universe: ≈ $13(10)^9$ years.

MT between vehicles stopping suddenly due to system causes: practically infinite.

System dependability: > 99.97%.

8. Noise Level

DFR p. 8-14 states: ”The APM Standards – Part I, ASCE 21-96, Section 2.2.1, states that the maximum noise emission for normal operation when measured at 50 feet from the guideway is 76 dBA. However, the frequency of PRT vehicle passage will be many vehicles every minute, which will create a noticeable impact.” Later in the same paragraph it states, “Because the guideway is elevated, and because noise is generally radiated on the line-of-sight, any significant noise emissions may have an unacceptable impact on adjacent residential sleeping quarters located above the ground floor”.

Here again we witness PB presenting a worst-case scenario for Taxi 2000 PRT. Based on the experience with the CabinTaxi system (see below), the noise level for the Taxi 2000 system will be less than 65 dbA. This is the noise level of a sewing machine or a typewriter. (Note that, since the decibel scale is exponential, 65 dbA is more than10 times less noise than the 76 dbA of the APM maximum). This number for the Taxi 2000 system is documented in the 1991 Stone & Webster Subsystems Design Report – see Attachments 8. Some noise will be generated in the Taxi 2000 chassis by the smooth tires running on smooth rails and some by the sliding contacts of the power pickup shoes. The material in the guideway covers will dampen these noise sources, and noise minimization is one criterion in designing them. Noise was not expressed as a concern by PB before the DFR was issued and no discussion on this subject took place between them and Taxi 2000.

An extensive program was undertaken by CabinTaxi PRT in Germany in the 1970's to make the noise emitted by the CabinTaxi system the lowest of all transportation systems. Evaluation of noise emissions was carried out from different positions, at long and short range, at different speeds, on both suspended and supported guideways. These tests showed that Cabintaxi had an average noise level of less than 65 dbA, that the average value over all track sections on the guideway was a continuous noise level of 60 dbA, and that, for a density of 20 vehicles per hour (nighttime), it showed an equivalent continuous noise level of 43 dbA (the level of whispering) – see Attachments 8. The exterior noise level of the CabinTaxi system was so low that concern was expressed that care must be take when crossing under the guideway (CabinTaxi had vehicles that rode suspended under the guideway as well as vehicles riding on top) to ensure that no vehicle was approaching. Didn't PB or JKH, their PRT sub-consultant, know about these tests on PRT? If they did, why did they portray noise levels in a "worst-case scenario" for Taxi 2000 PRT? Considering the above documented tests, it would have been proper for them to mention in the DFR that Taxi 2000 could have the lowest noise level of all transportation systems.

⦿ Attachments 8

9. Technical Evaluation

DFR p. 8-3 states: "The actual power requirements of this [PRT] technology are not yet known." Taxi 2000 has calculated in detail the power requirements of the Taxi 2000 system and these calculations are available. PB did not ask for them.

DFR p.8-4 states: "Due to the unproven nature of the vehicle, a somewhat higher than normal spare ration of 20 percent (140) vehicles is indicated to maintain an operating fleet of 700 vehicles. Based on the shortest vehicle-component MTBF (Mean Time Before Failure) given in the above-mentioned FMEA (Failure Modes and Effects Analysis – see Attachments 6) paper (this component would be the vehicle air conditioner), the maintenance float in a Taxi 2000 fleet need be only about 2% (10 vehicles). PB did not discuss with Taxi 2000 the latter's in-depth analysis of failure modes and effects on the percentage of spare vehicles required.

10. Bridges

The DFR makes some interesting statements with regard to use of the bridges by the various alternatives.

DFR p. 8-24, on Shared Use Lanes for VT: The DFR states that VT proposes shared use of vehicular lanes on the Clay Wade Bailey, Taylor-Southgate and Veterans Memorial Bridges. The DFR does not specify whether one or two lanes would be used on the Clay Wade Bailey Bridge or the Veterans Memorial Bridge. Per the answers from PB dated 6/2/01 to "Questions for OKI Demand Modeling Meeting" submitted by the SLC, PB states that, "It is assumed that each river crossing will have two sets of tracks" – see Attachments 11. The DFR should have stated that the Trolley on the Clay Wade Bailey and Veterans Memorial Bridges would use two vehicular lanes.

⦿ Attachments 11

Use of Lanes by PRT: The DFR states that if it is not possible to cantilever PRT guideways off the existing bridge structures, then PRT may require the exclusive use of vehicular lanes. While the SLC agrees with the DFR that the feasibility of attaching guideways to the bridge structures requires additional study, the SLC has never proposed exclusive use of vehicular lanes and does not intend to propose such an approach to the river crossings. A study commissioned by the SLC and conducted by Pflum, Klausmeier & Gehrum, Inc. listed three options for crossing the Clay Wade Bailey Bridge, only one of which used cantilevered guideways, and three options for crossing the L&N Bridge, only one of which used cantilevered guideways. None of the PRT options for any of the bridges required exclusive or shared-use of vehicle lanes. The report for this study, "A Study Of The Sky Loop Crossing The Ohio And The Licking Rivers" can be found at http://www.skyloop.org/cals/BridgeCommitteeReport2a.pdf.

A New Veterans Memorial Bridge: PB stated at the 7/17/01 CALSC meeting that VT will require a replacement Veterans Memorial Bridge to be built and that the new bridge will have 6 lanes – 4 vehicular and 2 for VT. The DFR omits this statement and the associated costs for VT in the VT option. PB also stated that the local communities intend to replace this bridge anyway. However the only bridge replacement in the KYTC six-year plan is for the 12th Street Bridge. Additionally PB stated at the 7/17/01 CALSC meeting that the PRT option will also require replacement of the Veterans Memorial Bridge. No substantiation or engineering analysis has been presented by PB for this claim, whereas the SLC Bridge Committee has provided a preliminary engineering analysis that cantilevering guideways off the existing bridge may be feasible. Furthermore, the DFR itself states that the feasibility of attaching guideways to the bridge structures requires additional study during a future engineering study.

11. Maintenance & Control Facility (MCF)

PB has created a totally enclosed, central facility for control, storage and maintenance that totals 68,000 SF whereas Taxi 2000's design for its maintenance and control facility is just 7,000 SF. (DFR, p. 6-4). Why is this?

PB makes two basic assumptions: First, they assume that all 700 vehicles (now 500) will have to be stored overnight in this facility, rather than in the public stations and on the vehicle storage guideways; and second, that Taxi 2000 will incur constant maintenance problems with vehicles that will be serviced at the maintenance and control facility.

We disagree with both assumptions.

The Sky Loop will store all vehicles not being serviced overnight in the three large empty-vehicle storage stations and at the public stations. And vehicle maintenance will be far less than PB assumes (see Section 12 below).

The 1991 Stone & Webster Subsystem Design Report devotes 9 pages to the description of the Taxi 2000 Maintenance and Control Facility. Shouldn't PB have considered this information before defining its own PRT MCF? But they were not able to do this because they did not ask Taxi 2000 for detailed information on its MCF design and functions.

12. Vehicle Storage

The Sky Loop would store about 317 vehicles (out of 500 vehicles needed under current assumptions) overnight in the three large storage stations, which are simply 2,583 linear feet (LF) of off-line elevated guideway covered to protect the vehicles from the elements, and at the public stations. If necessary, these stations could be patrolled by security guards to minimize vandalism. Certainly each would have security cameras linked to the central control facility. One wonders how this risk differs from that of any large parking lot at night? PRT vehicles are stored elevated, so the risk would be even less than a street-level parking lot.

DFR p. 6-4 says Taxi 2000 proposes storage of 100 vehicles in storage-only stations. This is incorrect. Taxi 2000 plans to store 317 vehicles at the three vehicle storage stations.

DFR p. 6-4 says that, as just stated above, "a total of one hundred vehicles will be stored in two storage-only stations" and that "the remaining 600 vehicles will require space within the maintenance facility. Statements in the DFR provide another illustration of the fact that PB doesn't understand PRT. Because statements in the DFR about where the PRT vehicles will all be stored at night demonstrate that PB assumes that the entire fleet will be "in storage for the night". This mindset is fixed in the conventional assumption that, because transit does not operate at night, storage facilities must be large enough to accommodate 100% of the fleet vehicles during periods when no service is being provided.

We must emphasize that the Sky Loop will be a 24-hours–a-day, seven-days-a-week operation, available for use all of the time, and that each of the public stations will be in operation around the clock. Thus, while sufficient berths exist in the passenger stations to accommodate 183 “parked” vehicles and while many of the “parked” vehicles at night may be idle, none of them are “in storage” but are, in fact, “in service” and ready to meet whatever transit demand actually exists.

13. Stations

PB nearly quadruples Taxi 2000’s original estimated cost for stations, by using a “worst-case scenario” approach, along with some erroneous assumptions.

First, PB enlarges the width of the Taxi 2000 station from 10 feet to 16 feet, while giving no justification (DFR, p. 6-2). PB states this is necessary to accommodate the elevator, stairs, ticket vending machines and related amenities. The drawing on DFR p. 6-3 gives a clue. This is an “attached” station, partially inside and partially outside a building. This differs materially from Taxi 2000’s typical prefabricated freestanding station, shown on p. 4-6. Once again, we see where PB redesigned the Taxi 2000 system, without consulting with Taxi 2000.

Further, PB is assuming longer wait times than those provided by Taxi 2000’s computer simulation for the Sky Loop guideway layout, which increases the need for passenger wait lines. Are they basing this on their and JKH’s experience with APM’s, much of which as we have noted does not apply to PRT?

In any case, the TAXI 2000 prefabricated station design would be about 38% smaller and much cheaper than the one created by PB.

PB also uses a “worst-case scenario” when it comes to passenger stations. It assumes that building owners won’t pay for a station in their building, and then adds the cost of these more expensive stations on to the system cost. SLC has always said that building owners who want interior or attached stations should pay this cost themselves, as a building improvement. If they won’t, then they should be served only by a public station – the less expensive, prefabricated, freestanding version. Nevertheless, we include an estimate for these interior or attached stations in Attachments 2.

⦿ Attachments 2

On p. 4-6 of the DFR, “Boarding Platform Configurations”, it says, “"Platform edge partitions and full-height doors (or possibly partial height gates)... will protect the passenger from falling from the platform. An option that could be considered... will be the placement of a railing on the platform edge, with gaps in the railing where the vehicle doors align for boarding and alighting. This design requires that the encroachment of a passenger into the space near the opening be detected, the movement of any vehicles in the area stopped and an alarm sounded..."Also, on the same page of the DFR, "The vehicle will not be permitted to move unless both the platform edge door and the vehicle doors indicate that they are fully closed and' locked'."

Here once again PB is applying APM standards to PRT – standards which don't apply to any other fixed guideway systems, such as light rail, commuter rail, heavy rail and subways. The APM standards being applied are ASCE APM Standard - Part 3, Section 10.2 and subsections thereafter.

But again we must recall that PRT differs in many ways from APM's. In this instance we note that the station platform is on the same level as the floor inside the vehicle. Considering that the floor of the vehicle chassis is only slightly more that 6 inches above the top of the guideway cover, one can envision that, at the edge of the boarding platform, there will be no "pit" but, rather, just a solid floor out from the platform edge six inches lower than the level of the station platform. This top of the guideway cover could be made of removable steel non-skid panels, would stretch the full width of the vehicle guideway to a vertical wall on the side opposite the platform, perhaps six feet away, interrupted only by the necessary five- or six-inch slot running down the center of the guideway.

Considering that very few subway systems anywhere in the world have such barricades as PB is requiring for PRT, and that subway platforms do have four- or five-foot drops down to the track level as well as exposed high-voltage third rails, this recommendation by PB conjures up the notion of a PRT operating hazard, where none in fact exists.

PB's APM restrictions also totally neglect the simple fact that, in a PRT station, stationary vehicles will normally be waiting at each boarding point when the passenger(s) arrive(s), and since the movement of each transit vehicle is individually controlled, no vehicle will ever move past a boarding point at more than creep speed. Compare this with the front end of a decelerating subway train (or even light rail street car) entering the area of a several-hundred-foot-long station platform during rush hour.

Once again we see that APM standards don't apply to PRT.

It is worth noting that the APM station platform requirement PB is attempting to impose on PRT doesn't even exist on all APM systems. For example, there are no barricades on some of the station platforms of the Miami People Mover (see photos below or go to http://cs1.presby.edu/~jtbell/transit/Miami/Metromover/GovtCenter.jpg, http://cs1.presby.edu/~jtbell/transit/Miami/Metromover/Bayfront.jpg).

Miami MetroMover: Bayfront Station and Government Square Station

Station platform ADA requirements are covered in section 10.3.1 (8) of ADAAG (http://www.access-board.gov/adaag/html/adaag2.htm#10.3). Platform screens are not required, but where they are not provided, a Detectable Warning complying with section 4.29 is required. Such detectable warnings shall comply with 4.29.2 and shall be 24 inches wide running the full length of the platform drop-off. Compliant Detectable Warnings are available in a variety of forms from ceramic tiles to metal plates.

The 1991 Stone & Webster Subsystem Design Report devotes 22 pages to the description of the Taxi 2000 stations. Shouldn't PB have considered this information before designing its own PRT stations? PB did not ask Taxi 2000 for detailed information on its stations design and functions.

14. Annual Operating Costs, System Maintenance & Maintenance Personnel

In Table 6-6 of the DFR, PB gives no detail of its estimated operating costs but arbitrarily adds $5,000,000 per year to Taxi 2000's original estimate. Attachments 9 includes a cost comparison of Taxi 2000 and PB and Taxi 2000's detailed breakdown of operating and maintenance costs into categories (vehicles, stations, guideway, central facility.

⦿ Attachments 9

The major difference between PB's operating cost estimate and Taxi 2000's is the estimated manpower needed. Taxi 2000 estimates 20 people plus 16 vehicle cleaners contracted out. PB estimates 119 people, per a projection made by PB for 700 (adjusted to 500 vehicles, this number would be 102). A look at PB's assumptions explains why– see Attachments 9.

⦿ Attachments 9

PB assumes 700 vehicles (now 500*) would require maintenance of 64 full time people, including 4 managers but excluding vehicle cleaners, who would thus working a total of 480 hours on maintenance per day. This is an average of 41 minutes per vehicle per day to keep each vehicle running. Taxi 2000's design, with dual redundancy for all critical parts, makes this level of maintenance totally unrealistic. Imagine if your automobile required on average one full day in the shop every 12 days.

That leaves 39 people for other duties: 7 full time for guideway maintenance, 4 for electrical problems, 4 for "instrumentation" (computer glitches?) 8 "helpers" (for what purpose?), 8 to monitor the control room, 6 storeroom attendants and shop helpers, and two general staff (CEO and secretary). Again, this assumes continual daily breakdowns and maintenance problems.

DFR p. 8-4 states, for PRT: "a spare ratio of 20% (140 vehicles) is indicted to maintain an operating fleet of 700 vehicles."

Taxi 2000 has pointed out that, based on the shortest vehicle-component MTBF (Mean Time Before Failure) given in the above-mentioned FMEA (Failure Modes and Effects Analysis – see Attachments 6) paper (this component would be the air conditioner), the maintenance float in a Taxi 2000 fleet need be only about 2%. So in a fleet of 500 vehicles, this would put 10 vehicles in maintenance at any one time. The maintenance float does not include routine maintenance, which is done in the off-peak periods when there is a surplus of vehicles.

⦿ Attachments 6

A 20% maintenance float, which PB says would be needed and is typical of large-vehicle automated transit systems, means that in a typical peak period 100 vehicles would have to be called in as a result of failures. Think what that would mean in regard to automobiles. In a city with, say, 1,000,000 automobiles (corresponding to a population of about 2,000,000) there would be 200,000 automobiles in shops for maintenance at any one time.

In this regard, see "Failure Modes and Effects Analysis " in Attachments 6. This is the test of reliability to which Taxi 2000 was put during the extensive design stage and will be required to demonstrate during prototype testing. If it bears out as designed, there is no way a staff anywhere near as large as that projected by PB would be needed.

⦿ Attachments 6

Relevant to PB's 20% maintenance float requirement for PRT, information provided by Mr. Robert Hendershot, the systems engineering manager for the Morgantown (W. Va.) PRT shows that, in 1997, for a fleet of 73 20-passenger vehicles with an actual operating

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* Regarding the PB maintenance personnel estimates when downsizing from a 700-vehicle fleet to a 500-vehicle fleet, this likely would reduce the number of vehicle mechanics in their staffing table from 60 to 43. All of the other staffing (e.g., supervisory personnel) would likely stay the same. This would make PB's total for a 500-vehicle fleet be 102 maintenance personnel.

time of 3,613.3 hours, the downtime was 27.5 hours, and that the mean downtime was only 10 minutes with a 21.3 hr. mean time between failures. *This represents a vehicle downtime of less than one percent (0.76%), or a total downtime for the whole fleet of 1.8 hrs per day.* And these very low numbers, much lower than numbers PB is projecting for the Taxi 2000 system, are generated from vehicles that have complicated steering mechanism, hydraulic brakes and rotary AC-drive motors and thus have many more parts that the Taxi 2000 vehicle. One wonders what APM system PB used as the basis for determining its maintenance personnel requirements for Taxi 2000 PRT.

Sky Loop System Staffing

The total staffing is twenty.

The four-person *executive office staff* is self-explanatory.

The *general manager* will be responsible for all day-to-day operations and maintenance. The *senior operations manager,* the *maintenance foreman,* the *station service* personnel, and the contract vehicle cleaning service will all report to him/her.

The three (3) *operations managers* and the six (6) *control system operators* will all work in the operations control center, a facility that operates 24 hours a day and 7 days a week. When and as it is necessary to close some part of the network down for maintenance, there will still be a need for someone in the control center. It will take only 4.2 operators to staff the 21 shifts per week. The extra manpower will cover absences and training. The *operations managers*, one of whom will be senior to the other two, will provide additional coverage in the control center during times of heavy network activity. They will also be responsible for analyzing operations, training operators, providing liaison with Taxi 2000 software engineers, and handling customer concerns.

The *maintenance foreman* will be a working foreman. He/she will supervise the mechanics, the electrician, and any contract maintenance that may be required on vehicles, stations, or guideways. It should be noted that the vehicles will use "line replaceable unit" subsystems. The design goal for each of these subsystems will be to be replaceable in *no more than ten minutes*. Thus, there will no need to tear vehicles or their power plants down in the way that buses and rail cars are torn down for maintenance purposes. Beyond that, the MTBF for all of the major subsystems in the vehicles (e.g., linear induction motors, VFD's, HVAC compressors, door actuators) will be measured in years. The estimate of less than *two hours of maintenance work per car per year* is *conservative.*

Some 1000 hours of maintenance time per year for the 500-vehicle fleet would leave 3800 man-hours a year (not counting the time of the foreman) for maintaining the stations, guideway, and shop facilities. (It is anticipated that maintenance personnel will not be restricted to craft lines by any labor contract.)

Station maintenance, other than electrical equipment (including TV cameras, lighting, communications systems, and ticketing machines) will be minimal. Station service personnel will clean the stations and service the ticket machines as necessary. This is estimated to take *no more than one-half of a man-hour per day per station*.

As for the guideway, it will be inspected *at least once a day* with an instrumented inspection car. A TV scan of the interior of the guideway will also provide a tape for supervisory review. Maintenance personnel will use the adjustment fixtures designed into the guideway structure to correct any guideway alignment anomalies. (Typically, one person can make these adjustments alone; the inspection software will tell him/her where and how much to do – this is not railway track.) Foundation settlement that cannot be corrected by the built-in adjustment fixtures will be corrected by mud jacking or shimming.

Taxi 2000 plans for vehicle cleaning to be contracted out to a regular cleaning service. The going rate for this work is $15.00 per man-hour, a rate that could not typically be matched by in-house personnel. Cleaning machines will do half of the work. A cleaning crew will do the other half. The use of machines and the small size of the vehicles make the PB estimate of *ten man-minutes per vehicle per day* excessive.

Vehicles will receive two types of cleaning: a washing inside and out with an automated machine *every other day* and a *5-minute hand cleaning of the interior every other day*. The hand cleaning will typically involve washing and vacuuming, as well as removal of any trash that might not be reached by either. For a car with a floor area of about 4 feet by 8 feet, this is generous treatment.

The Sky Loop will not need 16 contract vehicle-cleaning personnel stipulated by PB; rather only about 9 workers will be needed to cover the estimated 350 man-hours of cleaning to be done each week.

Parsons Brinckerhoff Staffing

PB does not seem to understand the PRT concept. The Sky Loop network would ordinarily operate *24 hours a day and 7 days a week*. Parts of the network would occasionally be shut down (probably in the early morning) for guideway or station maintenance or for modifications to the network (such as adding new loops); but even then the control room would be continuously manned.

There would be no need to have 4 operators in the control room as PB suggests. Monitoring of the CCTV cameras would not be necessary except in the event of incidents, and tapes would always be looped for review after the fact. After riders became accustomed to the use of the system, there would also be no need for continuous voice communication with them – again, except for the occasional incident. The CCTV and communications systems will be configured for ease of operator use, in any case. The operators will be concerned principally with monitoring the computer control system, and it will be largely self-administering.

As for vehicle maintenance, the PB staffing table assumes that each vehicle would receive about *120 man-hours of maintenance each year* or *approximately 14 man-minutes of maintenance each week*. We cannot imagine what would require that much attention.

By the same token, there would be no need for 3 tool-room attendants, let alone shop helpers. The shop will be small, and clean.

As for fixed plant maintenance, the PB staffing chart calls for a total of 23 people where Sky Loop staffing calls for about three. Two things make the big difference between railroad-type maintenance that requires large crews and the minimal maintenance required by the Taxi 2000 design. The most important is that the Sky Loop vehicles are *very* light, and so they will impose little wear and very light loads on the fixed plant. Second, the guideway design incorporates alignment adjustment fixtures, so that most of the anomalies that develop – and there will be some – can be adjusted out with a wrench. (No track jacks or lining bars…) There are, moreover, only 13 miles of guideway in this initial Sky Loop system.

At the same time, PB proposes an executive staff too thin to run a business that could gross as much as $20 million per year.

15. Engineering Costs, Construction Management, Project Contingency

By applying high percentages to all its previous inflated costs, PB comes up with a huge figure for these items.

Nevertheless, we acknowledge the need for a reasonable number for these items, and have added substantial amounts for them. (Attachments 2, “Cost Comparison of Sky Loop”, p. 2.)

⦿ Attachments 2

As to engineering and construction management, one must realize that Taxi 2000 PRT already has a design. The vehicles, guideway, stations and posts will be prefabricated off-site and will only require assembly on-site once the route is determined and foundations are installed. This will require some engineering to pick the exact spots for posts, stations, guideway, etc. But is the $62,000,000 (27% of total construction costs) estimated by PB anywhere near realistic? Dr. Martin Lowson, of the Advanced Transport Group in Bristol, England, who is currently building the prototype for their ULTra PRT in the U.K., has told us that his consultants have told him that a maximum of 15% of relevant construction costs are necessary for engineering and construction management. Perhaps PB is applying the same formula to PRT that it used for the TSM – SouthBank Shuttle, where capital costs are much lower.

We agree that an overall project contingency is appropriate, but apply 10% on our much lower costs, rather than the 10-20% on the much higher costs used by PB.

Our revised estimate of total capital costs is shown in “Cost Comparison of Sky Loop” in Attachments 2.

⦿ Attachments 2

16. Right-of-Way Costs

Here again, PB employs a worst-case scenario when estimating these costs.

PB builds on its earlier assumptions on the size of the central facility, which of course would require much more right-of-way for a 68,000 SF building than a 7,000 SF building.

Second, PB assumes that its larger stations, guideways, posts and foundations will all require right-of-way to be bought from both public and private entities and that building owners will charge the Sky Loop rent, at current office rates, for a 30-year lease, for space on three floors inside their buildings (DFR, pp. 6-3, 6-4.) We wonder what basis PB has for this notion? The station will enhance the value of the property to the building owner. If a building owner insists on charging for a station, they simply won't get one in their building.

17. Raytheon's PRT 2000

DFR p. 8-26 states, " The failure of the Raytheon Prototype program is an indication of the technical and financial hurdles the system must overcome to enter commercial operation."

In the mid-1990's, the Raytheon Corp. of Marlboro, Mass., undertook a prototype program for the Chicago RTA as the first step in building a Taxi 2000-type PRT in Rosemont, Ill. Full-scale vehicles (3) and guideway test track were built and operated. Unfortunately, in the development stages, the Raytheon engineers failed to check with Taxi 2000 and went off and designed their own system. Nevertheless, they successfully demonstrated among other things, merging, headways and station stop routines as required by RTA. Much time and expense was spent developing the electronic control system, which proved successful. (See Attachments 7).

⦿ Attachments 7

Raytheon used a four-person vehicle configuration, ordinary electric motors instead of LIM's (Linear Induction Motors), automotive mechanical braking in each wheel along with other changes which drove up vehicle weight (the Raytheon vehicles weighed almost 4000 lbs.), requiring a massive and much heavier guideway all of which increased the cost of the system to over $40 M per mile. In the end the Chicago RTA decided they couldn't afford the project for Rosemont. The fact remains that Raytheon demonstrated that PRT can be built. Their mistake was that they chose to ignore the principles of minimization, as PB has done in designing its PRT system for the CALS.

PB states that the "failure" of the Raytheon/Chicago RTA PRT project demonstrates the technical and financial hurdles that must be overcome before PRT can enter commercial operation. Since Taxi 2000 PRT was the design that was supposed to be built for the Chicago RTA Rosemont project, what in fact this project demonstrates is that failure will result if the principles of minimization are not applied.

18. Capacities of the CAL Alternatives

It is very surprising that the DFR doesn't address the capacities of the various CAL alternatives, since capacity is the measure of how many passengers a given system can handle. Surely how many passengers a system can carry would be of interest to committee members who have the responsibility of whether and how best to commit millions of dollars of taxpayer's money to do just that – move people. Comparing the capacities of the systems being considered gives one an understanding of what is each system's potential for moving people in the downtown areas served by the CAL. An explanation of what exactly capacity is, how it is determined and the how the capacities for the CAL alternative were determined can be found in Attachments 10.

⦿ Attachments 11

Capacities of CAL Alternatives

Alternative	Existing SB Shuttle	SB Shuttle TSM	Trolley	Sky Loop
No. of Vehicles	7	16	6	500
Passengers/Vehicle	34	28	40	1.2
Average Speed	7.8 mph	10.2 mph	10.8 mph	23.2 mph
Headway	15 min.	10 min.	14.4 min.	0.5 sec.
% Empty Vehicles	-	-	-	20%
Capacity*	**272**	**336**	**320**	**4896**

*passengers per hour

Based on information presented in the DFR, we have determined the capacities for the existing SouthBank Shuttle, the Shuttle-TSM, the Trolley and PRT. These are shown in the table above. The PRT capacity figure is the average of five recent runs of the Taxi 2000 Sky Loop network simulation (operations model) – see Attachments 10.

⦿ Attachments 10

Although the capacities for the existing Shuttle, the Shuttle-TSM and the Trolley are low, which is to PRT's advantage, we would nevertheless like to point out some problems observed while searching the DFR for the numbers on which to base our calculations for capacities. We do this to illustrate our contention that the requirements for the Shuttle and Trolley alternative are generally given best-case treatment in the DFR while those for PRT are generally given worst-case treatment.

Regarding the Trolley, DFR p. 5-14 states, “A total of 7 vehicles will be needed to operate the system, including one spare.” And, “The VT alternative utilizes a circular route approximately 8 miles… in length…” (for a total of 16 miles). Six vehicles covering 16 miles means a vehicle every 2.7 miles. At an average speed of 11 mph (see table above) it would take a Trolley 0.24 hrs to go 2.7 miles. 0.24 hours equals 14.4 minutes. Therefore *it is not possible for the Trolley system as proposed by PB to operate at 10 min. headways,* as specified on p. 5-14 in the DFR.

Regarding the SouthBank Shuttle, we challenge the claim that a TSM-assisted Shuttle can actually experience a 30+% increase in average speed, over the same city streets. Certainly, headways can be reduced by adding more buses. Trip times could also be reduced by shortening the routes and/or eliminating bus stops. But what factor will actually increase the average speed over a given distance by 30%? At the 7/17/01 CALSC meeting, a committee member pointed out that a study had been done on using TSM around Government Square to facilitate Metro/SORTA buses in and out of that hub and he was told the results of the study indicated it wouldn’t work there, which we assume to mean TSM didn’t provide much benefit to the buses or perhaps would have negative impact on other vehicular traffic.

And since we are addressing the Shuttle and best-case treatment, we question how TSM for the Shuttle will be able to cut walk times to bus stops in half, as is claimed in Table 8-1 on p. 8-10. This could <u>only</u> be done by increasing the number and distribution of bus stops, which flies in the face of the increase in speed claimed for the Shuttle-TSM. Most significantly, this table, like other things we have pointed out in this rebuttal, casts doubt on a whole array of numbers utilized by the consultant to compare the relative merits of the various technologies under study.

19. Wait Times

The key to obtaining realistic demand model results, in addition to using a model of sufficient sophistication to be able to model the data, is to use accurate inputs to the models for each mode. One of the key elements considered in a demand model is wait times. It is very important to have realistic wait times to use in determining ridership estimates. This is because in the modal split (determining what percentage of riders will use which transit mode) wait time is weighted by a factor of 2.25[*] (it counts as more than real time because people do not like to wait). Since wait time is penalized in the models, excessive wait time can have a negative impact on the ridership estimates. We believe this is the case with PB’s demand model results for PRT.

In an email letter dated 8/22/01 in which the SLC was sent the demand model results for PRT, David Ory of PB said, “It is assumed that, during the Peak period, it takes an average of 6 minutes to go from the sidewalk near the station to departing in a vehicle. The 6

[*] The 2.25 wait time penalty is shown in the calculations for the answer to Question 10 to “Questions for OKI Demand Modeling Meeting” – see Attachments 14.

minutes includes the time it takes to go from the sidewalk up to the station, the time to buy a ticket (if need be) at the station, any wait time which may occur before the vehicle arrives, and the time it takes to get into the vehicle before departing. This value is constant across all stations" – see Attachments 11.

⦿ Attachments 11

In an email letter of 8/31/01, Mr. Ory says, "The "wait time" of 2 [during off-peak hours] to 4 [during peak hours] minutes is not directly comparable to the Taxi2000 simulation estimated wait time of 0.63 minutes. The "wait time" in our models is composed of two elements. The first element is the time it takes to walk up the stairs, or take the elevator, from the sidewalk to the platform as well as the time it takes to purchase tickets (if necessary) and move to the center of the platform to prepare to board a PRT vehicle. The second element is the same as the "wait time" in the Taxi2000 simulation -- the average time a traveler must wait until an available PRT vehicle arrives -- plus the time it takes to actually board the vehicle."

He continues, "During the peak period, the increased congestion of the walk ways and stations increases the time to walk up the stairs, or wait and take the elevator, purchase tickets, and move to the center of the platform, to about 3 minutes. The increased demand on the system increases the wait time to about 1 minute, on average. Again, this actual wait time is similar to the wait time derived in the Taxi 2000 simulation." – see Attachments 11.

⦿ Attachments 11

Unfortunately, the 4-minute or 6-minute peak period wait times PB used[*] for PRT are not "wait time" as demand models normally use the term. Wait time is the time that a rider WAITS for the next bus or train, not the time walking up or down stairs, time buying tickets, or even time getting to the bus/trolley/PRT stop. In a PRT network, the "wait time" is very short.

Mr. Ory says in his 8/31/01 letter cited above that during the peak hours the "real" wait time for PRT is 1 minute. Which means that the other part of their wait time – lets call it "in-station" time – is either 3 minutes (4 minutes minus 1 minute) or 5 minutes (6 minutes minus one minute).

The 3-minute or 5-minute "in-station" time assumption by PB to walk from the sidewalk to and up the stairway, then to the fare machine and then to the boarding platform is excessive. Especially considering it is likely that a commuter will have an encoded pass with his/her normal work or home destination station pre-selected, thus allowing him/her to bypass the fare machine. Riders at all familiar with the ticketing procedure will take no more than 15 seconds to get their ticket. Moving to the center of a platform no more than ten feet wide will take little time. The time to do all of this prior to actually waiting for the PRT car, which in many instances will be there waiting to be boarded, should routinely take no more than 30-60 seconds.

[*] From the above letters it is not clear whether PB used 6-minute or 4-minute times for PRT.

Mr. Ory, in his 8/31/01 letter, assumes increased congestion within the PRT stations during peak period hours. On what is he basing this assumption? PB's own results for PRT from their demand model show that station congestion will not be a problem for PRT. Their results show an average of 2,320 passengers per peak period hour for PRT. As there are 183 stations berths where these passengers can board a PRT car, fewer than 13 passengers will, on the average, use a berth in one hour. That's 4.7 minutes for each and every passenger, on the average, between the passenger just departing and the one who will depart afterward. Considering that two and even three passengers will be boarding some of the cars, even more time will be available for each passenger. Sky Loop stations will not be congested, such as PB assumes, during the peak hours.

If this excessive "in-station" time that PB has assumed for PRT were factored in as "straight" time, that would be bad enough. But, as pointed out above, wait time is assigned a penalty of 2.25 times the real time when it is run through the demand model. So that in the case of PRT, the "in-station" wait times of 3 minutes or 5 minutes are looked at as if they are actually 6.75 minutes or 11.25 minutes, respectively. The latter, and not the 3 minutes or 5 minutes real time, is the time that's added to the trip being considered by the demand model.

It will be very interesting to, when all of the results from PB's demand model are finally released, find out what kind of "in-station" wait times PB has assigned to the Shuttle and the Trolley. Because, if the other alternatives don't have similar unrealistic "in-station" times factored into their total trip times, then PRT will have been put at big disadvantage in the determination of ridership and the modal split for the CALS.

The results of the demand model for PRT show an average of almost 20,000 trips per day. But the SLC has estimated the ridership for the Sky Loop will be 30,000 per day. Just imagine what the results of the demand model would have been if PB had used realistic in-station times and had used a demand model sophisticated enough to properly model PRT. See Section 20–Travel Demand Model.

A 4-minute or 6-minute wait time cannot be correct. The SLC has requested that PB re-run their demand model using a wait time of 1 minute. PB has responded by saying "it is unnecessary to re-run the model." (See Section 23–Headway Sensitivity Analysis).

Once again, PB has made assumptions that put the Sky Loop system in the poorest possible light.

(Wait times are also addressed in the following section–Travel Demand Model).

We found it very interesting that the DFR did not address at all door-to-door travel times, when the data to do so was in hand. Door-to-door travel time is the time required for the entire trip. It is a sum of the walk time from the point of origin to the station, the wait time at the station, the trip time and the walk time to the destination.

Door-to-door travel times for the CALS alternatives are given in the table below.

Comparison of Door-to-Door Tavel Times

(Time in minutes)	Existing SBS	SBS-TSM	Trolley	PRT
Walk Time	20 (10x2)	10(5x2)	10(5x2)	10(5x2)
Wait time	10	5	7.5	1
Trip Time	17.7	10.3	8.5	6.5
Total	**47.7**	**25.3**	**28**	**17.5**

The difference between door-to-door travel time between PRT and the other alternatives is significant. For example, the door-to-door travel time for PRT is approximately 31% less than the Shuttle–TSM.

20. Travel Demand Model

Since attracting passengers is the reason to build and operate a transit system, ridership estimation is a crucial task in performing a credible evaluation of alternatives. Ridership estimation cannot be performed as precisely as many other estimates since it tries to capture the behavior of people. Much effort has gone into the development of travel demand models over the past decades. Most of this effort has focused on highways and conventional transit, characterized by a limited number of fixed routes and scheduled service. Personal Rapid Transit offers such a great leap in level of service over conventional transit that existing models cannot adequately estimate its ridership. Existing models simply were never designed to do this.

It is understandable that PB used existing models and techniques to accomplish their mission for this study. They did not have the assignment, budget, or time to do otherwise. Under these circumstances PB had a special challenge and duty to use the existing models with great care, precision, objectivity, and creativity. They needed to accomplish two basic objectives, good absolute numbers and good relative numbers. In an absolute sense the models should predict the actual ridership that would be measured if the mode were built and operated. In a relative sense the models should discriminate fairly among the competing modes, both in direction and magnitude. In other words, if PRT offers vastly superior service than the other modes then it should not just win, but should win decisively.

If the models are well constructed, properly calibrated, receive accurate inputs, and are properly run, then the results for conventional modes should be good on an absolute and a relative basis. After all, these models are the industry standard, are used in almost all such studies, and are relied upon for decision making at the local, state, and federal level. The challenge for PB is to use these same models to produce PRT results of equivalent quality. Alas, the inherent limitations of the models make this difficult and maybe impossible. PRT service is distributed closely to most destinations within the study area. Level of service approaches the ideal. Rather than waiting at a stop for a scheduled bus or train, making stops enroute, possibly standing, and making a transfer, the PRT passenger boards a private vehicle without waiting, is seated, and travels non-stop to his/her destination. Existing travel demand models are simply too crude to properly simulate this level of service.

Accepting this state-of-the-art, PB at a very minimum needed to input accurate data into the models for PRT. The waiting times, travel speeds, and station wave-offs used by PB are very significantly at odds with the results produced by the Taxi 2000 simulation model and other similar simulations (see table in Section3–Headway Sensitivity Analysis). If PB had valid reasons for not using these inputs they should have clearly stated them. Such reasons would have to:

- Indicate that PB thoroughly understands how the Taxi 2000 simulation model works
- Point out specific flaws in the Taxi 2000 model
- Show in detail how PB's own inputs were derived

Another challenge for PB was to generate and distribute PRT trips in a model with a basic unit of analysis, the Traffic Analysis Zone (TAZ), so large that it contains more than one PRT station in several cases. At a minimum there should be a TAZ for each station so that the means of access to the station (a walk trip) and the demographics are accurate for the representative person in that zone. PB handled this problem by using a single average access time to one station in the zone. Demographics for the entire zone represented users of this one station. The other stations in the zone received no trips. Later the trips to the one station were allocated among all the stations in the zone. It is probable that this approach significantly underestimated the number of people in a zone who would have used a nearby PRT station.

The following sections discuss these problems in more detail.

Limitations of PB's Travel Demand Model

DFR p. 3-7 states: "modeling PRT offers a variety of challenges." Existing models were never designed or calibrated to model PRT. As a work-around PB modeled PRT as 14 transit lines. But in the 28-station CALS network there are the equivalent of 378 express transit lines*, each on a dedicated lane and with a headway of a minute or less. How can 14 lines substitute for 378?"

DFR p. 3-7 explains various work-around methods PB used to create zone-to-zone travel times. PB assumed (without explanation) a 23 mph operating speed and added 10 per-

*28 stations each connected to 27 others in both directions (28 times 27 divided by 2).

cent to travel time for possible station wave-offs, when the Taxi 2000 computer simulation for the Sky Loop is set up so that there can be no more than one wave-off per 10,000 trips. Why didn't PB use a travel time matrix directly from the Taxi 2000 simulation model that is far more accurate than anything they could create? PB could have iterated the process by giving Taxi 2000 their ridership numbers as input into its simulation program until equilibrium was achieved.

In typical conventional transit ridership modeling several TAZ's are assigned to a single station. With PRT, PB had to assign several stations to a single Traffic Analysis Zone (TAZ). Since the TAZ's used by PB contain several stations and assume that all traffic comes from the centroid[**], depending upon where PB put the stations with respect to the centroids can make a huge difference in ridership.

If a TAZ is so large that several PRT stations are within it, then the model is too gross to fully capture PRT's very high level of service. In PB's model one of the TAZ's is served by four stations and four other TAZ's are served by two stations each. PB did the best they could under the circumstances by distributing a TAZ's trips equally among the stations but in a fully satisfactory model this would not be necessary. These are indications that models PB used never were designed to handle PRT's unique characteristics

Limitations of PB's Travel Demand Model Results

The input PB used for PRT should have agreed in all respects with the Taxi 2000 simulation results. Looking at Table 8-1 indicates that this is not the case. A 4-minute wait time for PRT cannot be correct. As pointed out above in Section 19–Wait Times, in the modal split model, wait time is usually weighted by a factor of 2.25, so an additional 3 minute looks the same to the model as an extra 6.75 min of ride time. Since wait time is penalized in the models, the 4-minute or 6 minute wait time used by PB for PRT very likely has had a large negative impact on the ridership estimates for PRT.

While the demand modeling performed by PB was flawed by both erroneous assumptions and the use of methodologies that are insufficiently refined to fully and accurately depict the characteristics of the Taxi 2000 Sky Loop PRT system, nevertheless, the detailed efforts that were made in this demand modeling study clearly indicate that, with the predicted daily PRT demand of 20,000, the SLC's estimate of 30,000+ is far more realistic than anyone on the CALSC might have previously thought. And these results demonstrate that, even considering the limits of the model, the performance characteristics of the Taxi 2000 Sky Loop circulator are far superior than either the SouthBank Shuttle or the Trolley options at getting people out of their cars, inducing usage of central area facilities, and effectively achieving the goals of a central area loop circulator system.

We look forward in the succeeding phase to performing a refined demand study that properly deals with the unique features of PRT.

[**] The point within a TAZ where all trips are assumed to start and end.

21. Ridership and Costs

Two of the most important factors in choosing a transit alternative are cost and ridership. The payoff for building a system is attracting many users. One wants to do this at the lowest cost. The Federal Transit Administration recognizes this in its most important criterion, total cost per new rider. PB has quadrupled PRT's cost and has seriously underestimated PRT ridership. The total cost per new rider is thus grossly distorted. This is a heavy and unfair burden for an alternative to carry into an evaluation. PB clearly does not understand the Taxi 2000 design, which has evolved from decades of rigorous analysis and testing. PB should have evaluated the PRT system as given to them and could have pointed out areas where they had concern. Instead they redesigned the system and burdened it with excessive weight and cost. PB used faulty inputs to the travel demand models and thereby underestimated ridership. Rather than use the solid outputs from the Taxi 2000 simulation model, they created long wait times and system operational delays, without explanation. A proper evaluation of alternatives would have taken the Taxi 2000 design, cost, and performance as given, on the basis that if it were selected Taxi 2000 would be contractually obligated to deliver what was promised. PB could have suggested areas where they felt that risk was greatest and suggested ways to minimize that risk. In short, PB created the PRT alternative that they evaluated. PB took this specific course of action without the CALS Committee's knowledge and approval.

22. Ridership and Sky Loop Income Projections

One of the key determinants of ridership on each technology will be the total time required, including station-to-station time, wait time at the station and walk time to and from each station. PB has done estimates for selected destinations (DFR, p. 8-10, 8-11).

The SLC has measured distances for the station-to-station times and have derived average speeds for both the selected trips separately and all of the trips combined. These are shown in the table below.

CALS DFR p. 8-11		**Station-to-Station Times, Miles, and Average Speed**											
Origin	**Destination**	**Existing SB Shuttle (min.)***	**MI.**	**MPH**	**TSM (min.)***	**MI.**	**MPH**	**Trolley (min.)***	**MI.**	**MPH**	**PRT (min.)***	**MI.**	**MPH**
Government Square	TANK Transit Center	8	1.36	**10.2**	7	1.36	**11.7**	12.4	2.08	**10.1**	7.5	3.21	**25.7**
Cincinnati Conv. Ctr.	Newport Aquarium	14	1.38	**5.9**	12	1.38	**6.9**	6.1	1.37	**13.5**	4.85	2.15	**26.6**
Fountain Square	Downtown Newport	6	1.34	***13.4***	5	1.34	***16.1***	6.8	1.39	**12.3**	6.9	2.33	**20.3**
Downtown Covington	Downtown Newport	23	2.19	**5.7**	5	1.13	***13.6***	6.8	1.00	**8.8**	6.9	2.32	**20.2**
Paul Brown Stadium	Covington Riverfront	16	1.25	**4.7**	14	1.25	**5.4**	9.8	1.15	**7.0**	7.2	3.08	**25.7**
Newport Aquarium	MainStrasse	39	4.40	**6.8**	19	2.51	**7.9**	9	2.00	**13.3**	5.8	2.03	**21.0**
	Average	17.7	1.99	7.8	10.3	1.50	10.2	8.5	1.50	10.8	6.5	2.52	23.2

The average speed for Shuttle TSM is 10.2 mph while it is only 7.8 mph for the existing Shuttle. We are told that the difference between the TSM Shuttle and the existing Shuttle is the TSM, i.e., the Transportation Systems Management, which the DFR says is traffic signal optimization (timing of signals so thoroughfares have more green time – this already exists on 4th and 5th Streets in Cincinnati, Newport and Covington) and transit signal priority (extending the traffic signals green time for a bus that is about to pass through an intersection). We seriously doubt that these measures alone will account for the increase of 2.4 mph (an increase of 30%) for the Shuttle TSM, and we thus questions the DFR's results, especially considering that traffic signalization is already optimized on 4th and 5th Streets in the three cities.

We also note that there appears to be no allowance for the effect of traffic congestion during peak periods on the Shuttle TSM and Trolley trip times and wonder why this is so. Traveling from the Cincinnati Convention Center to the Newport Aquarium during the evening rush hour in 6.1 minutes is a bit hard to believe. PRT travel times, in contrast to those of the other alternatives, will not be affected by traffic congestion.

Next, DFR Table 8-1 (p. 8-10) assumes average walk time to stations of 5 minutes for all three technologies, and average wait time of 4 minutes for PRT and only 5 minutes for SS TSM and VT. The 4-minute wait time is far too long for PRT. The Taxi 2000 Sky Loop computer simulation shows an average of less that 30 seconds wait time at a station, with vehicles waiting at the station (thus no wait time) approximately 90% of the time. PB's use of the 4-minute wait time in their demand model likely had significant negative impact on their travel demand model's ridership figures for PRT. (See Section– Travel Demand Model for a more detailed discussion of the impact of using a 4-minute wait time).

PB assumed that wave-offs at stations (which would happen to a PRT vehicle if all station berths were full) will occur 10% of the time, and added this to its time estimate for PRT. The Taxi 2000 system is designed for one wave-off per 10,000 trips, and this has been tested in hundreds of simulations.

Finally, one must realize that as the PRT system is expanded to serve larger areas, all vehicles still go non-stop from origin to destination whereas, the larger Shuttle TSM or Trolley systems become, the greater the negative impact on travel times, because of the increased number of stops along the way.

The assumption of a 4-minute wait time for PRT creates a worst-case scenario for PRT, while doing no such thing for the Shuttle TSM and the Trolley. This will inevitably lead to underestimating PRT demand and overestimating Shuttle TSM and Trolley demand. In other words, demand results for PRT will be negatively impacted to a significant degree by this wait time assumption by PB.

Regarding the ridership figures obtained from the PB's travel demand model, the weekday demand for PRT of nearly 20,000 trips per day – see Attachments 11 - is encouraging. Because, considering the negative effect of the flawed assumptions and the limitations of the demand mode, this is evidence that SLC's estimate of 30,000 trips per day is reasonable. While weekend demand may well be less than weekday demand, PRT will still be available on weekends 24 hours a day on demand, while schedules for the Shuttle and the Trolley are likely to be reduced. This would imply an even larger modal split to PRT on the weekends.

⦿ Attachments 11

This section of this Rebuttal is concluded by referring to a revised version of the Sky Loop Financial Plan, with updated capital and operating costs, found in Attachments 2 and 12. As stated many times by SLC, our goal is to have the Sky Loop be a self-supporting, profitable enterprise. Documents in Attachments 2 demonstrate that this is a reasonable goal. In fact, the Sky Loop will be quite profitable at our revised cost estimate, *and still remain profitable if capital costs are doubled.*

⦿ Attachments 2 & 10

23. Headway Sensitivity Analysis

As noted earlier in Section 5–Headways, prior to the issuance of the DFR on 7/17/01, Taxi 2000 had disputed JKH's intended requirement that the minimum operating headways of vehicles be limited to 5 seconds until Taxi 2000 "demonstrates safe operation below this level". On 6/21/01, JKH stipulated that Taxi 2000 would need to perform a headway sensitivity analysis, when PB obtained the results for PRT from its travel demand model, by running the demand model results through the Taxi 2000 "operation model" (the Sky Loop network simulation). This was prior to release of the DFR, where the travel demand model assumptions and methods were first fully revealed. The SLC and Taxi 2000 were told that the purpose of the requested headway sensitivity analysis was to evaluate the effects of an increase in vehicle headways from 0.5 to 5.0 seconds on the ability of the PRT system to handle the projected ridership. PB furnished the results of the demand model for PRT to the SLC on 8/22/01.

As discussed in Section 20–Travel Demand Model, the demand modeling performed by PB was flawed by both erroneous assumptions and the use of methodologies that are insufficiently refined to fully and accurately depict the characteristics of the Taxi 2000 Sky Loop PRT system. Considering this, on 8/31/01 the SLC requested that PB run the demand model again using the parameters of 1-minute peak period wait time and 0.01% wave-offs in place of the 4–minute wait time and the 10% wave-offs PB used in their previous run of the demand model. The SLC requested this because the former numbers are typical of those generated by the Taxi 2000 operation model and are much more comparable to wait times reported from other simulations (see table below). On 8/31/01 PB responded that "it was unnecessary to re-run the model." – see Attachments 11.

⦿ Attachments 11

Simulation Studies Addressing Wait Time In PRT

Study	Wait Times
Aerospace Corporation. PRT III*, pp. 345-368	80% of waits 20 sec to 50 sec 95% of waits 1 min to 1.5 min 99% of waits <= 2 min
K. Thangavelu, DeLew Cather PRT III, pp. 329-344	No real PRT was considered, but for a 3-sec. headway system the waits were less than 2 min
Alain Kornhauser, Steven Strong, and Paul Mottola, Princeton Univ. PRT III, pp. 377-384	Fig. 3 shows maximum wait time dropping as vehicle occupancy drops with about one minute with an occupancy of 1.5 persons.
Cabintaxi/Cabinlift Final Report, U. S. DOT and SNV, Germany. UMTA-MA-06-0067-77-02	On the bottom of page 4-189 it is stated that with the best selection of parameters, the waits are all < 3 min, with 80% to 90% less than one minute.
Neil Sher and Paul Anderson Honeywell, PRT II**, pp. 401-416.	With 2 sec. headway and 8-pass vehicles, they show average wait times of 66 to 75 sec.
Roesler, Williams, Ford and Waddell, APL, Johns Hopkins U. PRT II, pp. 425-437.	With unrestricted routing they show wait times of 40 to 85 sec.
Harold York, Bell Labs PRT II, pp. 439-447.	40 to 85 sec average wait, maximum about 3 min.
Martin Ross and Alan Melgaard, IBM Corporation	Demand Responsive Single Party 42 sec. Demand Responsive Multiple Party 212 sec.
Ingemar Andreasson Molndal, Sweden *Vehicle Distribution in Large Personal Rapid Transit Systems , 1994*	http://faculty.washington.edu/jbs/itrans/ingsim.htm 1.3 min. waiting for cab; 99% < 3.0 min.

*from: Personal Rapid Transit III; Progress, Problems and Potential of a promising new for of public transportation as reported ath the 1975 International Conference on Personal Rapid Transit. Denver, Colo. September 16-19, 1975.

**PRT II is an edited collection of papers from the 1973 Internation Conference on Personal Rapid Transit.

As stated in Section 5–Headways, the 5-second headway limitation is needless at this point in time in the multi-phased study and Sky Loop implementation process recommended by the SLC. This is particularly so since that program is dependent on Taxi 2000 prototype development and safety testing at fractional-second headways. Thus PB's requirement that Taxi 2000 perform an headway sensitivity analysis by setting up the simulation with 5-second minimum headways and then running the PB ridership data was also pointless, even more so in light of the flaws in PB's current travel demand model. Doing such an analysis is irrelevant to whether a vehicle can run safely at fractional-second headway. The safe headway capability is determined by the engineering of the system and its computer controls, not by ridership.

Furthermore, the predicted daily weekday PRT demand of nearly 20,000 that has resulted from PB's travel demand modeling contains 13,916 passengers during 2 daily peak periods totaling 6 hours which, when averaged, is 2,319 passengers per peak hour. In order to achieve desired system performance criteria, such as wait times under one minute, a headway significantly below 5 seconds will obviously be required. Considering the above, SLC and Taxi 2000 believe there is no merit to conducting a headway sensitivity analysis and thus do not plan to do so.

In the Sky Loop Phase 2 program recommended by the SLC, it is intended that improved demand modeling that properly deals with the unique characteristics of PRT will be performed in conjunction with network simulations.

24. Other Statements Made in the DFR That We Dispute

DFR p. 2-6: "LRT is cost-effective…" A system that covers only 25-30% of its annual operating costs is not cost effective.

DFR p. 2-9: "the overall length (of the Taxi 2000 PRT vehicle) is assumed to be approximately 10 feet." Taxi 2000's design is 8.5 feet.

DFR p. 2-11: "the vehicle door… have inherent problems. If the side and top door opening is used, the weather-tight sealing of the vehicle will be very difficult to maintain." No more so than autos. This will be solved during the early prototype stage.

DFR p. 2-11: "and, if only the side panel opens, there will be a propensity for people to strike their head as they stoop and enter the low vehicle." Prof. Martin Lowson, of the Advanced Transport Group in the U.K, has informed us that the prototype vehicle for their ULTra PRT which has been in existence for over eighteen months, has a flat-floor entry, and that likely more than 1000 people have gotten in and out of this vehicle without a single instance of head striking.

DFR p. 2-13: "Emergency walks will be provided on the entire station sidings." Taxi 2000 feels this is unnecessary, as the mean time between failure (MTBF) for vehicles will be so long as to be essentially forever.

⦿ Attachments 6

DFR p. 2-14: "The proposed operating system does not provide allowances in the design for collision impact absorption between vehicle…" The design of the vehicles does so very explicitly. That is the function of the shock absorbing coupler/bumper – see Attachments 6.

⦿ Attachments 6

25. Visual and Architectural Integration

DFR p. 8-17 states: "The aerial guideway structure and its supports will cause a significant visual impact even when no PRT vehicles are present. These impacts affect not only the observer on the street but also residents and building occupants whose view are obstructed by the guideway. In addition, residents particularly may find that the presence of the PRT vehicle and its passenger represents a significant loss of privacy."

Visual and architectural integration with the urban environment is important for all transit systems, given the benefits they provide. By its nature, having been designed for minimum size, weight and cost, the Taxi 2000 PRT system will integrate more readily into its surroundings than any other kind of elevated transit system. Additionally there will be number of steps in planning and designing the Sky Loop PRT system, from network routing and the design of the guideways, stations and vehicles to treatment of existing elevated utilities that reduce visual and architectural concerns and facilitate integration. Furthermore, the last 150 years of urban history have amply demonstrated that, as we have utilized new technologies for enhanced mobility, power, and communications, we place less importance on the visual intrusiveness of these systems while the evolving built-environment is adapted to their presence. Beyond these aspects, the Sky Loop PRT system will add a new, active and exciting dimension to our regional core, a dimension of architecture-in-motion. It will become a visible demonstration of our community's leadership in urban redevelopment in the new century while preserving the valued elements of our past.

Network Routing: Since drawing up its first PRT network in 1998, the SLC has always sought routes that, while offering the greatest transport service, avoided as much as possible transecting designated historic areas and running in front of other historic structures. Only two blocks of one historic district are traversed, along 4th Street in Covington between the Licking River and Greenup Street, which is also a major traffic corridor. The rest of the routing, being as it is located in the CBDs and riverfronts of the three cities, passes almost entirely in front of modern structures. The SLC continues to explore alternate routing that minimizes interfacing with older buildings.

Guideways: The Taxi 2000 guideway with its covers is just a little over three feet square in cross section (39 inches by 39 inches), which means it is just five percent of the cross-sectional area of a traditional elevated rail system. It is far smaller than any other APM system guideway and miniscule by comparison to the expressway ramps and highway bridges we take for granted today in our urban core. The external appearance can be varied to suit any specific location, both through the use of various colors and surface treatments and designs on the guideway covers, thus helping to blend the system into the existing street environment and building facades.
(See http://faculty.washington.edu/~jbs/itrans/gavle.htm).

Supporting Posts: The guideway posts are only two feet in diameter at the base – not much larger than many posts found along sidewalk edges today. Since the typical post will be 16 feet high, street and parking signage and traffic signals can, in many instances, be mounted to the posts. Post design can be varied to accommodate street lighting, such as with an inverted-L post and, like the guideway covers, can have varied surface treatments and design features to help them blend into their immediate surroundings. Where desired, instead of using a single vertical post, the guideway may be supported by an arch configuration that spans the width of a street. In such a case the posts can be placed among curbside trees while the small guideway runs overhead down the center of the thoroughfare.

Vehicle Elevation & Treatment: The typical post and guideway height will place the bottom of the vehicles at about 19 feet elevation. The great majority of buildings that the Sky Loop will pass by are commercial, corporate or other institutional structures. Few of them have residential use on the lower floors. Furthermore, a study of the facades of CBD buildings shows that floor elevations vary greatly, so vehicles won't pass in front of either second- or third-floor windows at a consistent level. Additionally, the ground-floor height of many CBD buildings is so great that the vehicles in some instances will likely pass along between windows of the ground and second stories. At an average line speed of 23 mph, vehicles will pass by quickly. The Taxi 2000 vehicles are designed to be quieter than all other motorized transport to be found on our public right-of-ways downtown today – they will make no more noise than a sewing machine or a typewriter. And the PRT vehicles will be neutral in color.

Elevated Utilities: The SLC proposes that above-ground electric, telephone and cable-TV utilities occurring in places along the PRT network be placed underground, thus removing what is often considered today a blight on the urban environment and, in the process, improving the visual appearance of these public corridors.

Stations: Similar to guideways and posts, stations can incorporate a variety of designs and treatments to help them complement and integrate with their immediate surroundings. Some of the stations located inside of buildings will actually be incorporated into the design of existing or new building structures.

All of these aspects will be studied and simulated in succeeding engineering and design phases of the Sky Loop program where community input and consensus will be sought before beginning any construction.

Will the Sky Loop guideways be visible? Yes, they definitely will. Will the Sky Loop guideways be visually intrusive? If at all, then only to a minor degree. They will certainly become less intrusive than the visual intrusions our community already deems acceptable and commonplace. Originally, the two to four lanes of interstate highway ramps and overpasses, which are a kind of guideway for automobiles, seemed visually intrusive to everyone. That's because they are huge slabs of cement supported by huge steel girders and because they block significantly large portions of scenic views. But over time virtually all of us have learned to take these massive highway structures for granted, so much so that now we ignore this aspect in our quest for greater mobility. If history teaches us anything, it teaches us that a community's perceptions change over time and they do so in an inverse relationship to the perceived benefits to the community. So, as our community places greater importance on mobility, it places less importance on the visual intrusiveness of the system that provides the enhanced mobility. The Sky Loop PRT Circulator, because of its high capacity (see Section 18–Capacities of the CAL Alternatives), will generate ridership far in excess of any current transit technology. What is that worth, when traffic problems are only going to worsen because existing transit technologies have proven they can't solve them?

In balance, the SLC is confident that this new high performance transport paradigm will actually improve the pedestrian friendliness and appearance of thoroughfares by significantly reducing the increasing pressure on and degradation of the urban environment caused by motorized surface vehicles.

- See: "Visual Intrusion Study of PRT Guideways in Gävle, Sweden", http://faculty.washington.edu/~jbs/itrans/gavle.htm, and "PRT Visual Impact: CalExpo", http://www.advancedtransit.org/visual.htm

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26. In Conclusion

PRT gives us the opportunity to develop a 21st century system that will provide safe, reliable and convenient service to all members of our community. As we now have an aging population, more people will be denied use of the automobile through physical disability or the inability to get insurance. With a system that provides superior service and that can be expanded into the larger community, we have an excellent opportunity to improve the quality of life in our community.

The risks are minimal. Full testing of a prototype will take place before any construction begins. Existing options have many risks -- cost over-runs, accidents, and an on-going need for subsidies by taxpayers. In America we have a history of seizing opportunities when they are presented. Think of the risks of building the trans-continental railroad, of putting in the first street railways. At that time, many said it could not be done, but far-sighted citizens and public officials decided to try and success was theirs. We believe the time is right to try again, and we hope this rebuttal provides you with enough accurate information that you feel it is the right time to move forward once again.

We hope you have found our rebuttal helpful in making a decision regarding the choice of the Locally Preferred Alternative for the CAL.