



Technology Meeting Needs of People

T2 and Its Business

T2 is a revolutionary means for moving people and goods so cost-effective that it can be built and operated as a profitable private business. Its cost-effectiveness results from a combination of excellent service and inherent economy.

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T2 Serving a Suburban Office Building

The Problem of Urban Transportation

The alternatives to the automobile usually considered today for movement of people in cities are heavy rail, light rail and buses. Electrically operated heavy-rail systems in the United States were introduced in New York, Boston, Philadelphia, Cleveland, and Chicago in the late 1890s. In recent times such systems have been built in San Francisco, Washington D.C., Atlanta, Baltimore and Miami. These systems have the advantage that their guideways are exclusive and hence can offer much higher average speeds than surface-rail systems (streetcars) operating in mixed traffic. But they have the disadvantage of extremely high cost, which means that few lines can be built.

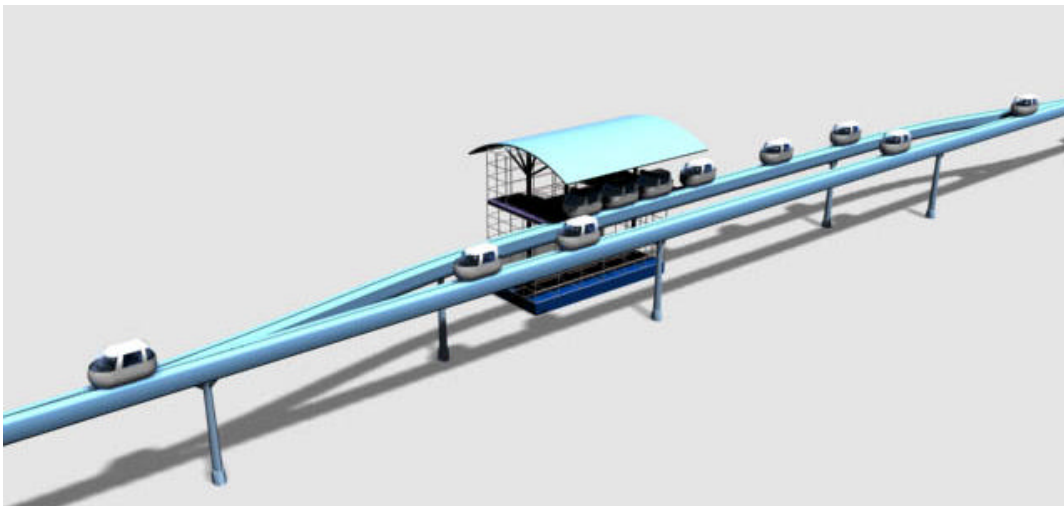
Because of the high cost, advocates of conventional rail transit decided in the mid 1970s that the surface-level streetcar was the only reasonable alternative available, and they came up with the brilliant marketing strategy of calling it "light rail," notwithstanding that the cars are generally heavier than heavy-rail cars! The rails can be "light" only if the cars travel at slow speeds, as did urban streetcars, which were introduced in the 1890s and expanded rapidly until 1917, when the mileage of active track declined as rapidly as it rose because of competition from the automobile. When "light-rail" cars are caused to travel at 50 to 60 mph between stops, the rails must be as heavy as those of the so-called heavy-rail systems. Because of operation on streets rather than on exclusive rights of way, light-rail systems cost roughly one third of heavy rail systems. They are therefore being considered and built in many cities; however, the characteristics of these systems cause several problems:

- 1) They are subject to the cross traffic of the city, which slows auto traffic thus increasing congestion and causes accidents.
- 2) The trains must stop on line and at every station. In so doing on city streets, the practical minimum schedule frequency is roughly 6 minutes or only 10 trains per hour, so to achieve say the capacity of one freeway lane, which is about 2000 passengers per hour, each train would have to accommodate at least 200 people. This results in large cars now weighing 105,000 lbs each – so heavy that the roadway underneath must be reinforced. Data show that the busiest light-rail line in the United States attracts only a fraction of the traffic of one freeway lane.
- 3) The stations must be placed at least one mile apart to achieve an average speed of even 20 mph because the trains must stop at every station. Such a speed is usually not competitive with auto average speeds. Slower speeds and long walks to a station result in disappointing ridership, so low that the data show that such systems have virtually no effect on congestion, which is customarily the main argument given the public for building them.

- 4) The system must be subsidized because of low ridership. The capital costs are paid entirely out of public funds, and on the average about two thirds of the operating costs are publicly funded.

The conventional alternative to urban rail is the bus, which was first introduced around 1910. In most cities, buses are the primary means of movement for people who can't afford automobiles – a dwindling portion of the population. Ridership is low mainly because it takes typically one to two hours longer each day for the average person to travel by bus rather than by automobile. Buses are much cheaper to acquire than rail systems, but because of frequent stopping and jerky motion they don't attract as much ridership as the heavier, smoother-riding, light-rail vehicles. However, because the service characteristics of both buses and light-rail systems are so inferior to those of the automobile, transit use in all but a few cities remains below three percent.

There is still a strong need to do something about increasing congestion. Many metropolitan areas are planning to spend over 50 percent of their transportation budgets over the next few decades on conventional transit, notwithstanding that their own data show that such an increase in the transit budget will result in, at most, less than one percent more urban trips taken by transit. With only the present options available, the future looks bleak. We are advised to tolerate increasing congestion and we accept unhealthy levels of air pollution, notwithstanding technical advances in emission reduction. Transportation departments are helpless to provide adequate mobility for an aging population living in the vast lower density areas of our cities and we continue to accept in the United States millions injured and roughly 40,000 people killed each year in auto accidents. There is a clear need for a new alternative, which requires understanding of fundamental ways to decrease costs while markedly increasing ridership.



A T2 Off-Line Station

The Solution

The direction public transportation must head has been known since a series of federally funded studies appeared in the late 1960s. These studies showed that if only conventional transit is deployed congestion will continually worsen, but if new personal rapid transport (PRT) systems could be widely deployed, they would attract enough riders to decrease congestion. Over the past thirty years the problem of design of an optimum PRT system has been studied, not only on paper but also by building experimental systems. The leading example of PRT today – Taxi 2000 (T2) – has been under development for two decades.

PRT minimizes cost by using many small, lightweight vehicles spread over a guideway, which can be of very light weight because its weight is proportional to the vehicle weight per unit of length. To keep the vehicles separate from common road traffic, the guideways are usually elevated. Thus the land saving is great because land is needed only for posts and stations. PRT maximizes ridership by using relatively small off-line stations. Such stations permit the service to be **nonstop** between any origin station and any desti-

nation station, and permit **vehicles to wait for people rather than having people wait for vehicles**. Further, the rider can travel in seated comfort and in private, either alone or with chosen companions, and at any time of day or night.

The use of reliable, in-vehicle switching, which has been developed, means that the guideways can be arranged in interconnected networks covering areas rather than just a corridor. Manual transferring is eliminated. The availability of highly reliable components used in redundant pairs and fully automatic control means that such a system is fully practical today and will provide a level of safety and reliability well beyond that possible with conventional systems, even at line capacities up to the equivalent of three freeway lanes of travel.¹ Since the vehicles bypass all intermediate stations, adding stations does not slow the traffic. Stations can be placed closer together than possible with conventional rail systems, thus making the system convenient to many more people. Personal security is achieved in stations by providing adequate lighting, motion sensors, television monitoring, two-way communication, and because the time spent in the station is very short. Since the trip time will be less in the central city than possible even with automobiles (they must stop at stop lights), the ridership can be expected to be many times higher than attained by conventional transit. (See Appendix C).

These system features result in substantial advantages for the community:

- High levels of transportation availability, using well under one percent of the community's land.
- No direct air pollution.
- Safety for both passengers and nearby pedestrians and motorists.
- Substantial reduction in transport noise.
- High energy efficiency – about four times better than an average auto.
- Minimum cost per passenger-mile, resulting in deficit-free operation.
- Accessibility to high-level transit service for a large fraction of the urban population.
- Very little disruption during installation.
- New freedom for older and mobility-impaired individuals.
- Livable higher density, meeting visions of new urbanists.
- A substantially improved urban environment.



A T2 Network in Downtown Minneapolis

The design of T2 was accomplished over many years starting by listing a comprehensive set of requirements and physical characteristics, which were derived from 1) comprehensive interdisciplinary analysis of the needs of the traveling public and the community; 2) mathematical analysis of the physical characteristics of a transport system required to minimize life-cycle cost per passenger-mile; 3) involvement in and

¹ J. E. Anderson, "PRT – Matching Capacity to Demand." Download from <http://www.taxi2000.com>.

study of numerous real-world planning studies; 4) careful study of about \$2 billion worth of work on experimental systems built during the 1970s in seven industrial countries, and 5) feedback from hundreds of presentations given at home and abroad. Over \$30,000,000 of sweat equity and treasure has gone into the T2 system with contributions from dozens of people and five major corporations.

A remarkable finding² was that the characteristics that minimize cost also maximize ridership. Most of the new transport-system designs, while automated to reduce operating cost, still used the service concept of the 19th Century – large vehicles stopping at all stations. The real breakthrough came when several innovators realized that a complete break with the past would be needed if they were to be able to compete economically with auto transport. Today, technology has reached the point where the new system is completely practical, and indeed during the 1990s the National Automated Highway Consortium demonstrated the key concept of safe, reliable operation at fractional second headways. A point of fundamental importance is that, over the past 15 years, we have developed the software package needed to run a T2 system of any size and shape. This is our major intellectual property and is unique in the world – five companies have sought to license it!

The T2 design is the industry leader in the field of PRT, having won competitions in SeaTac, Chicago and Cincinnati, while no other similar system has won any competitions. Details of the design and operation of T2 are described on <http://www.taxi2000.com/>



Getting where we are today

A long struggle has been required to bring the new system to commercial reality. Reflection on past failures of similar systems to achieve commercial success shows that these failures occurred because not until recently have there been enough people on all sides of the problem – engineers, planners, public officials, economists, investors, and interested citizens – to form a critical mass of those who appreciate both the compelling need to find a solution to the problem of congestion and that T2 constitutes an important solution. The Internet has made possible the study of material such as we have on our web site by an ever-increasing number of people – now worldwide.

An important conclusion from our experience is that at least the initial investment in T2 hardware will come from private sources and is likely to relate to privately funded applications. Notwithstanding the need for solutions to congestion, conflicting interests have prevented governments from acquiring the knowledge base needed to lead the development of a revolutionary system like T2, and there are too many conflicting agendas to expect governments to obtain the necessary knowledge base before T2 is fully implemented. Government money without government management would interest us, but has been unlikely.

² J. E. Anderson, "Optimization of Transit System Characteristics." Download from <http://www.taxi2000.com/>.

In 1989 the Chairman of the Northeastern Illinois Regional Transportation Authority said: "We know we can't solve our transportation problems in the Chicago Area with just more roads and more conventional rail systems. There must be a rocket scientist out there somewhere with a new idea." We met them shortly thereafter and they immediately embarked on a program to acquire PRT, first with a request for proposals for a pair of \$1,500,000 design studies. Taxi 2000 Corporation (T2C) won one of these studies with Stone & Webster as prime contractor. Unfortunately, S&W could not help finance the next phase, which would be a \$40,000,000 program leading to a full-scale test track, so Raytheon Company joined T2C and matched the RTA's \$20,000,000 commitment, with the work to be done in one of its governmental divisions. The RTA staff was not equipped to handle such a project and therefore hired a firm to do so. Since there were no firms known to them skilled in PRT technology they hired a firm skilled in the closest technology – large-vehicle people movers. Unfortunately the differences between such systems and true PRT are profound. The resulting compromises resulted in a system too large and too expensive to find a market. T2C was able to free itself so that by January 2000 it was able to offer its system independently. During the 1990s we were able to respond to planners interested in applications of T2. There have been enough of them – several dozen – to convince us that the market is very large, large enough to require the major new industry described in Appendix A. To be interested in investing in our enterprise, it is of course necessary to be convinced that we have the technology, plans and people needed to succeed in a reasonable period of time.

After January 2000 we were able to initiate serious planning that could lead to a practical business plan. At first it was felt that we needed to raise in an initial offering close to \$30,000,000 to build a test and marketing facility, and to establish a significant business and marketing organization. It was found, however, that those who could provide such funds needed to see that we had an application committed, but those who could commit to an application wanted to see the test hardware up and running and a supplier team in place – a classic "chicken-and-egg problem." *The roadblock was the lack of hardware.* People in major national television networks have told us they would do stories once we have hardware up and running. We needed a way to initiate hardware development in a much smaller step.

Solving the Chicken-and-Egg Problem



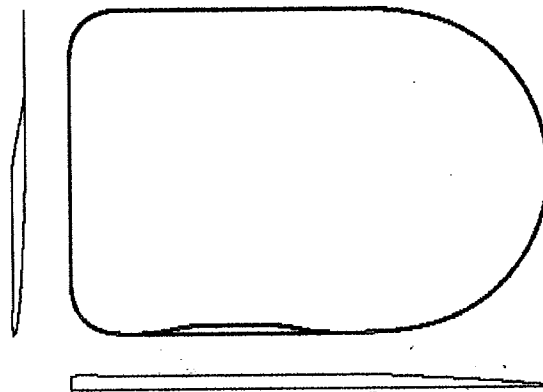
The T2 Phase I Prototype Vehicle to be located at 8050 University Avenue, Fridley, MN.

The solution came through the Securities and Exchange Commission 504 Plan that permits a company to raise up to \$1,000,000 from up to 35 unsophisticated investors with investments as small as \$5000 and any number of sophisticated investors. A number of people had asked how they could invest and the 504 Plan showed the way. Our cost analysis showed that with \$1,000,000 we would be able to 1) build one full-scale vehicle operating on a 60-ft segment of guideway, which will permit us to demonstrate all of the basic features of T2 (our Phase I Prototype); and 2) develop and market a plan to raise funds for the next larger step – the Phase II test program described below. The 504 Plan was first distributed in April 2002 and by mid August enough had been raised to begin letting contracts, which showed the power of the idea among those who know us.

Getting Hardware Ready; Phase I

Once we had a practical way to get hardware up and running, we began getting the designs ready to bid and we sought suppliers who could carry out the various tasks. We have rented enough space at 8050 University Avenue in Fridley, MN to house our Phase I Prototype (one vehicle on 60 ft of guideway). Short Elliot Hendrickson is supplying power engineering, and other services. BendTec, Inc. of Duluth is building the guideway, for which Krech Ojard & Associates of Duluth has provided the final structural analysis and drawings. **redgroup** of Minneapolis is designing the cabin. The Mechanical Engineering Shop at the University of Minnesota is fabricating the chassis. Knutson Construction Company has agreed to build our Phase II Test and & Marketing Facility on land they own at 105th and Central in Blaine, MN, for which Millerbernd Mfg of Winsted, MN, will fabricate the posts. We have sufficient talent within T2C to design, order, and install the necessary control components, which today are commodities. We will obtain linear induction motors and their drives from Force Engineering, Ltd. in England; assemblies of wheels, axles, and bearings from Aerol, Inc. in Los Angeles; switch actuators from Ledex in Vandalia, OH; etc. We expect to have Phase I in operation by mid January 2003.

The Test Program - Phase II



A Minimum Phase-II Test Facility

Properties of a Minimum Phase-II Test Loop

Speed in the large curve can be up to 38 mph.

Speed in the small curves can be no more than 20 mph.

Dimensions of Loop: 636 ft x 426 ft.

Total Guideway Length: 2138.5 ft.

Length of Off-Line Station Guideway: 266 ft.

The elevation view below the plan view of the guideway shows the station guideway 16 ft above the ground, then sloping downward on the right at a 3% grade to a ground clearance of 6 ft.

The left hand elevation shows an upward grade of 10%.

Both elevations are shown double scale compared to plan view. Flow is assumed counterclockwise.

The test track may be located so that it would later connect with the first application and serve as the maintenance and storage yard for that system. The reasons the Phase-II program is needed are given in Appendix B. The company needs to attract \$12 million to complete Phase II and about an equal amount for market and business development. We believe it will be much easier to attract these funds once we have demonstrated competence by building the Phase-I system. Such funds may come from an angel investor or a developer of an application who sees the wisdom of seeking funds for that application with the Phase-II system as part of the overall contract.

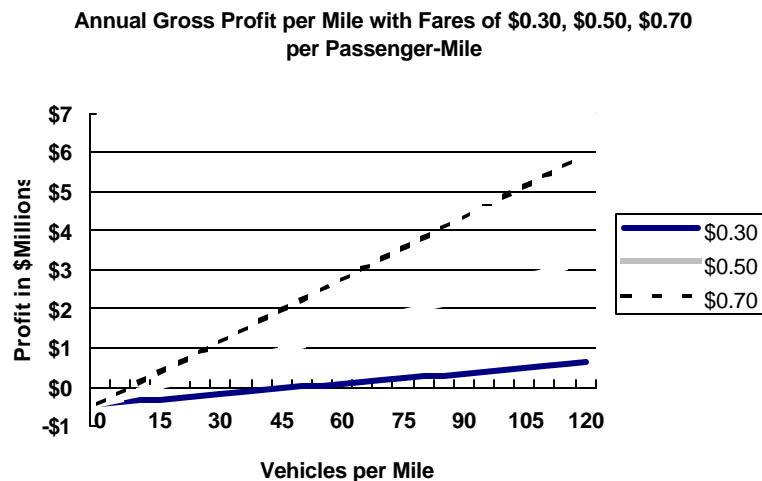
The Potential Market for T2

How can we estimate the potential market for T2 in the United States? One way is to start with the amount of transit that exists today in the United States. According to the APTA 1997 Transit Fact Book, in 1995 there were in the United States 7.9 billion trips taken on transit with an average trip length of 4.87 miles, giving 38.5 billion passenger-miles of travel by transit. This is slightly less than one percent of the total number of passenger-miles of travel in urban areas in the United States and slightly less than three percent of the trips. Counting empty vehicles, a T2 system will average about one person per vehicle. A reasonable average speed for T2 in the denser portions of an urban area is 25 miles per hour. Data show that the daily number of miles traveled by a T2 vehicle, being a private, demand-responsive system like the automobile, will be about 11.5 times the peak-hour travel; and the yearly number of miles traveled by a T2 vehicle will be about 320 times the weekday travel. Thus each vehicle will travel about $(25)(11.5)(320) = 92,000$ miles per year. Multiplying this number by the number of vehicles gives the yearly number of vehicle-miles taken by T2. So the total number of T2 vehicles required to serve all of the passenger-miles taken by transit in the United States would be $(38,500,000,000/92,000) = 418,000$.

But, whereas transit attracts a little less than one percent of U. S. passenger-miles of ground travel, estimates show that it is reasonable to expect T2 to attract many more trips in the denser portions of urban areas. Moreover, T2 will be applicable to shopping centers, medical centers, airports, universities, national parks, private development projects, etc. where conventional transit is used hardly at all. To get a feeling for the magnitudes, suppose that at full deployment PRT would attract only as many trips as conventional transit carries now. It is reasonable to assume, on the basis of many studies, that in the average application we will require about 40 vehicles per mile of guideway. Thus to carry as many passenger-miles as conventional transit carries now $(418,000/40) = 10,450$ miles of guideway would be required. At an estimated overall system price of \$8 million/mi this is a market of \$84 billion. Considering the need everywhere and the construction time required in other major transportation projects, this could be accomplished in perhaps 30 years. Tempered with Regis McKenna's remark: "in emerging markets, numbers are rarely reliable," would the truth be higher or lower? What would it be, taking into account the international market? How would the T2C share of the market shake out in face of competition?

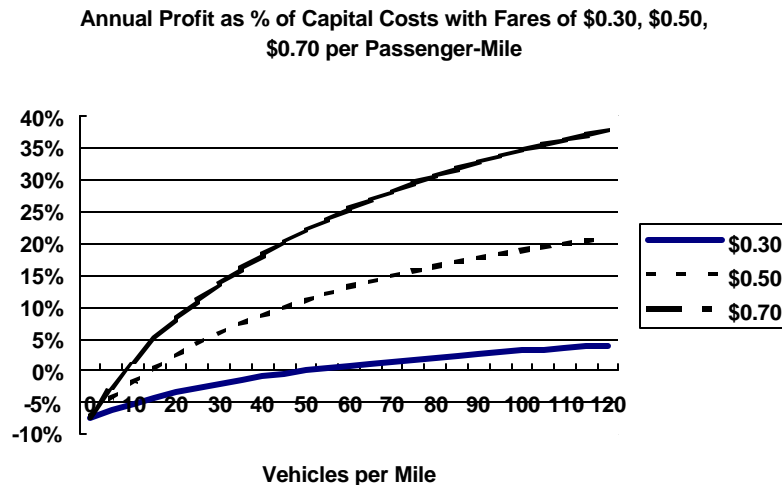
A critically important factor is the potential ridership that can be attracted to a T2 system. Because of the substantially improved speed and quality of service, it can be expected that T2 ridership will be a great deal more than is possible in conventional transit. How much more is conjecture before these systems are built, but a number of studies have attempted, using the tools of the trade, to estimate ridership on PRT systems. Some of these studies, summarized in Appendix C, show that it is not unreasonable to expect a third of the trips on PRT in an area in which it is used.

The Gross Profit Resulting from Building T2 Systems



The above chart is based on detailed estimates of the costs of the components of the T2 system, and include all costs for overhead. The annual gross profit per mile to the company that purchases T2 systems and collects the revenue is represented by the above graph as a function of the number of vehicles per mile for three levels of fare charged per mile of service. We have found that applications use between about 20 and 120 vehicles per mile. The required number of vehicles per mile is calculated to meet peak demand, and thus depends on ridership, which will decline as fare increases. By comparison, a fare of \$0.50 per passenger-mile is typical of urban bus systems; and, because of their poor service characteristics, typically two-thirds of their operating cost is subsidized.

The annual profit as a percentage of the up-front capital costs is illustrated in the following chart. For example, a system requiring 60 vehicles per mile while charging a fare of \$0.50 per passenger-mile would recover its capital costs in about seven years, following which the profit per mile per year would be about \$1,500,000 every year thereafter. On this basis, part of the profits can be used to finance expansion of T2 systems.



The Net Profit to Taxi 2000 Corporation

The graph on page 8 shows the *annual* gross profit per mile of guideway. Also on page 8 the market possible for T2 in the U. S. was compared to what it would be if all conventional transit systems would be replaced by PRT. This likely will not be possible, but ridership analysis shows that PRT ridership will be many times conventional transit ridership in the areas where it will be used. The total market for PRT in the U. S. and the world can't be estimated with any confidence in advance of actual experience; but study of its service characteristics, the estimates of ridership already mentioned, and the interest already shown indicates that the market for T2 systems will be large enough to keep the industry busy for decades. It is not unreasonable to project the market for T2 systems as a multiple of the \$84 billion calculated above.

It will of course take time for this market to build up. After the first successful operating system is in place, it can be expected that transportation-consulting firms will find it necessary to become educated in the planning of these new transport systems and that courses in universities on the theory, design and planning of them will begin to emerge. After the first few installations have had several years of operating experience, which can be expected to occur in about six or seven years, explosive growth in deployments can be expected until the market saturates.

The Business

The aim of **Taxi 2000 Corporation** is to commercialize the T2 system fully through the steps described below, to seek applications aggressively throughout the world, and to maintain leadership position in the field of PRT, of which T2 is the leading example. T2C and its partners will engage in marketing, planning or supervision of planning of specific systems, software improvement and maintenance, specification development, product improvement, training, solving institutional problems, and coordinating the activities of a

consortium of suppliers capable of building T2 systems and franchising the building of these systems in locations around the world. Different suppliers will of course serve markets in different geographic areas.

1. We have raised the money needed to complete our Phase-I Prototype.

We need to accomplish a successful demonstration of our hardware in the least expensive way practical, which is to build one vehicle, operate it on a short section of guideway, and to demonstrate station operations and ticketing. Thus far we have raised about \$550,000. We need to fill out the \$1,000,000 permitted under SEC 504 and have extended the deadline for our offering to January 31, 2003.

2. Our contractors are fabricating the components of for our Phase-I Prototype, which we will install and display it at 8050 University Ave, Fridley, MN. This project is giving the team hands-on experience with the design of the vehicle, the guideway, the vehicle control system, the power system, and the ticketing system. We expect to have Phase I in operation by mid January 2003.
3. Obtain up-to-date costs of all components of our outdoor test track (Phase-II Prototype) by obtaining bids from the companies already identified.
4. Advertise progress on our web site and elsewhere.

Significant progress has already resulted because of publicity in newspapers, magazines, television, and our web page. We will expand the publicity our program has received by all media available to us.

5. Search for angel investors or private developers who both need a T2 system and could provide the funds needed to finance our Phase II Prototype as well as a first installation.

It has become clear through the experience in working with a public agency a decade ago that attempting to get funding through cities or states is problematical. It will be subject to uncertainty at least until our system is up and running. We are seeking developers of the many private projects around the world that badly need means of reducing congestion and desire to develop auto-free zones.

6. Consider opportunities that have been or may be presented to us.



A large T2 Station at an Arena

It is important to note that building the Prototype systems need not slow down opening of the first revenue system, and is essential to it. While it is being built, site work on the Phase-II test track and the detailed design of the Phase-II guideway can be carried out so that it could be possible to start building the Phase-II test track by mid 2003, and to have it in operation by Spring 2004, during which time the Phase-II vehicles could be designed and built. Once the site for the first operating system is identified, it will take at

least 18 to 24 months to do the detailed planning and site design, during which time the basic testing on the Phase-II system will have been completed, thus preparing the design and production teams to build the first operating system.

The Core Team

Chairman of the Board: A. Scheffer Lang
 President and CEO: Dr. J. Edward Anderson
 Director: Edmund W. F. Rydell
 Director and Vice President for Control and Software: John E. Braff
 Vice President for Application Studies: Raymond A. MacDonald
 Vice President for Marketing: Benzi Rosenski
 Director of Business Development: Jeral Poskey
 Manager of Operations: Mike Lester
 Software Development: David Maymudes
 Architecture: Richard Wolfgramm
 (See <http://www.taxi2000.com/> for resumes.)

Many more people are assisting the effort. As of the date of this document, more than 60 people are involved in one way or another on a volunteer basis. Also, the companies mentioned on page 7 are providing critically needed services. Numerous competent people are ready to join the team when funds are available, and some of them have been making important contributions. The team will be strengthened if we can recruit a person who could, after a period of indoctrination and activity, take over the role of company CEO. Finding such a person or a strategic partner is a priority for the company.



T2 on a Cincinnati Street

What have Others Said About PRT and Taxi 2000?

1. "The safety design philosophy of Taxi 2000 deserves praise." Technical Committee on Personal Rapid Transit, Advanced Transit Association, *Journal of Advanced Transportation*, 22:3(1988).
2. "Taxi 2000 and its approach to PRT are first class." Walter H. Stowell, Senior Vice President and General Manager, Raytheon Equipment Division, following intensive two-week study in March 1990.
3. "The Taxi 2000 system is an inherently low-risk development because it is based on mature technology." "We have a very high level of confidence that it will work." "It is a straightforward application." Stone & Webster Engineering Corporation, final report to the Chicago Regional Transportation Authority, April 1992.

4. "I am confident that PRT will prove to be a risk that will pay enormous dividends for this region." Thomas J. McCracken Jr., Chicago RTA Chairman, *PRT Update*, Sept. 1996.
5. "Our recommendation is therefore clear—a PRT system provides such a broad range of desired qualities that it should be given highest priority in research, development, testing, and demonstration for implementation in the urban environment." Göran Tegnér, Business Manager International, TRANSEK Consultants Company, Solna, Sweden.
6. "Advanced PRT systems of the type proposed in this article provide a cost-effective and environmentally advantageous solution to the problems of transport in the 21st century." Martin V. Lowson, Director, Advanced Transit Group, University of Bristol, United Kingdom.
7. "Technical solutions to urban congestion do exist and are now available in financially viable terms with the advent of PRT technology, which offers the way to achieve all of our objectives while offering enhanced urban form and improved lifestyle." Raymond A. MacDonald, Transportation Consultant, Woo-Bo Enterprise Company, Seoul, Korea.
8. "PRT has a definite, emerging place in American transportation systems." Dr. Lonnie E. Haefner, International Editor-in-Chief of the John Wiley journal *Infrastructure*.
9. "Even when road capacity is sufficient for transport needs, the energy investment in a PRT system can be recovered in four or five years." Eva Gustavsson, Swedish Road and Transport Research Institute, *Journal of Advanced Transportation*, 30:3(1996).
10. "Personal Rapid Transit is the more promising solution for the mobility needs of a sustainable urban future." Andrew Euston, Office of Community Planning and Development, U. S. Department of Housing and Urban Development, February 1997.
11. "Personal rapid transit is one technology that holds great promise for urban transit systems." Emory Bundy, Seattle political scientist. <http://faculty.washington.edu/~jbs/itrans/bundden.htm>.
12. "The Taxi 2000 PRT system is our primary selected technology for our project." Sky Loop Committee, Cincinnati, <http://www.skyloop.org/>.

(Quotes 5 through 8 come from a special issue of *Infrastructure* devoted to Personal Rapid Transit Systems, Spring 1997, based on papers from the International Conference on PRT and other Emerging Transportation Systems, sponsored by the ITS Institute, Center for Transportation Studies, University of Minnesota, November 18-20, 1996.)



T2 Spanning a Freeway

Conclusion

We have the technology and core team needed to build the first full-scale T2 hardware and we are building it. We know from a great deal of experience with the market that there is a huge pent-up demand for T2. But we know also that it is unlikely that we will obtain the funds needed to build the first application until the basic hardware is in operation. We therefore seek investors who both understand the benefits and have the necessary confidence that our team, which will grow substantially, can actualize the potential of T2. For more information, see the company web page.

Prepared by
J. Edward Anderson



T2 in a Hotel Lobby

Appendix A. The T2 Industry

1. **System Owner.** This could be a public or private entity, responsible for seeing that the system is operated satisfactorily under a franchise from Taxi 2000 Corporation. This includes concern for safety, reliability, cleanliness, public relations, advertising, fare collection, etc. Once we find a financial partner with substantial resources, the combined entity may wish to take on this role. The owner will of course enjoy the net profit from the system.
2. **Marketing.** Without marketing there can be no business. Marketing will cause knowledge of and the characteristics of T2 to become widespread. It will be necessary to prepare videos, CDs, print material, displays, virtual-reality presentations, etc; attend and participate in conferences and trade shows; meet one-on-one with potential clients; arrange presentations; and do all that is necessary to find clients interested in purchasing a T2 system so that the site-planning-and-design team can go to work.
3. **Financing.** The function of this group is to locate and secure the financing necessary to build specific systems.
4. **Site Planning and Design.** Each application will require a team of architects, engineers, and planners to work with local officials to locate lines and stations, perform ridership analysis, simulate the operation, and do the detailed design needed to provide plans to the general contractor, who will supervise the installation. There are many transportation-consulting firms that have traditionally done this work under contract. T2C will most likely work with such firms to supervise, explain factors that are novel to T2, and maintain standards specific to T2.

5. **Specification Development and Supervision.** This is the primary engineering task needed to insure safety, reliability, service and cost containment. It is a task that is never finished because there will be a continual stream of new ideas, products, procedures, and materials that must be considered and incorporated in specifications for new systems in order to stay ahead of competition and maximize profit for the owner. This function can also be called research and development. It encompasses the core engineering, and will include experts in all of the hardware and software subsystems who will gather and analyze information on the performance of existing systems, recommend improvements, design and supervise testing, and follow new developments that may advantageously be incorporated into the system. People in this division will maintain cost, weight, and dependability models of the system.

6. **Manufacturing.**
 - a. Chassis. This is an aluminum frame to which are attached the wheels, motors, control components, switch, parking brake, bumpers, and air-conditioning compressor. The assembly and testing of the chassis should be performed very close to T2C because it is the "high-tech" component of the system – the core item – and is critical to performance and safety. The chassis frame and all of its components will be subcontracted.
 - b. Cabin. Subcontract to a firm experienced in vehicle design and assembly, under specifications and supervision from T2C.
 - c. Guideway. Subcontract to a steel fabricator skilled in precision bending of steel and capable of at least using and possibly designing the necessary computerized jigs and fixtures under supervision from T2C. While the chassis and cabin are standard items, the shape of the guideway to match the curves, hills and speeds of each application vary. Thus there will be a regular flow of data on the coordinates of guideways to the steel fabricator that will require close coordination, cooperation and inspection.
 - d. Station. There will be a wide variety of station designs depending on the needs of the owner or community in which the system is to be built; however, there needs to be a standardized prefabricated design for those who wish to minimize cost while meeting requirements. T2C will be responsible for developing and maintaining specifications for the equipment needed in the station (destination selection, fare collection, elevator, lights, television surveillance, motion detectors, voice communication system) and the standardized station-building design, with its details subcontracted to a qualified architect.
 - e. Ticketing System. Destination selection and fare collection are aspects of the ticketing system. Its specifications differ from those required in a conventional rail system and must be specified and monitored by T2C.
 - f. Power Supply. This equipment is commercially available and will be specified by the consulting firm doing the site design, to specifications developed by T2C.
 - g. Communication and Control. The hardware is composed of available commodities. The software will be supplied and maintained by T2C under license to the system owner.
 - h. Maintenance Facilities. The maintenance operations, layout and use of automated equipment must be carefully designed. While preliminary designs have been developed, this task is probably best subcontracted to a firm expert in such operations. The facilities will be built under the supervision of a general contractor retained to install the whole system.
 - i. Vehicle-Storage Facilities. There are many configurations in which vehicles can be stored. The design is likely to be site-specific under the supervision of the general contractor. Storage need not be in heated buildings. Minimum storage can be along a siding with a low-cost roof and siding to keep snow and ice off the vehicles in the winter and the sun off them in the summer. There is ample time from retrieval from storage to the nearest station for the cabin interiors to reach the comfort-temperature range.
 - j. Administration Facilities. These will be built under supervision of the general contractor.

7. **General Contractor.** Takes the contract to do all of the site preparation and installation.

8. **System Operator.** It is likely that separate companies will be set up to operate T2 systems for a fee from the owner. These companies would do the actual work of maintaining safety, reliability, cleanliness, etc. T2C's responsibility will be to set standards and oversee the operations.

9. **Training.** People will need training for system operations, planning and engineering all the way up to the graduate level. T2C must therefore establish a *Training Institute*. Any person to be engaged in systems operations will have to be a graduate of this institute. There is much information that a planner needs to know to plan a T2 system successfully, so short courses for planners will have to be developed and taken as a prerequisite to assignment to a specific project. Engineers will need more detailed training, so courses of a year or more in duration will have to be taught.
10. **Government Relations.** There are many regulations and standards that may affect the deployment and operation of T2 systems and, as a result, T2C needs people skilled in government relations to monitor and lobby to protect the company's interests.
11. **Legal.** There will be a great deal of work related to contracts and agreements, and to be certain that the company does not violate any applicable laws.
12. **Accounting.**
13. **Administration.**



An Arch as an Alternative Guideway Support

Appendix B. Why we need the Phase II Test Program.

- 1) To prove safety and reliability in advance of the first application.
- 2) To enable an insurance company to establish a liability rate.
- 3) To verify various human-factors issues including ride comfort before the first deployment.
- 4) To prove system capital and operating costs.
- 5) To train a team of engineers to do something they have not done before.
- 6) To correct errors before the first people-moving deployment.
- 7) To provide an environment in which the best locations can be found to place sensors, such as thermocouples or strain gages, to detect incipient failures.
- 8) To provide a facility around which to train T2 engineers, planners and technicians.
- 9) To provide assurance that the first operating system will be successful.
- 10) To provide a controlled environment in which artificially induced test conditions can exceed normal parameters.
- 11) To be the major means for marketing the Taxi 2000 system.
- 12) To answer objections and questions usually raised by national consulting firms asked to evaluate T2.

- 13) To establish T2 as “proven technology” for comparison with other transit technologies in major investment studies, which is required for Federal funding of any new system.
- 14) To attract capital from venture funds or other investors in order to build an operating company to market and sell T2.

Appendix C. Ridership Analysis

The most significant justification for working to introduce a totally new kind of public transport is that it is expected, based on its service characteristics, to be able to attract many more riders than possible with conventional transit. A number of studies have been performed to estimate PRT ridership. Here are the most important:

1. Paper by Francis P. D. Navin, “Time Costs in Personal Rapid Transit,” *Personal Rapid Transit II*, University of Minnesota, 1974. The author was then Assistant Professor of Civil Engineering, University of British Columbia. He found that observed behavior of conventional-transit riders agrees with the results of analytical ridership models if the model considers total trip time in the form

$$\text{Ride time} + C_{\text{walk}} \times \text{Walk time} + C_{\text{wait}} \times \text{Wait time} + C_{\text{transfer}} \times \text{Transfer time}$$

	Low	High
C_{walk}	1.65	2.08
C_{wait}	4.15	6.34
C_{transfer}	6.62	10.0

By applying a model that treated time in this way, he found that for a PRT system in which the walk was three minutes, the wait and transfer times were zero and the travel speed was 40 mph, for data for Minneapolis the fraction of total trips that would be attracted to PRT (the mode split to PRT) was over 50%, and that the mode split to PRT increased with the travel distance.

2. The Aerospace Corporation. Irving, J. H., Bernstein, H., Olson, C. L., and Buyan, J. 1978. *Fundamentals of Personal Rapid Transit*, Lexington Books, D. C. Heath and Company, Lexington, MA. This book records the work of The Aerospace Corporation on personal rapid transit. It contains a chapter on Ridership that describes a so-called “Monte Carlo” Mode Split Model. The term “Monte Carlo” means that the origin and destination of a trip are selected at random from a distribution and other attributes of the traveler are also selected at random from their distributions. For this trip the walk time, wait time, and ride time for PRT are calculated; the fare is taken into account; a value of time is taken into account so that the times become costs; and similar quantities are computed for the auto trip, provided an auto is available. The trip is assigned to the mode for which, considering actual and perceived costs, the cost is less. The process is repeated until it converges to a steady value. By applying such a model to traffic in Los Angeles, the Aerospace Corporation PRT group settled on a mode split to PRT of 34% in their economic analysis.

3. Indianapolis. In 1979-1980 a study sponsored jointly by the State of Indiana and the Urban Mass Transportation Administration was performed of automated transit systems for downtown Indianapolis. Vehicles designed for 100, 60, 40, 20, 12, and 3 passengers were included and networks suitable for each vehicle size were laid out. Ridership estimates were developed by the consultant, Barton Aschman Associates, for each system. The 3-passenger-vehicle system used in the study was a PRT system developed by DEMAG+MBB in Germany called Cabintaxi. For this system the layout had 12.2 miles of guideway and 46 stations. The guideway covered an area two miles in the east-west direction and one mile in the north-south direction. The consultant estimated that the ridership on the PRT system would be about 100,000 passenger-trips per day. The total internal travel in the central business district (CBD) can be expected to be about two trips per person on each day. The daytime population of a CBD is composed of residents, workers, shoppers, tourists and other visitors. A comprehensive study by Kenworthy-Laube³ shows data on CBD jobs for a number of U. S. cities but

³ J. R. Kenworthy and F. B. Laube, *An International Sourcebook of Automobile Dependence in Cities, 1969-1990*, University Press of Colorado, Boulder, CO, 1999.

not Indianapolis. For example, in 1990 Denver had 111,887 jobs in a 2.46 sq-mi CBD and Detroit had 93,012 jobs in a 1.4 sq-mi CBD. So, since Indianapolis is of roughly comparable size, we can estimate the number of jobs in the Indianapolis CBD at the time frame of interest in the 1980 study to be roughly 100,000. The typical ratio of jobs to population in U. S. CBDs is about 10, so we can neglect the residents, but the number of shoppers, tourists, and other visitors must be significant. Assuming one of these people for every job gives a daytime population of roughly 200,000 persons, more than a quarter of which will be students, staff, faculty and visitors at the University complex in the Indianapolis study area. In a typical metropolitan area there are about four vehicle trips per person on each day so it is conservative to assume that in the CBD there are about 1.5 such internal trips, which would give 300,000 trips per day. With these assumptions the modal split to PRT is about 33%.

4. Swedish Studies. The Swedish Transport and Communications Research Board sponsored a series of studies of PRT in Swedish cities that resulted in 1998 in the report "PRT—a Suitable Transport System for Urban Areas in Sweden?" The conclusion of the report is that in Gothenburg an area-wide PRT system would attract 23% of all transport passengers, and 40% of the trips to and from the city center.

5. A Mode-Split Model. In 1974-5 the T2C President worked at the Colorado Regional Transport District on a large study of transit alternatives. His main task was to monitor and help direct the ridership studies, and in so doing, he became thoroughly familiar with the methods used and he worked with two of the top ridership professionals in the U. S., James McLynn and Gordon Schultz. The method used is based on a so-called "logit model." Using the coefficients used by transit professionals, he developed such a model for a generic square city, which is presented on <http://www.taxi2000.com/>. The key factors are walk time, wait time, transfer time, and ride time as discussed by Professor Navin in #1 above. With these factors appropriate to a grid bus system, he got mode splits to bus of about one percent. Substituting times appropriate to PRT, the mode split increases to the neighborhood of 30%. This result is consistent with the results presented above and makes logical sense because of the value people generally place on their travel time.

6. A Ridership study for Downtown Minneapolis. In 2001 SRF Consulting Group, Inc. of Minneapolis performed a ridership study of a PRT system in Downtown Minneapolis. The results of the study are reported in the paper "PRT Forecasts for Downtown Minneapolis." It can be found under "Publications" on <http://www.taxi2000.com/>. The PRT system had 11.3 miles of guideway, 33 stations, and 650 vehicles. With a fare of \$1 and an average waiting time of one minute the study estimated ridership as 64,100 trips per day. The system was estimated to cost about \$95 million. On that basis, taking into account all costs (capital and operation) the breakeven fare on this system is about 60 cents per trip. So the system will actually generate net revenue, which is unheard of with conventional transit.



Appendix D. A Testimonial

(A-5D (11-73))

FIELD
MESSAGE

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FROM: USIS Bonn

TO: USIA WASHINGTON

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E.O. 11652: N/A

88
MESSAGE NO.November 30, 1977
DATESUBJECT: New Transportation Technologies Discussions in
Duesseldorf

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SUMMARY: VOLUNTARY SPEAKER J. EDWARD ANDERSON, PROFESSOR OF MECHANICAL ENGINEERING, UNIVERSITY OF MINNESOTA, AND PROMINENT SPOKESMAN FOR NEW TRANSPORTATION TECHNOLOGIES HAD INFORMAL LUNCHEON DISCUSSION WITH NORTH RHINE-WESTPHALIA'S AND DUESSELDORF CITY'S LEADING TRANSPORTATION OFFICIALS. EXPERT EXCHANGES WERE PROFITABLE. COMPLEXITY OF U.S. PROBLEMS STRESSED AS WERE IMAGINATIVE RANGE OF SOLUTIONS BEING DEVELOPED:

A group of nine senior German officials concerned with planning and implementation of state and city transportation systems met on November 22, 1977, with Dr. Anderson, a personable and, as far as the post could judge, totally informed researcher now specializing in the field of new transportation technologies.

USIS Duesseldorf, during the past few years, has had a variety of occasions to bring together experts in the field of urban planning and, particularly, new transportation systems-- primarily because the state of Northrhine Westphalia has taken a leading position in the construction of new vehicles and systems.

These expert discussions, so called, were often less than fulfilling, from the post's point of view, because German experts' attitudes toward our experts lay somewhere between bemusement and condescension. The negative aspects of our transportation planning were all too well known-- BART, electric car failures and immense public transportation system deficits provided the grist for horror stories at our expense.

The discussions with Anderson and the planners went a little differently and the post feels satisfied that a slight dent was made in upper level smugness. First of all, Anderson was impressive in showing that easy solutions are not always best. He had also calculated costs, deficits, etc. comparatively and

PAGE 1 OF 2

DRAFTED BY

USIS Duesseldorf: PJReuss:un

DATE

Nov. 23, 1977

APPROVED BY:

John P. Clyne

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PAGE 1 OF 2ENCL. NO. FIELD MSG. NO. 88FROM USIS Bonn

was able to show that systems currently in vogue in Europe are not necessarily the most effective, either aesthetically or cost effectively. Our planners became aware, we hope, that considerable intelligence and imagination exists in the U.S. planning process, that political considerations need not always be crass, and that the best of all possible transportation worlds has not yet been reached, but would be more reachable if more substantive interchanges could take place between people working on similar problems.

The atmospherics of the brief but intense session reflected this change from genial scepticism through alertness toward a final flurry of name and address exchanges, requests for additional information and thanks for an unusual exposure.



Alexander A. Krieforth
Country Public Affairs Officer

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