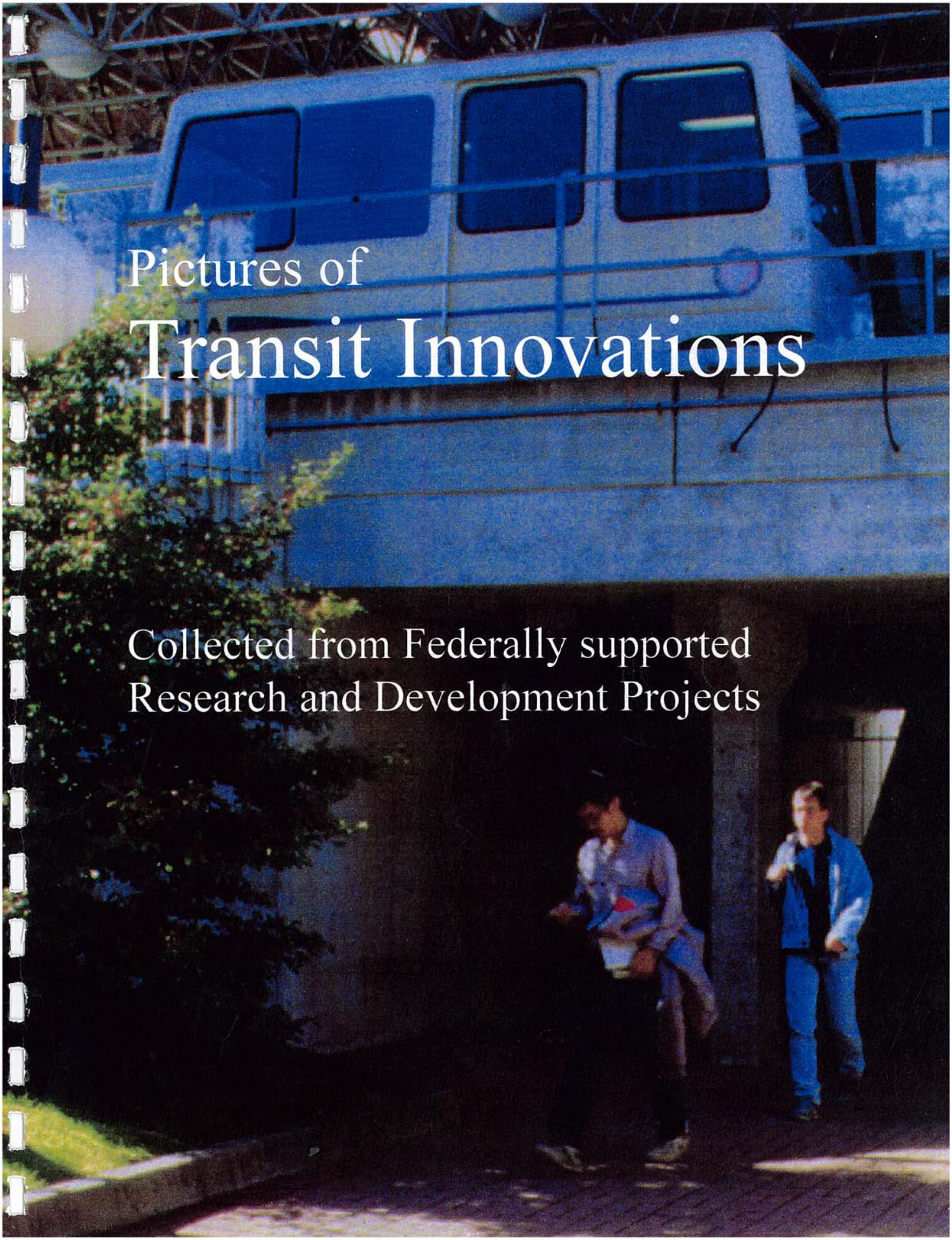
Pictures of Transit Innovations

Collected from Federally supported Research and Development Projects



Pictures of

Transit Innovations

Collected from Federally Supported
Research and Development Projects

Projects sponsored by the Federal Transit Administration
(originally the Urban Mass Transit Adminstration),
U. S, Department of Transportation

Collected and described by James R. Dumke

Edited by Jeffrey G. Mora

FOREWORD

This booklet is picture-driven. As such, it cannot be considered an accurate historical record of transit research and development sponsored by the U.S. Department of Transportation's Urban Mass Transportation Administration (UMTA), and its successor, the Federal Transit Administration (FTA).

In 1972, UMTA had 192 studies and development projects underway. By 1980 it was managing over 600 projects. The projects described in this document represent only a fraction of the overall research and development program and consist of those that were recorded in photographs that were readily available.

Hundreds of projects are omitted that were not photogenic, such as:

Engineering, socioeconomic, and systems performance studies,
Engineering computer programs,
Cost/benefit studies,
Materials, structural, and controls systems research,
Transit management computer programs,
Maintenance equipment and procedures,
Training materials and methods,
and many more.

Cover: Morgantown Personal Rapid Transit
Photo: West Verginia University Photographic Services.

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1. OVERVIEW

Photo: Miami-Dade Transit Agency

How Federal Transit Research and Development (R&D) Got Started

Transit R&D began as a small part of the "Great Society" programs managed by the Department of Housing and Urban Development (HUD). In the mid-1960's, cities across the nation were experiencing demonstrations and riots. At the same time, the use of public transportation was approaching an all-time low and privately owned bus and rail companies were in danger of going bankrupt. In addition, the major railroads were abandoning unprofitable commuter rail services. Rolling stock, tracks, tunnels, stations, signals, etc. were suffering from neglected maintenance.

Photo: Washington Metropolitan Area Transit Authority

About 13 percent of early mass transit funding was to be used for technical improvements that could be replicated in cities with similar problems. These "demonstrations" provided a way that HUD could help local governments modernize the technologies used by their transit authorities.. By this means, partial federal funding was made available for such programs as automatic train controls, fare collection machines, commuter rail improvements, and the use of two-way radios in subways.

Photo: Massachusetts Bay Transportation Authority

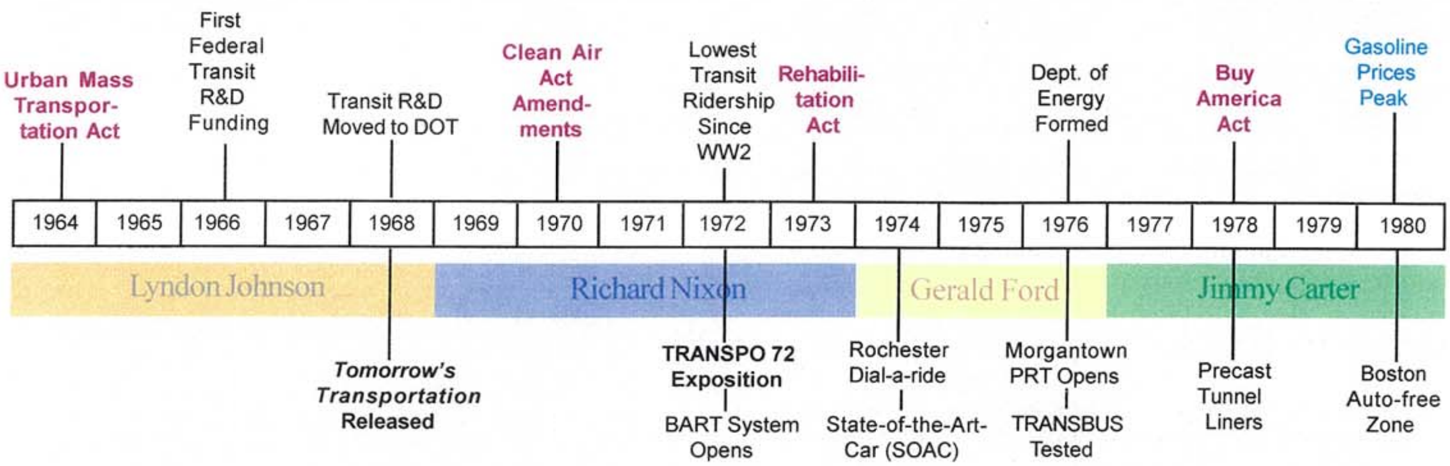
By 1966, after it had become clear that urban transit technologies were behind other modes of transportation, Congress authorized HUD to conduct a comprehensive program of research, development, and demonstrations - including studies to define new systems for the future of urban transit. The study report, ***Tomorrow's Transportation***, set the stage for much of the federally sponsored transit research in the following decade.

Photo: Metropolitan Atlanta Transit Authority

Above are recent photographs of the Metromover in Miami, the Metro in Washington, DC, the Green Line in Boston, and a MARTA bus in Atlanta.

In 1968, responsibility for urban transit was transferred from HUD to the Urban Mass Transportation Administration (UMTA) in the new Department of Transportation (DOT). In 1991, UMTA was renamed the Federal Tansit Administration (FTA).

Transit Research and Development Timeline



Forces That Shaped the Federal Transit R&D Program

The **Urban Mass Transportation Act** of 1964 provided federal funds for the improvement of local and regional public transportation, including funds for regional planning and technology demonstrations. Amendments in 1966 authorized a broad program of research, development and demonstrations that would relieve urban transportation needs, improve service, or minimize costs.

Tomorrow's Transportation, a comprehensive plan for advanced transit R&D, was released in 1968. To obtain industry and popular support for R&D, several new systems concepts were displayed at the **TRANSPO 72 Exhibition.**

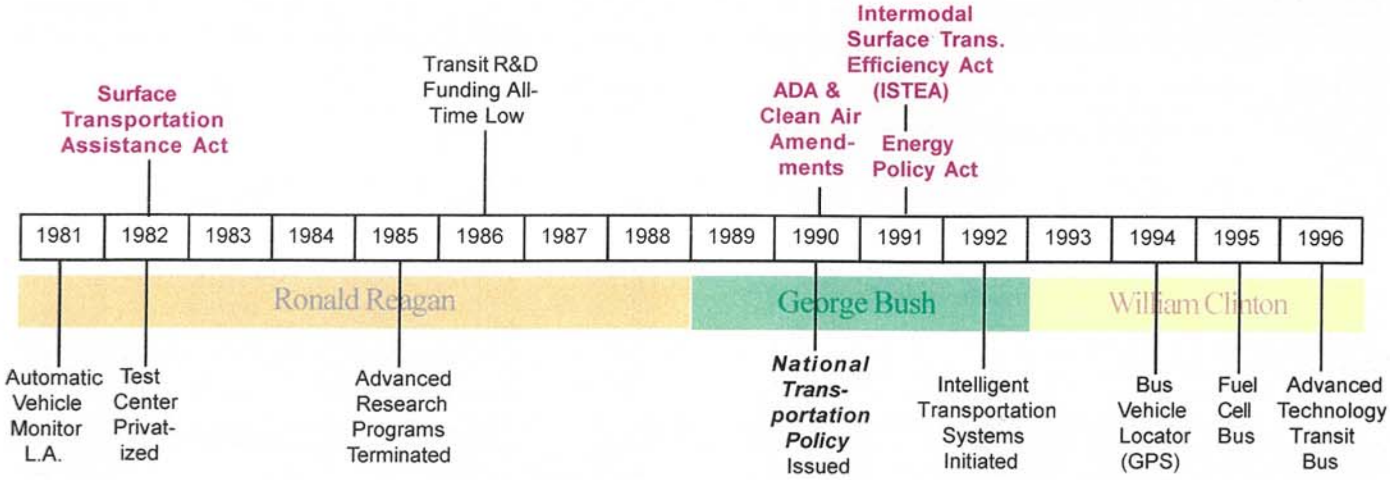
In 1970 the **Clean Air Act** Amendments to the National Environmental Policy Act, made public transportation an important potential force for reducing air pollution. The amendments strengthened the reasons for expanding transit, and for developing clean bus systems.

The **Rehabilitation Act** of 1973 required that no individual be denied the benefits of any program receiving federal funds solely by reason of a handicap. In compliance, the Secretary mandated schedules for improving the accessibility of new buses and new rail facilities. The mandate led to increased research on accessibility.

Perhaps the most influential external force on the program in its early years, however, resulted from the **OPEC Oil Embargo**. For UMTA the real and potential shortage of petroleum-based fuels led to expanded research into alternative fuels, new bus and rail propulsion units, and energy conservation and recovery systems.

By the mid-1970's increased interaction with the community of transit providers led UMTA to shift more of its R&D program to work that would help existing rail and bus systems. Formation of the **American Public Transit Association (APTA)** in 1974 and a series of **R&D Priority Conferences** sponsored by UMTA and APTA made it clear that, due to age and neglected maintenance, the new public authorities would have to replace most of the nation's transit fleets within a very few years.

Thus, instead of whole vehicles and systems, UMTA's research began to focus on vehicle components, and on computerized vehicle dispatch systems, scheduling systems, customer information systems, etc. These systems were needed to reduce the labor costs that amounted to almost 80 percent of operating costs. In addition to hardware and software developments, the program included uniform evaluations of transit planning, service, and management innovations.



With the **change of Administration in 1981**, policies regarding mass transit changed dramatically. The new policies called for more local decision authority, but also a greater reliance on local sources of funding. Research and development was to be left mostly to the private sector. Within a few years, UMTA's R&D funding was reduced significantly. Some programs continued along with technical assistance to transit authorities. UMTA's R&D budget reached an all-time low in 1986.

In 1990 the President and Congress put new demands on the transit community. The **Americans with Disabilities Act (ADA)** put teeth into earlier mandates to serve riders with disabilities. All forms and levels of disability were to be accommodated including visual, hearing, and mental impairments. Supplemental paratransit services were to be provided if regularly scheduled service routes were not equipped to handle disabled passengers. In addition, a new set of **Clean Air Act Amendments** strengthened air quality standards and imposed penalties on cities for non-attainment. Stricter standards on bus emissions were also levied on transit authorities.

In the same year the Secretary of Transportation released the first comprehensive statement of **National Transportation Policy**. It provided a blueprint for solidifying goals, identifying problems, assigning priorities, and allocating resources. In response, UMTA planned a revitalized program that would assure that transit could meet needs of the 21st century.

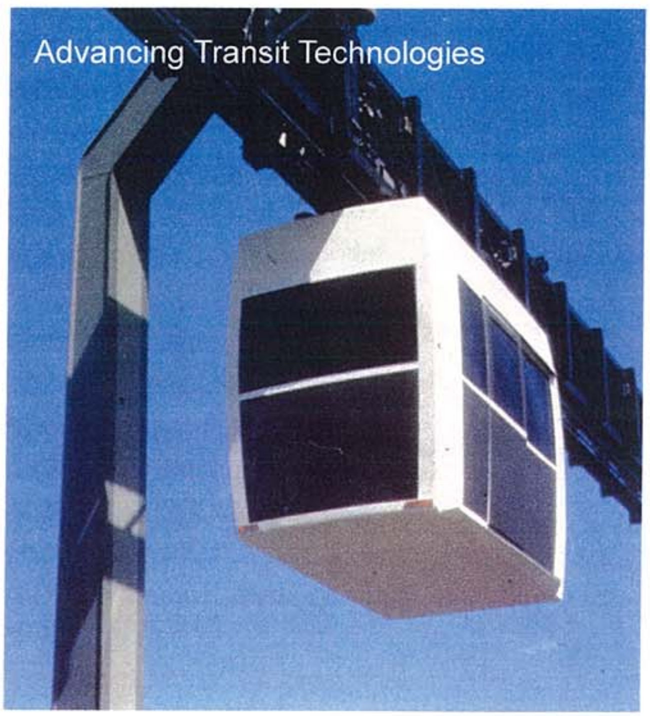
Renewal came in 1991 in the form of **ISTEA**, the **Intermodal Surface Transportation Efficiency Act**. In answer to growing highway congestion, and on completion of the Interstate Highway system, the Administration and Congress provided a higher level of funding for public transportation and greater flexibility to local authorities in the use of federal funds. Transit planning and research was given new life. The popularity of "Intelligent Transportation Systems" concepts helped obtain budget authority to resume research in hardware and software technology applications, and in the area of human services ISTEA also changed the name of UMTA to the Federal Transit Administration (FTA).

In 1992 the **Energy Policy Act** gave new impetus to electric power and alternative fuels by requiring the use of non-petroleum fuels in all new buses bought after 1999 for major cities. At the direction of Congress, FTA began development of advanced bus propulsion systems and vehicles.

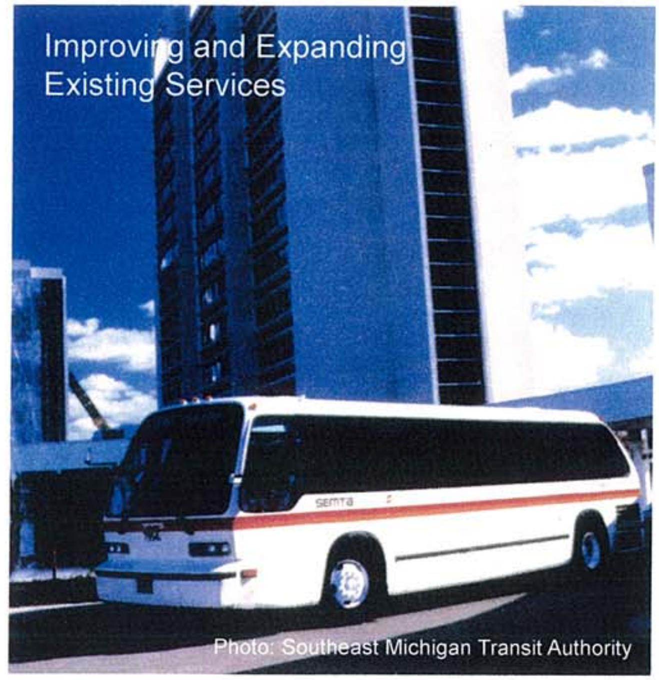
Evolution of the Federal Transit R&D Program

As shown in the timeline, the federal transit R&D program has undergone several major changes. It has responded to many external events, including changes in Administration priorities, significant new national goals, new legislation, and by specific directions from Congress and the White House. Internally, it has evolved through experience as well as by cost/benefit studies, and by feedback from the transit industry.

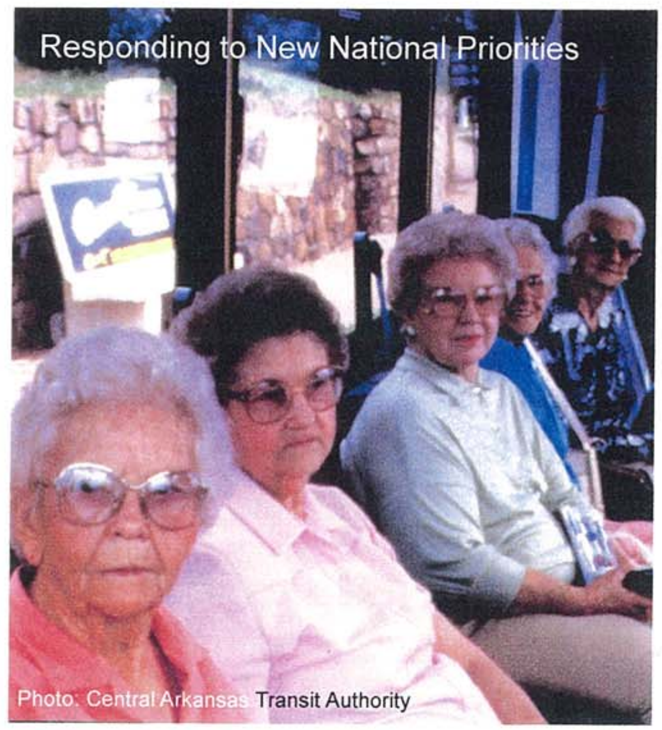
Since 1968, the transit R&D program has responded to these external and internal forces by emphasizing several different missions. Some of the more prominent initiatives are illustrated here.



Transit's initial mission under HUD was to help reverse the decline of inner cities. It was believed that modern technology could provide the best answers. "If we can get to the moon, we can see to it that people can get to work." The approach was to develop and demonstrate advanced systems based on the "systems approach" and technologies that were highly successful in military and space programs.



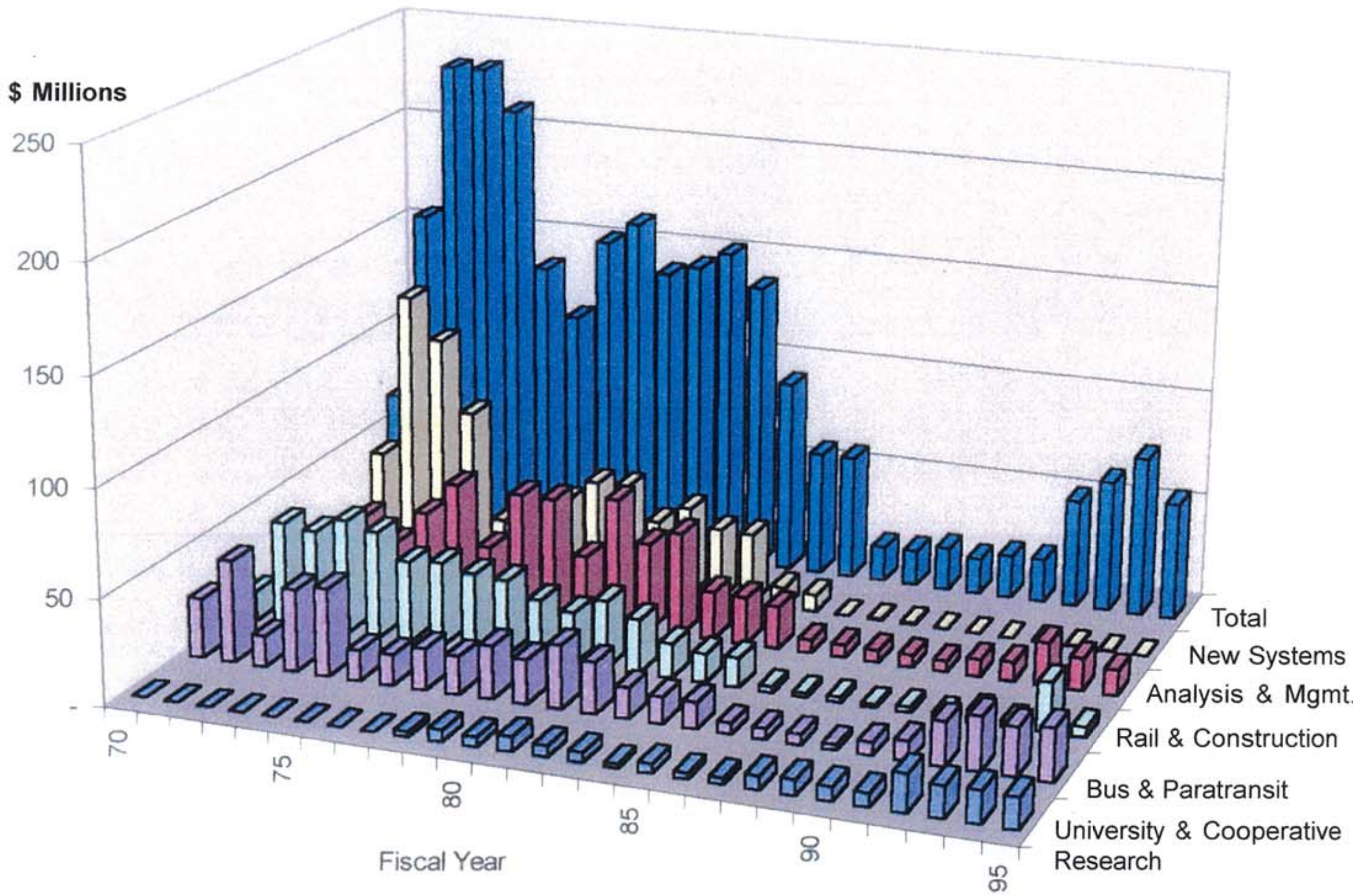
In the early 1970's it was also clear that cities needed to protect their investment in existing systems. The next emphasis was on improving the existing bus and rail systems that were losing their ability to maintain service.



In the 1970's R&D missions were expanded to include developments aimed at:

1) **insuring mobility for handicapped and elderly riders.**
2) **improving air quality,**
3) **conserving petroleum fuels, and**
4) **providing service in rural areas,**

FTA Annual Budget Authority in 1995 Dollars



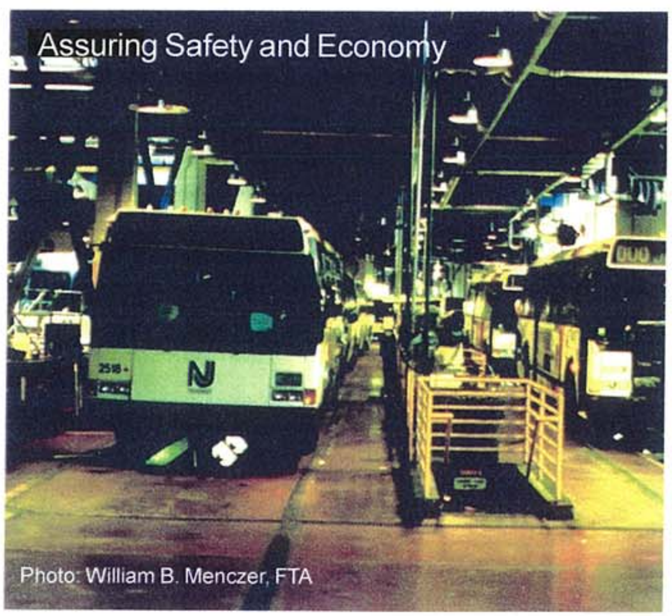


Photo: William B. Menczer, FTA

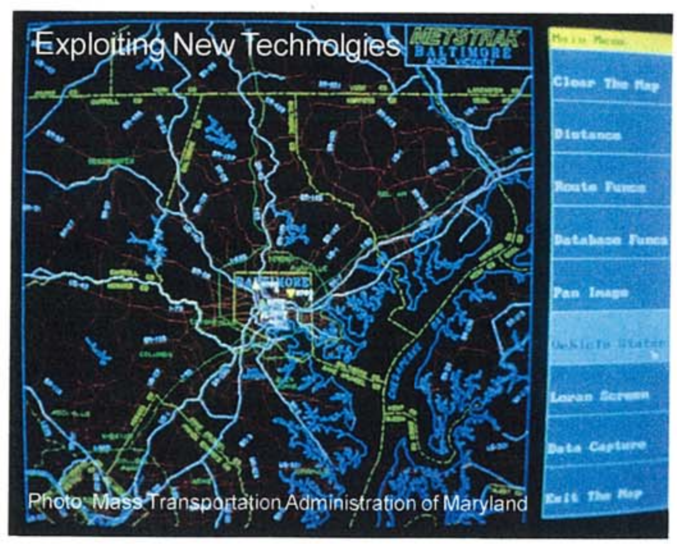


Photo: Mass Transportation Administration of Maryland

In the early 1980's, budget considerations prevailed. The market for transit equipment was believed to provide enough incentive for technical improvements by private industry. For the most part, the federal role was limited to safety research, technical assistance to transit agencies, and dissemination of transit agency experience with introducing technologies.

5) In the early 1990's, FTA focused on taking advantage of the low costs of communications and computing technologies. In addition, stricter air quality deadlines revived research on alternative fuels and more fuel-efficient propulsion systems. Many of the "Intelligent transportation" projects were initiated by Congress and resulted in an increase in the R&D budget. The projects have significantly improved the efficiency of transit agency management.

Modernistic vehicles glided silently through downtown and out into the countryside in popular visions of the "city of the future" long before the Federal Government became involved in urban transportation.

2. NEW SYSTEMS

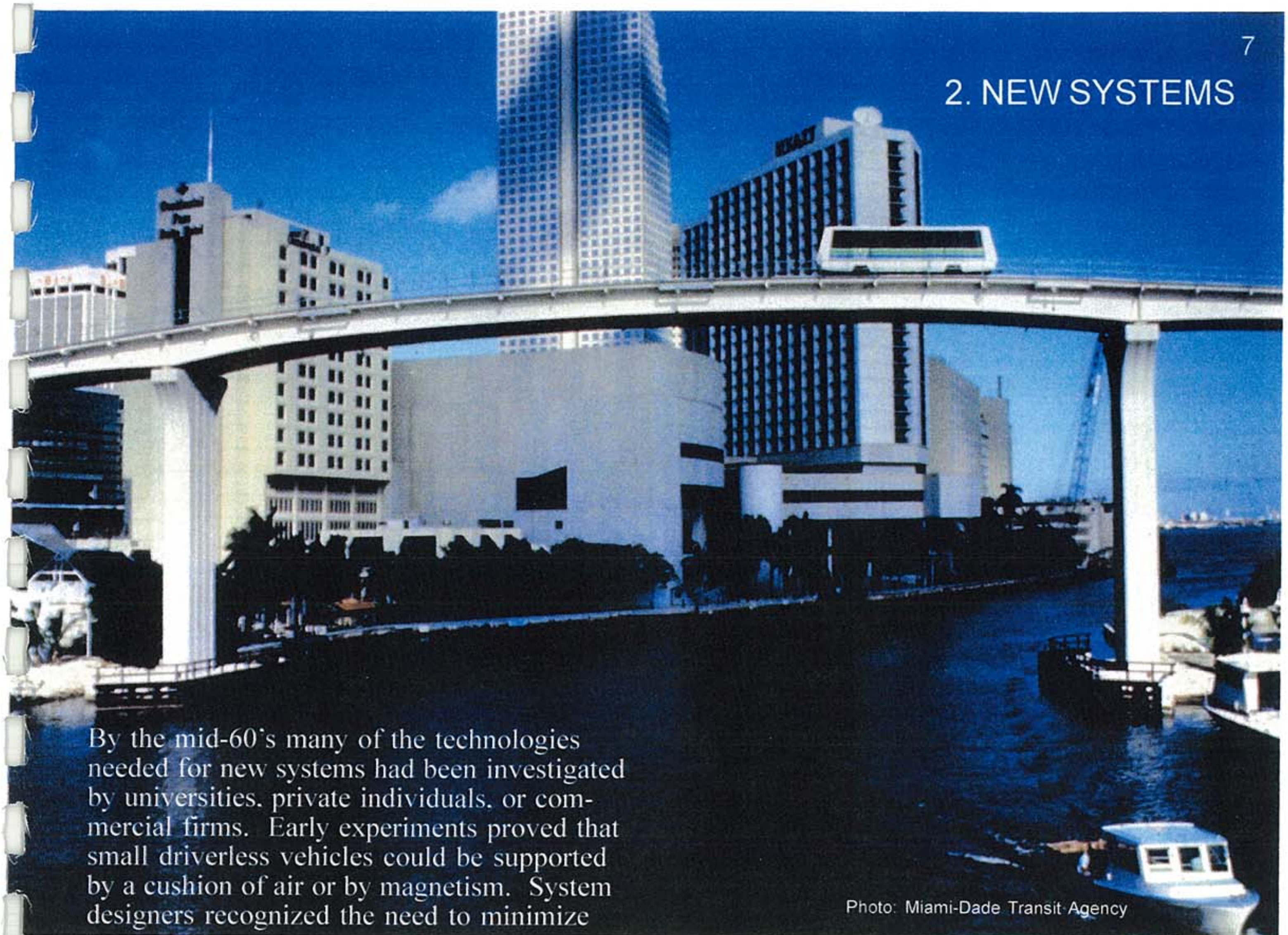


Photo: Miami-Dade Transit Agency

By the mid-60's many of the technologies needed for new systems had been investigated by universities, private individuals, or commercial firms. Early experiments proved that small driverless vehicles could be supported by a cushion of air or by magnetism. System designers recognized the need to minimize vehicle weight to keep the guideways unobtrusive. They also understood the need for automation so that the cars could operate at close spacing.

The studies originated by HUD and summarized in 1968 in ***Tomorrow's Transportation*** recommended investigation of four classes of automated systems:

1. **Personal Rapid Transit (PRT)** systems that could move from 1 to 6 passengers at high speeds non-stop to their destinations,

2. **Dual Mode** commuter systems where small vehicles would operate as private automobiles when disengaged from a public carrier, or bus systems that would use automated guideways for the main part of the trip;

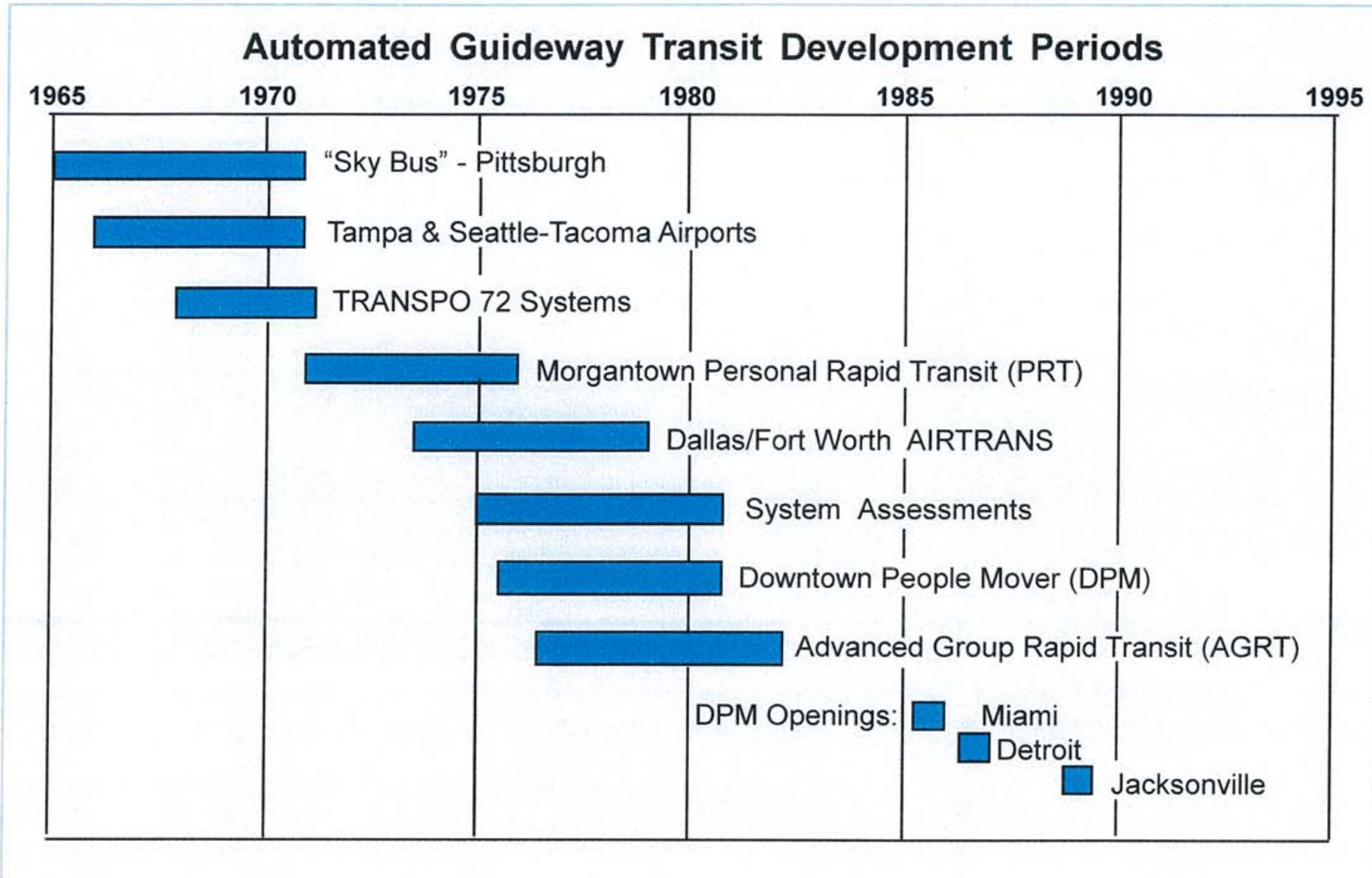
3. **Fast Transit Links** would move high volumes of passengers between downtown ctivity centers and the suburbs; and,

4. **Moving Belts or Capsules** that could move volumes of people within activity centers and would complement the high speed systems.

PRT system concepts have been the subject of much serious study and are still being debated. Although proved technically feasible, the cost of a high capacity system that could take the place of subways could be prohibitive. The UMTA program was changed later to emphasize larger, slower vehicles for city centers.

After a series of technical and cost-effectiveness studies, UMTA discontinued work on **Dual Mode** concepts. Propulsion and suspension technologies for **Fast Transit Links** were tested and found to be feasible, but expensive.

Moving Walkways were considered impractical for downtown distribution use unless their speed could be increased. UMTA tested two promising accelerating walkway systems but terminated the projects when R&D funding was reduced.



Automated Guideway Transit (AGT)

The chart shows the timing of major AGT system developments in the U.S. The term "automated guideway transit" was used by UMTA to include shuttle and loop systems as well as personal rapid transit (PRT). The "**Sky Bus**" in Pittsburgh and shuttle systems at the **Tampa** and **Seattle-Tacoma Airports** were underway before UMTA began AGT developments.

To encourage private industry, the Secretary of Transportation created the **TRANSPO 72** Exhibition at the site of Dulles International Airport near Washington, DC. Four companies were awarded funds to display operating models of automated transit systems for urban use.

The first operating systems that used most of the technologies needed for PRT were built in the early 70's at **Morgantown**, West Virginia and at the Dallas/Fort Worth Airport (DFW). UMTA funded development of the Morgantown system and tests of potential urban applications of the **AIRTRANS** System at DFW.

System Assessments. From 1975 to 1981 UMTA evaluated over 20 foreign and domestic systems that were developed without UMTA funds and could be used for transit.

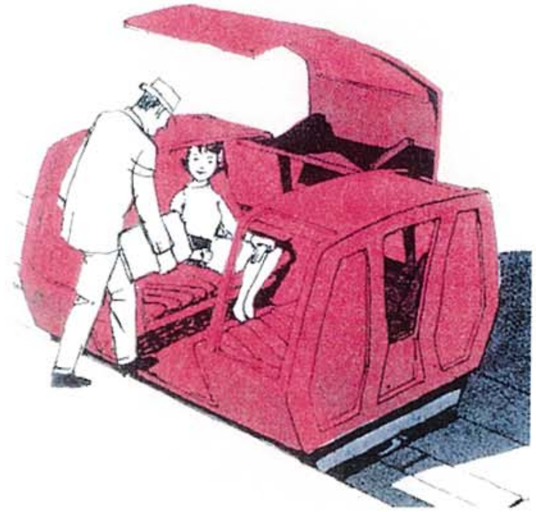
The **Downtown People Mover (DPM)** Program was created to assist cities with the study and engineering design of specific AGT applications.

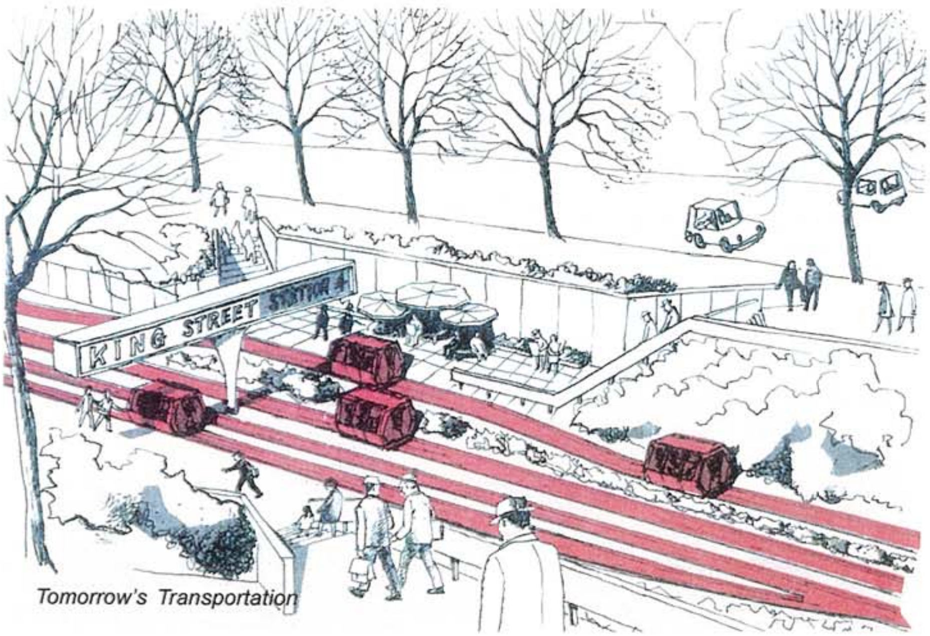
At about the same time, the PRT concept evolved into **Advanced Group Rapid Transit (AGRT)** which could provide PRT-type service over a large area with larger vehicles than were envisioned for PRT. The program included development and test of vehicles with magnetic, air cushion, and rubber tire suspensions.

R&D funds for the DPM and AGRT programs were terminated in the early 1980's, but cities were permitted to use their allocation of transit capital assistance funds for DPM construction. Three cities elected to do so: **Miami, Detroit** and **Jacksonville**.

The Personal Rapid Transit (PRT) Concept

The principal automated guideway system recommended for investigation in ***Tomorrow's Transportation*** was a high-speed, high capacity PRT for use in major metropolitan areas. To exceed the capabilities of existing rail and bus systems, such a system would require off-line stations and switching capabilities. The system would also require its vehicles to operate with very short distances between cars and a high degree of automation. Studies at that time (1968) indicated that the necessary control technologies were within the state-of-the-art.





Tomorrow's Transportation

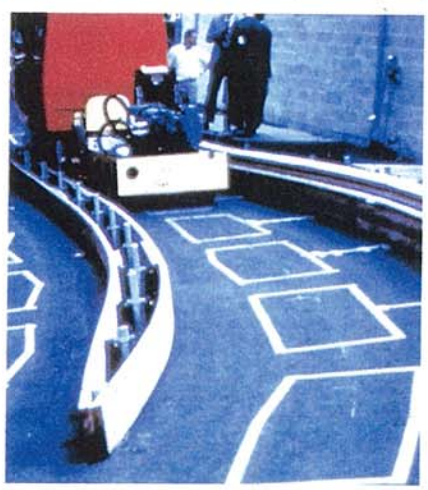
The driverless vehicle (above) was defined in ***Tomorrow's Transportation*** as about the size of a small automobile that was capable of moving passengers directly to their destinations at 50 to 70 mph.

Cars would await passengers at off-line stations (left) and, after being boarded, would accelerate and slip into the main stream of traffic.

By 1968, UMTA had received over 20 proposals for such systems from industry and universities.

Three of the systems that preceeded UMTA's development programs are shown below.

The **Schwebebahn** in Wuppertal, Germany is essentially a streetcar suspended from a monorail. It was repaired after World War II and has operated successfully since 1901.



The **Alden Self-Transit System** experimental model used a rubber-tired vehicle that had electrical pickups and lateral steering wheels on the car sides.

The **Varo Monocab** was a PRT-sized vehicle that was suspended from an overhead rail. Its technology was exhibited at TRANSPO 72.

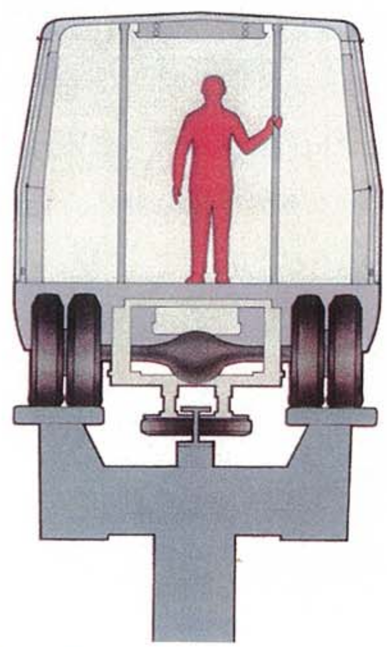
Transit Expressway

Developed in the early 1960's by the Westinghouse Transportation Division, the transit expressway was designed primarily to meet the market for clean, quiet, automated shuttle or loop systems that could move high volumes of people over relatively short distances. By 1981 seven Transit Expressway systems were in operation, mostly at airports.

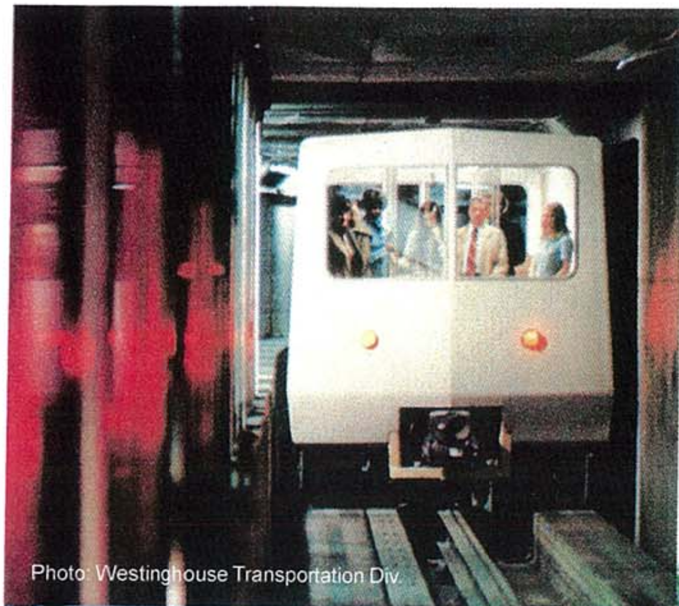
"Sky Bus" (above) was the first Transit Expressway system open to the public. It was built in South Park, Pittsburgh by Westinghouse in 1963 and operated until 1966. Later, UMTA funded Westinghouse to develop an urban prototype.

At **Tampa Airport** (below) shuttles to remote terminals opened in 1971. The cars were replaced in 1995 after more than a million miles each.

Photo: Westinghouse Transportation Div.



Transit Expressway vehicles were supported by rubber tires on relatively narrow concrete "tracks." Steering was by lateral wheels in a center I-beam which also provided power for the electric motors.

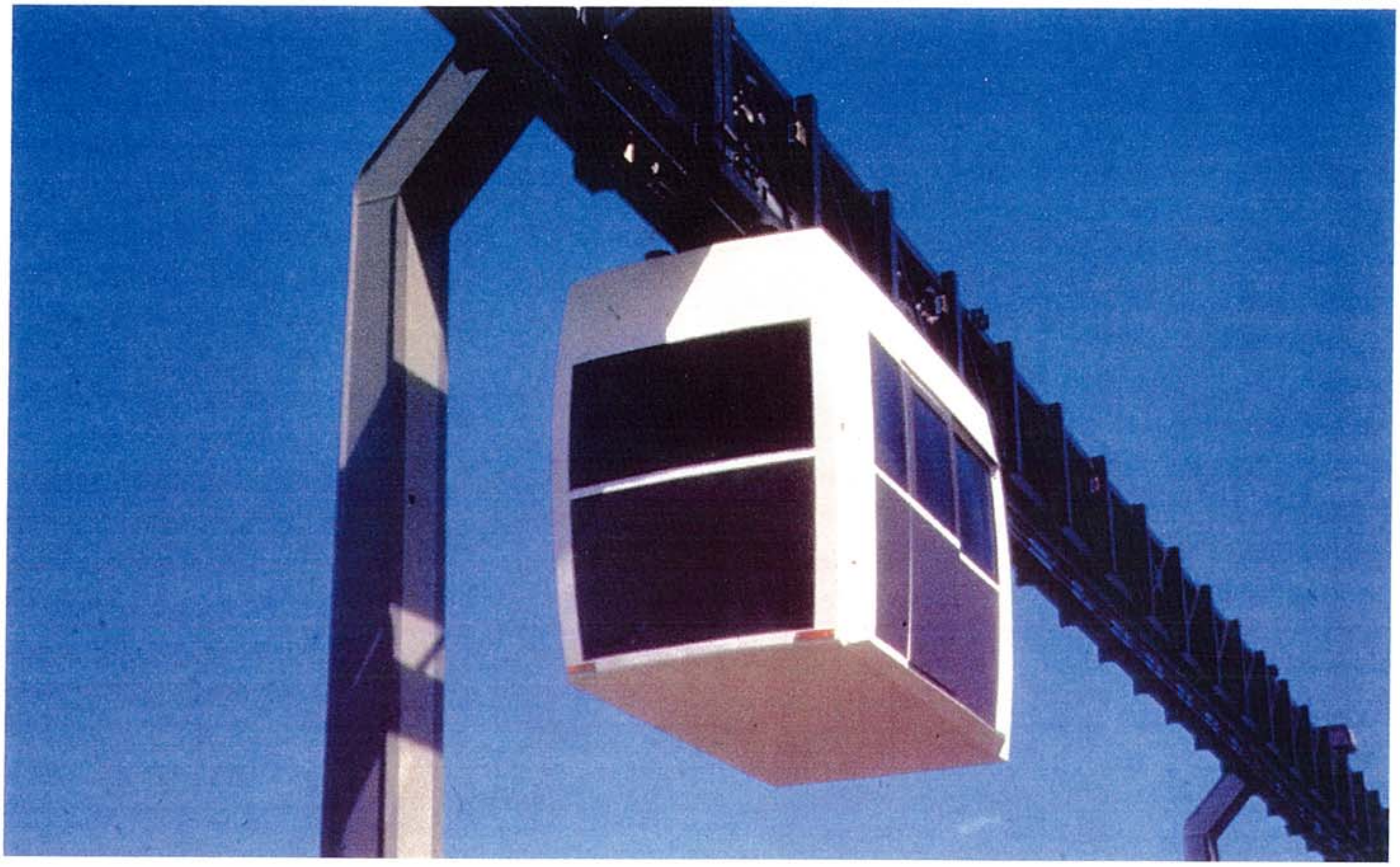


Seattle-Tacoma Airport (left) was next in 1972 with a Transit Expressway system that had two single-lane loops and was entirely underground.

Busch Gardens, a theme park in Williamsburg, Viginia, installed a 1.3 mile loop system (below) in 1975.

Interior of a car at **Busch Gardens.**

Miami Airport (above) and Atlanta Airport installed dual-lane shuttles in 1980.



TRANSPO 72

The TRANSPO 72 Exhibition was sponsored by the U.S. Department of Transportation at Dulles International Airport near Washington, DC. It included exhibits by over 400 U.S. and foreign companies showcasing new developments in all modes of transportation: air, rail, highway, maritime, and urban.

To promote development of innovative systems for urban transit, UMTA awarded a total of $6M to four companies that were selected to provide operating demonstrations of their technologies.

The exhibits were financed mostly by the participating companies who had only 10 months to prepare for the show. Due to the short lead-time, the demonstrations were limited to minor changes in existing technologies. All four systems were automated, electrically powered, and intended for urban transit use.

The TRANSPO 72 **Rohr Monocab** (above) was suspended by rubber-tired wheels from an overhead rail. It used technologies that the Rohr Corporation had acquired only one year earlier from Varo Inc. of Garland, Texas. Shortly before Rohr obtained the Monocab technologies, Varo invented a means for switching that did not require moving the rail.

The **Bendix Dashaveyor** (above) used rubber-tired wheels running on narrow "tracks" in an enclosed roadway. After a short time, the Bendix Corporation dropped their transit system product line in favor of control systems, and developed the control system for the Morgantown PRT. The transportation unit of Bendix was acquired by AlliedSignal in 1983.

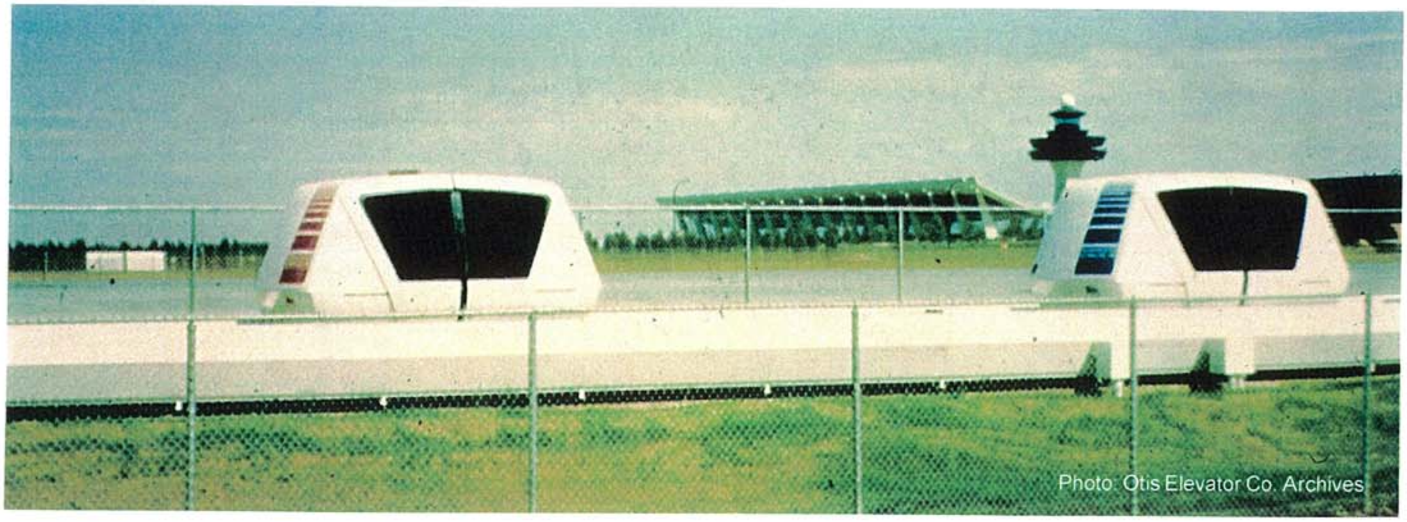


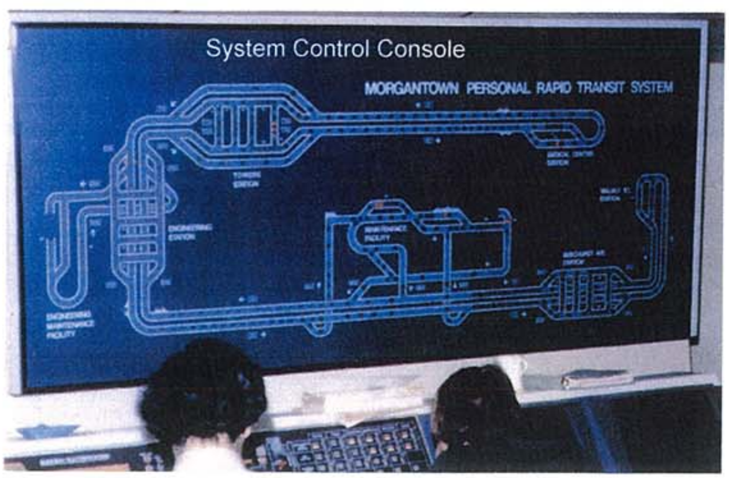
Photo: Otis Elevator Co. Archives

At TRANSPO 72, the **TTI-Otis** vehicles (above and right) were supported by a cushion of air and propelled by linear induction. The system was conceived at General Motors Research Laboratories in the early 1960's based on ground effect vehicles being developed for the Army. In 1969, the design team separated from GM and incorporated as Transportation Technology, Inc. (TTI). Shortly before TRANSPO 72, TTI became an affiliate of the Otis Elevator Company.


Photo: Otis Elevator Co. Archives

The **Ford ACT** (Automatically Controlled Transportation) vehicles (below) used rubber tires on a concrete guideway. As with the three other systems, the Ford demonstration included an operating station, vehicles, and about 600 feet of guideway.

Photos: WVU Photographic Services



System Control Console

Morgantown Personal Rapid Transit

Morgantown, West Virginia is the site of the first Personal Rapid Transit (PRT) system to see revenue service in the U.S.. Its initial segment was opened to West Virginia University students in 1975 as an UMTA-sponsored demonstration program. Boeing Aerospace Company was the system manager.

The system was designed to be accessible by disabled riders and to operate in severe weather. It is fully automatic and uses electrically powered rubber-tired vehicles on exclusive guideways. Since 1975, the system has been expanded to include five stations, 73 vehicles, and 8.7 miles of single-lane guideway.

Except for the size of its vehicles (up to 20 pasengers) the system incorporates most of the PRT capabilities indicated in early studies. Its unique features include off-line stations, vehicles on demand, and non-stop travel to destinations.

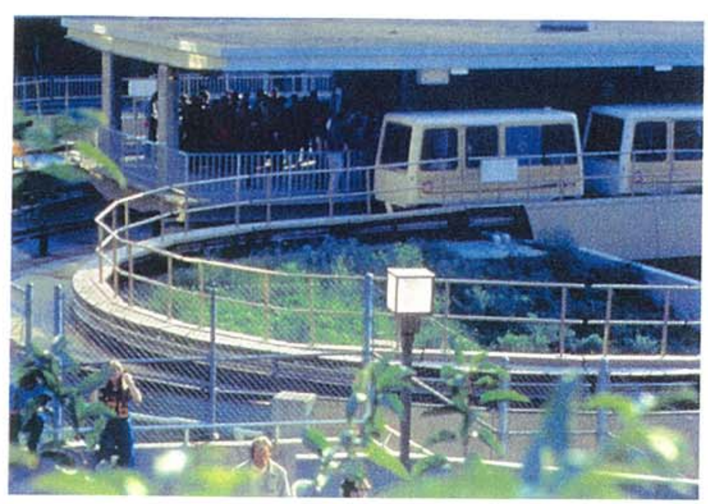
Photo: WVU Photographic Services

Photo: WVU Photographic Services

Morgantown is home to the West Virginia University campus and is located in a relatively narrow valley. Traffic problems in town became extremely severe in the late 60's as the campus began to expand at three separate locations along Main Street.

Today, West Virginia University's PRT operates in all kinds of weather at speeds up to 30 mph. It is safe, quiet, and non-polluting and serves over 19,000 students, 7500 employees, and residents of Morgantown.

Photo: The Boeing Company



AIRTRANS

Now known as the Airport Train, AIRTRANS was completed in 1974 by Vought Corporation at Dallas/Fort Worth Airport. By 1979, the fully automatic system operated 68 vehicles with 53 stations on 13 miles of guideway..

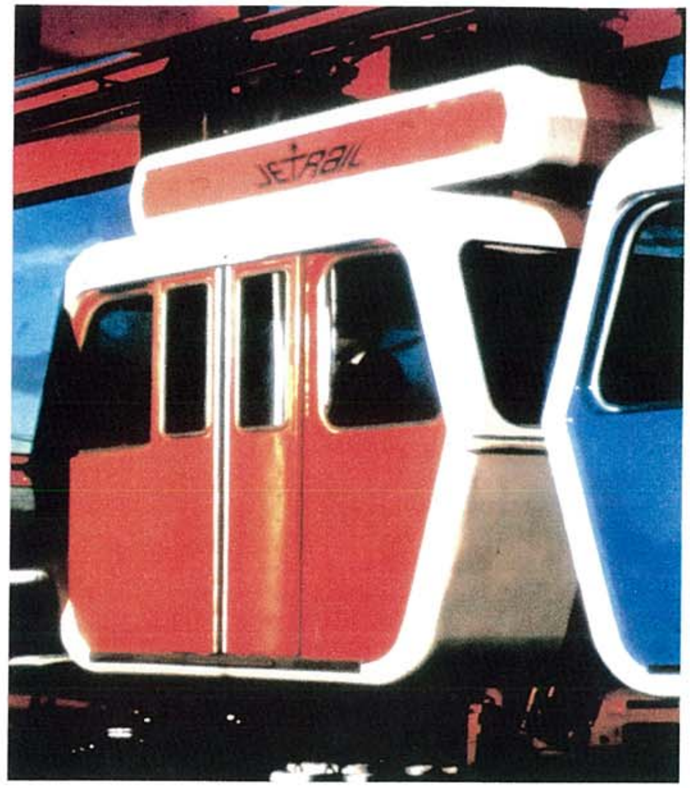
Because AIRTRANS had many of the characteristics needed for urban use, UMTA funded a number of studies and improvements to make it more suitable for the urban environment.

Between 1976 and 1979 tests were made of a prototype urban vehicle that could reach speeds up to 35 mph and had improved reliability, controls, and ride quality. Cold weather capabilities were tested using an environmental chamber.

This control center at Dallas/Fort Worth Airport is capable of directing automated vehicles on several different routes to deliver passengers, baggage, mail, and trash.

Between 1974 and 1979, AIRTRANS carried over 22 million riders and travelled 16 million vehicle miles. It delivers passengers directly tosatellite terminals and to remote sites, such as parking lots.

System Assessments



Assessments of economic, operational, and technical performance were conducted by UMTA on sixteen operating domestic and foreign people movers between 1974 and 1981. Most of the systems were developed by private industry and installed by airports, amusement parks, and local authorities. The purpose of the UMTA studies was to evaluate promising technologies.

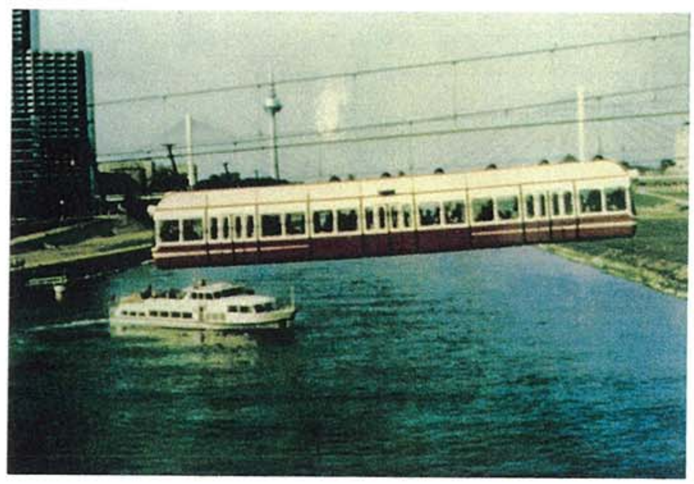
The **Jetrail** system at Love Field in Dallas (top right) was installed by Titan PRT Systems, Inc. It was the first system in the U.S. to operate in a demand-responsive mode. Vehicles were suspended on wheels from an overhead rail and were propelled by linear induction. The system operated reliably for more than 13 years until passenger airlines moved to the new Dallas-Fort Worth Airport.

The **UNIMOBIL Tourister** system (right) is a monorail built by Universal Mobility, Inc. of Salt Lake City. By 1979, seven UNIMOBIL systems were installed and operating in the U.S.. The technologies have recently been acquired by Bombardier of Canada.

The **Ford Fairlane** (below) is a later model of the Ford Motor Company Automatically Controlled Transportation (ACT) system that was demonstrated at TRANSPO 72. This system was installed at the Fairlane shopping center in Dearborn, Michigan. It used rubber-tired vehicles with electric motors in a shuttle system that had both off-line and on-line stations. Ford discontinued its marketing of people movers in 1975.

Photo: Battman for RIOC

The **Roosevelt Island Tramway** (above) in New York City is operated by the Roosevelt Island Operating Corporation, a unit of New York State Government. It crosses the East River between Manhattan and the island in 4.5 minutes. The system was built by Vonroll Co. (Swiss) in 1976.



The Mueller **Aerobus** system (above) was developed and manufactured in Zurich, Switzerland. It operated for six months during an exposition in Mannheim, Germany.

The **UTDC ICTS** system (left) is an automated steel wheel on steel rail system propelled by linear induction. Its technology is used by the Skytrain in Vancouver, B.C. and by the Downtown People Mover in Detroit, MI. The UTDC (Urban Transportation Development Corp.) was established by the Province of Ontario in 1973. The ICTS design was acquired by Bombardier Transportation in 1992.

The **Otis Duke University** system (above) is a further development of the TTI-Otis people mover that was demonstrated at EXPO 72. It operates on elevated and ground-level guideways between buildings at the Duke University Medical Center in Durham, NC. It uses Otis' HOVAIR air cushion suspension and is propelled by linear induction. Because there are no tracks or wheels, the vehicles can be moved vertically by elevator to serve off-line stations on several floor levels.

Photo: Houston Airport System Archives

The **Interterminal Train** at Bush Intercontinental Airport, Houston (above) was installed by Rohr Corporation in 1977. It is entirely underground and has 1.3 miles of guideway with five stations. Guidance is provided by an H-shaped aluminum beam bolted to the concrete roadbed. The beam carries electrical contact rails, cables, and way-side electronic controls.

Transette (left) was a loop system which used a moving belt to control and propel passive vehicles. This experimental system was designed and built at the Georgia Institute of Technology.

Photo: Community Transportation Services

WEDway was a further development of the system designed by Walt Disney Productions for the New York Worlds Fair in 1964. Three years later, a system was installed at Disneyland in California. Cars are supported by rubber wheels on steel rails imbedded in the Guideway and are driven by electric motors. WEDway systems use a unique rotating platform for passenger loading that does not require stopping the cars.

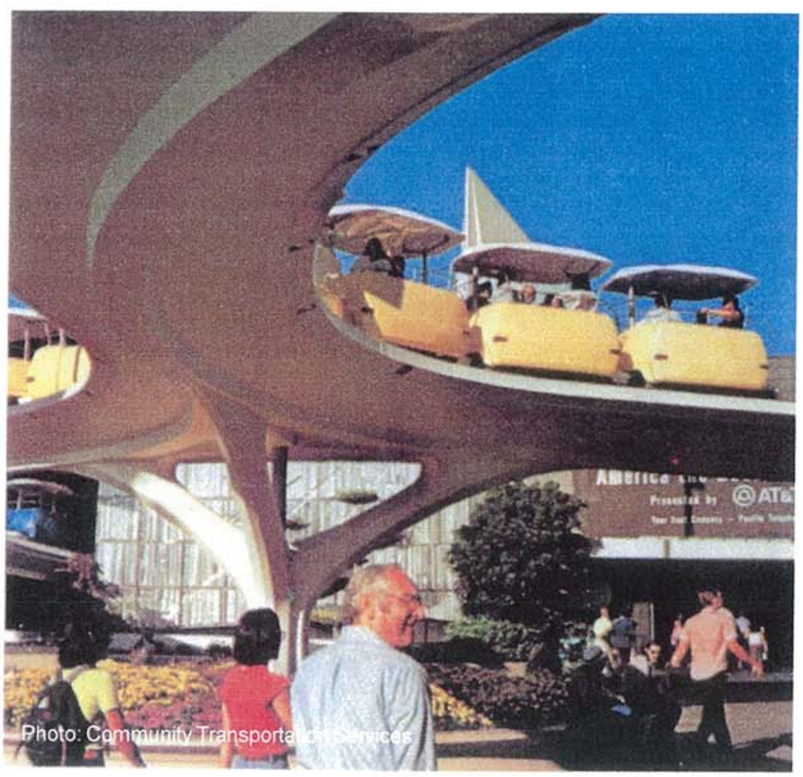


Photo: Community Transportation Services

Photo: Community Transportation Services

Another WEDway system (above) was installed at Disney World in 1975. It is similar, but uses linear induction for propulsion and braking.

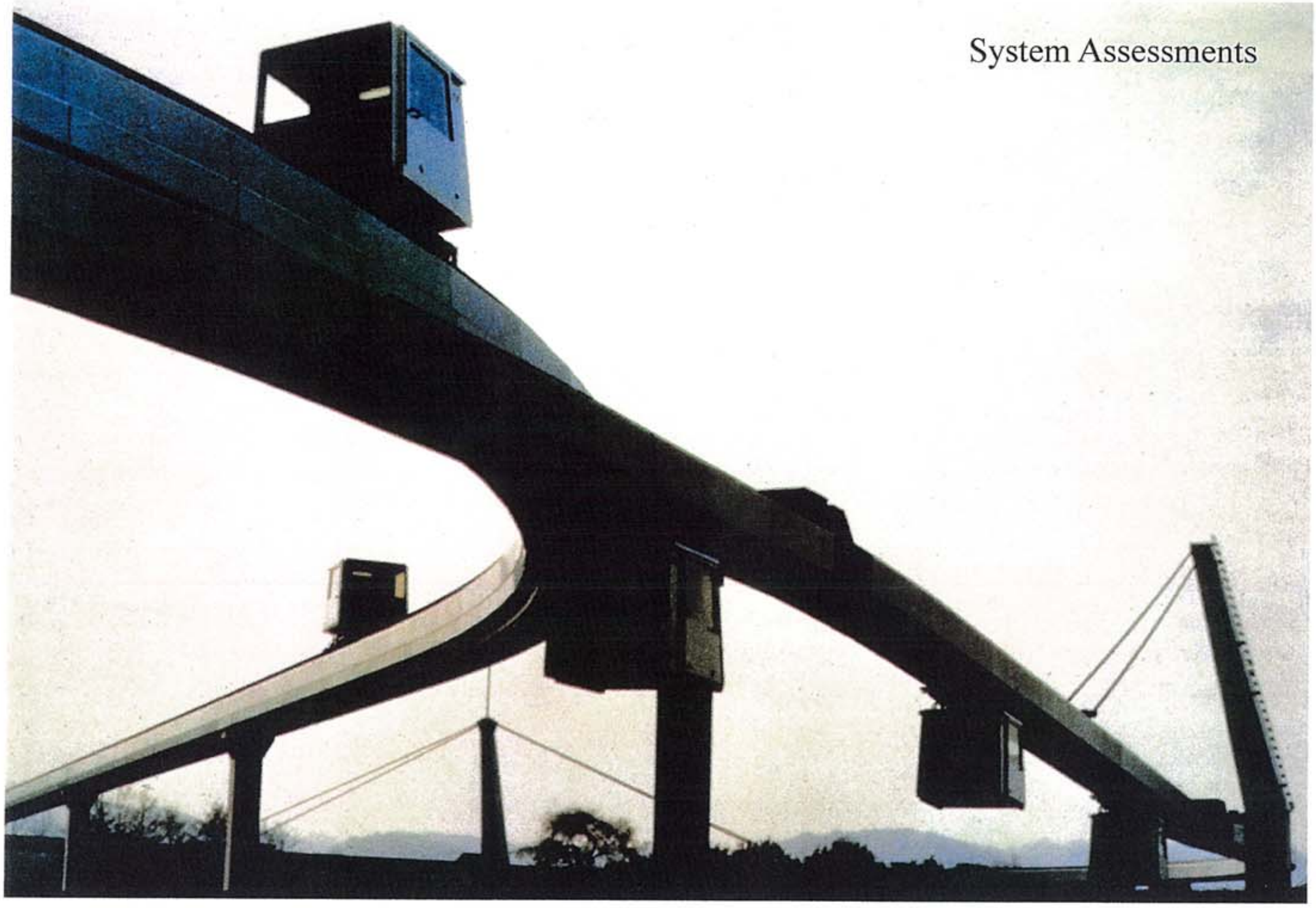


Photo: DMAG+*MBB*

Cabinentaxi is shown above and at left at its test facility in Hagen,Westphalia, Germany. It had cars both above and below the guideway and had off-line stations, "personal-sized" vehicles, linear induction propulsion, and speeds up to 22 mph. It demonstrated the principal technical performance requirements for PRT.

Development of Cabinentaxi was started in 1969 by two private corporations (DMAG and Messerschmidt-Bolkow-Blohm, MBB). Cabinentaxi and the 12-passenger Cabinenlift Downtown People Mover System were funded as a combined program by the German Government from 1972 to 1979.

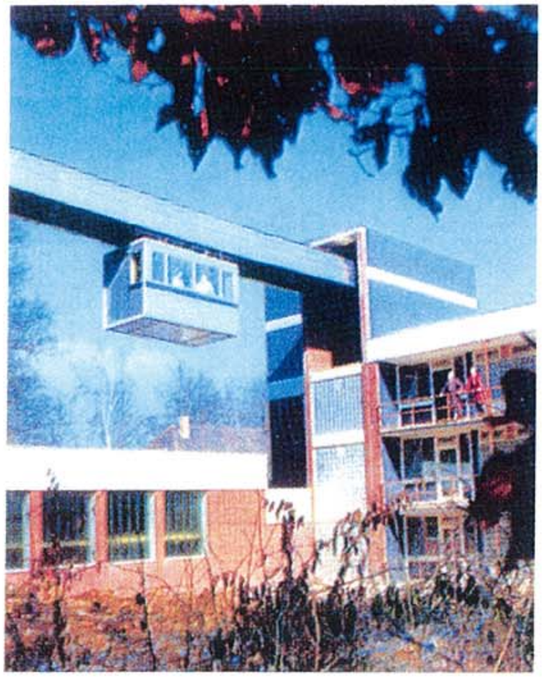


Photo: DEMAG+*MBB*

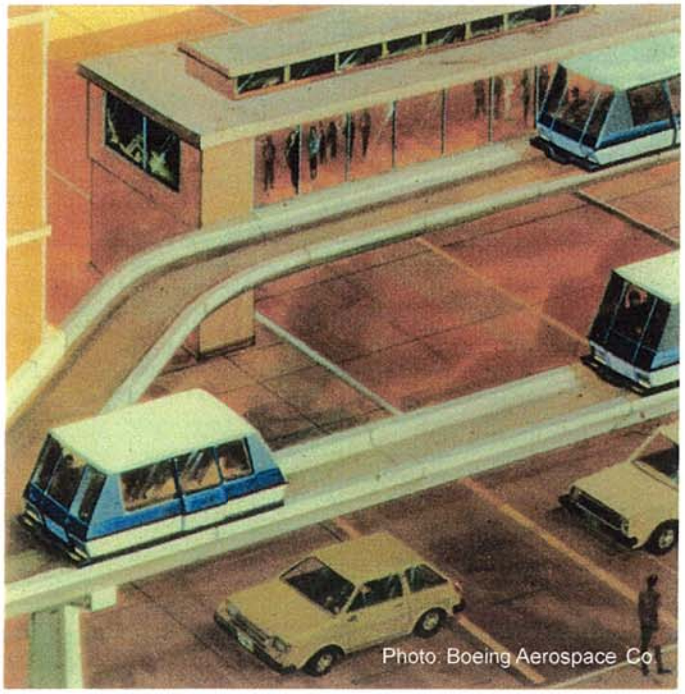
Cabinenlift Is shown above in 1975 at its first installation, a shuttle system at Ziegenheim District Hospital in Germany. The vehicles could transport hospital beds with attendants between buildings. The system at right is a later development that was designed for urban applications. Plans to install a system In Hamburg in 1980 were abandoned because of funding limitations.

Photo: MATRA Transport

The Val system (above) was developed by Matra Transport and operates in Lille,France. It was studied by UMTA in 1979. In 1983 Lille had 38 trains, 16 stations and 8 miles of guideway.

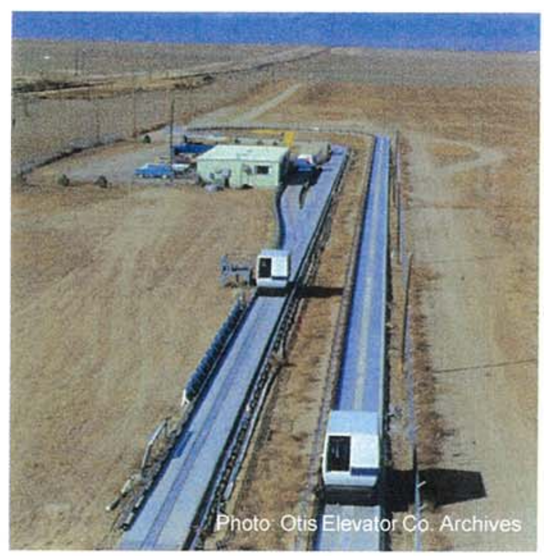
Advanced Group Rapid Transit (AGRT)

In 1976 UMTA awarded contracts to Boeing, Otis, and Rohr for preliminary designs of systems using advanced technologies that could serve metropolitan regions. Specifications called for a peak capacity of 14,000 seats per lane mile using 12-seat vehicles. The system was to be suitable for collection and distribution in central business districts with short travel times and few intermediate stops. The program was limited in 1979 to development and testing of critical subsystems and technologies and was concluded in 1983.



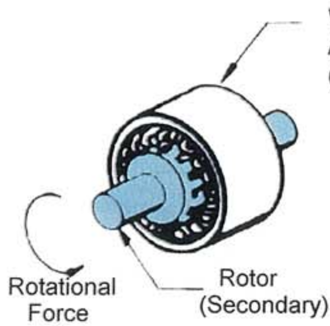
The **Boeing AGRT** system (above) was an outgrowth of the Morgantown design. It used rubber-tired vehicles steered by side-mounted wheels in a U-shaped reinforced concrete guideway.

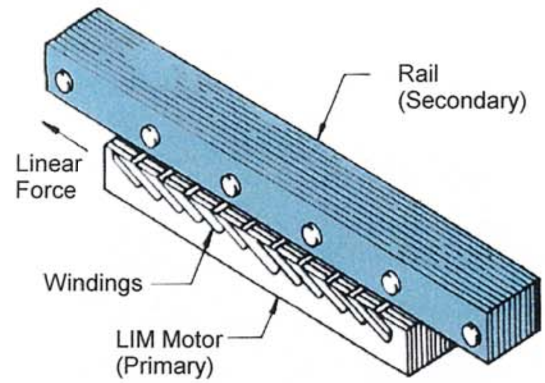
The **Rohr AGRT** (right) used magnetic forces between the primary and secondary of its linear induction motor to suspend as well as to propel and brake its "Romag" vehicle. Starting with the original Monocab design, Rohr developed both the suspended and supported vehicles shown. During the AGRT Program, this magnetic levitation (Maglev) technology was acquired under license by Boeing.



The **Otis AGRT** system used a vehicle with air cushion suspension and a single-sided linear induction motor (LIM). The LIM primary is on board and the secondary is embedded in the center of the U-shaped concrete guideway. Otis prototype car bodies are shown at left and at the Otis test track in Colorado on the right. The vehicles were nearly identical to those of the Duke University Medical Center system.

Linear Induction





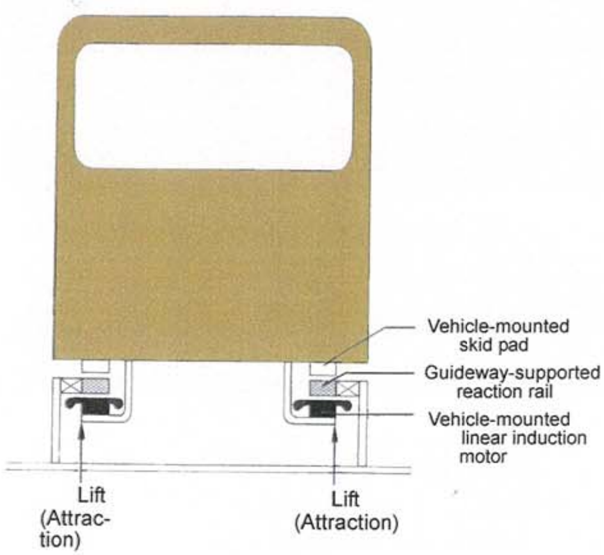
Rotary Motor

Using alternating current as a power source, the windings in the outside (primary) of rotary motors induce fluctuating magnetic fields in opposing sheets of steel in the rotor. Alternating attraction and repulsion by the electromagnets in the primary turn the rotor.

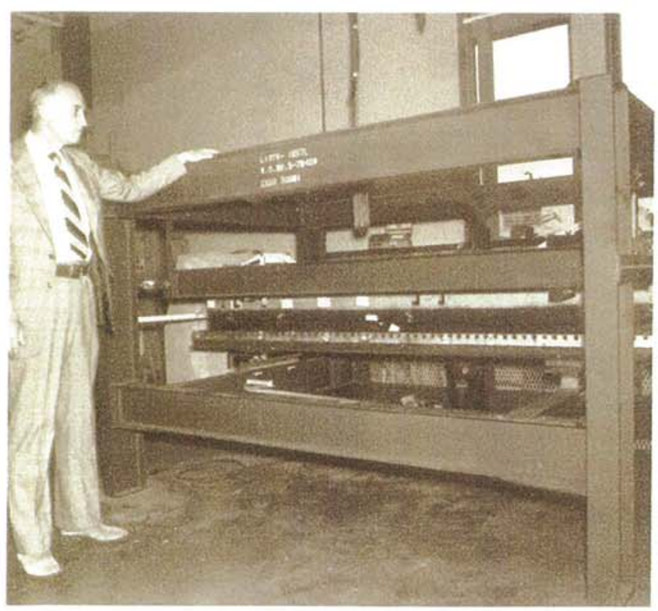
Linear Induction Motor (LIM)

A linear induction motor has the armature and rotor stretched out in a straight line. The advantages are that propulsion, braking, and steering can all be accomplished with the same hardware. The vehicles are quieter and lighter, since parts of the motor and brakes are contained in the guideway.

Magnetic Levitation (Maglev)



Maglev goes one step further, using much the same equipment as LIM except that the induced magnetism is also used to support the vehicles. Vehicles have been demonstrated on high-speed test tracks in both Germany and Japan.



This **Guideway Test Beam** was used in 1977 to conduct tests of both the propulsion and levitation properties of linear propulsion motors. Federal support for maglev research and development has been intermittent over three decades.

Downtown People Mover (DPM) Program

Drawing of Proposed DPM in Los Angeles

Superimposed drawing of DPM in Detroit

The DPM program was designed to test urban applications of existing people mover technologies. In 1976, 38 cities submitted proposals and four cities were chosen for the first tier: Los Angeles, Miami, Detroit, and St. Paul. A second group of cities, which included Jacksonville, were awarded technical studies grants in 1978.

The first tier cities were about to proceed with final engineering and construction when the program was terminated. This change was part of a new policy to use UMTA's limited R&D resources to improve conventional transit systems.

Despite cancellation of the demonstration program, Detroit, Miami, and Jacksonville elected to install people movers, using a portion of their regular capital assistance grants.

The **Miami Metromover** (below) has a 1.9 mile double-lane downtown loop with added extensions that bring the total coverage to 4.4 miles. It uses relatively large rubber-tired vehicles by AEG-Westinghouse (now Adtranz) that had their origins in the Skybus Technology. The loop opened in 1985.

Photo: Miami-Dade Transit Agency

Photo: Detroit Transportation Corporation

The **Detroit Downtown Peoplemover** (above) is a fully automated steel wheel on steel rail system with linear propulsion. It consists of a single lane loop of 2.9 miles and has 13 stations connecting downtown hotels, shopping, and convention and sports centers. Cars complete the loop in about 14 minutes. The system is known for the outstanding works of art that are incorporated in every station. The system was developed and built by the Urban Transportation Development Corporation (UTDC) of Ontario, Canada. The system technologies were acquired by Bombardier Transportation in 1992.

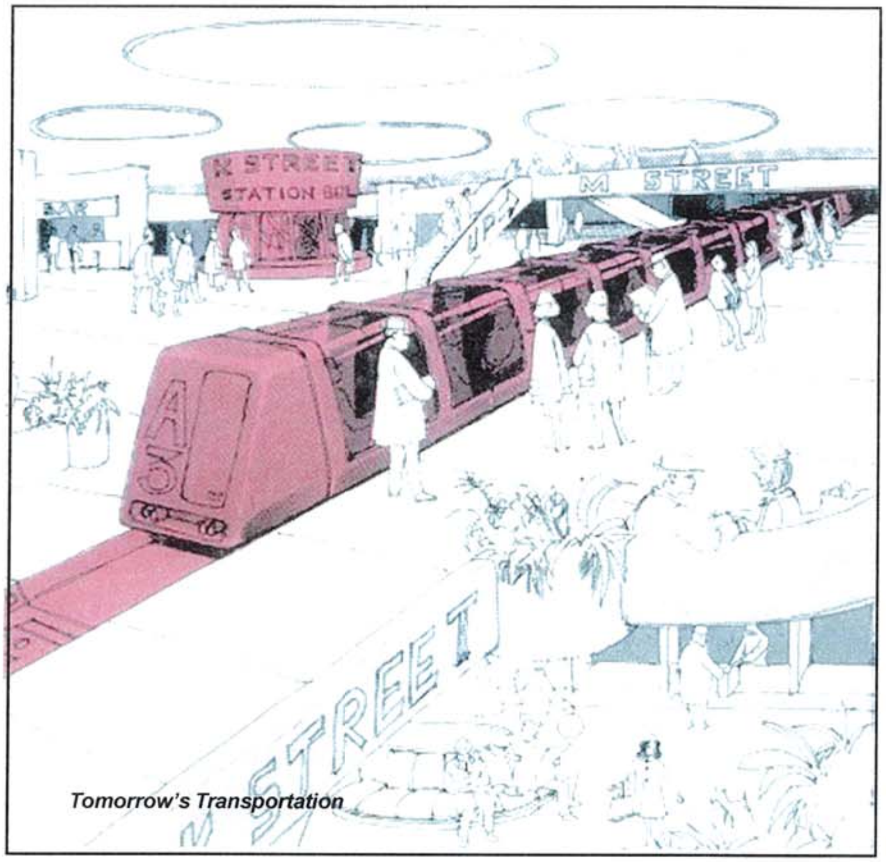
The **Jacksonville Skyway** (right) is a 2.5 mile dual-guideway monorail system spanning the St. John's river. It has eight stations serving the central business district. The initial 3-station segment opened in 1989 with technology supplied by MATRA of France. Bombardier Transportation, Inc. of Canada was selected in 1994 to replace and extend the original system. The system is based on the UNIMOBIL technology acquired by Bombardier from Urban Mobility, Inc.

Photo: Jacksonville Transportation Authority

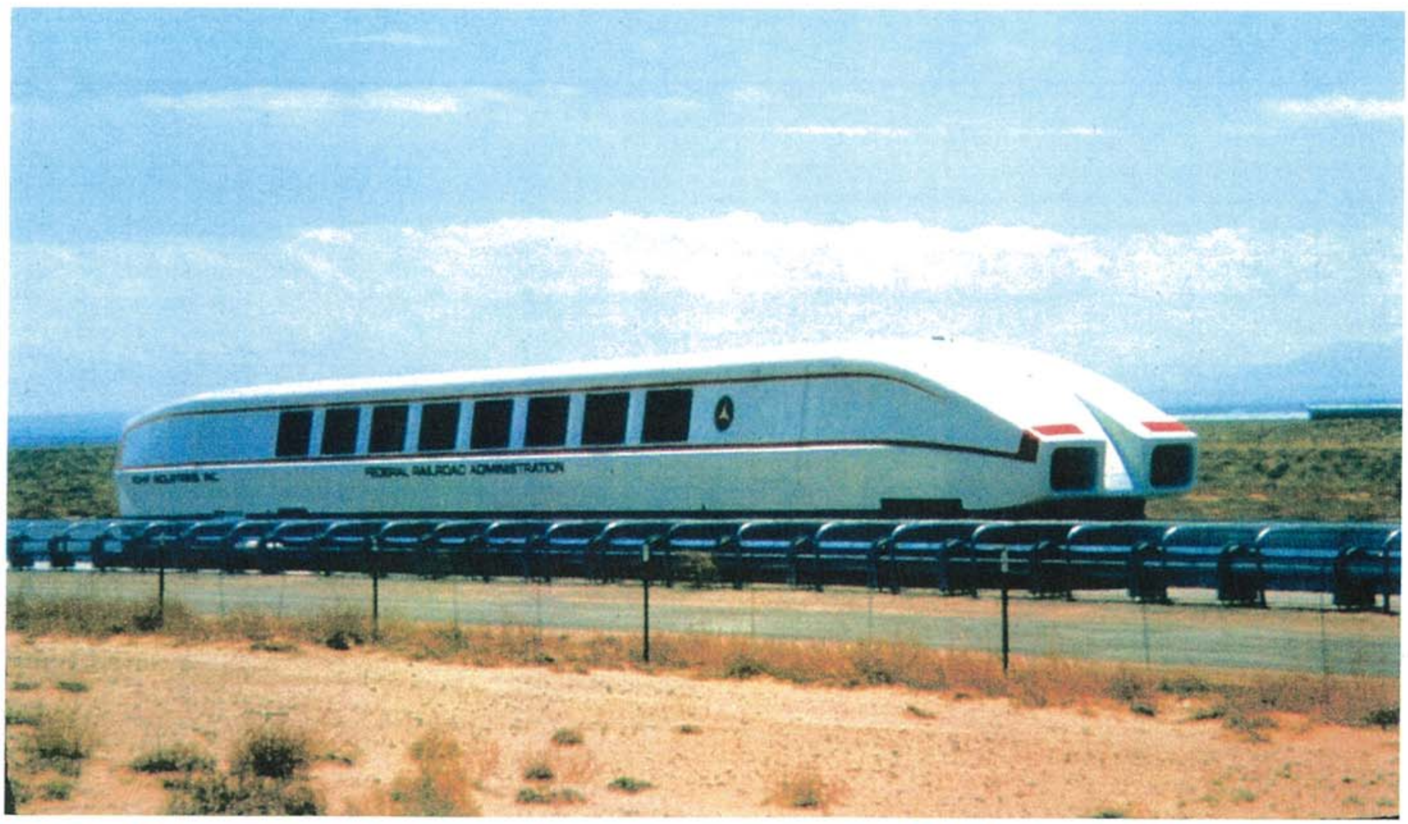
Fast Transit Links

During the first half of the 1970's, UMTA explored applications of automated guideway technologies to high-speed, high-capacity systems that could be used for commuting and for connecting major urban activity centers.

Federal Railroad Administration (FRA) and UMTA studies of intercity systems (mostly for the Northeast Corridor) showed that wheeled vehicles would not be practical for speeds much over 200 mph. Air cushion (and later maglev) were the preferred suspension technologies, as was linear induction for propulsion.

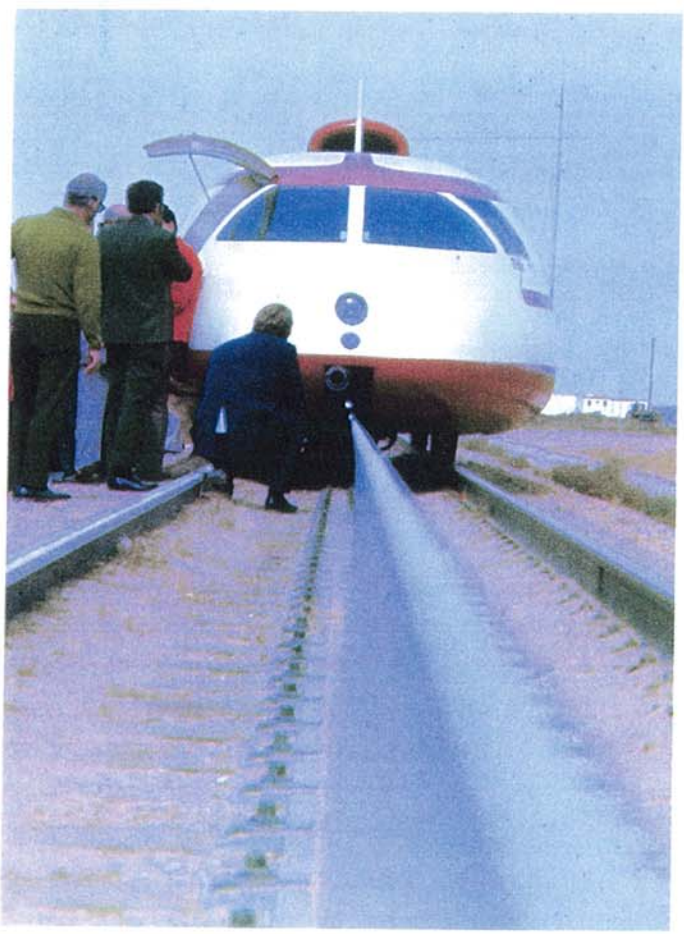


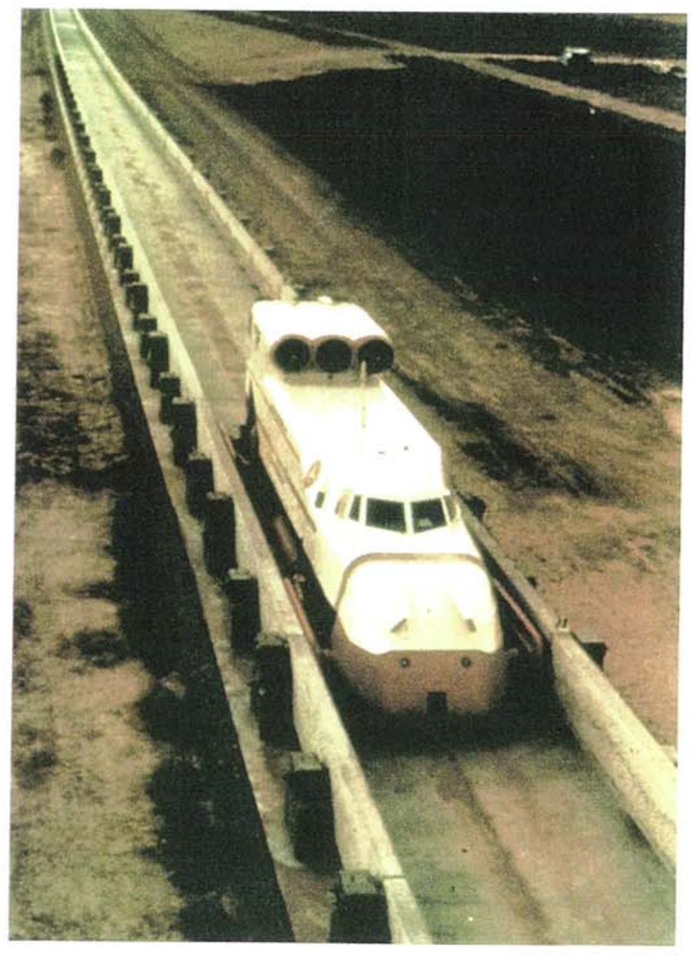
Tomorrow's Transportation



UTACV - The Urban Tracked Air Cushion Vehicle (above) was developed by Rohr Corp. for UMTA in 1973. It was guided, as well as suspended by air cushion. Electric power was collected from wayside power rails. Propulsion was by linear induction with an aluminum reaction rail centered in the guideway. The vehicle was 90 feet long and had 90 passenger seats. Its tested speed was limited to 145 mph by the length of the test guideway. In 1974 Congress determined that all further TACV research should be funded by the Federal Railroad Administration and UTACV was turned over to the FRA. In 1975 all research on high speed ground transportation was terminated by Congress.

LIMRV - The Linear Induction Motor Research Vehicle (above and below) is shown at the Transportation Test Center in 1972. It was used by the FRA to refine propulsion methods. The aluminum reaction rail is in the center of the tracks. Electrical power was obtained from a turbine powered generator.

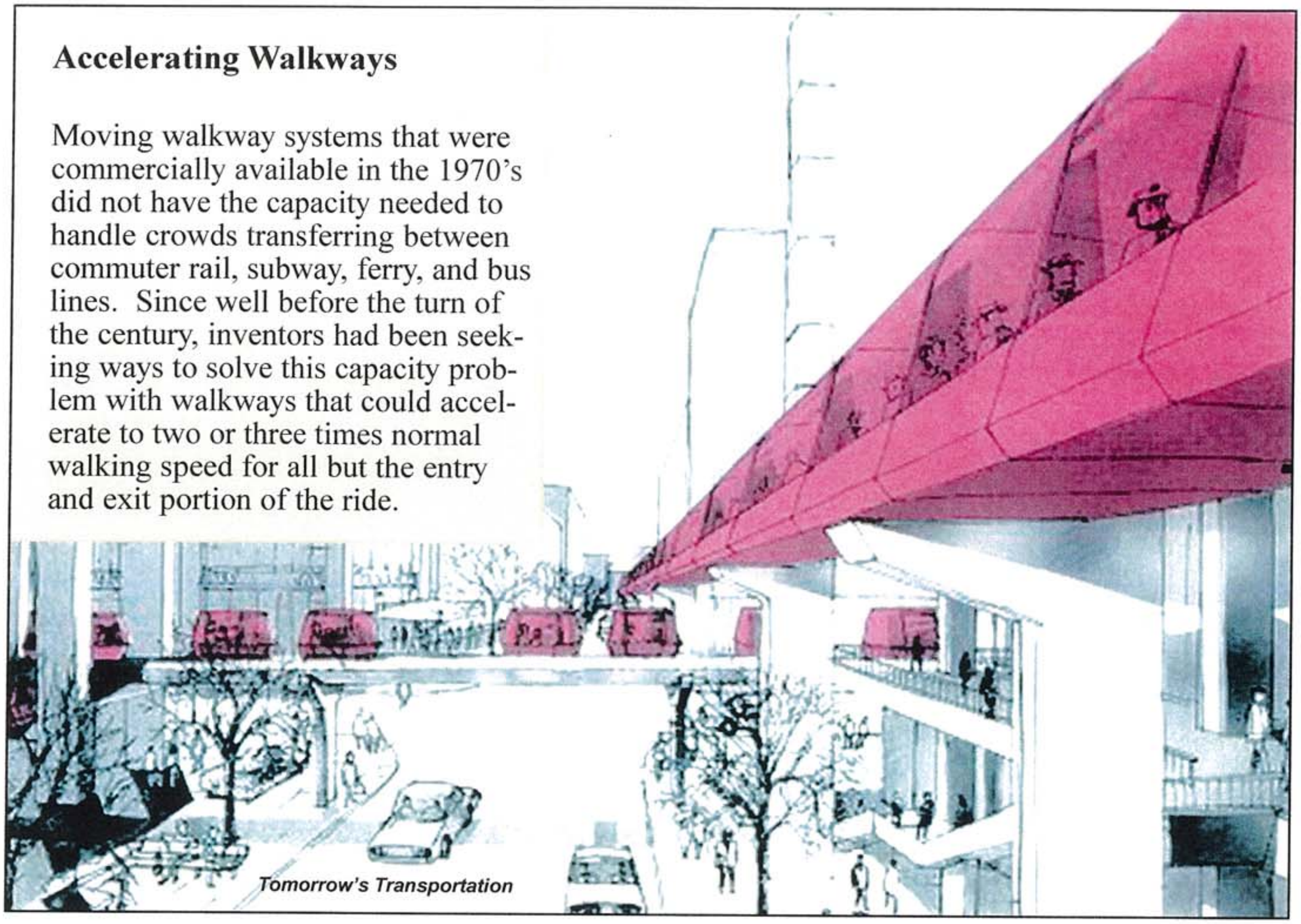




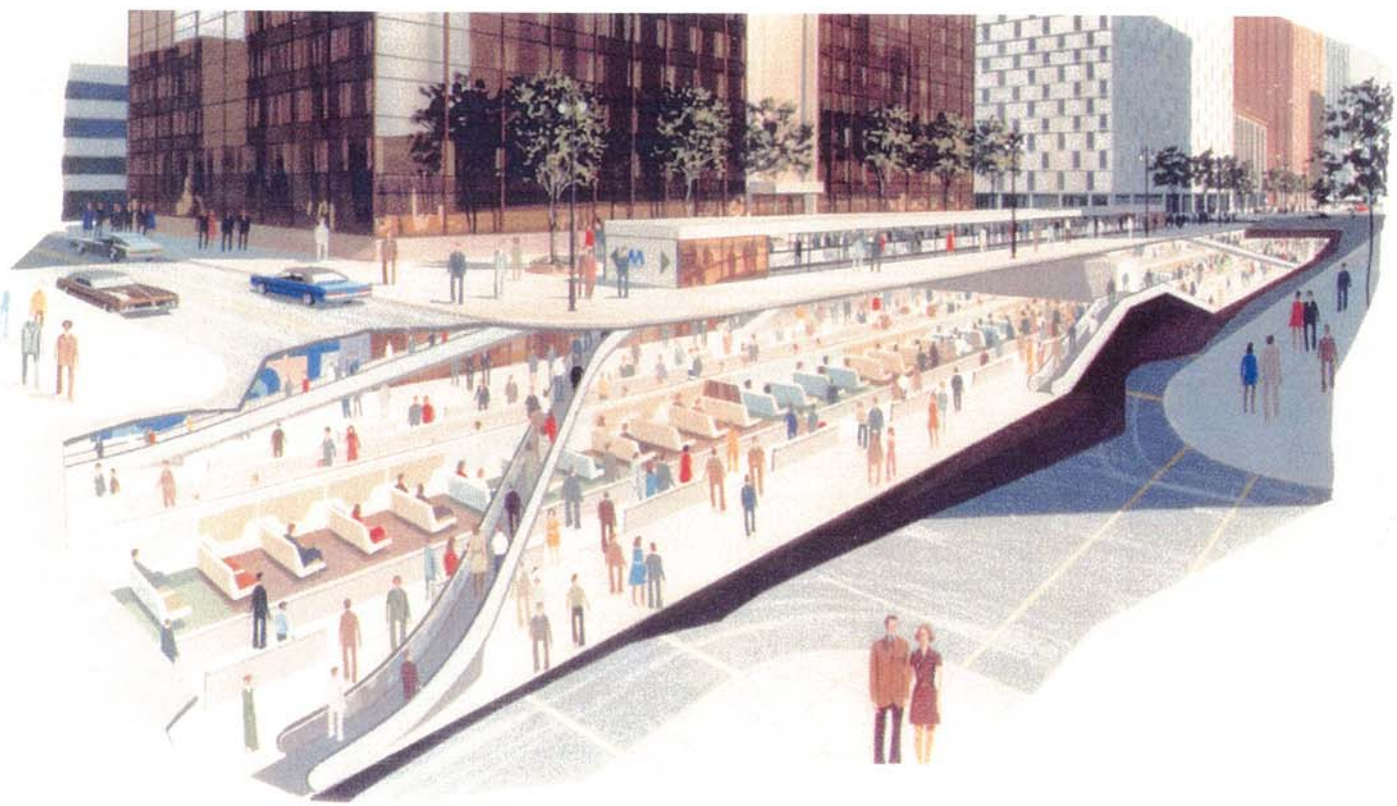
TLRV - The Tracked Levitated Research Vehicle (above in 1971) was used by the FRA to develop air cushion suspension and guidance technologies. Power was also obtained from jet-type turbines.

Accelerating Walkways

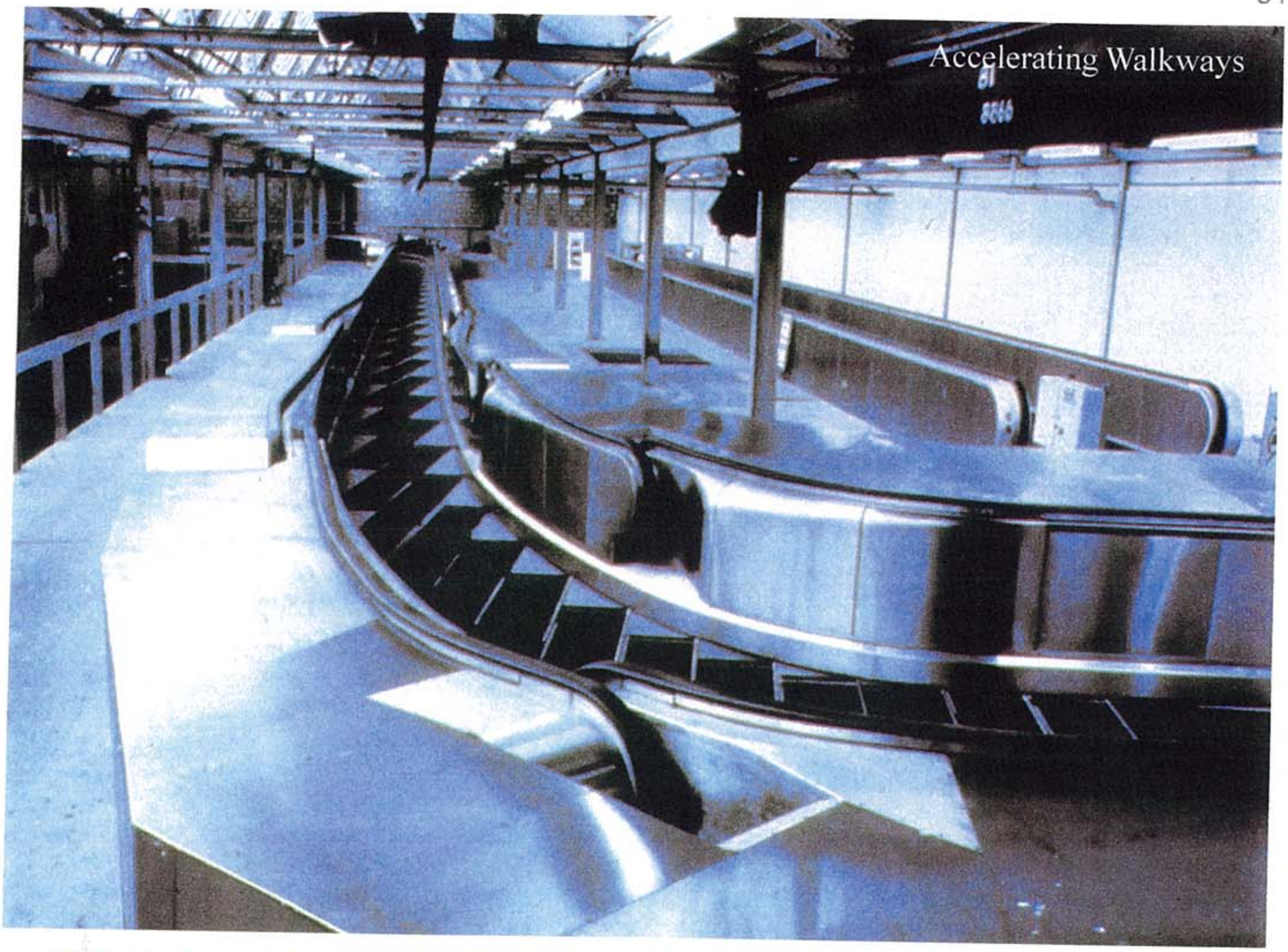
Moving walkway systems that were commercially available in the 1970's did not have the capacity needed to handle crowds transferring between commuter rail, subway, ferry, and bus lines. Since well before the turn of the century, inventors had been seeking ways to solve this capacity problem with walkways that could accelerate to two or three times normal walking speed for all but the entry and exit portion of the ride.



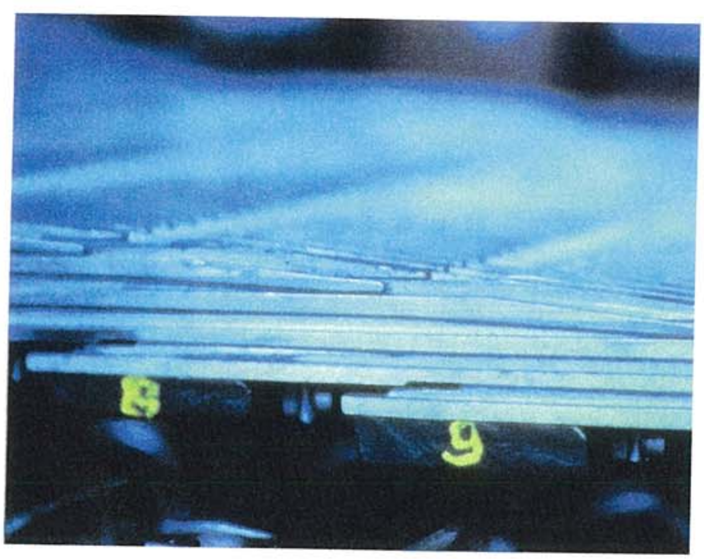
Tomorrow's Transportation

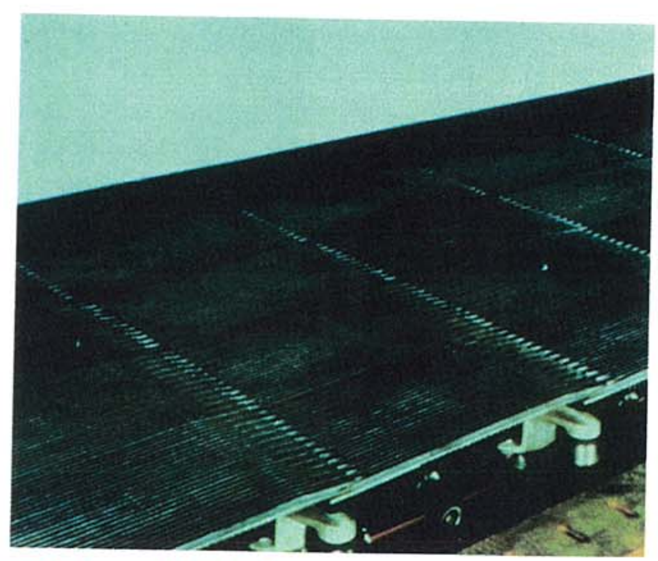


A variety of moving walkway concepts were submitted to UMTA in 1974. The system shown above involved two moving belts. One (for boarding) moved at walking speed. The other (with seats) moved twice as fast..



Starting in 1976, UMTA sponsored cost-benefit studies and safety tests of several prototype accelerating walkways that used sliding plates, stretchable panels, or interlocking fingers similar to escalator treads. The projects were terminated in 1982. The **Dunlop** prototype accelerating walkway (above) was developed by Dunlop Tyre Co. of England. It used sliding plates with curved sections to provide the reduced speeds needed for entry and exit.





The **TRAX** system was developed by Ateliers et Chantiers de Bretagne (ACB) in France. It used tread plates with intermeshing fingers to extend the treadway for the faster portion of the ride. In the left photo the plates are compressed for the slow portion. On the right the plates are stretched.

No other common form of public transportation can beat the passenger-carrying capacity of rapid rail. It could be the best solution for densely populated regions with radial commuting patterns.

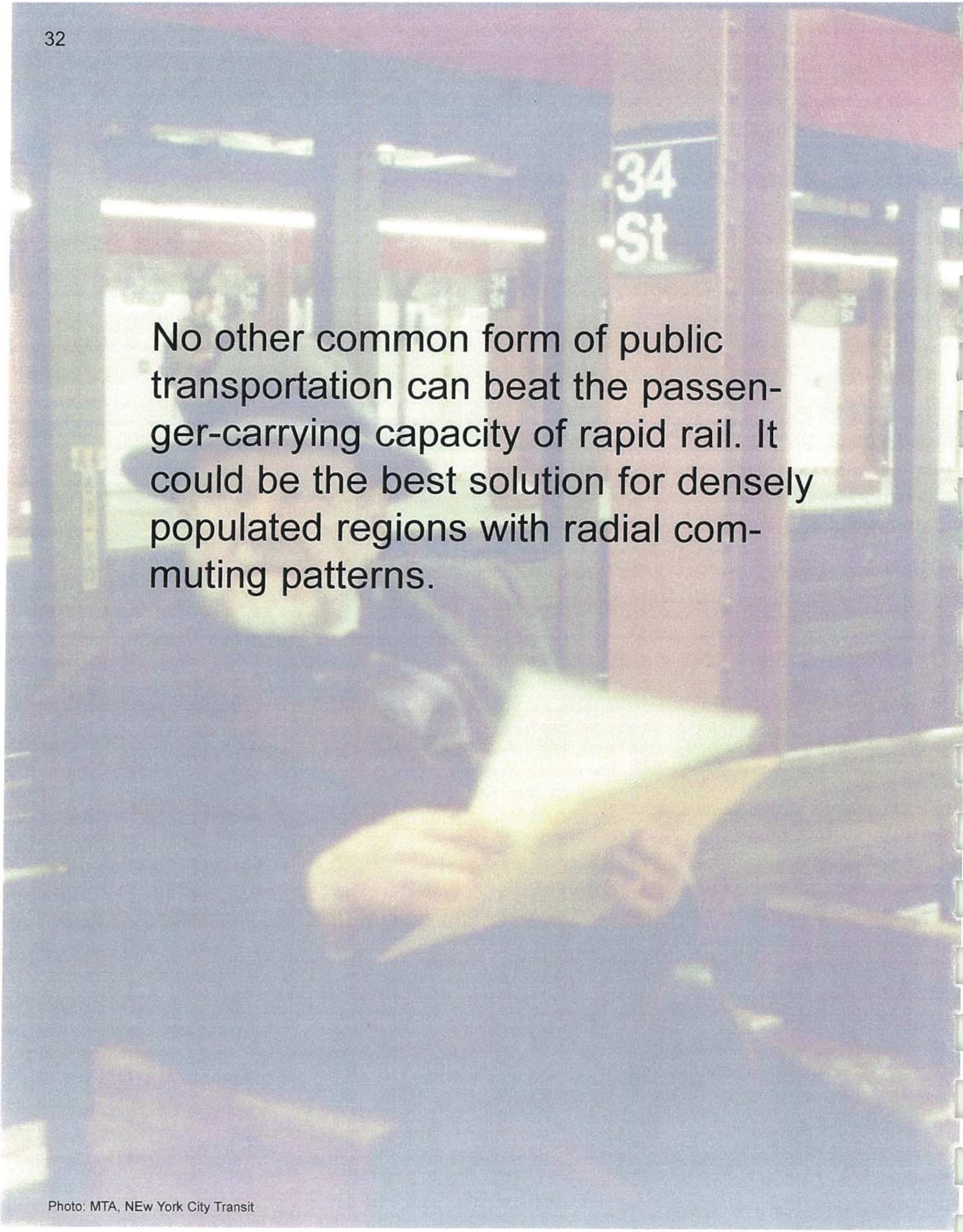


Photo: MTA, NEw York City Transit

Photo: Washington Metropolitan Area Transit Authority

Rail Systems

During its first decade, UMTA's main efforts in rail transit were aimed at helping cities to build new systems and rebuld or expand their existing networks. These rail modes included **Light Rail** (trolley) and **Commuter Rail** systems, as well as **Rapid Rail** (subways and elevated) lines.

In 1970, only five U.S. cities were served by **Rapid Rail**: New York, Chicago, Boston, Philadelphia,and Cleveland. At that time, it had been over 50 years since a new rapid rail system was built in America.

By 1970, only seven street railway systems had survived. Because the last new streetcar model (the PCC car) had been introduced in 1935/36, UMTA supported development of a new **Light Rail Vehicle (LRV)** would allow cities to modernize or expand their systems at minimum costs.

The initial emphasis in **Commuter Rail** development was on a dual-powered railcar that could operate on electrified and non-electrified tracks. Such a vehicle would enable transit authorities to expand their service areas quickly without the costs of electrification.

In addition to whole vehicles, the rail program included development of a broad range of vehicle subsystem and train control system improvements. These included research into noise reduction, energy conservation, winterization, and electromagnetic interference.

When it became clear in 1981 that Federal funding would not be available for new rail starts, the program of rail vehicle and systems research was cut back to projects that could help transit agencies to meet critical near-term safety, accessibility, and maintenance needs.

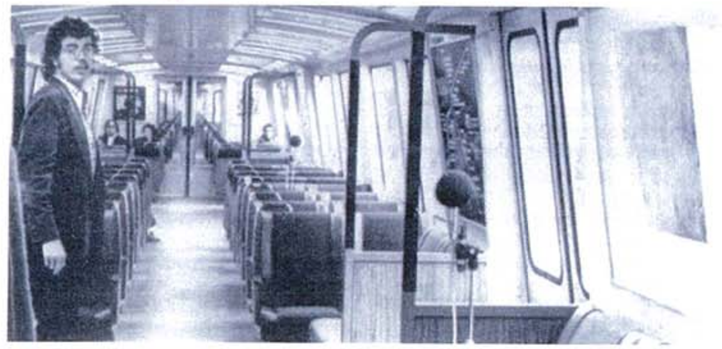
BART (Bay Area Rapid Transit)

By the time UMTA's R&D program was started, development and construction of the BART system (in the San Francisco region) was well underway. It was funded by the three counties served, and managed by a new agency.

As one of its first rail projects, UMTA joined BART in a program to develop ten prototype cars. Tests of these cars suggested improvements for the BART revenue service fleet and provided ideas for future UMTA development programs.

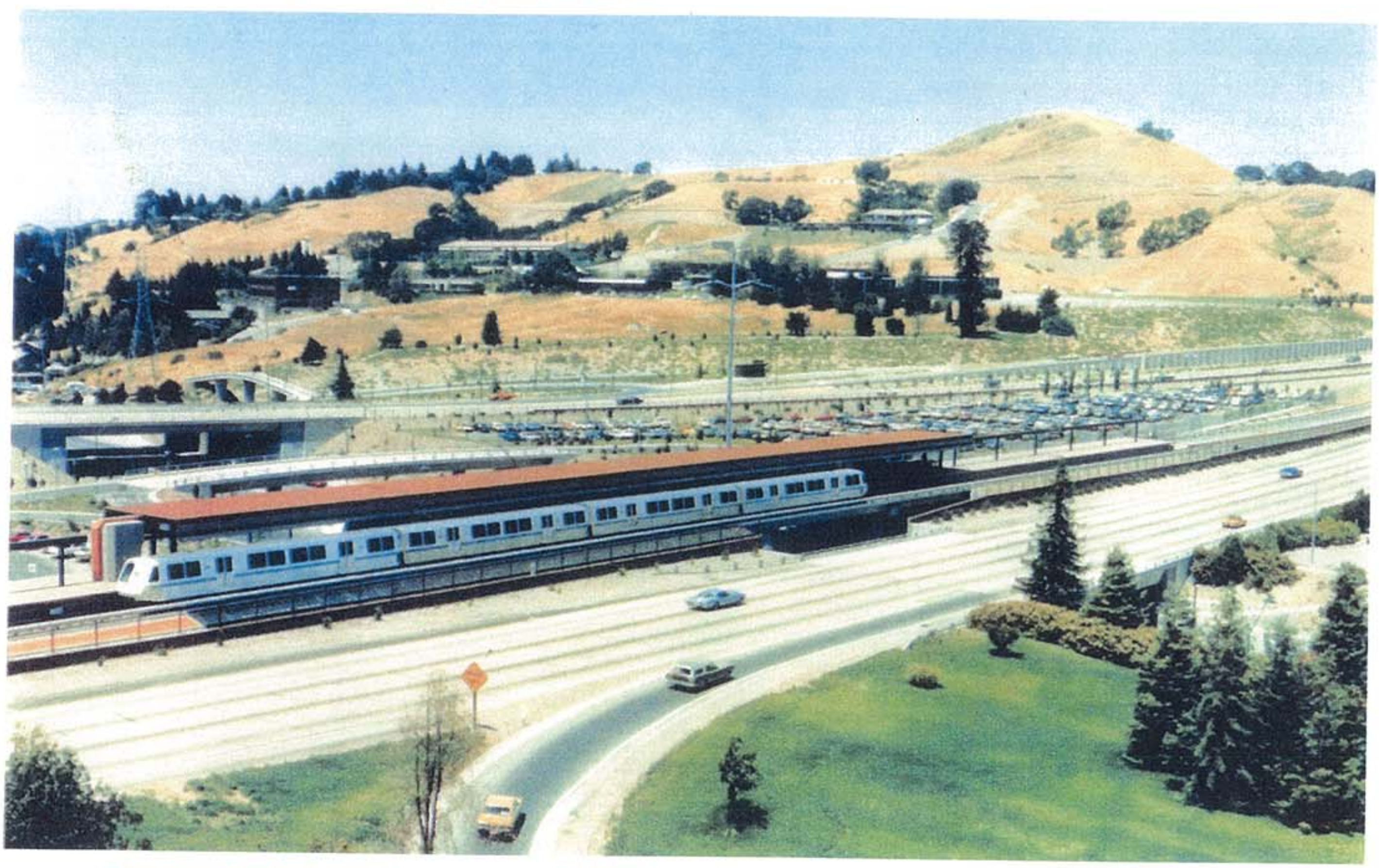
The BART District was created in 1957, construction began in 1964, and the first link opened in 1972.

With a modern rail sytem in operation UMTA was able to evaluate many current technologies. Here microphones are being used to measure methods for reducing noise in both underground stations and car interiors.

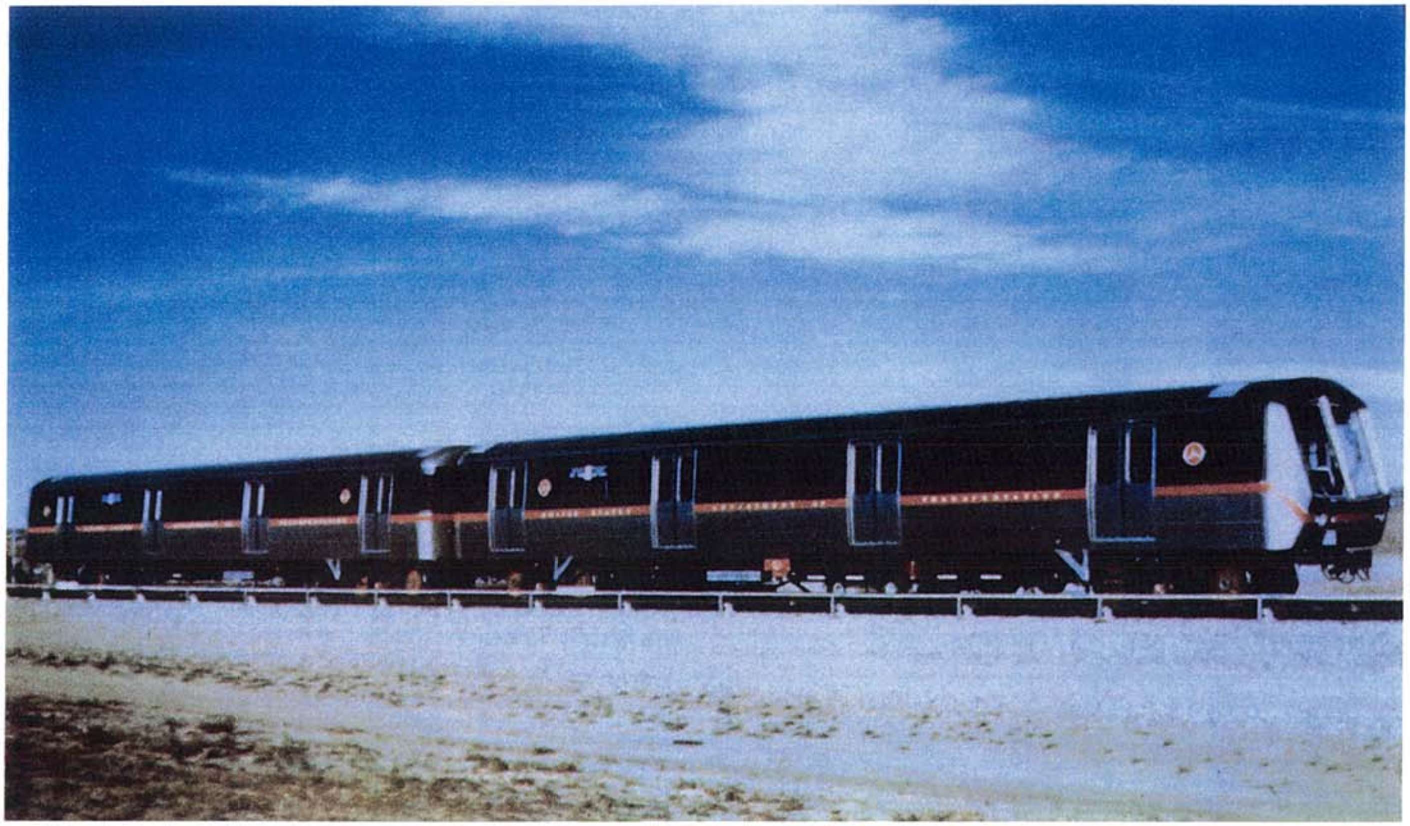


The **BART** system used automatic train controls and a display and operations control center. Construction of the Transbay Tube was considered a landmark engineering accomplishment. All stations were made accessible for passengers in wheelchairs. The system now has 670 railcars, 81 miles of track, and 31 stations.

This is a 1971 publicity photo of the **BART** prototype train which was designed and manufactured by Rohr Corporation of Chula Vista, California. Cars had aluminum bodies, were air conditioned and could operate at speeds up to 80 mph..



Because it was an entirely new system, **BART** was able to use innovative approaches to system layout. Here the tracks share the right-of-way with U.S. Route 24 for 11 miles in Alameda and Contra Costa Counties. Note the station with parking lot for commuters and easy access to the highway.



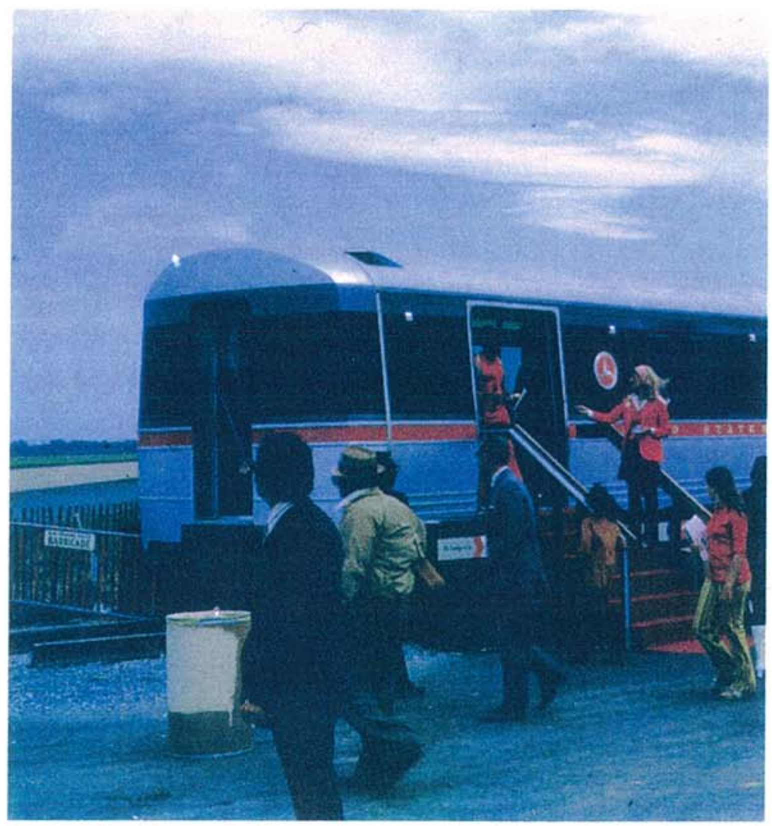
The **State-of-the Art Cars** that were demonstrated and tested in five cities are shown above at the Department of Transportation Test Center in Pueblo, Colorado.

State-of -the-Art-Car (SOAC)

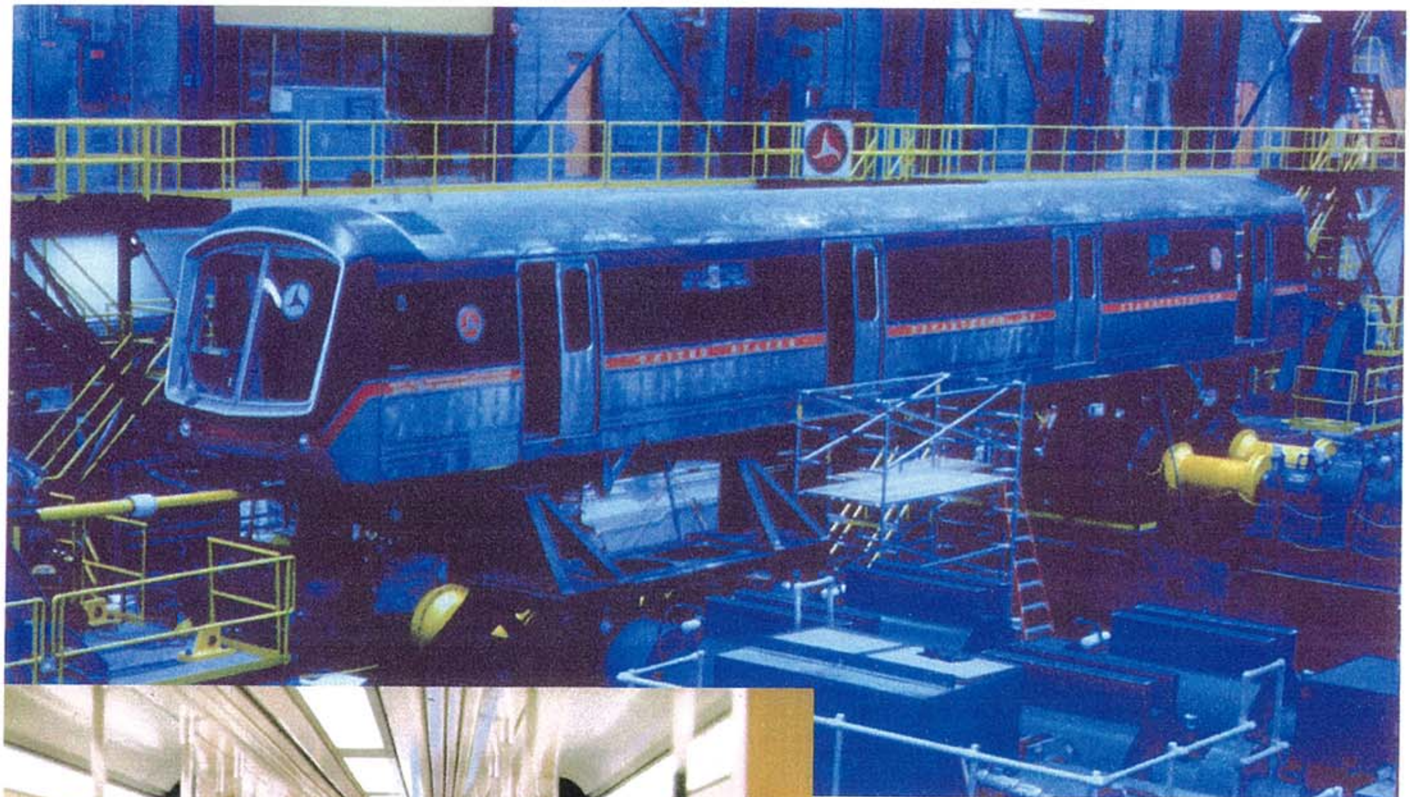
In 1971, using the BART prototypes as a baseline, UMTA sponsored development of a rapid rail car that incorporated the best new proven technologies. Two cars were built by the St. Louis Car Division of General Steel Industries. The cars featured a solid state propulsion control system, air-ride trucks, and modern styling.

The pair of SOAC cars were first tested at the DOT Transportation Test Center (TTC) in Pueblo, Colorado. After the tests in Pueblo the cars were demonstrated and tested in passenger service in five cities.

The new systems provided much improved ride quality with smoother starting and stopping and a quieter ride. The modern DC propulsion control system also contributed to energy savings. After the SOAC tests, these features were included in most new railcar purchases.



A mockup of the **SOAC** (shown above) was displayed at TRANSPO 72. It was built to obtain transit agency and public comments on overall design of the car.



SOAC was tested (above) in 1973 in a newly-built Rail Dynamics Laboratory at the Department of Transportation Test Center (TTC) in Pueblo, CO. The test stand could handle whole railcars and locomotives for performance testing and for tests of to shock and vibration resistance.

At left is the interior of one of the SOACs in New York City. The live demonstrations were conducted in part to obtain rider reaction to ride quality and interior design improvements.

ACT-1 (Advanced Concept Train)

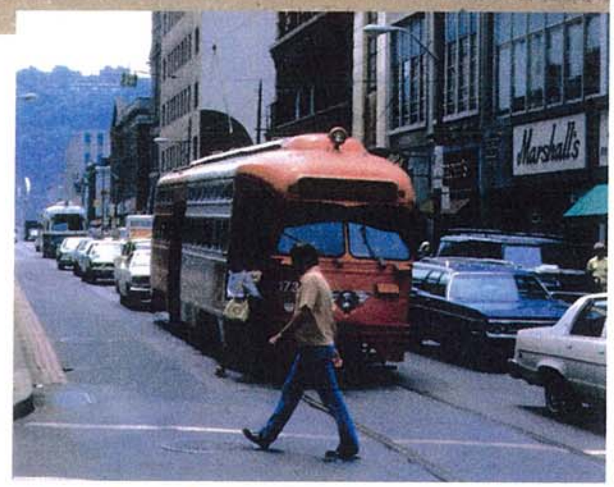
ACT-1 was developed shortly after SOAC to test more advanced sub-sytems. It included a new lightweight truck, a flywheel energy-storage system, an aluminum frame with composite body panels, and modular interiors. The train was tested extensively at TTC in 1977 and 1978. However, few of the advanced features were adopted by the rail transit industry.

ACT-1 in 1975, shortly before delivery to UMTA

Light Rail

In the early 70's UMTA funded Boston's MBTA and San Francisco's MUNI to develop a standard specification for a modern vehicle to replace their aging fleets. A total of 275 of the new **Standard Light Rail Vehicles (SLRVs)** were designed and built by Boeing Vertol. The cars were longer than existing streetcars and were articulated (could bend in the middle) to accomodate tight turns. They also had solid state propulsion controls and much improved ride quality.

As with many innovations, the SLRVs had reliability problems. No other cities purchased vehicles from Boeing Vertol. However, since 1978, most new light rail vehicles have included SLRV-type articulation and propulsion control features.



The first standard streetcars were produced between 1936 and 1952. The vehicles were commissioned by the presidents of transit companies (hence the name: PCC cars). They were extremely serviceable and popular..

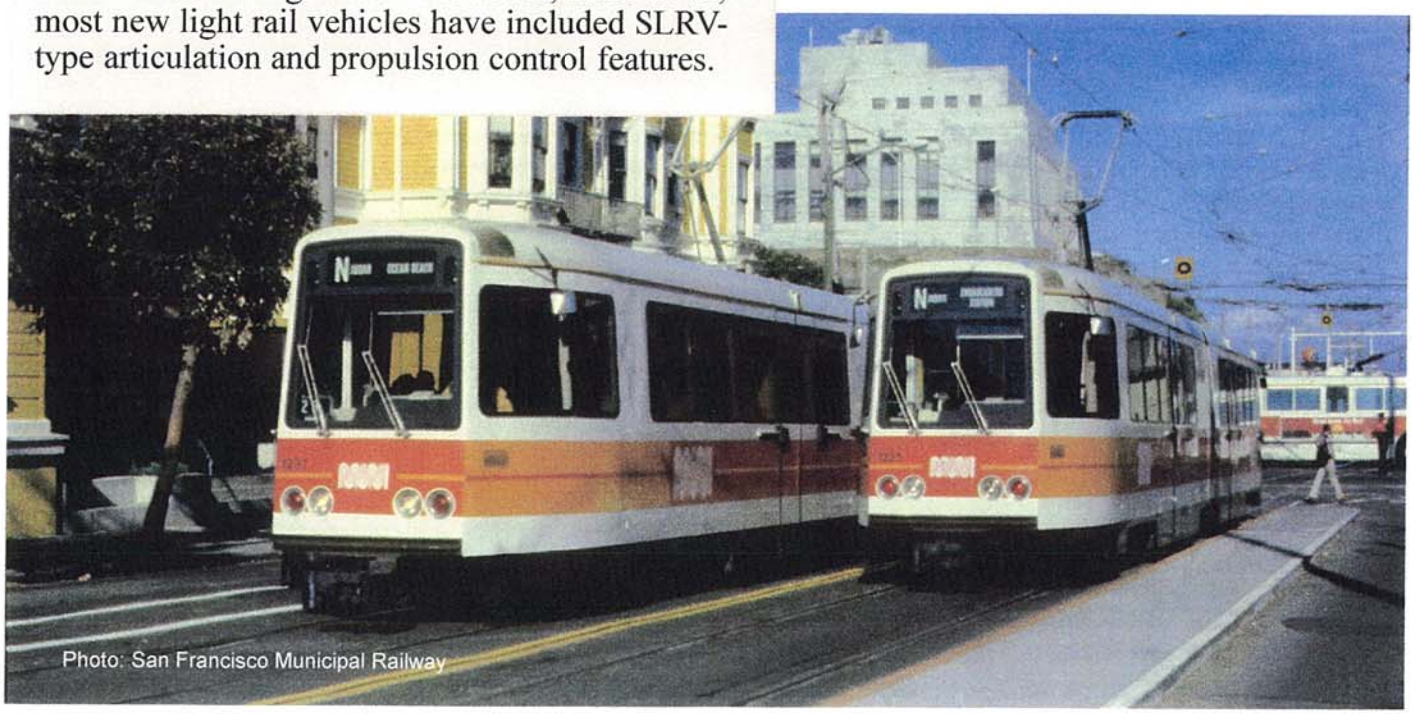


Photo: San Francisco Municipal Railway

Photo: San Francisco Municipal Railway

The SLRV introduced transit agencies to boarding passengers from street level by use of a moveable step or by level boarding from a platform, Although no U.S. manufacturers entered the light rail vehicle field after Boeing Vertol, the popularity of light rail has continued to grow - especially in locations that do not require vehicles to share right-of-way with city automobile traffic

Shown here are the underground San Francisco Market Street platform in 1981, the SLRV interior, and (below) a later model car on the St. Louis, MO Metrolink in 1994.

Photo: Bi-State Development Agency

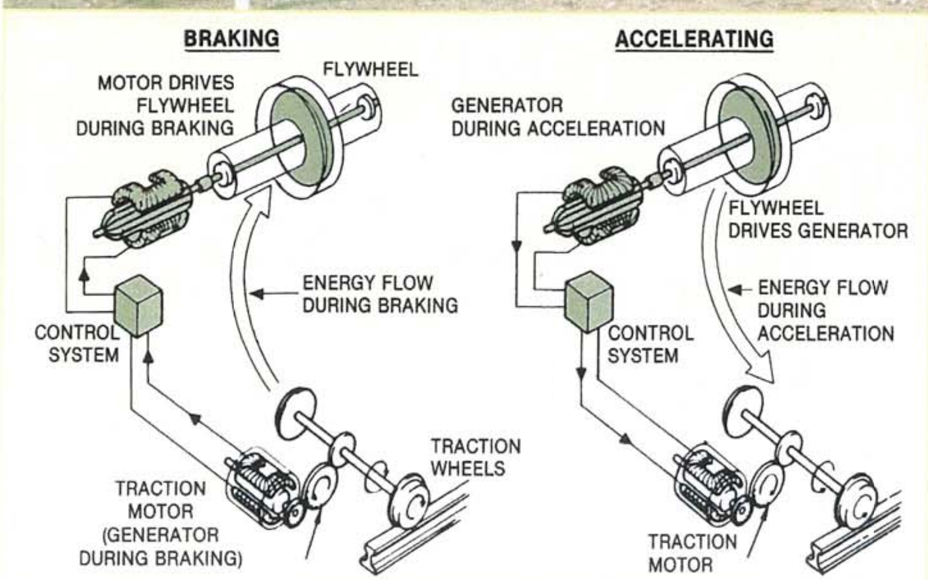
Energy Conservation Projects

From 1971 until after the crisis caused by the OPEC oil embargo, UMTA sponsored several rail energy conservation projects. These included a gas turbine/electric (GT/E) commuter rail car and a stored energy (flywheel) propulsion system for rapid rail.

The GT/E propulsion system had the advantage of being able to use a variety of fuels.

Although a 30% reduction in electrical energy was recorded in tests of the energy storage cars, by 1978, energy costs no longer appeared to warrant the costs of the new systems.

A 1975 photo of the gas turbine/electric train built by Garrett AiResearch for the New York MTA. The MTA used this and a trainset built by GE to compare gas turbines vs. electrification for extending its commuter rail lines.



The two conventional R32 transit cars shown above were retrofitted with flywheel energy storage systems and tested at TTC and in New York City.

As shown in the diagram, braking energy (normally dissipated as heat) is used by the traction motor to generate electrical power that spins the flywheel. During acceleration, the flywheel and attached motor-generator produce elecrical energy to assist in driving the railcar's traction motors.

Alternating Current (AC) Propulsion

From the beginning of the streetcar era (1880's), all electrically powered railcars have used direct current to drive their traction motors. Although AC induction motors were invented early, they were not used to drive railcars because Thomas Edison believed AC was unsafe, and because controlling the speed of the motor depended on being able to change the alternating current frequency.

The advantages of induction motors are: 1) they do not need brushes and commutators and can be sealed, greatly reducing maintenance costs, 2) they are more energy-efficient, and 3) they can be used in braking to regenerate power.

In 1972 and in 1982, as power control improvements became available, UMTA funded demonstrations of AC propulsion on rapid rail systems. The first production systems were ordered in 1986 by Seattle for trolley coaches and in 1987 by Philadelphia for commuter railcars. Today, AC systems have been widely accepted and are being used nationwide.

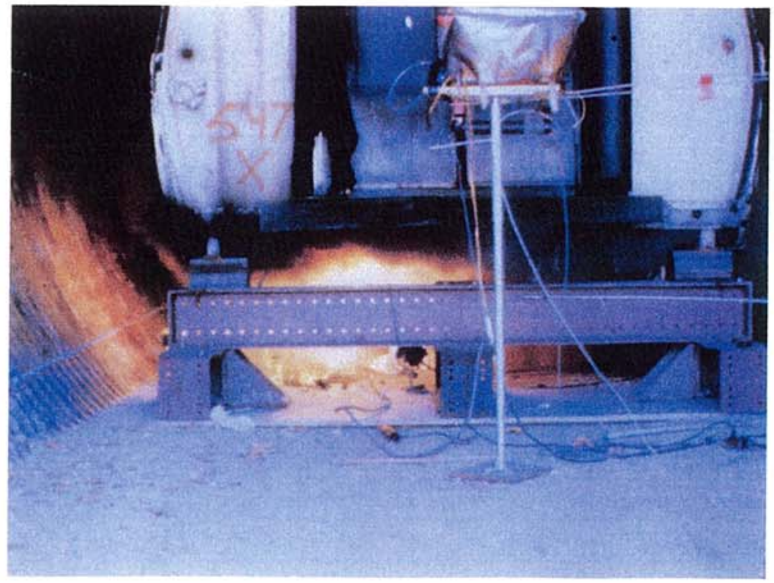
This AC-powered railcar was tested in 1974 on Cleveland Transit System's Airport Line with help from an UMTA demonstration grant. CTS (now Greater Cleveland Regional Transit Authority) began experiments with AC propulsion in 1969.

This AC traction motor was developed by Westinghouse Air Brake Company (WABCO) in the early 1980,s under UMTA's Subsystem Technology Applications Program. It has a totally sealed casing that protects the motor from harsh transit environments and does not need the commutators and brushes that require continuing maintenance in DC motors.

Rail Safety and Security

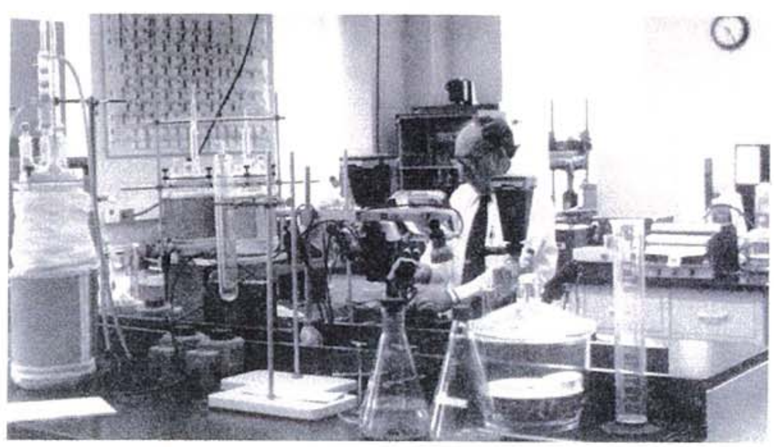
In 1976 UMTA established a high level Office to assure attention to the safety and reliability of systems being funded under the Urban Mass Transportation Acts. Its main purpose was to assist transit agencies to plan and implement safety and system assurance programs. Emphasis was on safety standards and the development of training programs, but the Office also conducted safety reviews and provided expert consulting support.

By 1979 the Office had completed a data bank containing test results of the fire resistance and toxicity of most materials used in transit. It had also initiated transit accident and reliability reporting systems. In 1981 its mission was expanded to meet growing concerns about passenger and employee security.



Following a fire in the BART Trans-bay tunnel, UMTA intensified fire safety research. Pictured above are tests of the interior effects of an underbody car fire. Propane burners were used to provide heat in a simulated tunnel (below)..

Evacuation drills prevent fumbling and help establish the best evacuation routes. Above is a drill at the Port Authority Trans-Hudson (PATH) system in New York City. in 1983.



A materials flammability and toxicity data base was established in 1979 at the Volpe Center in Cambridge, MA. Critical data has been made available to all modes of transportation.

In 1981 the UMTA Safety Program was expanded to cover the common security concerns of transit agencies. These included purse-snatching, mugging, and holdups at fare collection booths. At left is a sophisticated security monitoring center at Miami's Metrorail.

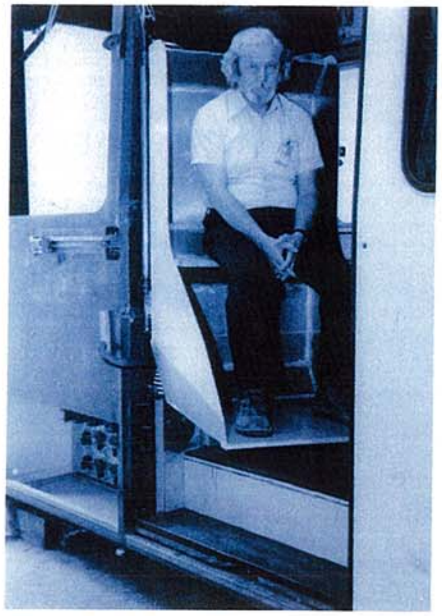
Both air and surface transportation terminals came under the threat of bombings in the early 1980's. Passenger storage lockers were especially susceptible. At right is a training program at the DOT Transportation Safety Institute in Oklahoma City that was expanded in 1982 to include management of explosives incidents.

Increasing popularity of light rail in the past two decades has led to some new safety concerns. Although the new systems mostly avoid crowded downtown streets, they often cross busy roads in suburbs. UMTA/FTA has supported studies of the best ways to minimize pedestrian and automobile accidents at grade crossings.

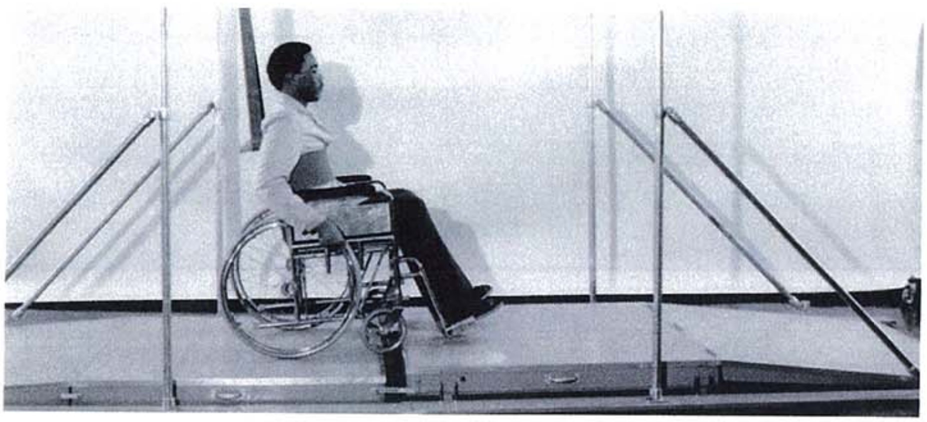
Rail Transit Accessibility

Starting in 1973, all new transit systems that used federal funds were required by DOT to be fully accessible to riders with disabilities. Older systems were to be upgraded on schedules approved by the Secretary.

Wheelchair accessibility on existing systems was rare and presented a real challenge to transit agencies. During its first two decades, UMTA performed extensive safety research. It also developed and tested lifts for all types of vehicles.



The wheelchair lifts (above) were developed in the late 1970"s for light rail and commuter rail systems that required steps for boarding.



Using the simulator shown at left, the Veterans Administration Research and Engineering Office helped establish safety guidelines for horizontal and vertical gaps between subway railcars and station platforms.

Commuter and light rail systems were especially difficult to make accessible, because of their low platforms. This "mini-high" plaform was adopted by the Sacramento RTD and several other light rail lines.

The Americans with Disabilities Act of 1990 extended accessibility and employment rights to all institutions serving the public. It also strengthened requirements to accomodate persons with sight and hearing impairments and resulted in more employment (and more public transportation needs) of people with disabilities.

The new rail lines built during the 70' and 80's experimented with tiles and other materials that could be felt underfoot and would warn passengers of the platform edge. Between 1991 and 1995, UMTA funded development and tests of plastic tactile materials that could be used on new and existing platforms. A light rail installation in Sacramento is shown on the left, and a Miami rapid rail platform on the right.

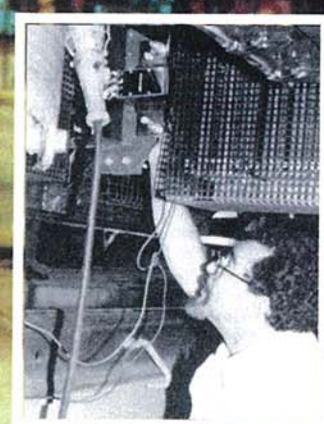
Rail Technologies

Because no new rail transit system designs had been introduced in over 60 years, urban rail technologies in the U.S. did not advance as rapidly as technologies in other transportation fields. With no capital grants available for new rail starts after 1980, UMTA directed its shrinking R&D funds to subsystem and technology projects that could improve the safety, reliability, efficiency, and comfort of existing systems.

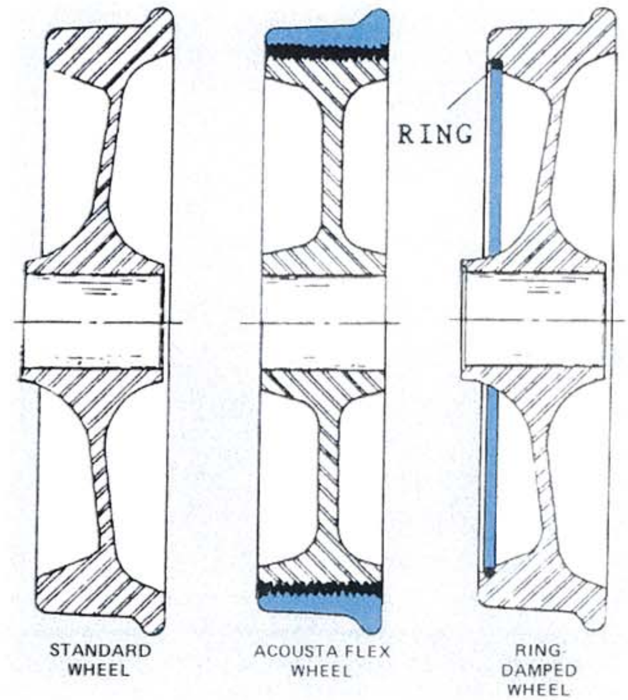
The emphasis was on low cost changes. In addition to the AC Propulsion Program, projects included improvements that would:

- Prevent Electromagnetic Interference,
- Reduce the effects of snow and ice,
- Reduce urban rail noise, and
- Increase the reliability of doors, auxiliary power supplies, and air conditioning.

In addition the program developed computer programs that optimized rail system energy use.

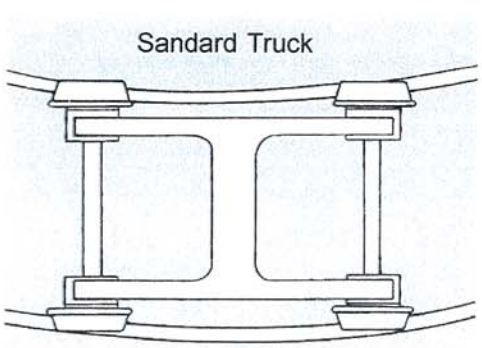


Instruments to measure electromagnetic fields are installed above on new MARTA railcars in Atlanta. The test program was necessary to detect and prevent interference between modern propulsion units and automated train controls.

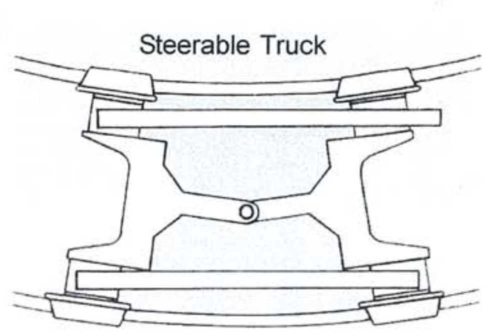


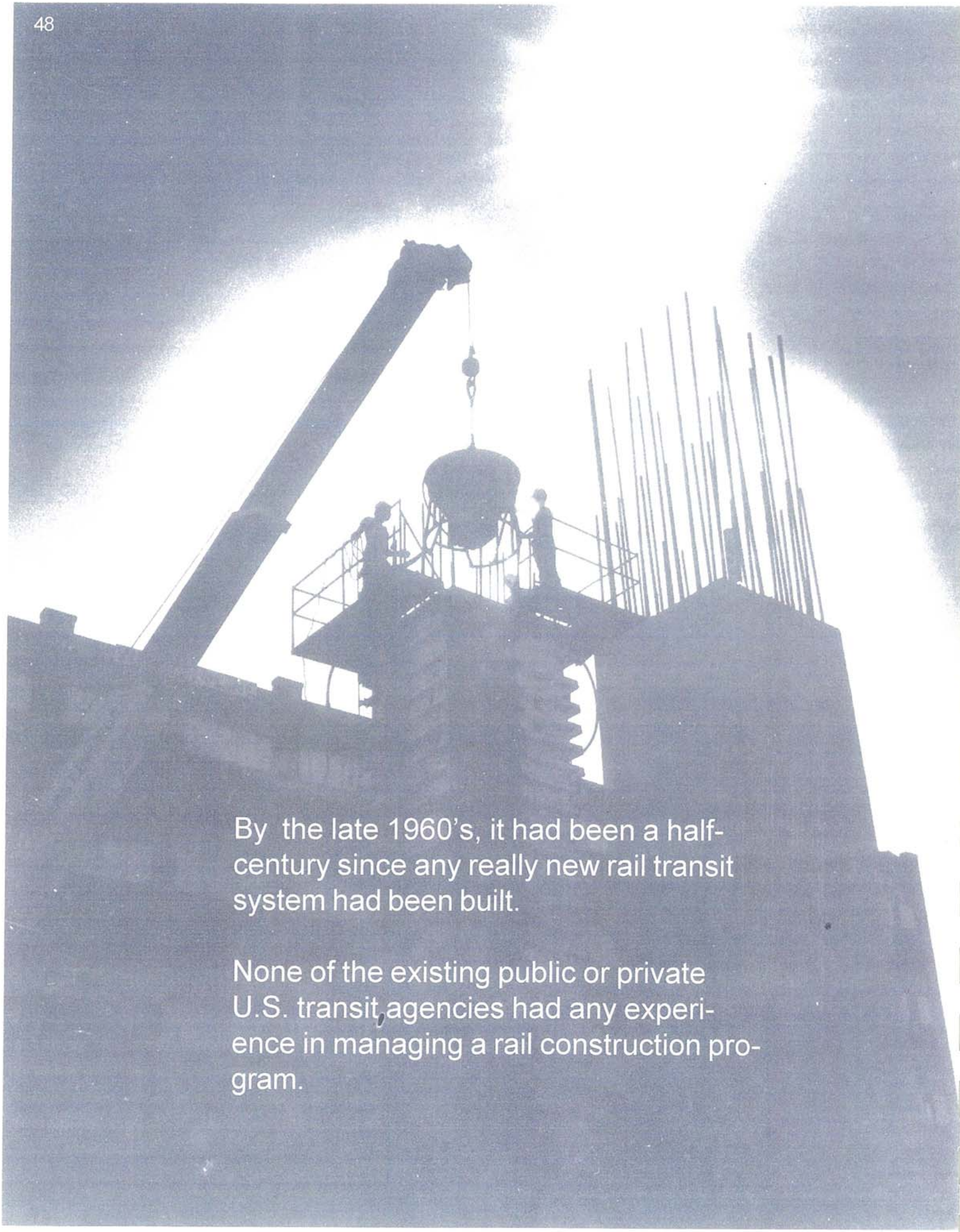
Urban rail noise can be uncomfotable for passengers, especially when railcars squeal on tight turns. During the 1970's, UMTA tested resilient wheels and damping methods to reduce groundborne as well as airborne noise. Above is a ring that dampens squeal vibrations when inserted into the wheel rim. Noise reduction methods are now used on most subway and light rail systems in the U.S.

"Screech Loop" at the Transportation Test Center in Boulder Colorado



Another means for reducing noise is to turn the wheels or axles so that the axis of each wheel remains perpendicular to the rails. Development of a steerable truck was terminated in 1981 and resumed in 1990. Interest was revived because steerable trucks have proved to provide significant reductions in wheel and rail wear.





By the late 1960's, it had been a half-century since any really new rail transit system had been built.

None of the existing public or private U.S. transit agencies had any experience in managing a rail construction program.

4. CONSTRUCTION

Dupont Circle Station, Washington, DC

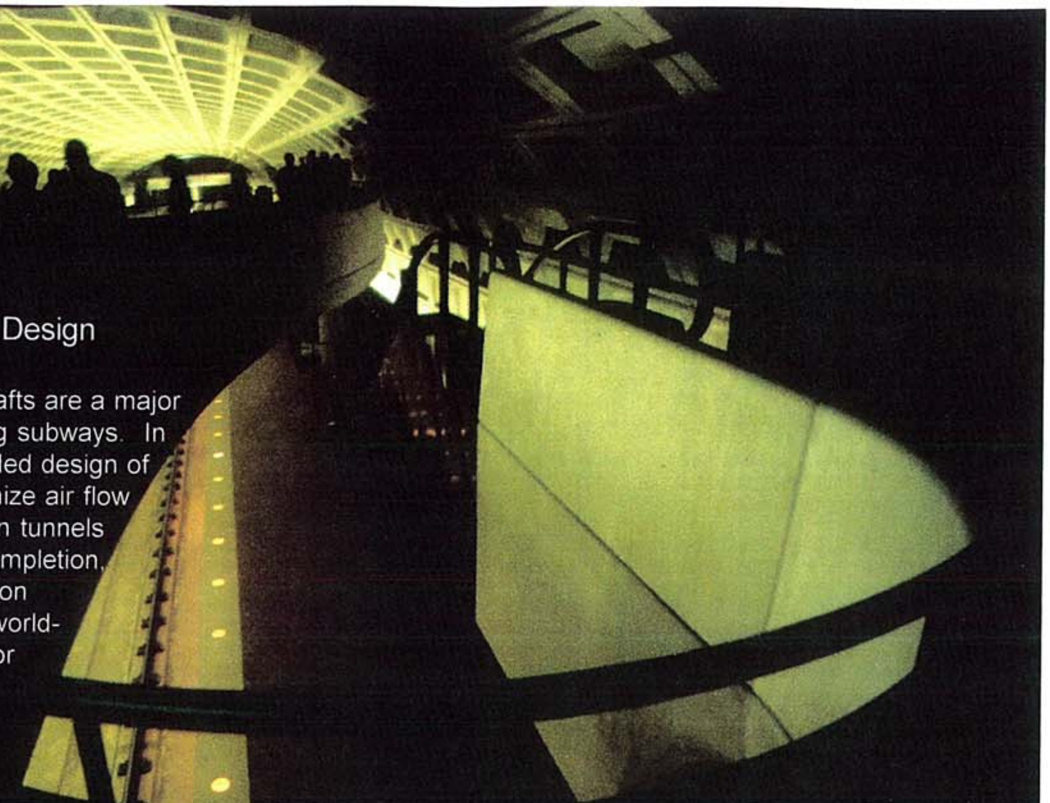
Photo: Paul Myatt for WMATA

Construction

When construction of new rapid rail systems resumed in the 1970's, the difficulty of introducing a new system (or extension) into a highly congested area was grossly underestimated. By 1980 elevated structures cost almost $40 million per route mile and underground construction in urban areas approached $100 million per route mile. To add to these problems, local governments demanded that disruption of businesses and highway traffic be held to a minimum.

To make the most of its R&D budget, UMTA focused on techniques for construction planning and management, and on new equipment and techniques that could reduce the costs of construction.

Harvard Square, Cambridge, MA

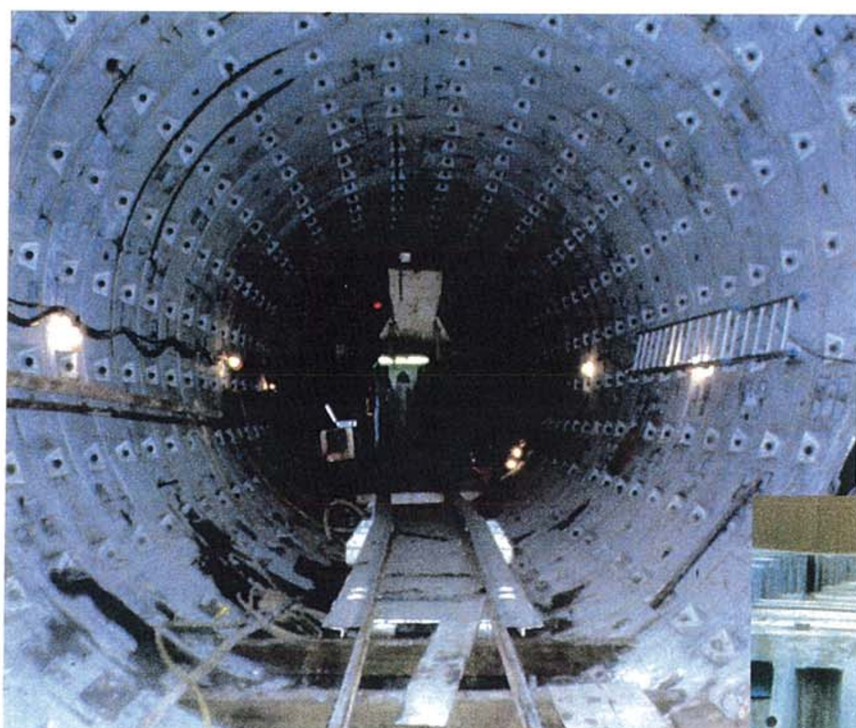


Subway Environmental Design

The costs of ventilation shafts are a major part of the costs of building subways. In the late 1970's, UMTA funded design of a computer model to optimize air flow and temperature controls in tunnels and stations. Since its completion, the model and its companion handbook has been used world-wide on virtually every major rail or transit tunnel.

In the late 1980's, the original computer program was expanded to include a fire model to address heat and smoke removal in the event of a major tunnel fire.

Ventilation for this underground station in Washington, DC was designed with the help of UMTA's simulation model and handbook.

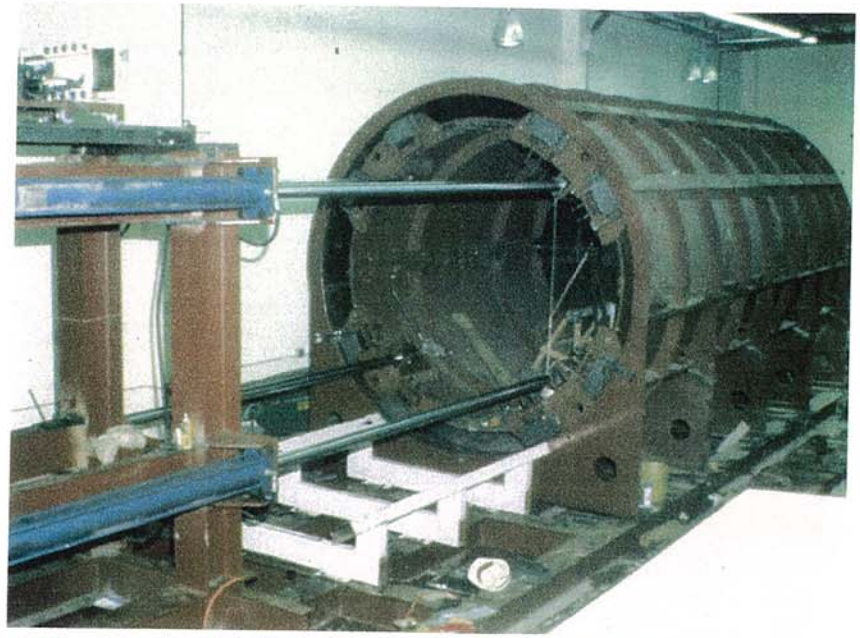


Tunneling Technologies

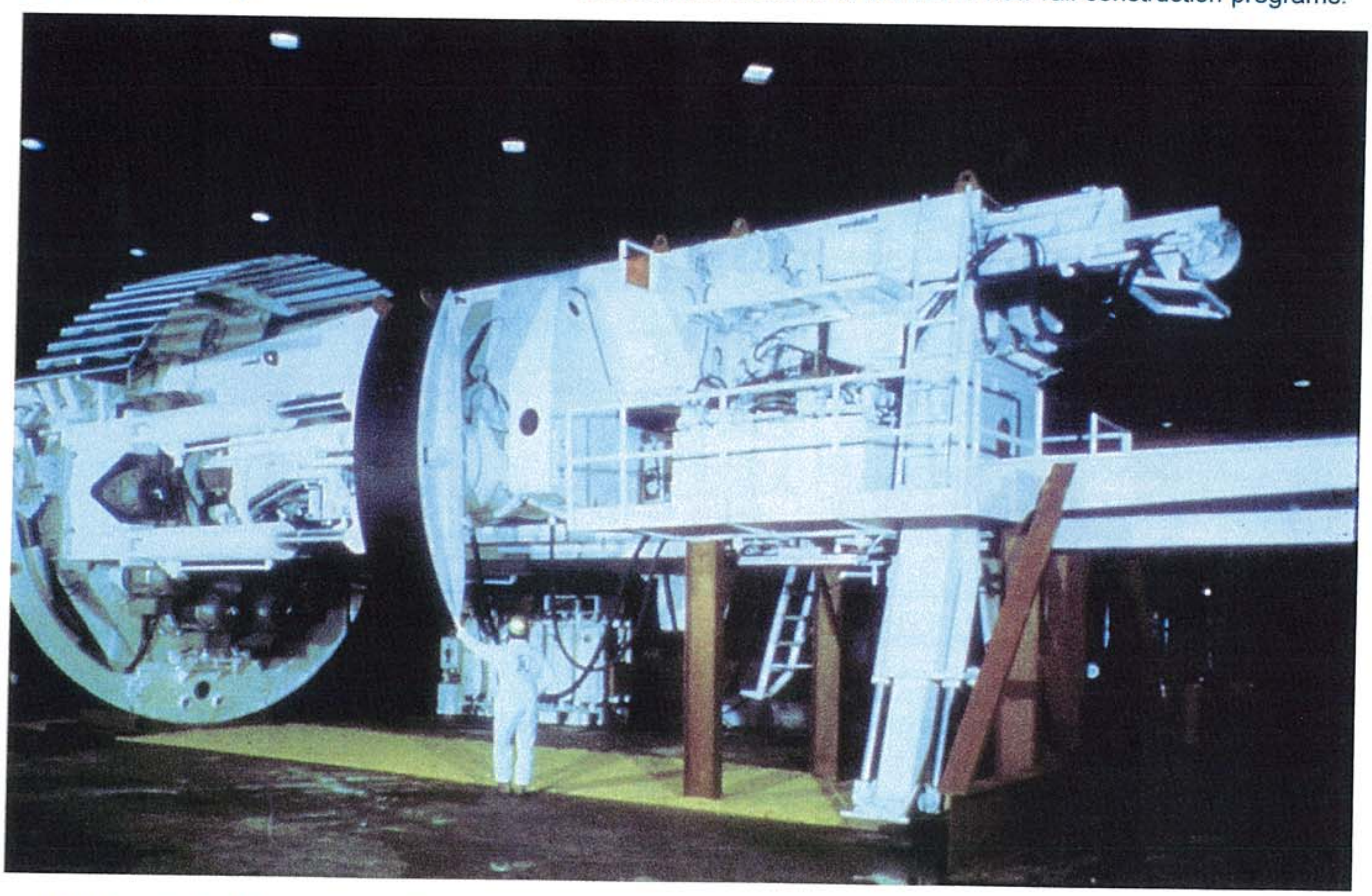
To help reduce construction costs, UMTA evaluated new foreign and domestic technologies and made the results available to U.S. agencies. Studies and tests included subsurface exploration and measurement techniques, excavation methods, soil and rock stabilization techniques, and how best to dispose of materials excavated from the tunnel.

Tunnel liners are essential in soft ground. The pre-cast concrete liners shown here were introduced to U.S. transit in 1976 in a section of Baltimore's Lexington Market tunnel. Costing about half as much as steel, precast concrete liners have been widely used ever since..

Grout Injection, a common European practice, was introduced in Washington and Baltimore tunnels. A mix of clay and cement was injected into soft ground to prevent intrusion of water and stabilize the soil in order to protect the worksite and nearby buildings.



The ability to create a continuous **Extruded Tunnel Liner** was demonstrated with this machine. The system was designed to attach to the cutting head of a tunnel boring machine. Quick-setting concrete was pumped into a sliding form to create a liner directly behind the cutting head, thus saving costs of both temporary and permanent liners. Although prototype tests were successful, the project was discontinued because of the halt in new rail construction programs.

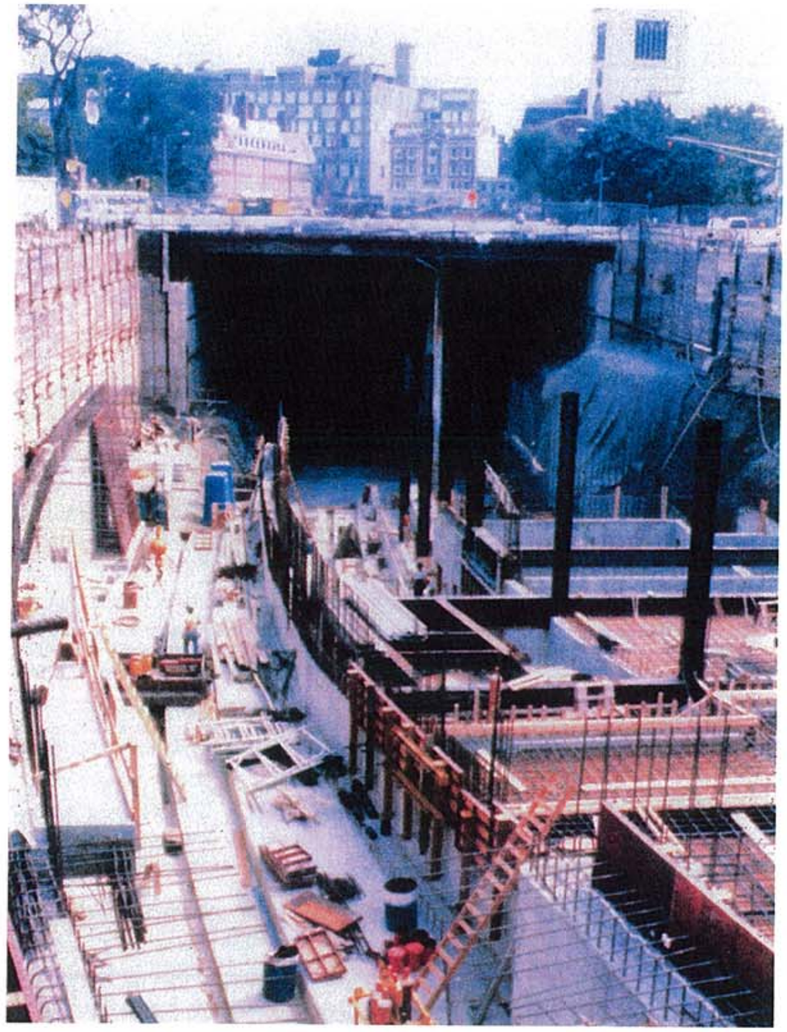


UMTA evaluated four models of tunnel boring machines that were used in construction of transit tunnels in Buffalo. These giant machines cost from $1 to $2 million each and can cut through hard rock at up to 20 feet per day. Because of the differences in performance among various cutting heads and types of rock, it was important for transit agencies to know the characteristics of each type. Results were shared with the tunneling industry.

Slurry Wall Construction

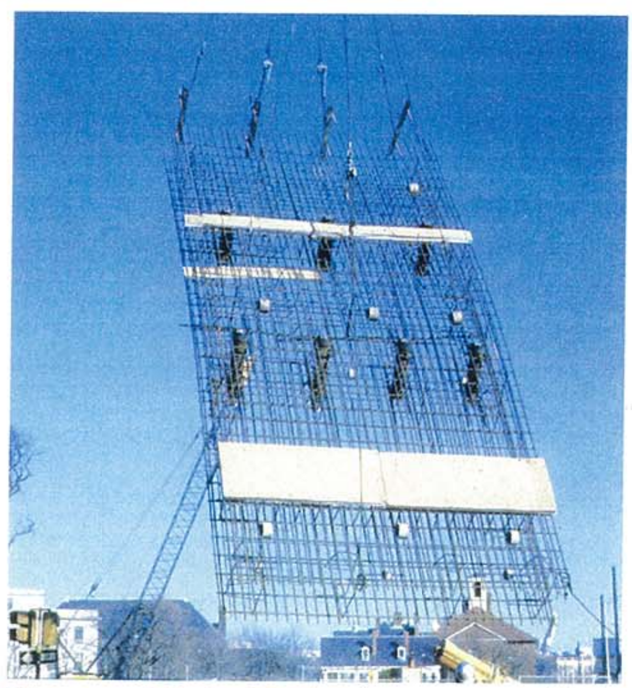
In 1979, the Federal Highway Administration and UMTA jointly monitored a new technique for construction of tunnels and stations in Cambridge, MA. It involved digging a narrow trench that was continually filled with a slurry mix of clay, fine sand, and water to keep the sides from falling in. When filled from the bottom up with concrete, the resulting walls were spanned with steel beams to maintain traffic flow. After the soils underneath were excavated, the same wall became a permanent side of the underground structure.

The slurry wall technique permitted construction within a few feet of businesses and historic buildings. Although automobile traffic, retail sales, and access to Harvard Yard were disrupted, they were not shut down. The technique saved millions of dollars, and is now used extensively in highway and transit construction.

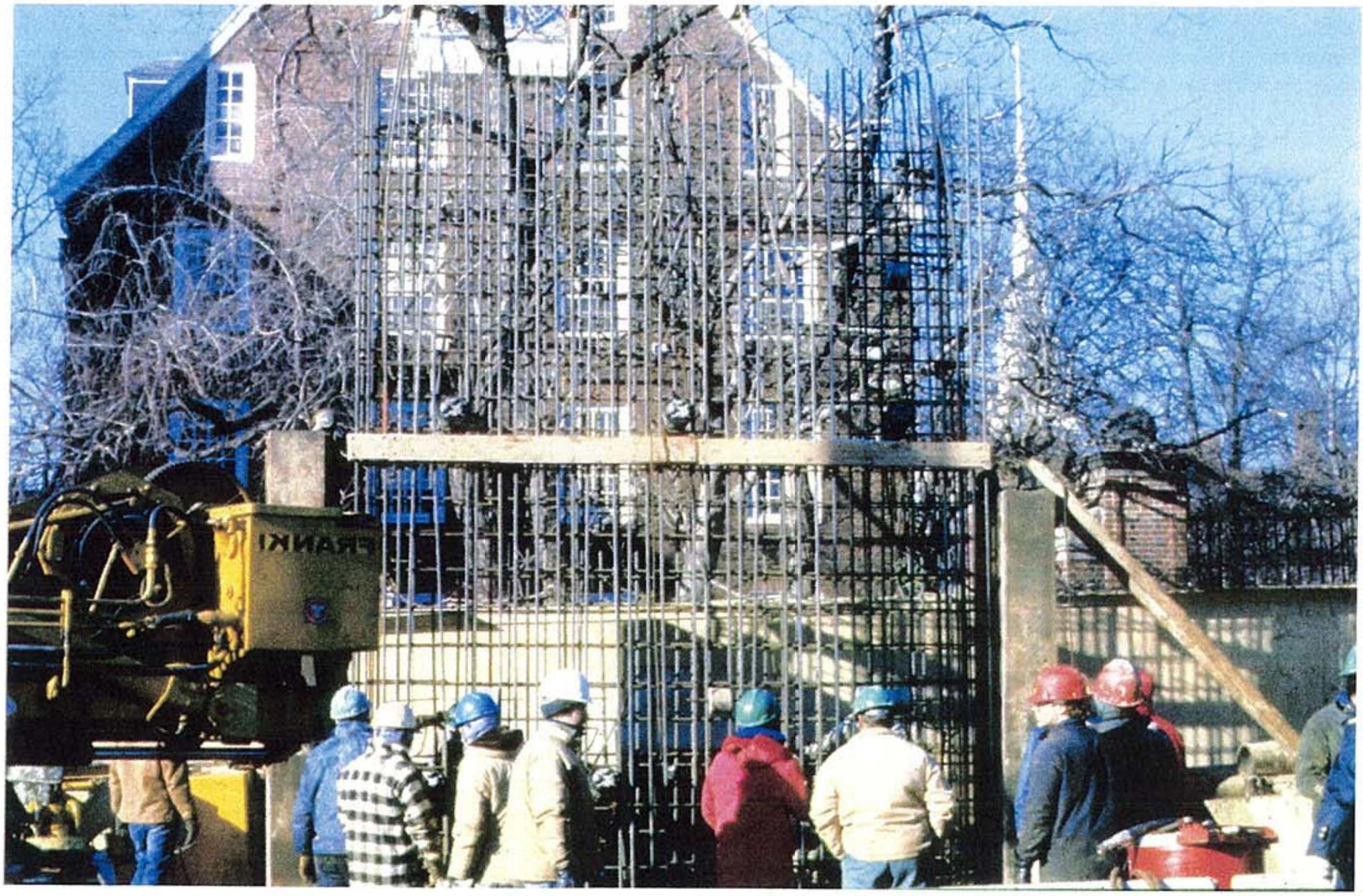


The slurry wall at the rear of this picture allowed large areas to be spanned without temporary support structures. It also avoided the costs of temporary pilings and wooden forms.

This specially designed clamshell was used to dig a narrow trench 40 feet deep. The slurry mix of clay and water was pumped into the trench as digging proceeded.



This cage of steel reinforcing bars was assembled on-site. It contained solid pieces that provided indentations and holes for crossbeams and anchors.



After the trench is excavated, the cage sections are lowered through the slurry. This section is only about five feet from a World War I memorial wall.

Next, concrete is piped to the bottom of the trench. As the concrete is added, the slurry rises to the top and is pumped off. It is then processed for re-use.

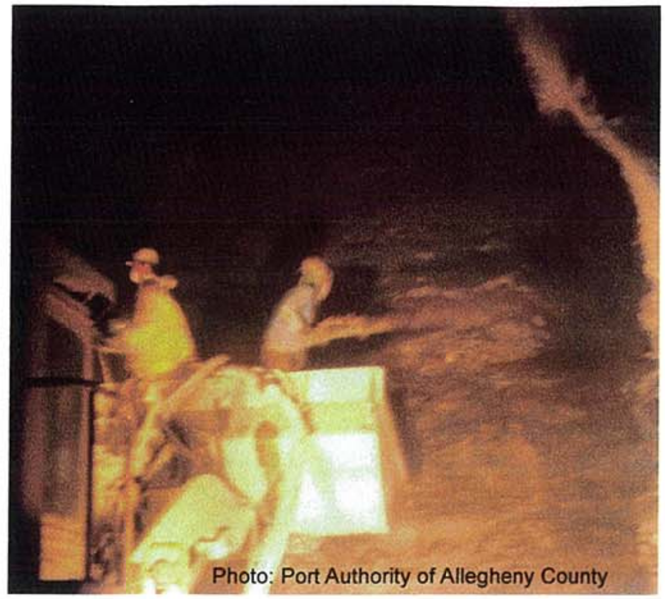
When the concrete has hardened, the tunnel is excavated and the walls are anchored to the soils outside the tunnel. Anchors consist of nests of reinforcing bars that are spread apart outside and then stabilized by injecting a grout.

New Austrian Tunneling Method (NATM)

The NATM was first used in Austria in 1954 to construct an aquaduct in soft ground at a power plant. Following several successful applications in Europe, it was used in the 1970's on more than two thirds of Germany's new transit tunnels. The method consisted of spraying shotcrete (a mixture of concrete and reinforcing fibers) to create a tunnel liner.

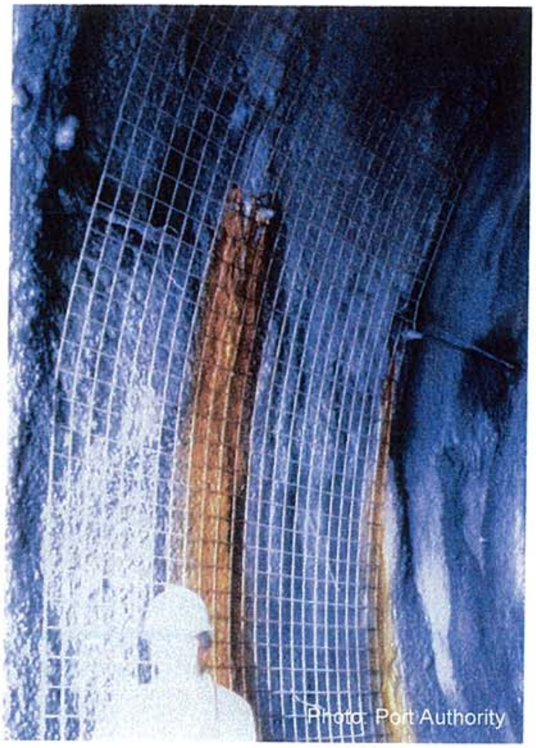
In 1979, The Port Authority of Allegheny County used the NATM in Pittsburgh using bolts set in pre-drilled holes in the rock facing. The resulting liner helped to support the rock mass located above. The Port Authority also pioneered a contracting approach that allowed design decisions to be made as actual rock conditions were observed. The method resulted in even greater savings than on earlier projects, and is now used widely in the U.S.

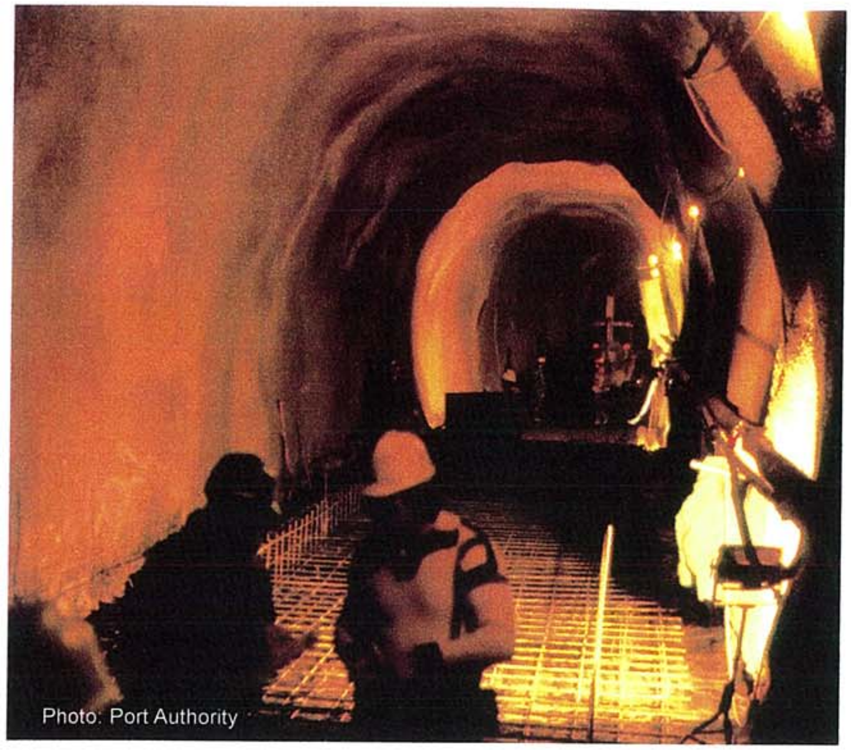
The NATM was applied to rock tunnel construction in New York City and Washington, D.C., saving more than $90 million over conventional tunnel lining methods.



The Port Authority of Allegheny County used the **New Austrian Tunneling Method** in constructing its Mount Lebanon Tunnel. The tunnel connects downtown Pittsburgh with communities to the south. It was needed for a new 22-mile light rail line.

After blasting and excavation were completed, the tunnel was sprayed with a mixture of concrete and reinforcing steel fibers (shotcrete) to create an outer tunnel lining.





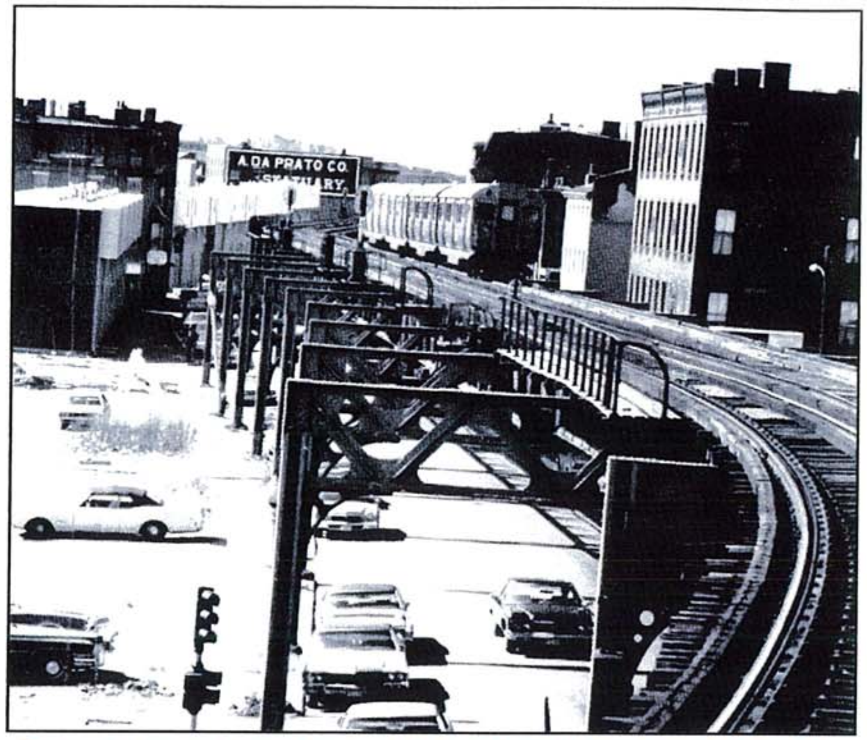
An inner tunnel liner was constructed where required for structural support. To accomplish this, wire mesh was fastened to bolts set into the concrete and rock, and the area was sprayed with additional shotcrete.

The photo at left above shows the outer liner with rockbolts and wire mesh attached. Stains from water intrusion are also visible. At right is the tunnel with inner liner complete. Below: the Mt. Lebenan tunnel in use.

Elevated Structures

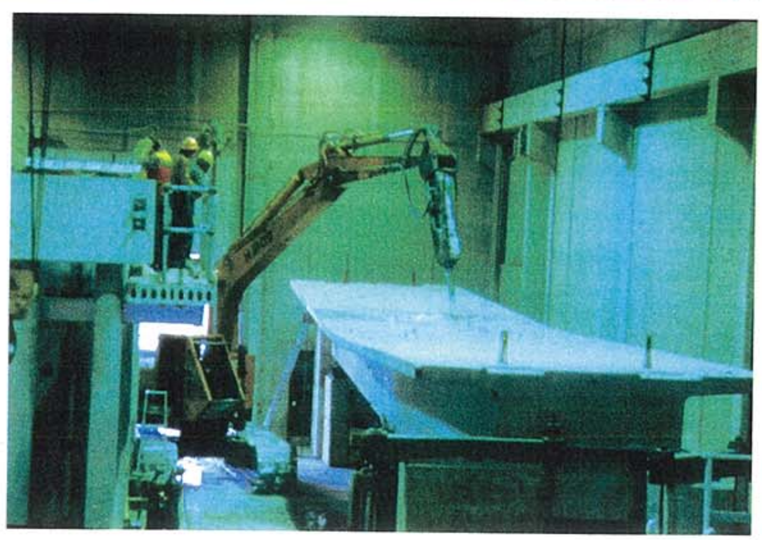
In 1978, UMTA began a series of brief studies aimed at developing improved design and construction procedures for aerial structures. The objectives were to obtain structures that were less obtrusive, while still reducing construction and maintenance costs. The studies used mathematical models to evaluate designs and produce design criteria for use by transit authorities.

In 1979, U.S. rapid rail transit systems had 423 miles of elevated track, 281 miles at grade level and 636 miles in tunnels. 56 more miles of elevated trackage were under construction.



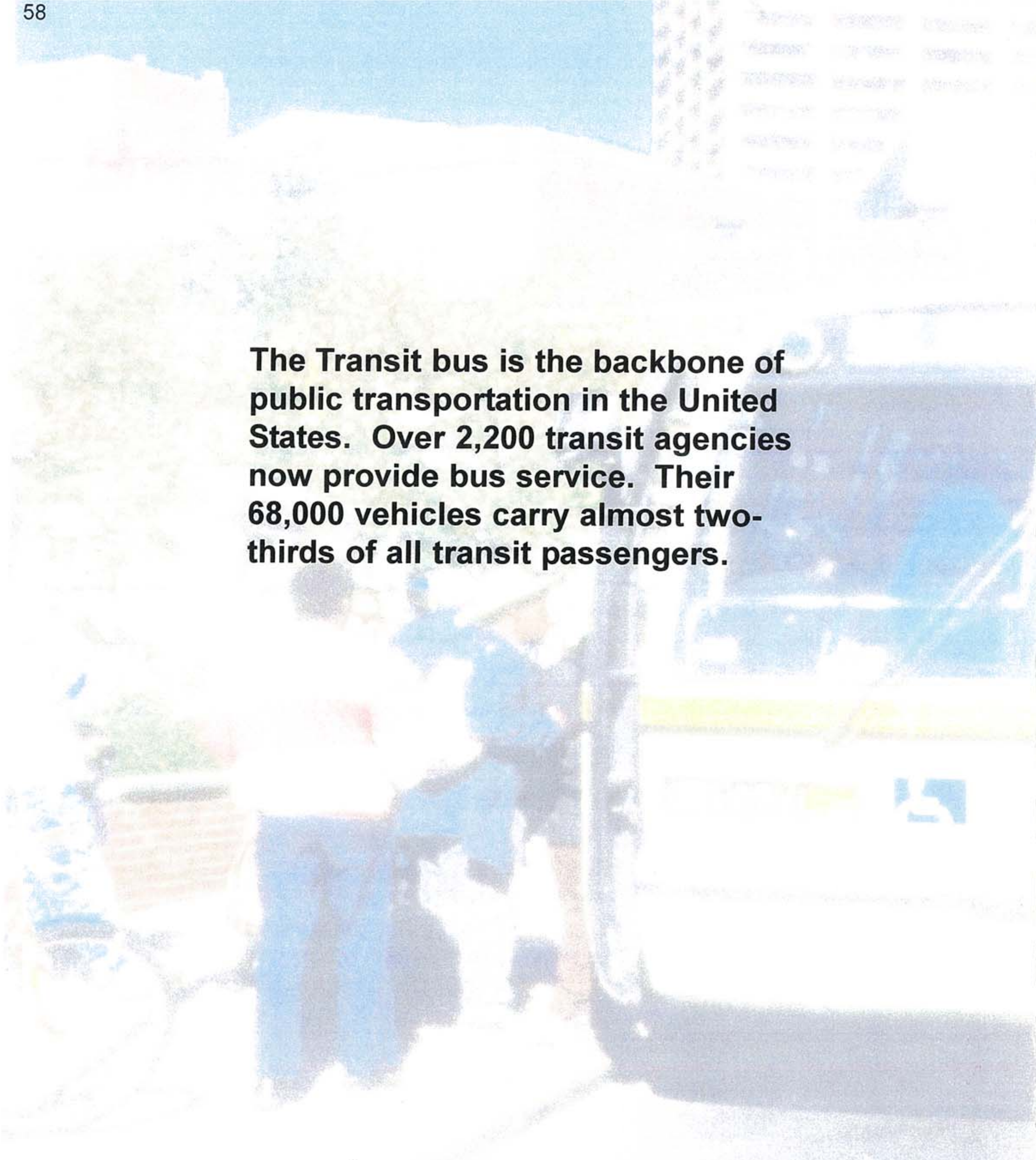
Elevated track sections built before 1960 were extremely noisy and unattractive. Train noise tended to resonate through the structure regardless of noise absorbing and shielding measures.

Beginning in the 1970's precast reinforced concrete structural members replaced steel for most new elevated construction. Above is a dual track and passenger station section of a Washington D.C. METRO extension.



Above, a double-tee girder is being installed on the Miami-Dade Metrorail system in 1981.

At right, a double-tee girder is bend-tested for the Miami-Dade Transit Authority.



The Transit bus is the backbone of public transportation in the United States. Over 2,200 transit agencies now provide bus service. Their 68,000 vehicles carry almost two-thirds of all transit passengers.

Photo: Massachusetts Bay Transportation Authority

5.0 BUS VEHICLES

Photo: Paul Myatt for WMATA

Bus Vehicles

When UMTA research and development began, the standard city bus was clearly the most affordable way to meet public transportation needs in cities and towns throughout the country. The vehicle that was available at that time was called the "New Look" bus (above and inset). It was produced by three manufacturers based on a design introduced by General Motors in 1959.

With their rear-mounted engines and distinctive styling, these buses were extremely rugged, often accumulating over 600,000 miles during a 12 to 15 year lifespan.

UMTA's first large-scale bus program focused on development of a modern 40-foot transit bus that could provide wheelchair accessibility. In 1971, UMTA sponsored development of three prototypes. Although developers of the "Transbus" used a systems approach and recent technologies, none of the versions were ever produced in quantity.

Increasing mandates to improve fuel economy, accessibility, and air quality led UMTA next to concentrate R&D resources on incremental improvements to bus components and to testing of commercially developed vehicles rather than on development of whole new vehicles.

Design and safety-testing of wheelchair lifts and wheelchair restraints were key issues addressed during the late 1970"s

Until R&D funds were reduced in the early 1980's, a substantial number of energy conser vation and air quality projects were also started, including battery propusion, energy storage technologies and alternative fuels

Transbus

After 1959, the market for transit buses had not induced any U.S. manufacturer to develop a bus that used modern automotive technologies. In 1971, UMTA launched a program to develop a standard city bus with substantial improvements in safety, accessibility, ride comfort, fuel economy, and maintainability. General Motors Corp., Rohr Industries Inc., and AM General Corp., each designed, built, and tested three prototype vehicles that met Transbus performance requirements.

In 1979, a consortium of transit operators advertised for bids for 530 buses meeting Transbus production specifications. However, bus manufacturers declined to bid, citing business decisions based on investment costs, estimated market, and the risks of employing relatively new technologies on a tight schedule.

Transbus prototypes at Pueblo, Colorado in 1974

An important design requirement of Transbus was a low floor that would provide easier access for elderly and handicapped riders. Above is the Rohr prototype bus in its kneeling position with ramp extended. All three prototypes had such a kneeling capability.

At left is the interior of one of the AM General prototypes. Modern styling was considered in evaluating prototypes and the appearance and ride comfort of all three models received excellent marks in public acceptance tests.

General Motors Corp.
Prototype Transbus

The GM prototype's body consisted of a welded stainless steel frame with outside panels of a fiberglass/acrylic composition. It was driven by a Detroit Diesel/Allison gas turbine engine and had tandem rear axles, a wide double door, and independent air suspension at all wheels.

Rohr Industries Inc.
Prototype Transbus

The Rohr Industries prototype body had a structure that used the outside shell of steel-reinfoced aluminum to provide much of the strength normally found in a chassis. The bus had two steering axles and two drive axles at the rear. It could obtain a kneeling height of 14 inches, allowing almost level entry from a curb.

AM General Corp.
Prototype Transbus

The AM General prototype also used the body shell for strength. Instead of aluminum, its skin consisted of steel stampings. Front and rear double doors pivoted inward. The bus was powered by a Caterpillar turbocharged diesel motor. Kneeling was controlled by hydraulics at front and rear.

A 1980 photo of a General Motor's RTS-04 series 40 ft. bus at the Southeast Michigan Transit Authority (now Detroit DOT). The bus featured a stainless steel unibody and stainless steel wheelwells.

Advanced Design Bus

Following the Transbus program, UMTA released an alternative Advanced Design Bus specification that provided for competitive bidding but relaxed several Transbus requirements. The specification was developed in cooperation with a working committee of the American Public Transit Association (APTA) that included both manufacturers and transit authorities.

After 1978, large quantities of Advanced Design Buses were produced, incorporating many of the technologies developed under Transbus including: shatterproof windows, a kneeling capability, impact-resistant plastic bumpers and side panels, substantial ride comfort improvements, and modern air conditioning.

The Grumman Flxible Model 870 featured energy-absorbant bumpers and a 71 percent parts reduction over the "new look" buses built by Flxible.

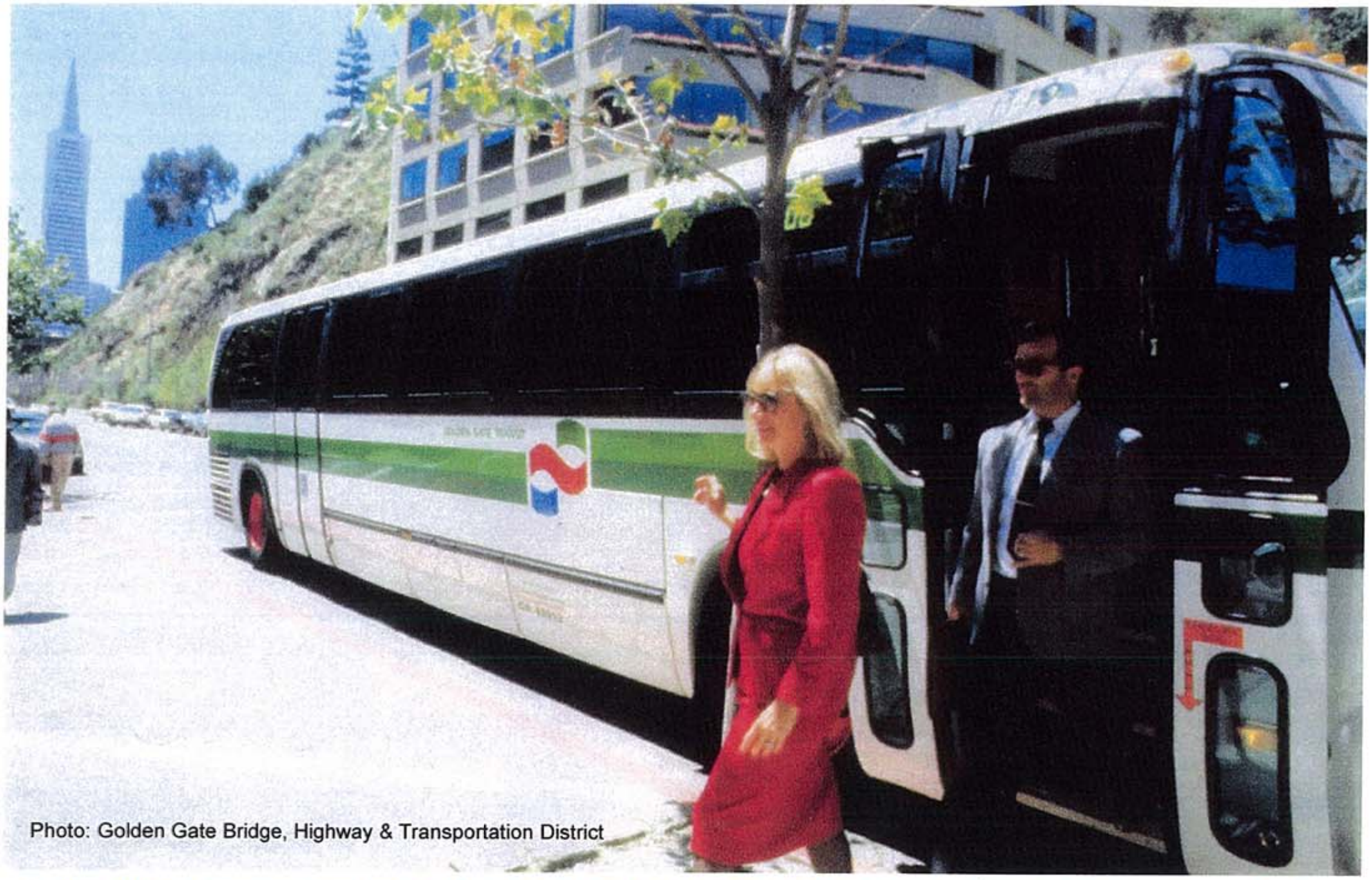


Photo: Golden Gate Bridge, Highway & Transportation District

In the 1980's improved versions of both the GM vehicle (above) and the Flxible model (below) were produced with openable windows and better fuel efficiency. In 1983 Flxible was sold to General Automotive Corporation (GAC) which produced more than 3,000 vehicles in the next five years.

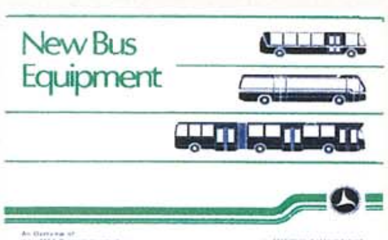
Photo: Washington Metropolitan Area Transit Authority

Photo: Gillig Corporation

Gillig 30 ft. Phantom 1981

New Bus Assessments

In the late 1970's, UMTA encouraged foreign and domestic bus manufacturers to demonstrate new vehicles at U.S. transit authorities. It also funded tests and test specification developments.



A new program in 1981 allowed transit authorities to buy innovative vehicles with Capital Assistance funds so that they could evaluate improvements in fuel economy, accessibility, and reliability.

The program was applied to buses of all popular sizes, including articulated and small buses (small buses are illustrated in *Chapter 6. Paratransit*).

Neoplan City Bus 1980

The Neoplan Company of Germany built a manufacturing plant in Colorado for the U.S. market. The Flyer Ind. bus (Canadian) was a modern version of the rugged 1959 GM New Look bus and became quite popular.

Flyer Industries D901 1979

AM General Articulated 1978

Bluebird Citybird 1980

In the 1970's, UMTA encouraged transit agencies to evaluate the high-capacity articulated buses being introduced into European cities. A joint venture between M.A.N. of Germany and AM General began delivery of production models in the U.S. in 1979. A prototype is shown above.

Following UMTA changes in procurement requirements in 1982, many more manufacturers entered the transit bus market. Small cities were especially in need of a medium-sized (30-40 ft.) bus. Above and at right are medium-sized transit buses built by experienced schoolbus manufacturers.

Carpenter Citybus 1982

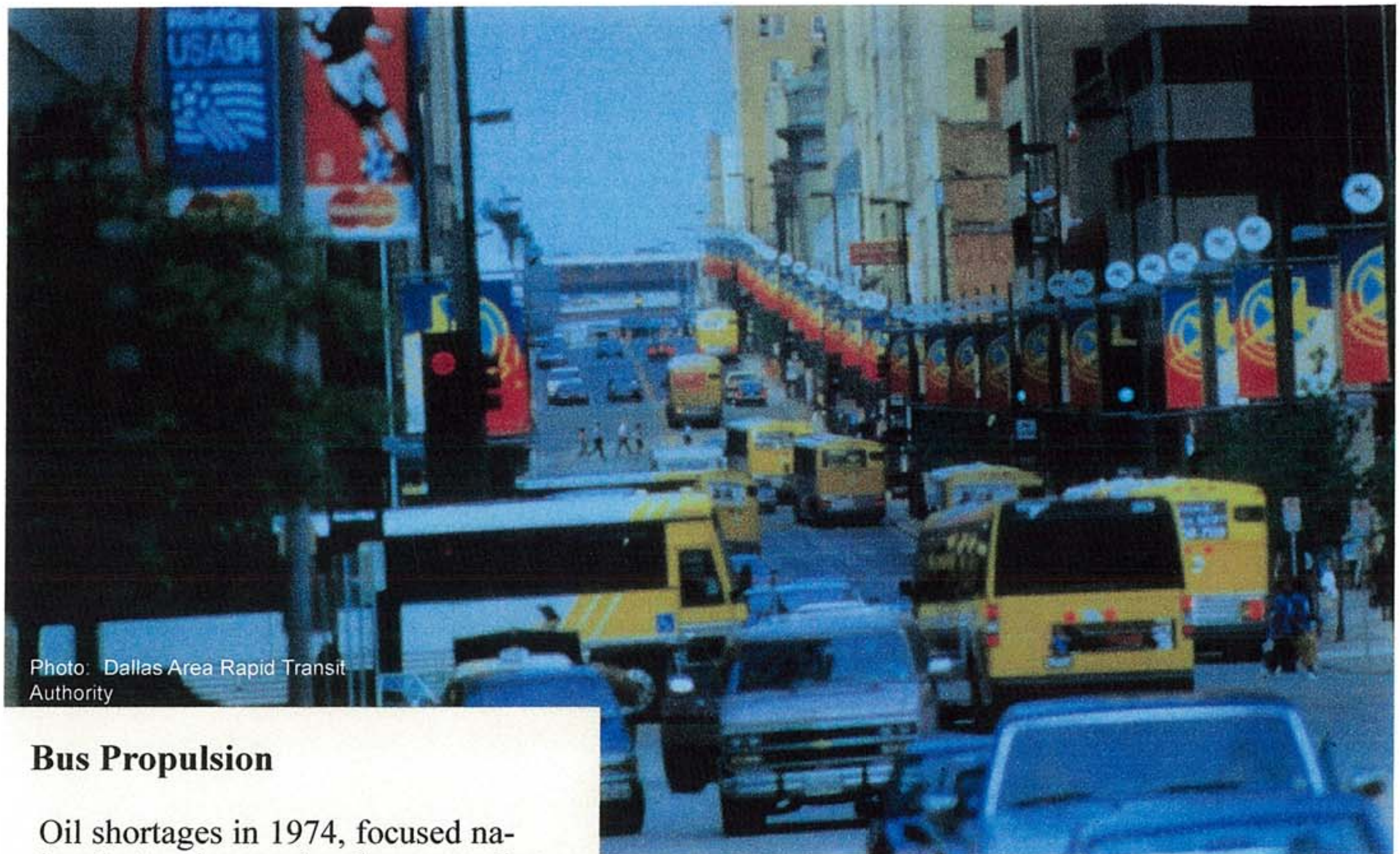


Photo: Dallas Area Rapid Transit Authority

Bus Propulsion

Oil shortages in 1974, focused national attention on developments that could reduce America's dependence on petroleum-based fuels. Because transit agencies own and maintain large fleets of similar vehicles they were among the first to be charged with improving the efficiency and reducing the emissions from their vehicles.

To that end, UMTA/FTA instituted studies and test projects in:

Battery Propulsion
Trolley Coach Improvements
Alternative Fuels, and
Hybrid Propulsion Systems

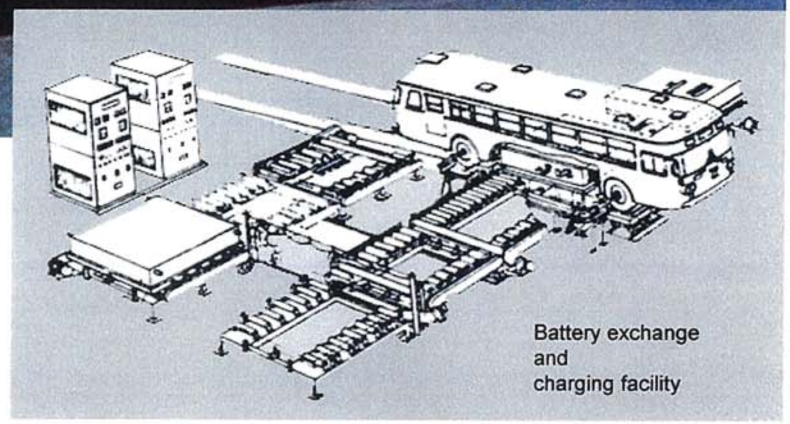
Although UMTA's advanced propulsion research programs were eliminated in the 1980's, Congress mandated a joint DOE/DOT program in 1986 to test the feasibility of using **Fuel Cells** (developed for space probes) as an entirely new electrical power source for urban buses.

Propulsion R&D was resumed in the early 1990's as a result of greatly strenthened Federal laws covering both clean air and energy conservation.

At the start of the propulsion program, existing privately-developed vehicles were evaluated for transit agency use. Above is a Lear Steambus in 1972.

In 1978 UMTA contributed to a major Department of Energy program to develop a gas turbine urban bus that could improve fuel efficiency and emissions and would be capable of using a variety of fuels.

Battery Bus 1975



Battery exchange and charging facility

Battery-powered buses were among the first new technologies to be considered for transit. Although they were operating in several European cities, the time needed for battery charging made most applications too expensive. Extra sets of batteries needed to be recharged and changed during the day to maintain schedule, and batteries needed to be totally replaced every few years.

However, with battery improvements in the 1980's, the clean, quiet characteristics of electric propulsion proved ideal for areas crowded with pedestrians. Below are the Santa Barbara Waterfront-Downtown Shuttle (operational in 1991) and the Denver Mall (open 1982).

Photo: Santa Barbara MTD

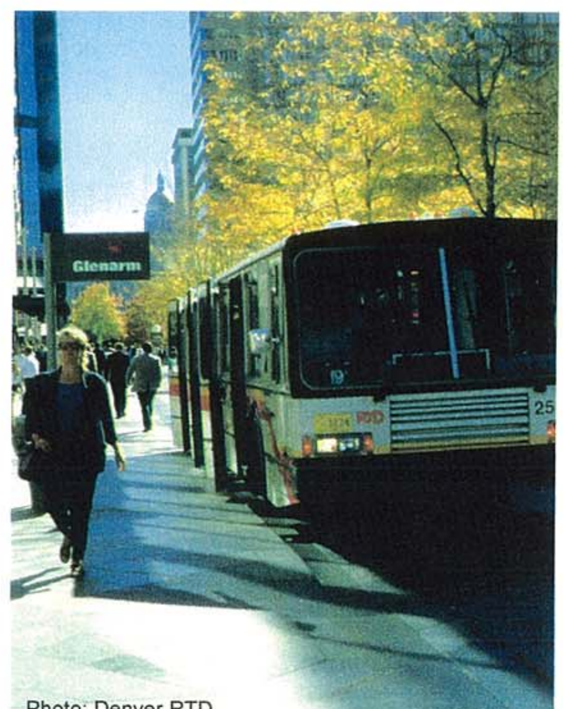
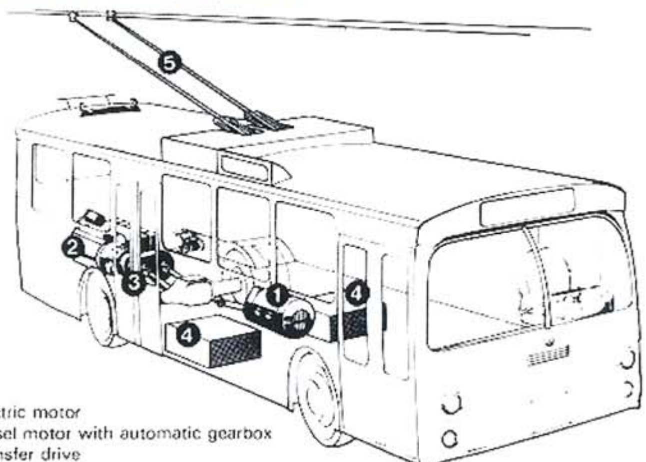


Photo: Denver RTD

Trolley Coach Improvements

Photo: www.sfu.ca/~dearmond by Ken Josephson

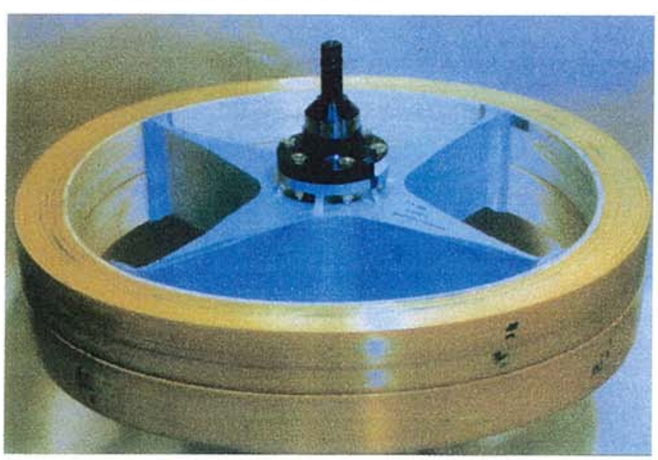
In the early 1980's UMTA sponsored a number of projects to investigate **Trolley Coach** improvements as a way to improve their performance, reduce air pollution, and conserve petroleum. San Francisco MUNI tested propulsion system improvements on these Flyer E800 model vehicles, including the use of alternating current motors. Manufacturers adopted the solid state control system improvements, but not alternating current propulsion.

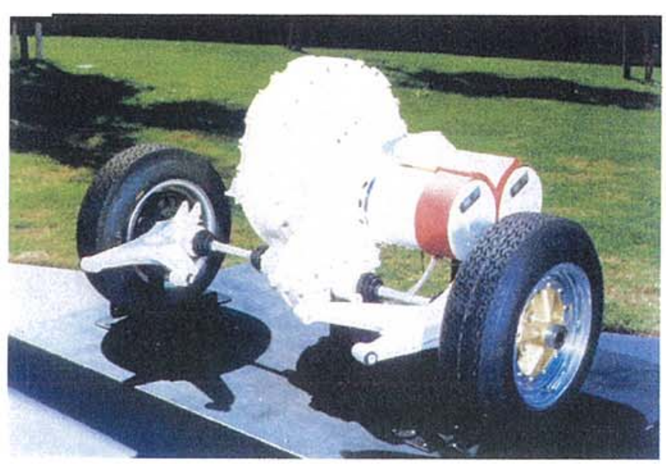


1. Electric motor
2. Diesel motor with automatic gearbox
3. Transfer drive
4. Current feed and electronic controls
5. Automatically controlled collector

To encourage broader use of electric power, UMTA/FTA developed and tested several varieties of systems that could allow vehicles to leave the overhead wires for parts of a route, or could operate in a power emergency.

Experiments included addition of batteries, a small diesel engine (as shown at left), or a high-speed flywheel. The experimental flywheel and its motor-generator unit are shown below in 1984. Only the automatically controlled power collector and additional use of diesel power were eventually adopted.





The petroleum shortages that began in 1974 sparked experiments with a wide variety of possible new fuels including the alcohols, propane, and natural gas. The alcohols could be made with renewable resources (wood and grain) and with coal, but were more expensive than the gases, and were found to corrode existing engines. Abpve is one of Sacramento RTD's fleet of buses powered with compressed natural gas (CNG).

Hybrid diesel-electric systems use a diesel engine, a generator, rechargeable batteries, and an electric motor to power the vehicle. This full-sized bus was developed by Orion Bus Industries of Canada and New York. It enables the diesel engine to operate with optimum fuel efficiency and minimum emissions.

Fuel Cells were examined as a possible source of electric power for buses under a joint DOE/DOT program established by congress in 1986. The program was based on feasibility studies conducted by Georgetown University and Los Alamos National Laboratory.

Three 30-foot heavy duty transit buses (right) were constructed in 1994 and were tested thoroughly under operating conditions.

The fuel cell produces electricity by combining hydrogen and oxygen in reverse electrolysis. Batteries are used to provide surge power and to store energy recovered from braking.

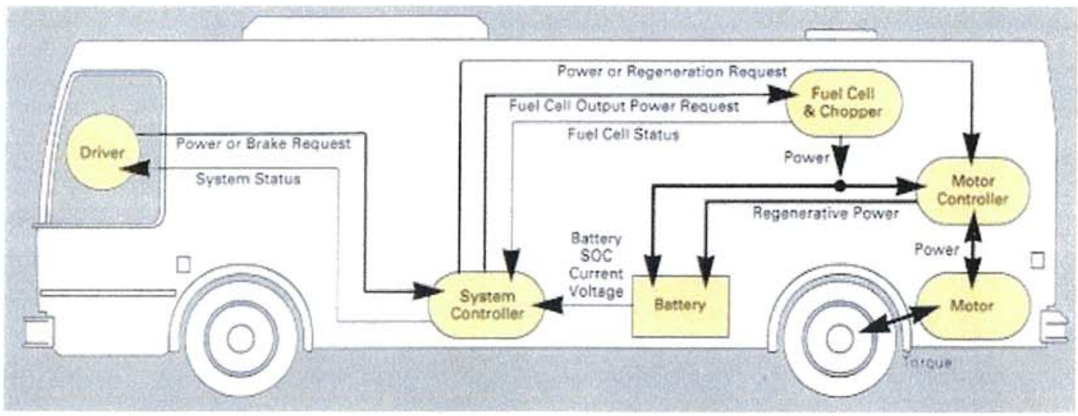


Photo: Georgetown University

As a result of the initial testing, 40-foot models were built that had double the power of the initial vehicles. These models (above) were designed to promote commercialization of fuel cells for transit use. Because they promise low or no pollution, research continues on fuel cells for non-transit use.

Bus Safety

UMTA safety programs in the 1970's aimed at assisting transit agencies to establish effective safety programs at the local level, including safety plans and educational programs, and research on common or critical safety and reliability problems. Among these was the materials flamability and toxicity database.

Bus Accessibility

Although most full-sized transit buses in the 1970's were not equipped to handle riders with disabilities, DOT regulations in 1979 required that one-half of all UMTA-supported peak-hour bus service be wheelchair accessible within ten years. This prompted rapid development of lifts and tie-downs since few buses had floors that were low enough to use a ramp.

In 1975, a series of safety training programs for bus system managers and bus operators was initiated for UMTA at the DOT Transportation Safety Institute (TSI) in Oklahoma City. Above is an early bus evacuation drill at TSI.

In 1989, bus safety and performance testing was consolidated at Pennsylvania State University's Pennsylvania Transportation Institute. Above is the Institute's Bus Testing and Research Center.

Tie-downs required extensive safety testing on each model of bus. Without being secured, the wheelchair and occupant become a projectile when the bus makes sudden stops or turns.

A variety of wheelchair lifts were tested in the 1980's. This front door "steplift" was preferred because the driver could assist riders most efficiently. However, to retain the steps for ambulatory riders, lift mechanisms were complicated.

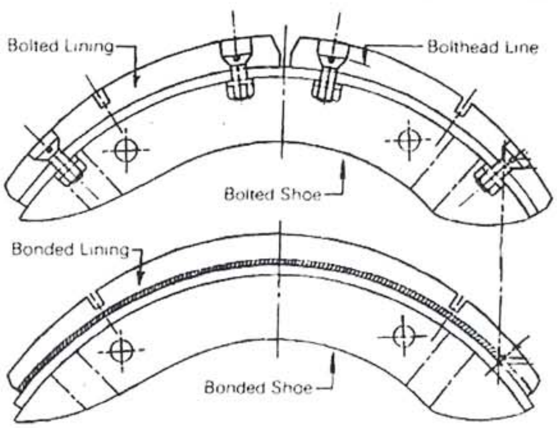
Bus Technologies

In 1980, UMTA project managers began meeting regularly with the American Public Transit Association's Bus Technology Committee to select developments that could help solve common problems with heavy-duty transit buses. The projects which were considered to be most promising were improvements in:

- Brake Lining Service Life
- Air Conditioners
- Transmission Reliability
- Bus Structure Computer Models
- Life Cycle Costing Methods

Brake lining wear was a high priority. Because of stop-and-go city traffic, replacements were frequent and costly. Bus down-time increased and replacement was labor-intensive.

Most of these projects resulted in improvements that have been adopted by the industry. For example, vehicle retarders (shown at right) are now optional on all models of standard city buses.

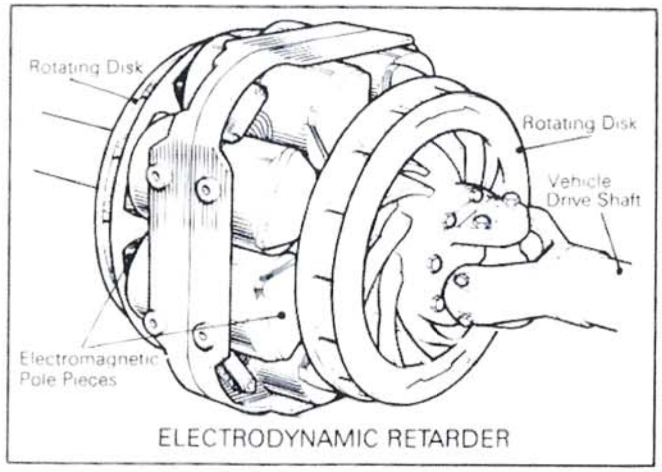


BRAKE LININGS

Bonded brake linings require specialized equipment but last longer by eliminating the bolt heads.

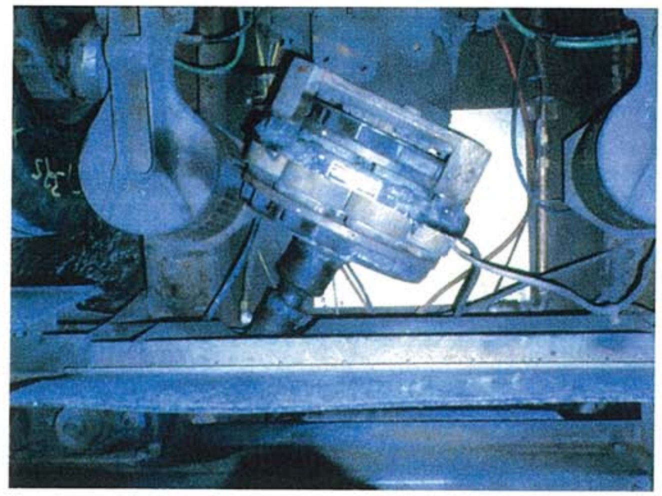
The Rotary Screw Compressor shown at right was an air conditioning improvement that was not adopted for automotive use even though the design was a major engineering advancement. Instead of pounding the refrigerant with pistons the compressor squeezes the gas between rotating screws. Vibration is minimized and compression can be controlled continuously instead of by on and off operation.

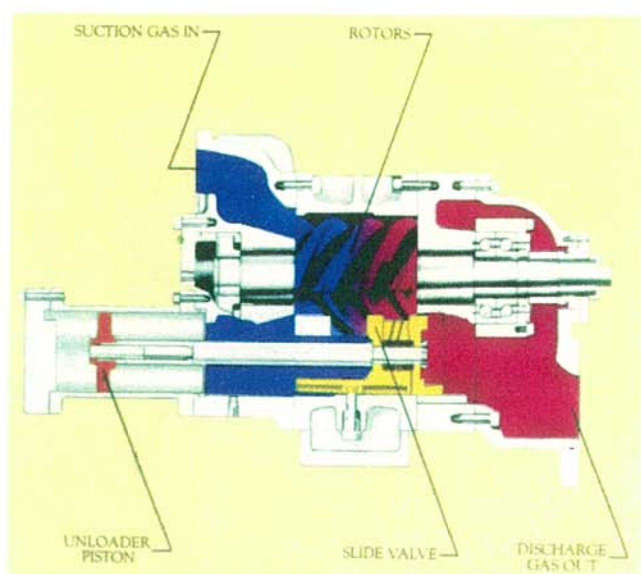
Because of costs, rotary screw compressors are now used largely for precision temperature controls and heavy duty air compressors.



ELECTRODYNAMIC RETARDER

Three types of **Vehicle Retarders** were evaluated for UMTA by the Michigan DOT. Retarders use methods other than friction to dissipate the heat of braking. They are designed to work off the brake pedal and slow the vehicle considerably before the friction brakes take hold. In the type shown here stationary electromagnets create a magnetic field and eddy currents produce a counterforce in the rotating disks. The disks are cooled by vents.





Photos: Northrup Grumman Corporation

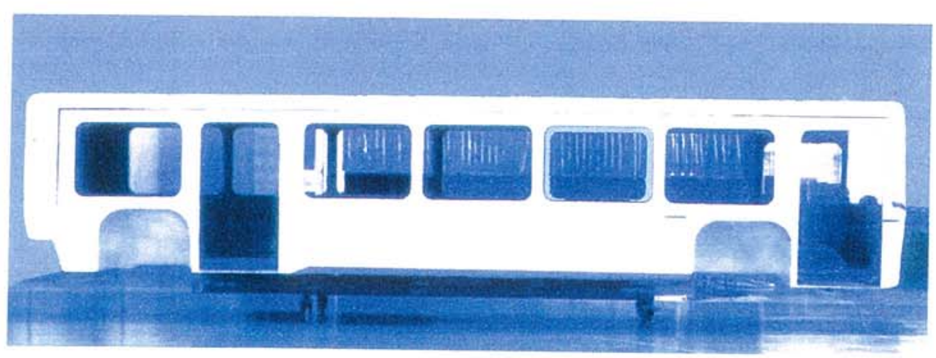
Advanced Technology Transit Bus

Renewed congressional support for transit research authorized by ISTEA prompted development in 1992 of a **lightweight, low-floor, low-emission** bus using proven advanced technologies. At over $41 M, it was the largest federal investment in a transit research project in two decades.

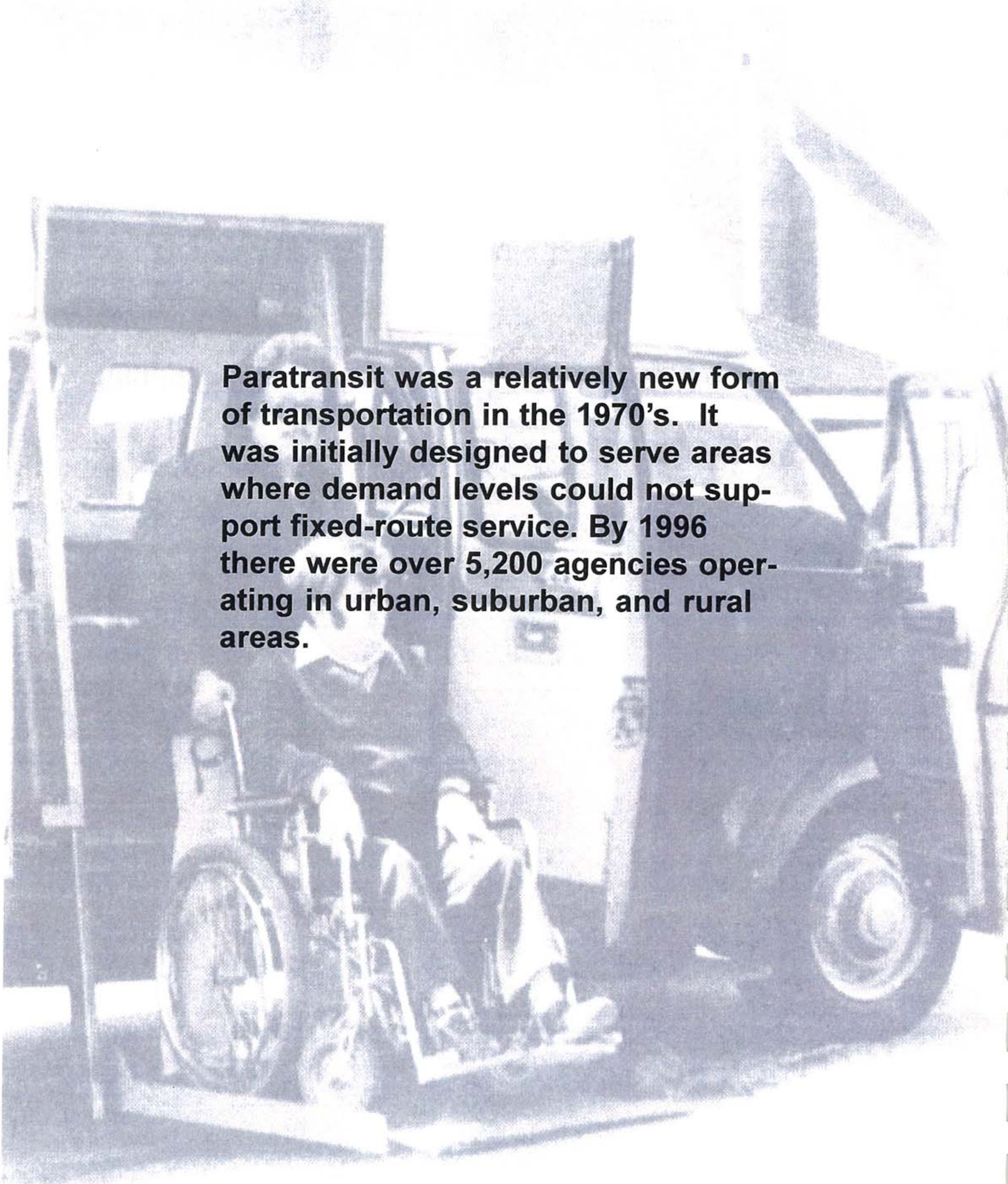
The bus was developed by Northrup Grumman Corporation under the direction of the Los Angeles County and Harris County (Houston) transit agencies, as well as a review board consisting of 22 other transit agencies. Six prototype vehicles were delivered in 1996 and 1997. Laboratory and field tests proved the bus to meet all design and operational requirements.

A low floor allows use of a ramp, rather than the more expensive and less reliable lifts.

The propulsion system is designed to conserve fossil fuels and emit fewer pollutants.



The one-piece body construction of fiberglass/epoxy, reinforced with graphite, uses boat hull fabrication techniques. It survives side impact and reduces vehicle weight by more than five tons over current models.



Paratransit was a relatively new form of transportation in the 1970's. It was initially designed to serve areas where demand levels could not support fixed-route service. By 1996 there were over 5,200 agencies operating in urban, suburban, and rural areas.

6. PARATRANSIT


Photo: Central Arkansas Transit Authority

Paratransit

Although vans and small buses were being used in the1960's for employment and medical programs, the idea of an areawide system that would be responsive to customer demand (dial-a-ride) was relatively new. Such a system could serve low density areas much more economically than full sized buses on fixed routes. It would also be more efficient than having separate agencies with seperate fleets of vehicles for each type of trip.

The concept (later known as paratransit) grew rapidly in the 70's especially after Congress mandated that transit agencies must provide service to elderly and handicapped riders. UMTA sponsored three kinds of programs to help county and local governments speed the acquisition of capabilities.

- Development of systems for routing, dispatch, and agency management,
- Demonstrations and uniform evaluations of innovative methods for providing service, and
- Testing of wheelchair lifts and ramps, and sharing of agency experience in buying vans and small buses.

In 1990, paratransit was given another boost by the Americans with Disabilities Act which now requires urban transit agencies to provide supplemental demand-responsive service to disabled riders that are not near accessible bus routes.


Tomorrow's Transportation

Dial-a-Bus would allow customers to call for pick-up from home or from streetside booths.

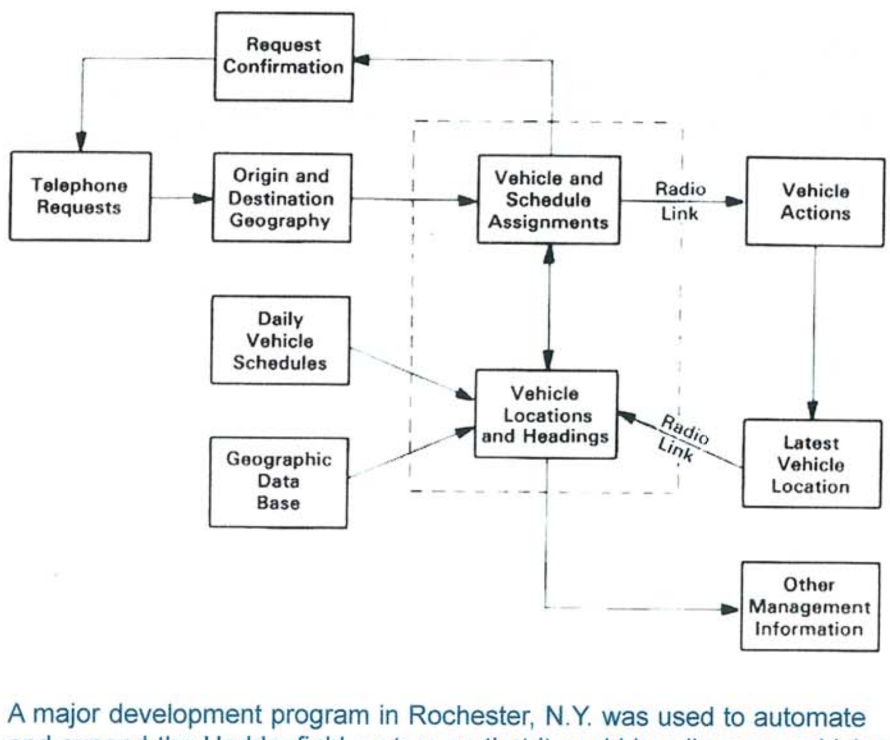
Dispatch Systems

To offer demand-responsive service, agencies needed new technologies to plan routes and to direct vehicles in real time. Before dial-a-ride, radios were rarely used by transit agencies, and vehicle routing, and scheduling systems required large mainframe computers.

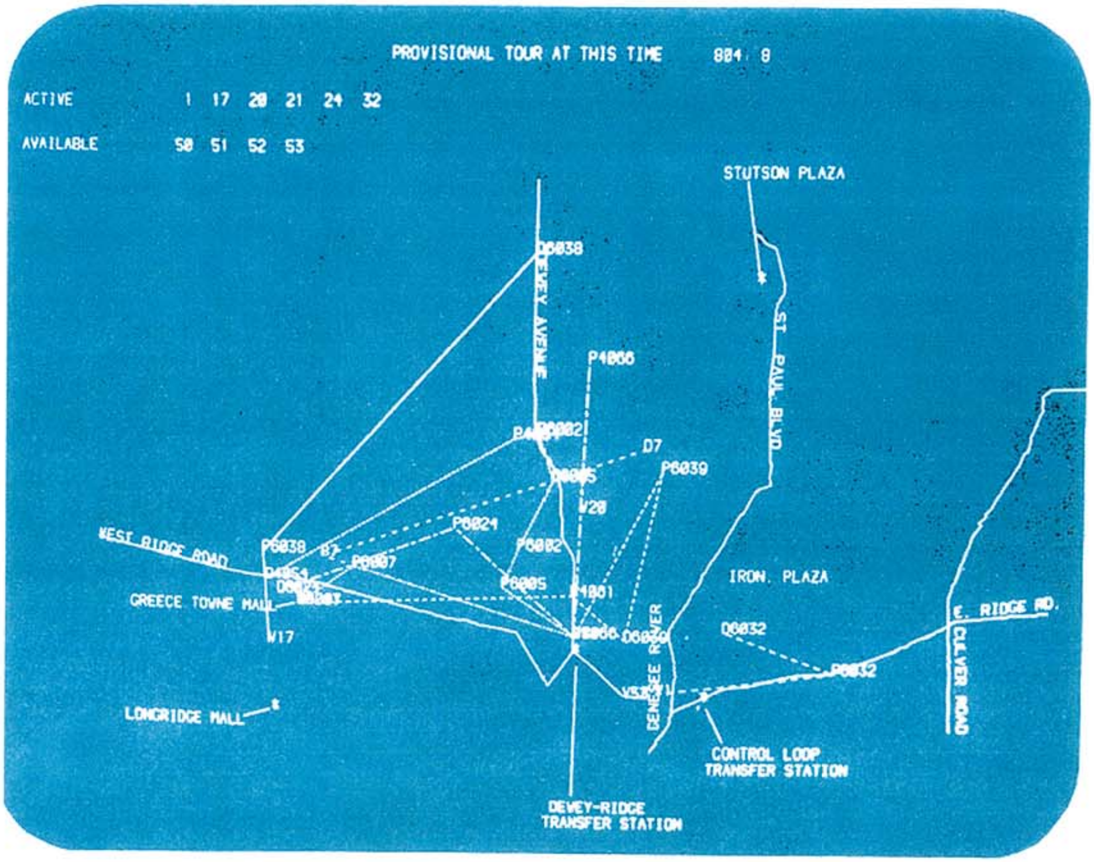
The initial program focused on studies to determine the needs for software that could be used with computing and communications equipment that small agencies could afford.

A project in Haddonfield, NJ showed that patronage grew with every expansion of the service area. The program next developed software for areawide systems and later continued developments that could take advantage of improving computing and communications equipment.

This dispatch center in Haddonfield, N. J. operated much like an airport control tower in 1971.



A major development program in Rochester, N.Y. was used to automate and expand the Haddonfield system so that it could handle more vehicles and cover more territory. Computer systems were developed to help dispatchers with the functions shown within the dotted box. Other improvements included automating communications with drivers, and systems for assigning priorities, and scheduling transfers.



The Rochester system was also used as a baseline for developing and testing displays for dispatchers (right).

Display screens gave the location and heading of each vehicle.

Vehicle communications were also automated, providing drivers with screen displays or printouts of pickup locations and times (below). The system software allowed regional agencies to handle a larger fleet of vehicles efficiently while still providing responsive service.

In the 1980's, the proliferation of small computers and the greatly reduced costs of communications equipment helped make automated dispatch and management systems more readily available to small and rural agencies as well as to urban and areawide providers.

One important question about paratransit was the efficiency of a regional, demand-responsive system in comparison to trips provided by many organizations for specific purposes. Above is a demand-responsive trip to a hospital in Rochester, NY in 1978.

Careful scheduling and suitable transfer sites were necessary to combine paratransit with fixed-routes. Above is a transfer site in Ann Arbor, MI in 1977.

Paratransit Service Variations

At first, institutions that provided demand-responsive transportation were outgrowths of the many individual agencies that served health, housing, and employment programs supported by federal departments.

For new agencies, the possible choices in organization structure, service area, schedules, routes, contracting methods, and scope of services were almost infinite. To help agencies select the most effective methods, UMTA evaluated over 70 paratransit systems between 1975 and 1985. A key feature of the demonstrations and case studies was the uniform method of measuring costs, service quality, and customer needs.

Vanpools were another form of paratransit. This program in Knoxville, TN leased vehicles to private parties to encourage ridesharing.

Timed transfers (above) was one of the operational methods studied. Transfers provide an efficient means for serving customers that require many different pick-up and drop-off sites such as commuters and shoppers.

Photo: Older Americans Transportation Service, Missouri

Rural transit has been an important factor in the growth of paratransit. In 1980 congress authorized UMTA to fund rural transit programs in all 50 states

Private taxi companies were another variety of paratransit, either providing shared-ride services (above), or as feeder services to local transit agencies. At right is a 1978 feeder service advertisement for the Westport, CT Transit District.

Photo: San Mateo County Transit District

Paratransit agency organizations evaluated by UMTA included systems managed by communities, towns, counties, regions, states, and urban transit authorities. Operations by agency employees and by private contractors were also evaluated including agencies that acted as a broker for private and non-profit providers.

Paratransit Vehicles

In the early days, paratransit agencies had difficulty obtaining small buses that were suitable for low density and rural service. The only vehicles available with wheelchair lifts had to be custom-built from modified vans or trucks.

Because the market for these vehicles was small, none of the major auto manufacturers were interested, and the custom-made vehicles were not entirely satisfactory. Truck chassis produced too stiff a ride for elderly passengers and van chassis did not hold up well under the intense use of paratransit service.

During the 70's, UMTA performed safety testing of wheelchair lifts and ramps and encouraged private industry to develop a small, low-floor bus with suitable endurance and ride-quality. It also organized national conferences so that vehicle buyers could exchange their experience with vehicles and write better procurement specifications.

During the 90's, the increased market for paratransit vehicles led to the availability of many more manufacturers and models of vehicles. By 1996, there were over 33,000 vehicles in demand-responsive service - more than half as many as were being used on fixed routes.

Standard Van

Modified Van

Body on Cutaway Truck or Van Chassis

Body on Step Van (Delivery Truck) Chassis

Pictured above are the vehicle models available in the 1970's.

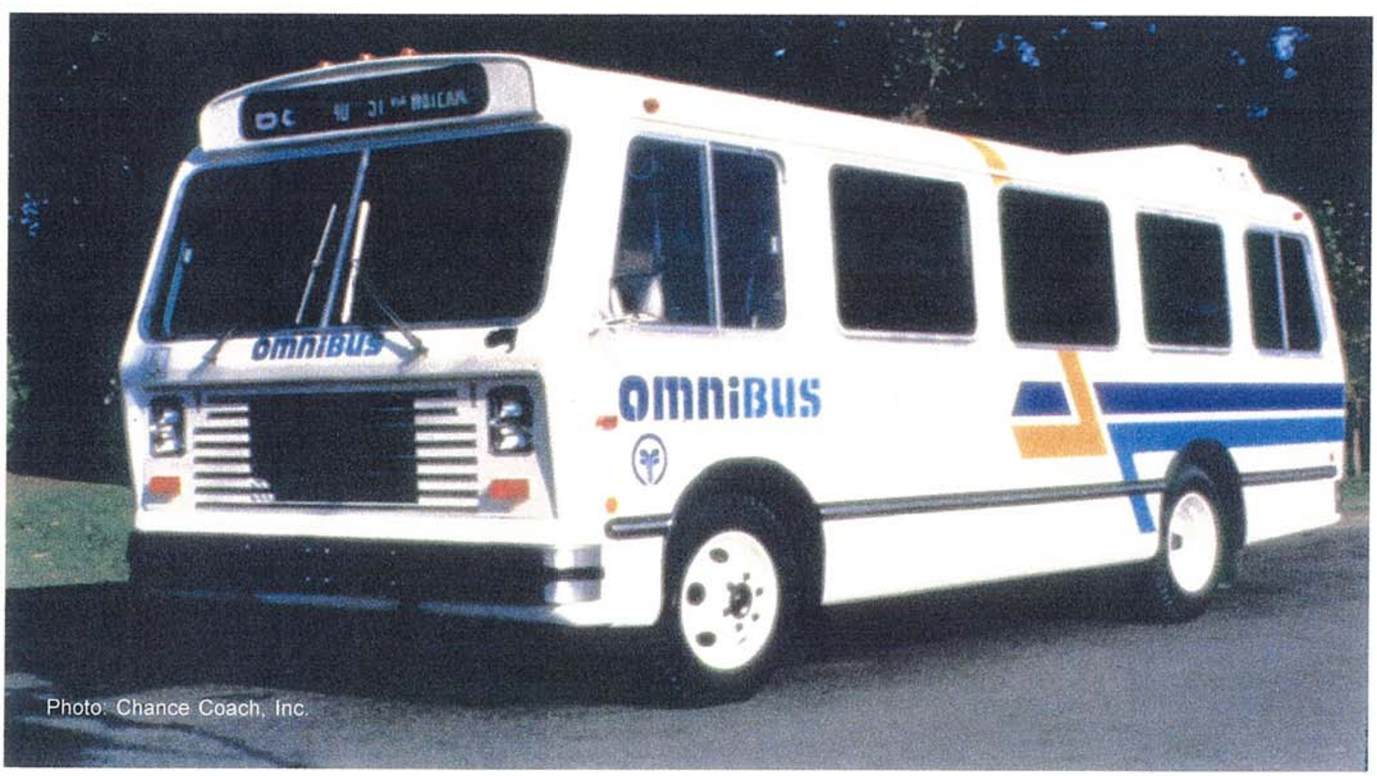


Photo: Chance Coach, Inc.

By 1980, small heavy duty buses began to appear on the market. They used the modern design practices of large buses, such as: air brakes, air suspension, lower floors, wide doors, and diesel engines. The buses were more expensive than modified vans or truck chassis, but had a longer life and better ride comfort.

UMTA's one effort in vehicle development consisted of sponsoring prototypes of vehicles that would be suitable for use as accessible taxis or private automobiles. In 1981 the program produced two prototype vehicles that used ramps and could be manufactured at reasonable cost

Although the prototypes performed well, they were never put into production. At about that time mainstream car manufacturers began high volume production of minivans and front-wheel drive vehicles. The minivans had wide doors and floors that were considerably lower than the floors on conventional vans.

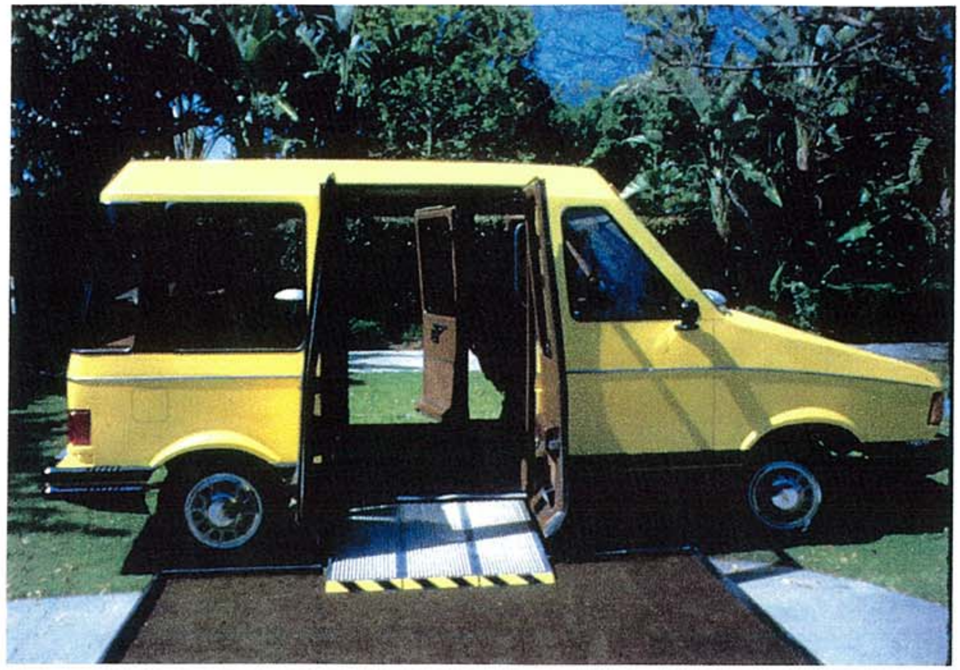


Photo: Metropolitan Atlanta Rapid Transit Authority

As a result of increased requirements to serve disabled riders, many models of vehicles are now available on the market. They have lower floors, wider doors, and greatly improved ride comfort, as well as factory-installed front or rear wheelchair lifts.

The transition from private to public ownership of urban transit was a major change that took place in different cities over about tthree decades starting after World War II. This change was helped by Federal grants that became available to local governments through HUD, and later through DOT. Congress recognized that ridership was declining and cities were not being served adequately by public transportation.

7.0 TRANSIT PLANNING AND MANAGEMENT

Photo: Santa Fe Trails Public Transit

Transit Planning and Management

At the time the Urban Mass Transportation Act was passed (1964) transit planning and management techniques were virtually non-existent outside the highway sector. Transit management was in a holding pattern during World War II, trying to cope with huge ridership increases. This was followed by an even greater decline after the war and conversion to public ownership.

The mission of the new public agencies was different from that of private companies. In addition to selling transportation, they were charged with solving societal problems and, in later years, to improving air quality, conserving fuels, and assuring equal access for people with disabilities.

The Transit Act of 1964 stimulated new thinking about planning tools specifically for transit, along with bringing contemporary management techniques into a public sector activity.

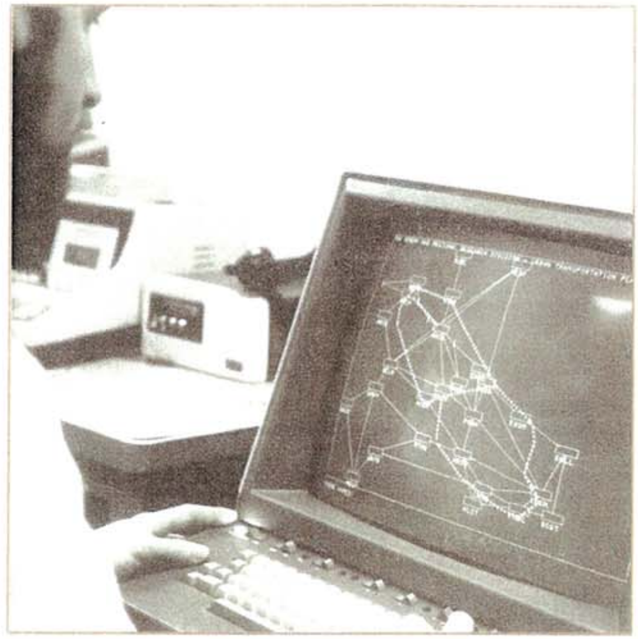
Innovations that followed included:

- Software for planning rail corridors and bus routes,
- Computers and communications for managing bus and rail operations,
- Automated schedule and route information for customers,
- Fare calculation software and fare collection equipment,
- Priority lanes for high-occupancy vehicles,
- Innovative financing, pricing, and marketing techniques, and
- Transit malls and auto restricted zones.

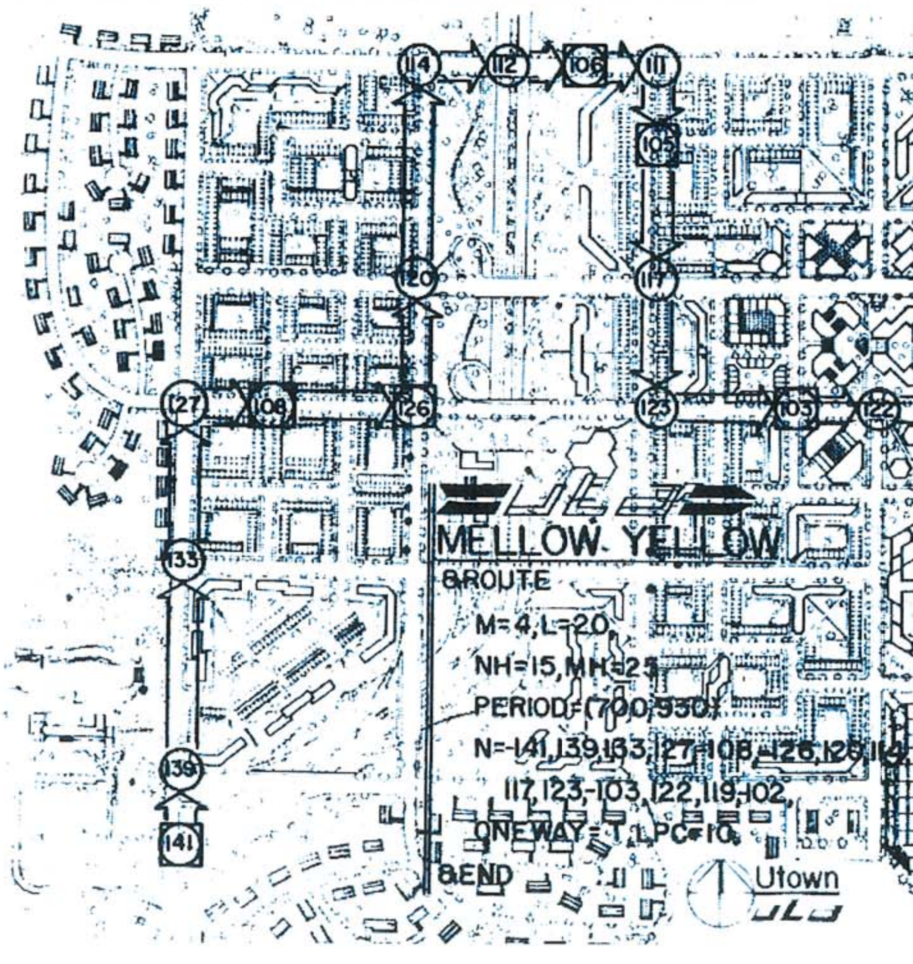
Transit Planning Systems

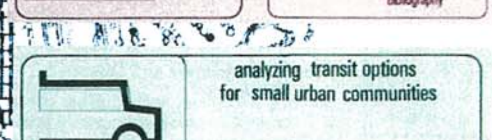
In 1970 UMTA and the Federal Highway Administration began joint development of the **Urban Transportation Planning System (UTPS)** to provide tools that could handle the complexities of highway and transit planning. The resulting system enabled planners to apply land-use and socio-economic data to local transportation networks, evaluate alternative routes, and predict energy, environmental, and economic impacts. By 1983, UTPS was being used by over 300 agencies.

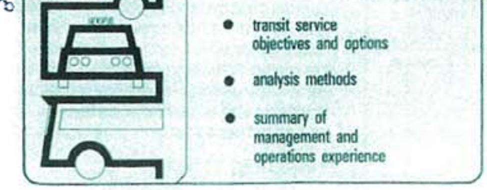
In the 1990's, **Geographic Information Systems (GIS)** became widely available and opened up a whole new world of tools that could be used for detailed analysis and planning. To promote use of GIS, FTA established a nationwide database of bus routes. The database was developed by Bridgewater (MA) State College and is available on the college's GeoGraphics Lab website.



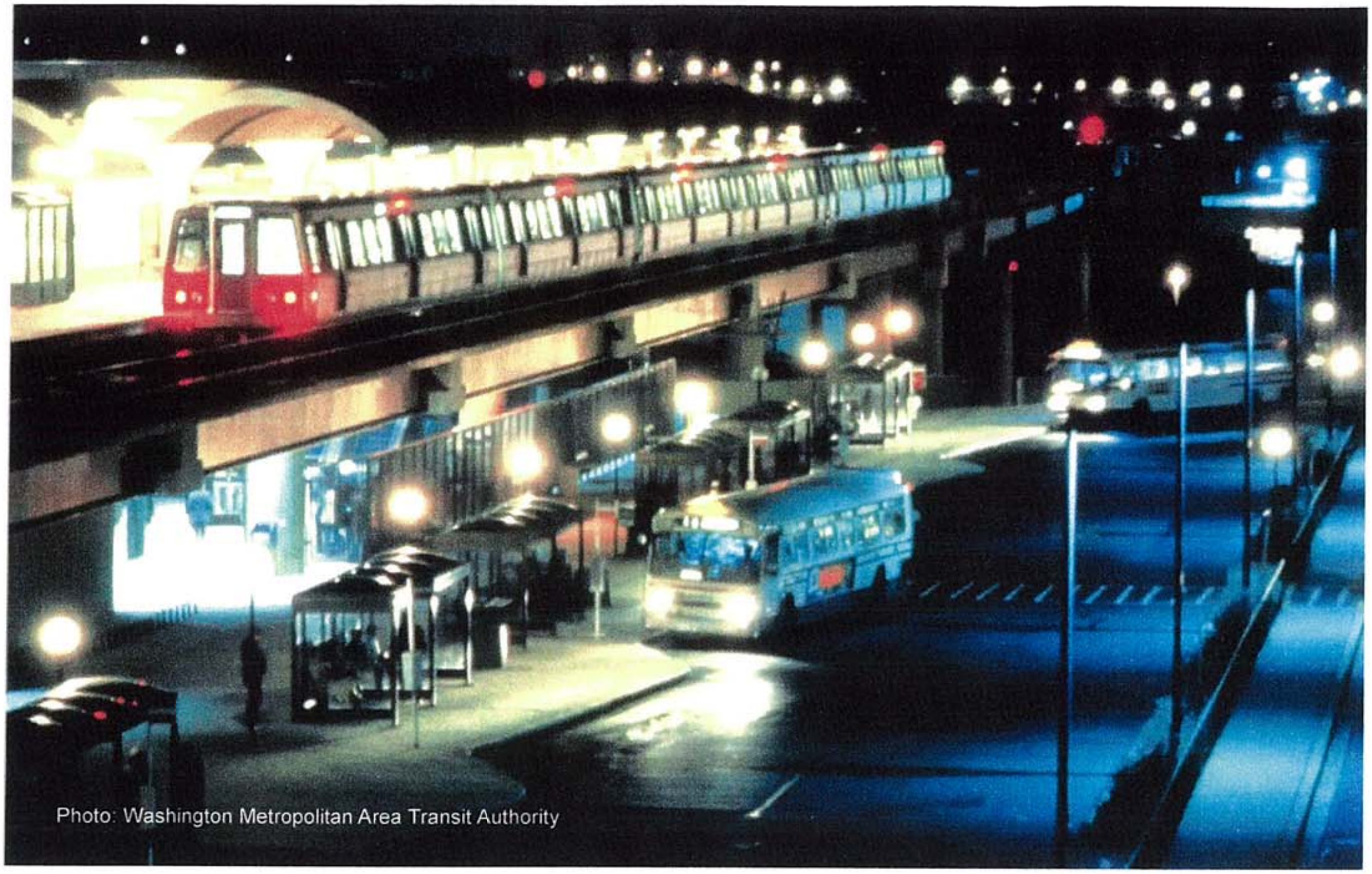
Two big advantages of computer-based planning tools were that they can handle large transportation networks (above) and can easily be adjusted to reflect alternative plans, changes in actual routes, or variations in travel demand.



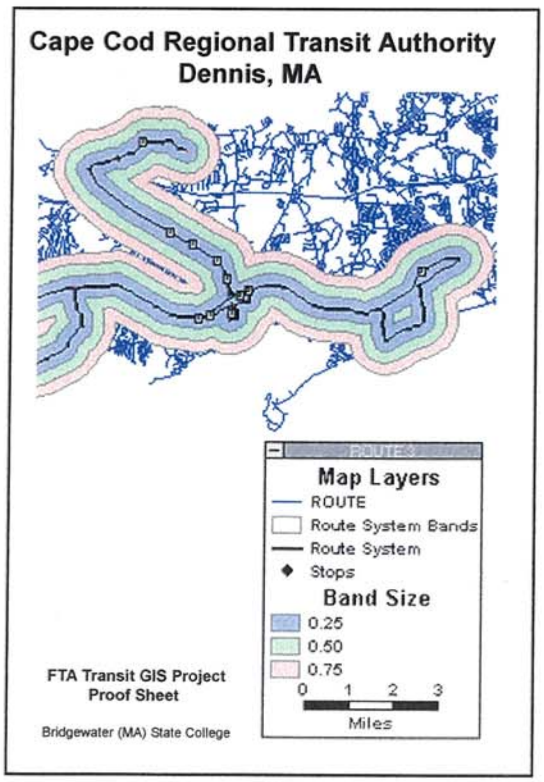


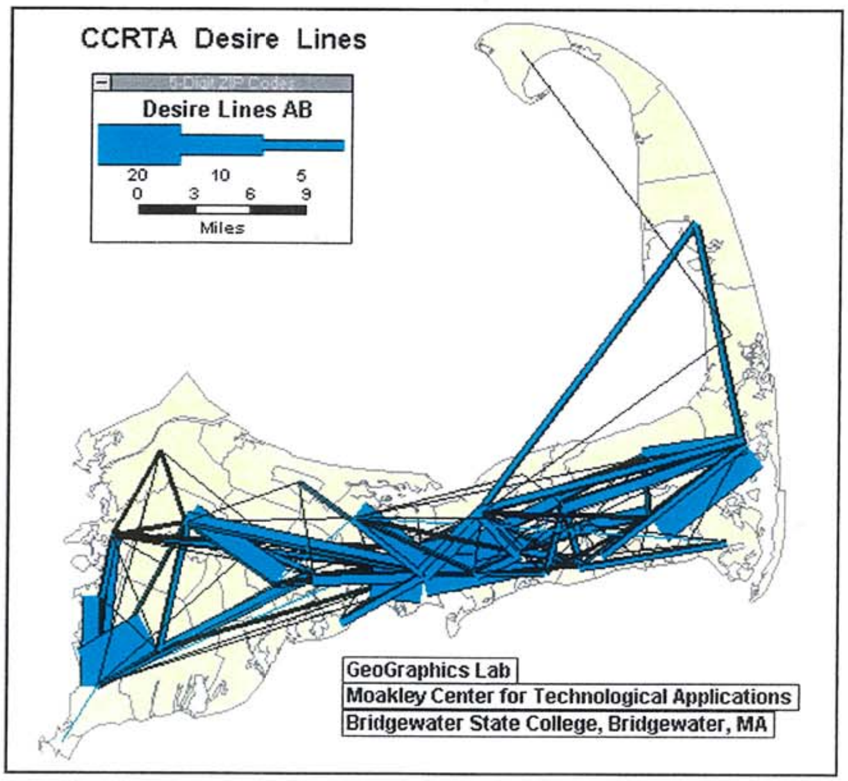


Above is a hypothetical problem used to teach planners to use one of the UTPS computer programs to plan optimum downtown bus routes and schedules.. At right are manuals developed for hand calculation.



After transit responsibilities were assumed by local governments, bus routes could be designed to complement (rather than compete with) rapid rail lines. Careful planning was essential because facility investments were involved - not just routes on existing streets. Above is a rail/bus intermodal facility in Washington DC.





Geographic Information Systems (GIS) are capable of processing volumes of data on each proposed service route, linking detailed information with accurate locations. The map at left shows distances from a bus route. The volume of customers between the same origin and destination is illustrated on the right.

Busways and High Occupancy Lanes

Over the years UMTA/FTA examined a wide range of priority treatments for High Occupancy Vehicles (HOV) to alleviate congestion. Case studies have produced valuable findings about costs and benefits, as well as practical guidance on where and how to apply them.

The studies showed that reserved lanes for buses and carpools are effective in increasing average vehicle occupancy and reducing travel times. They also showed that workability and public acceptance depend on how reserve lanes are approached. Projects that involved taking a lane away from general traffic produced significant negative public reaction, while the ones which were built in underused parts of the freeways were highly successful.

By 1990 over 150 high occupancy projects were operational in 35 urban areas.

Shirley Highway (I-95) introduced bus only lanes to the U.S. in 1971. It was later opened up to car and van pools. It is the main commuter link from Northern Virginia to Washington D.C., and was accomplished by joint efforts of The Virginia Highway Department, Federal Highway Department and UMTA. It became a model for other cities throughout the country..

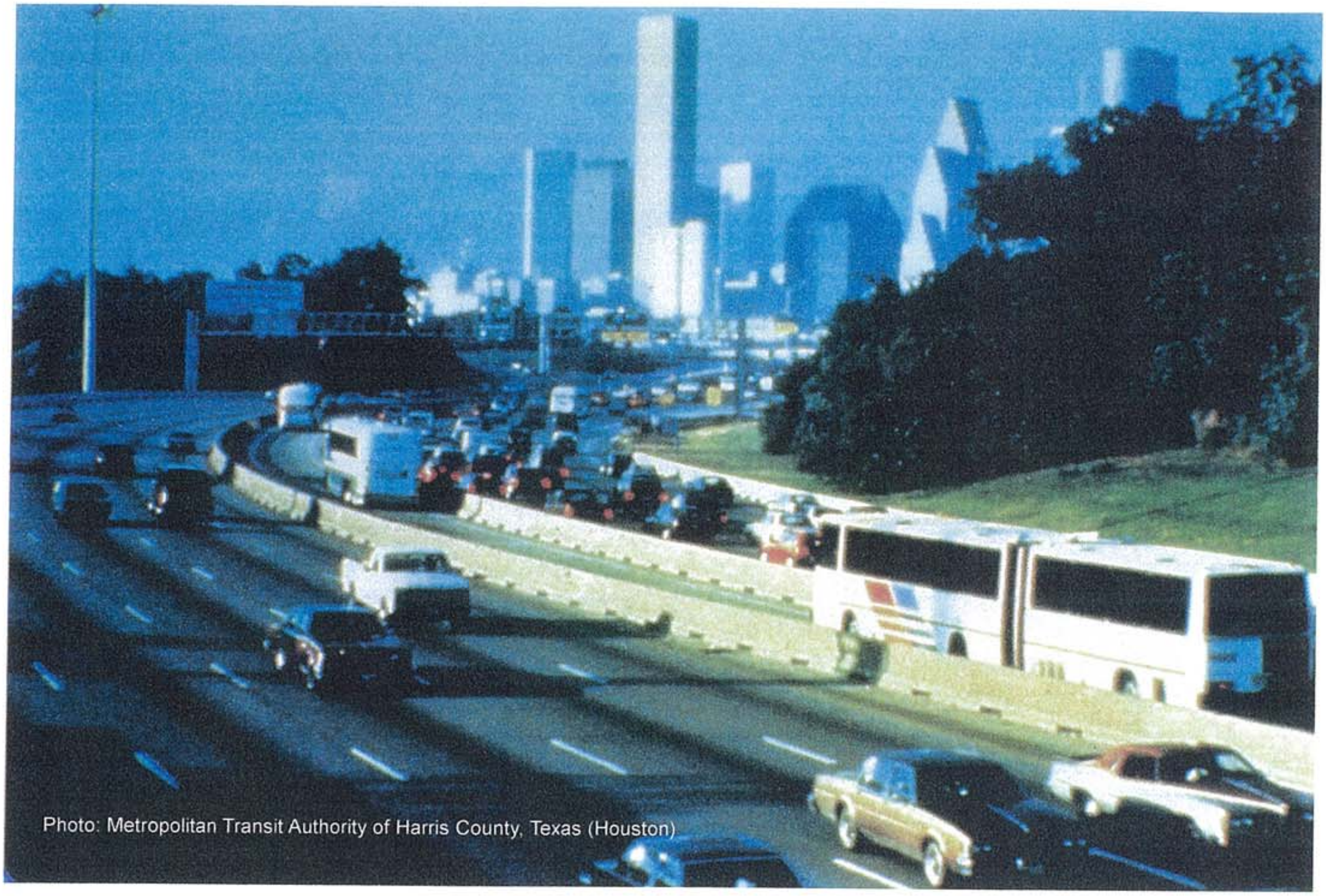
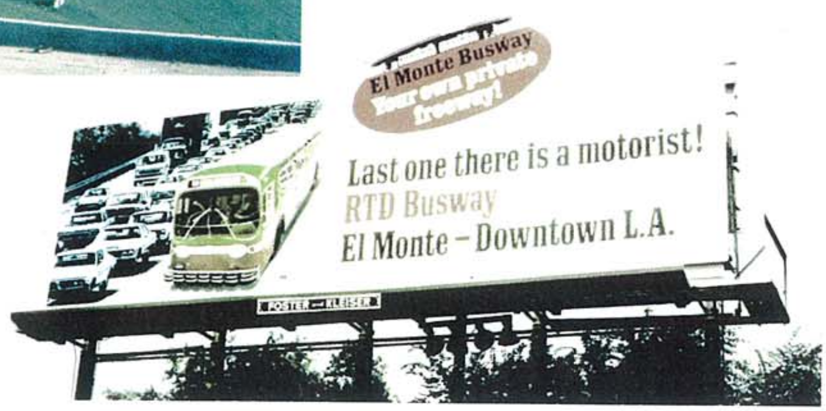


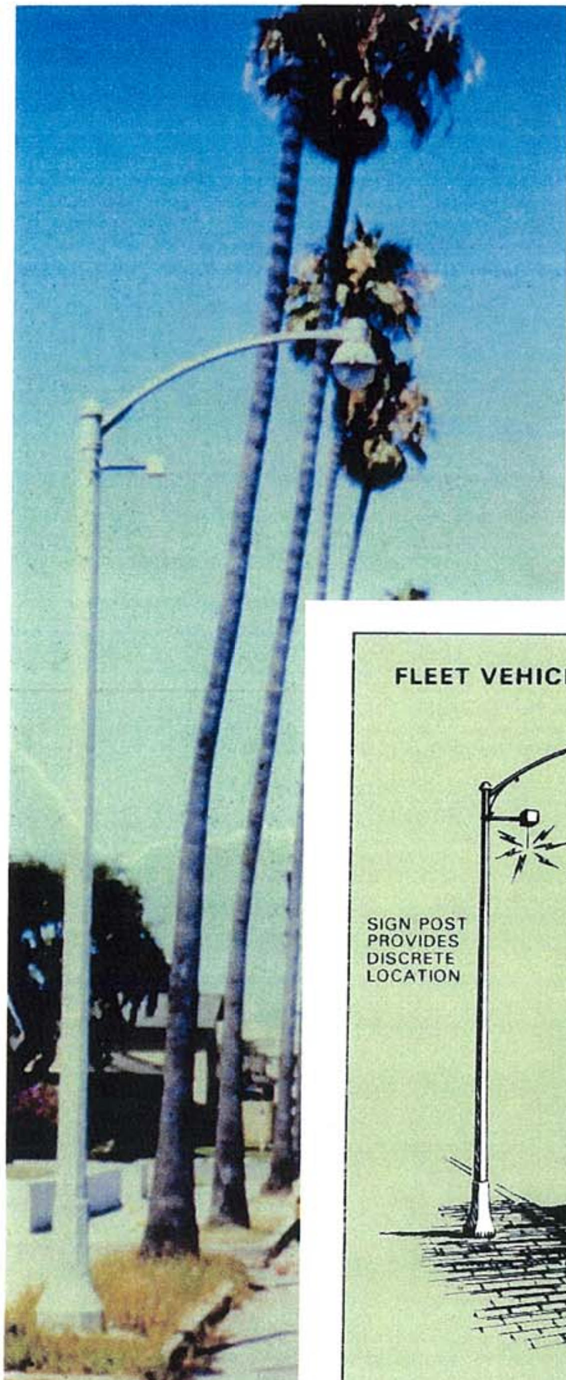
Photo: Metropolitan Transit Authority of Harris County, Texas (Houston)

In some cities, planners suggested using highway median strips for rail transit service. However, use of these rights-of-way for bus service and carpools turned out to be more popular with the public and less costly than rail service.

In 1979, the city of Houston built a ten-mile contraflow lane (above) providing an extra lane inbound in the morning and outbound at night. Houston now has over 80 miles of HOV lanes.

The El Monte Busway in Los Angeles uses the median of the San Bernardino Freeway. It features two-way traffic and separate ramps for bus access. Above is one of the system terminals that provides parking and transfers to local routes.

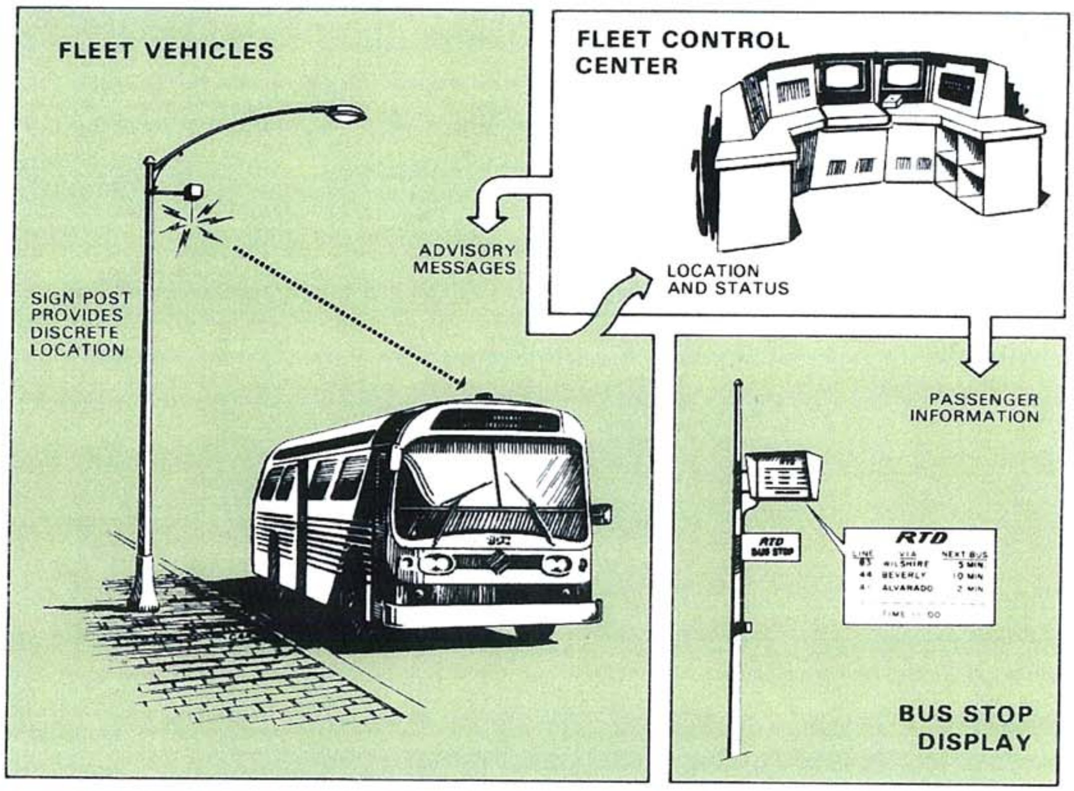


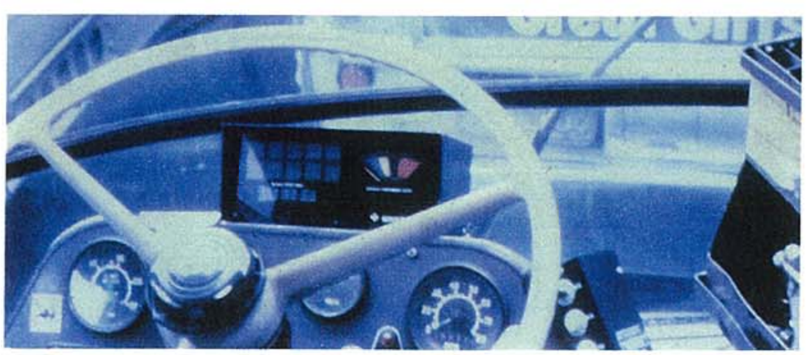


Automatic Vehicle Locators

In the 1960's, radio manufacturers began to market systems which could be used to improve the management of taxis, police, or fire vehicles. The concept also appeared to be useful to transit agencies that had numerous routes and large fleets of buses.

In 1974, UMTA and the Southern California Rapid Transit District (SCRTD) launched an experimental project on Wilshire Boulevard. The projct proved that the idea was technically feasible and could save operating costs. However, the system was too complex and expensive to interest other transit agencies.





The test system in Los Angeles used a "signpost" method for vehicle location. Small transmitters were attached to lightposts every few blocks along the route. A unit in the bus measured proximity and sent the reading to headquarters. Bus operators could also signal an emergency and receive schedule adjustments from the fleet control center. Photographs show a signpost transmitter, driver display, and customer information display.


Photo: King County DOT

Fifteen years after the Wilshire Boulevard experiment, the cost of communications and computers had dropped significantly, and mapping and business software was commercially available. Bus transit agencies reasoned that they could save money and provide better service with "real time" management of their routes. By 1993, 56 agencies were either operating or installing systems using a variety of location, communications, and management techniques. Above is the control console at Seattle Metro.

In the 1990's, funding for Intelligent Transportation Systems projects and availability of satellite-based Geo-Positioning Systems (GPS) made automatic vehicle locators even more attractive. At right and below are the control console and a screen display at the MTA in Baltimore. The display can zoom in to show individual buses.

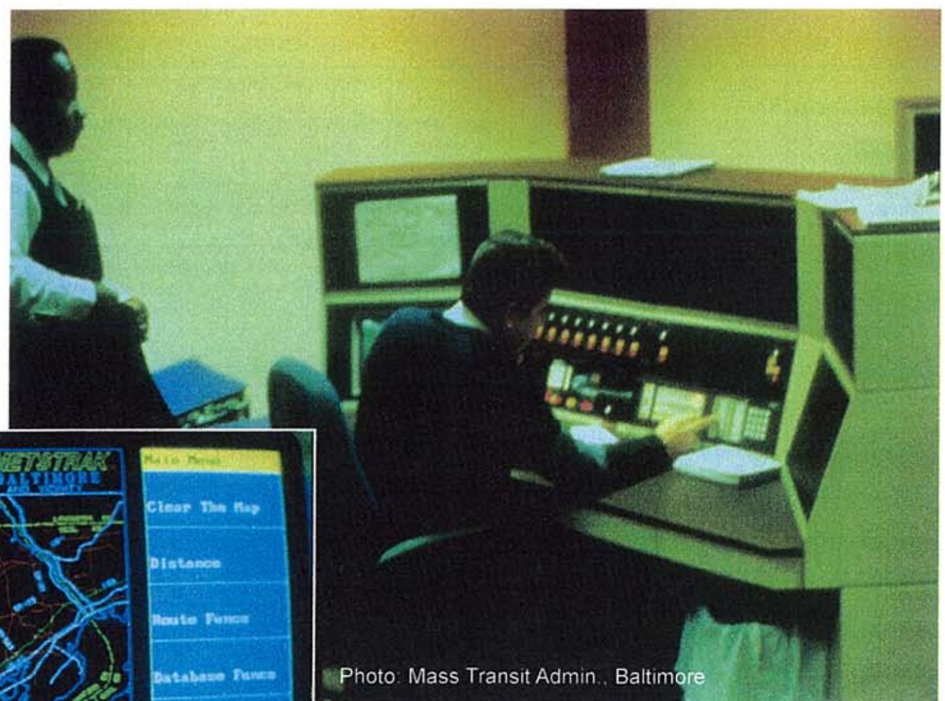


Photo: Mass Transit Admin., Baltimore

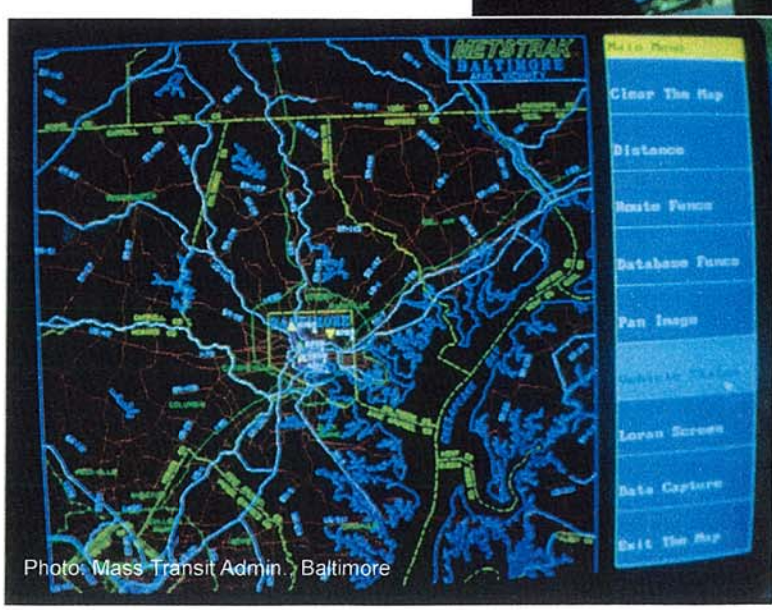
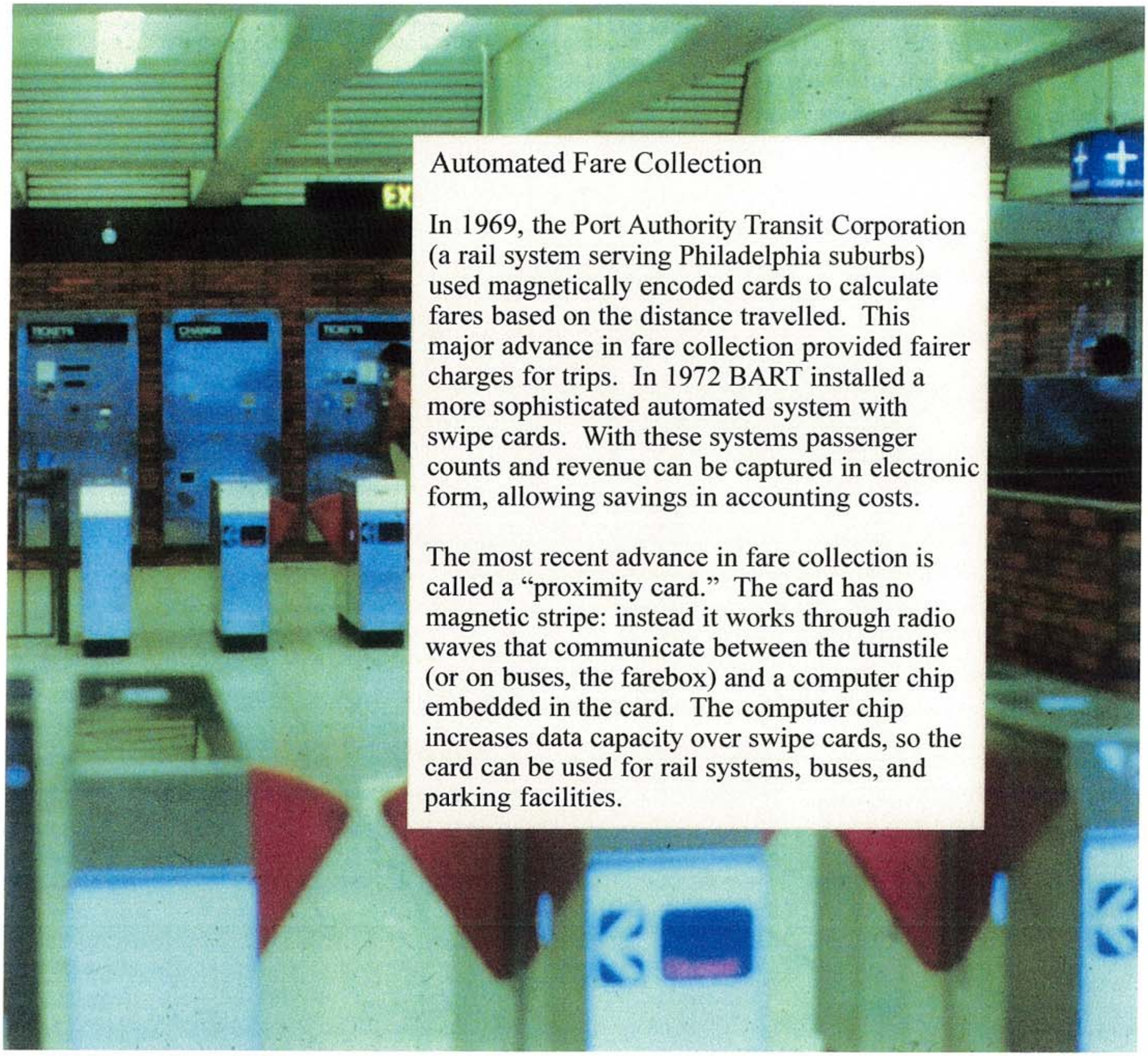


Photo: Mass Transit Admin., Baltimore

Automated vehicle tracking has several benefits beyond the ability to adjust schedules in real time. Historical schedule performance can be captured in digital form and used to improve route planning. Actual status can be used to inform riders about the arrival time of the next bus.



Automated Fare Collection

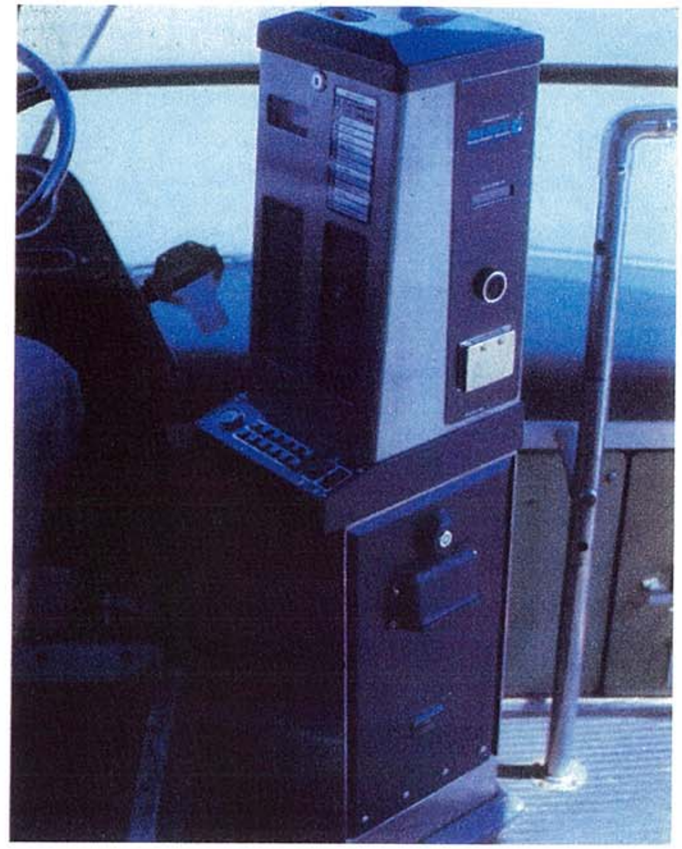
In 1969, the Port Authority Transit Corporation (a rail system serving Philadelphia suburbs) used magnetically encoded cards to calculate fares based on the distance travelled. This major advance in fare collection provided fairer charges for trips. In 1972 BART installed a more sophisticated automated system with swipe cards. With these systems passenger counts and revenue can be captured in electronic form, allowing savings in accounting costs.

The most recent advance in fare collection is called a "proximity card." The card has no magnetic stripe: instead it works through radio waves that communicate between the turnstile (or on buses, the farebox) and a computer chip embedded in the card. The computer chip increases data capacity over swipe cards, so the card can be used for rail systems, buses, and parking facilities.

Modern turnstiles and machines for buying tickets (cards) are shown above in Washington DC. Instead of making change, attendants are on hand to help passengers.

Before electronic fare collection was introduced, passengers had to arrive with the right change or stop to obtain change or tokens at a booth. Collecting and counting the money was unreliable and costly. At left is a bus farebox in Houston and at right a New York City Turnstile - both in the early 1960's.

Ticket vending machines were initially designed to make change and dispense paper tickets for trips to various zones. Later versions dispensed swipe cards to be used on entering and leaving stations.



Electronically registering fareboxes on buses and vending machines at subways made a huge difference in administrative costs for agencies. They also virtually eliminated bus holdups because drivers are not able to open the fareboxes.

Proximity cards need only to be held close to the target reader. They work better than magnetically encoded swipe cards in bad weather and are much more versatile.

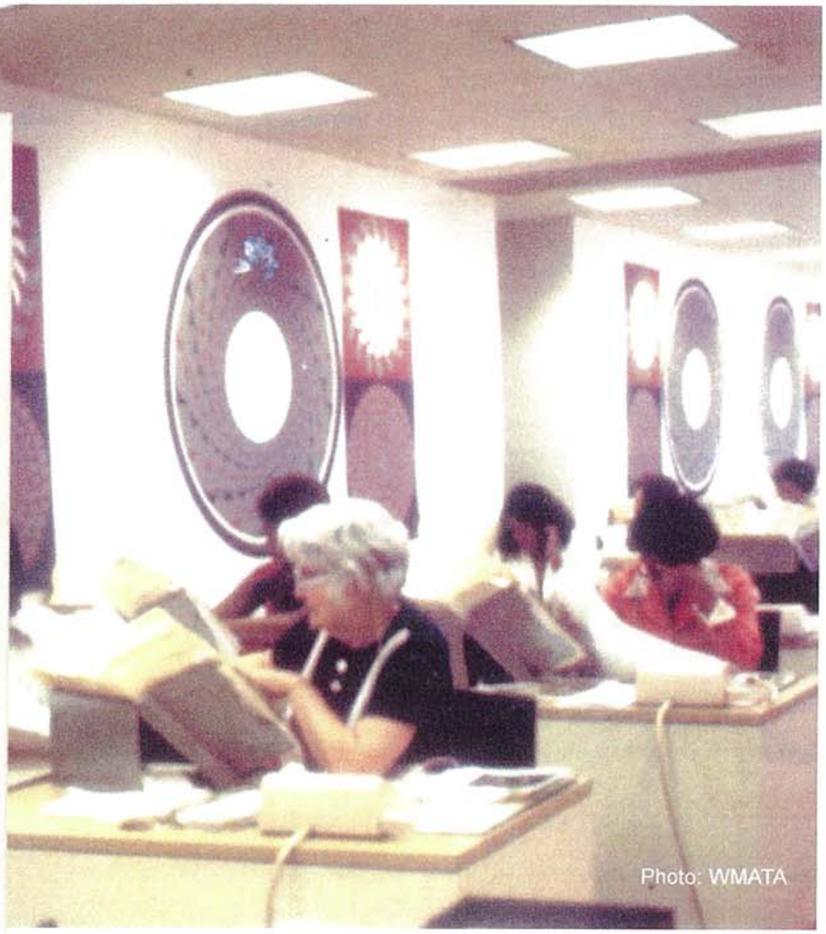
Traveler Information Systems

If it is easy for people to find out about transit, they are more likely to use it. In 1976 UMTA began sponsoring demonstrations of technologies that would help phone operators provide better and quicker information on routes, schedules, and fares.

Automated traveler information systems enabled callers to give their desired origin, destination, and arrival time, and the computer could derive the fastest and least expensive itinerary.

During the 1980's UMTA also sponsored demonstrations of interactive map displays for visitors at airports and other terminals.

In the 1990's inexpensive Geographic Information Systems added map display capabilities. By adding GPS receivers to each bus, the transit system can now show internet users a map giving the location of all of its vehicles in real time.



With 875 routes in a 1500-square mile coverage area, transit in Washington (DC) required a map and schedules book that was over a foot thick. The books (above in 1978) were replaced in 1981 by a computerized data base and terminal (below).

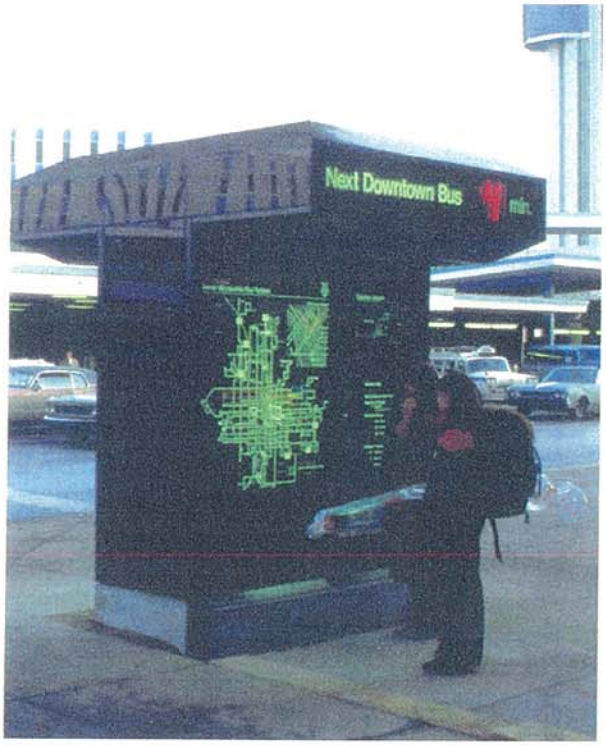


Photo: Metropolitan Atlanta Rapid Transit Authority

Schedule and route information is essential for visitors to be able to use public transportation. During the 1980's airport kiosks progressed from departure notices (above) to interactive screens with real-time reports on bus and train progress

```
GOING      * * * I T I N E R A R Y   O R   S C H E D U L E * * *
ORIG: PL:( 13027 WELBY WAY                                  )   COM:(NHO )
DEST: PL:(UCLA*                                             )   COM:(     )
WHEN: TIME:(09:      )  DAY:( )      LV/AR:(AR)     MIN T/X:( )
LINES:(     ,       ,      )

FROM: 13027 W. WELBY WAY, NHO                                  09:00A  THU AR
TO  : *UCLA, LA                                                MIN T

 165S 07:35A W-VANOWEN/ETHEL                      07:40A VANOWEN/VAN NUYS
  88S 07:54A S-VAN NUYS/VANOWEN                   08:37A HILGARD/STRATHMORE-UCLA, ISD

****   88 IS AN EXPRESS BUS-- SEE SERVICE RESTRICTION
     ET:  62 MINS          FARE: $ 0.80

 159S 07:50A S-COLDWATER CYN/VANOWEN
  35N 08:11A W-VENTURA/WHITSETT-LAUREL TER
  88S 08:26A W-VENTURA/SEPULVEDA-FARS

****   88 IS AN EXPRESS BUS-- SEE SERVICE R
     ET:  59 MINS          FARE: $ 0.80
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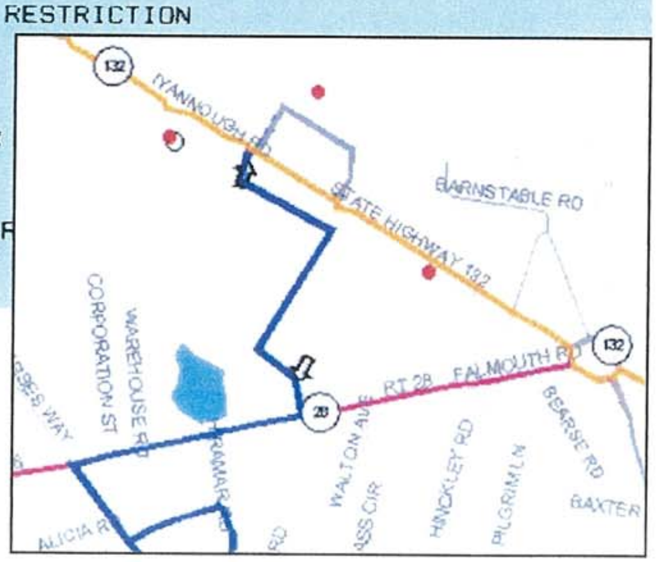
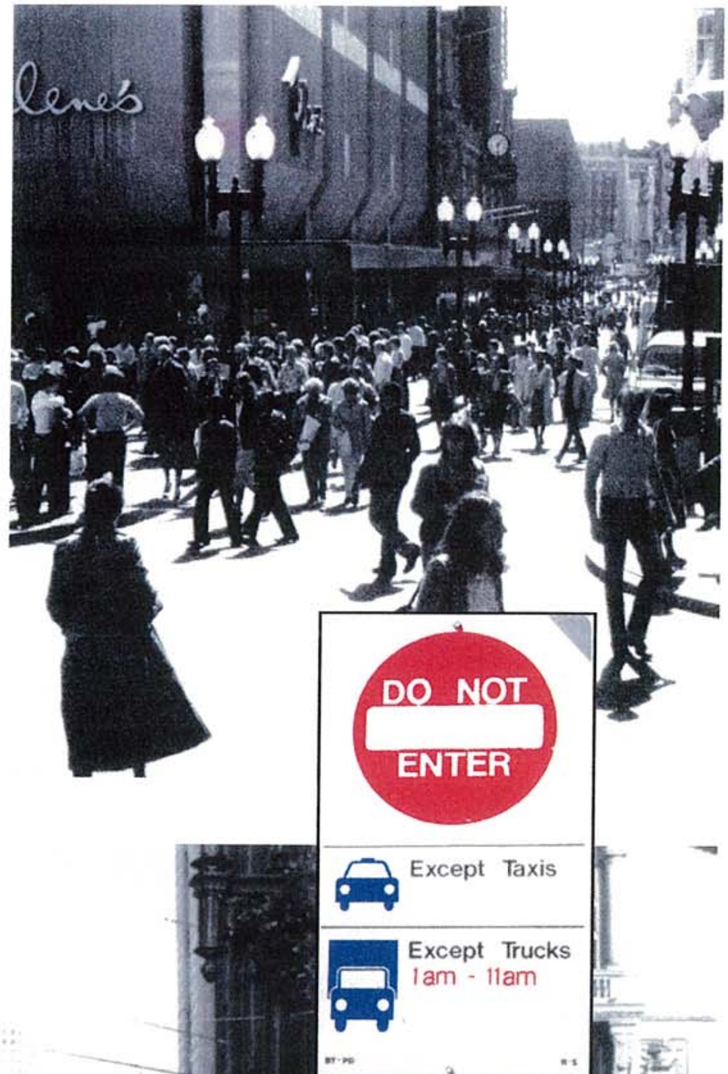


Trip planning information has evolved from the screen display used by phone operators in a San Fernando Valley pilot project in 1982 to real-time displays of bus status on the internet. The Cape Cod Transit website shows bus stops (red dots) and the location and direction of buses (arrows). Internet users can obtain details by pointing and clicking.

Auto Restricted Zones (ARZ's)

A variety of approaches to improving downtown mobility and economic viability were tested between 1978 and 1984. Prohibition of automobiles in part of a central business district was risky in that mechants sometimes opposed the auto-free concept.

In the 1980's UMTA supported demonstrations of ARZ's in four cities and studies of **Transit Malls** in nine cities. The projects which appear to be most successful are those that combined safe, pedestrian-friendly streets with improved downtown transit service.



One of the first ARZ demonstrations was Boston's "Downtown Crossing." It restricted traffic in a 10-block area in the heart of the retail district. Four major streets were fully restricted and quickly became filled with people. The district is well served by subways and automobile traffic movement has adjusted to the change.

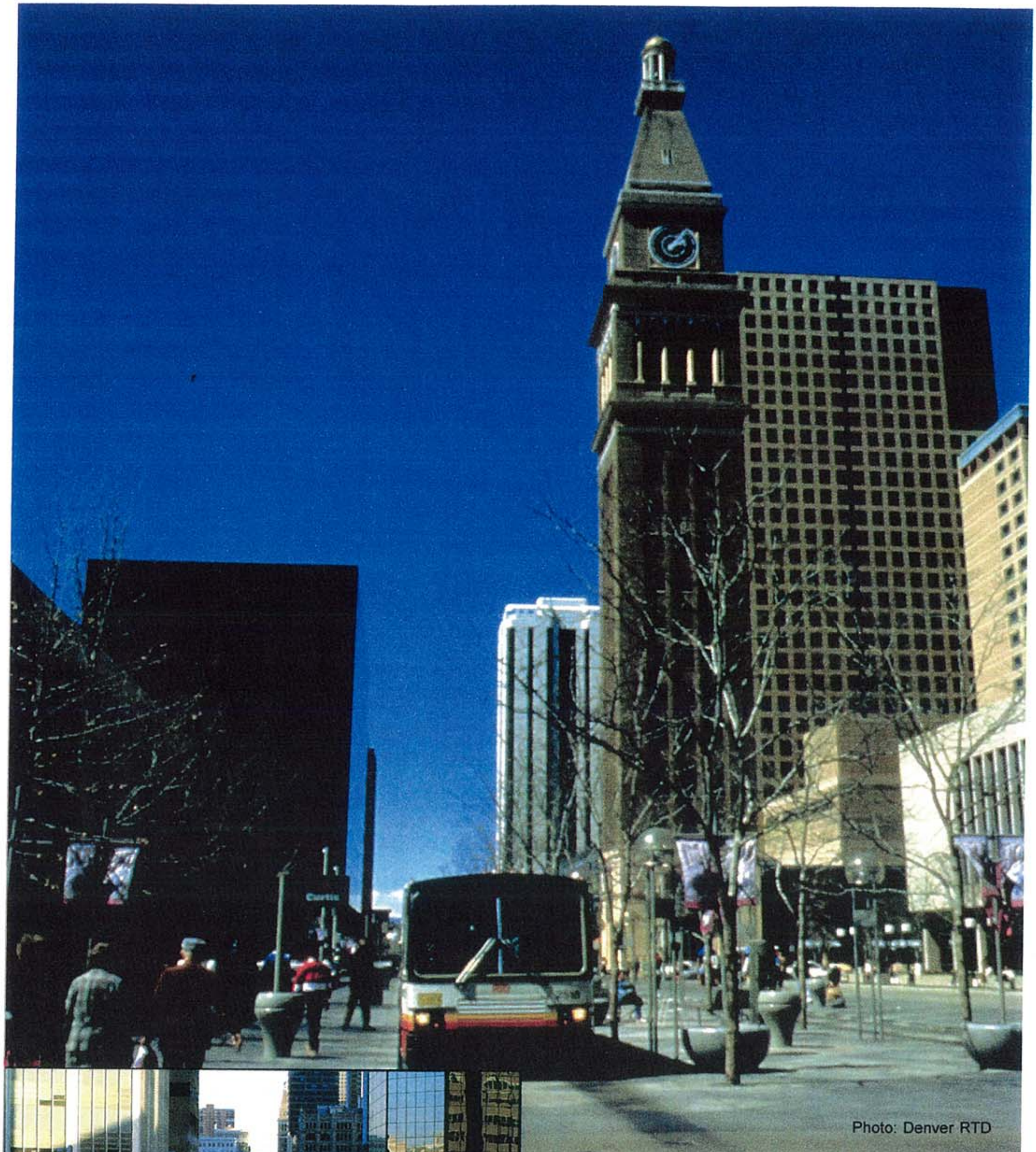


Photo: Denver RTD

Photo: Denver RTD

Denver's 16th Street Mall (above) runs for 16 city blocks between Union Station and the State Capital (left). It is intersected by Denver RTD local and regional bus lines as well as light rail. It spans Denver's retail, hotel, financial, goverment, and entertainment districts and has revitalized the downtown. It is extremely popular. The mall's free shuttle provides rides to more than 45,000 passengers a day.

Pricing and Marketing

Advertising and market analysis were rare before local governments took over responsibility for transit. To compete with growing automobile travel, transit managements had to adopt new business practices such as pricing strategies, and public relations, as well as advertising and marketing..

Because these fields were new to transit, UMTA assisted the industry by assassing the effectiveness of new and existing pricing and marketing strategies being used by agencies. Over 35 methods were evaluated by case studies and funded demonstrations, including advertising media and ad designs, free-fare transit, promotional fare incentives, fare reductions, and fare prepayment tecxhniques. .

During the 1980's promotional and advertising ideas were shared liberally within the transit community, UMTA's contribution was to provide uniform measures of effectiveness of the different techniques.

Promotional fare incentives and fare reductions were studied in six cities. Making it easier to find out about the advantages of using transit proved to be an important factor in attracting new riders.

Making it easier for customers to pay for rides was another factor in attracting customers. Prepayment methods and fare collection techniques were evaluated in eleven cities.

Photo: Tri-Met Portland

The **Downtown Transit Mall** in **Portland, Oregon** (above) is in one of six fare-free zones that were evaluated by UMTA. In general, such zones were found not to improve systemwide revenue even though they increase the use of public transportation and helped revitalize the city center. This popular mall in Portland is served by Tri-Met bus lines and is intersected by light rail, streetcar, and vintage trolley lines.

Photo: MTA Baltimore

User-side subsidies proved to be the most economic method for transit agencies to serve disabled and needy city residents. Studies in ten cities showed that subsidies for special user groups were not objectionable to the general public and were less costly than general price reductions.

SOURCES

Project Descriptions - were derived from Project Direcories published annually by UMTA/FTA.

Technical Results: From the begining of UMTA, it has been a policy to make all technical reports of research or development funded in part or in whole with public funds available to the public through the National Technical Information Service (NTIS), a service provided by the U.S. Department of Commerce. In addition, FTA annually publishes a volume of abstracts of all technical reports.

The outcome of many of the projects was obtained from websites maintained by transit agencies, manufacturers, system operators, research centers, libraries, and fan clubs. Many of these sources loaned slides or mailed up-to-date pictures and status information in respose to letters and e-mail.

Pictures: The majority of pictures in this volume were scanned from color slides collected by the early Associate Administrators for Research and Development: George Pastor and Peter Benjamin. The slides were maintained and cataloged by Edith Rodano at FTA. Other photos without credits were supplied by UMTA staff members and by staff engineers at the Volpe National Transportation Center in Cambridge, MA.

New (to the author) pictures were obtained from the organizations credited on the pictures themselves. Many of the gaps in project pictures were filled recently by coleagues at FTA and the Volpe Center, namely: William B.Menczer Jeffrey Mora, Joseph Goodman, Ronald Boneau, Raymond Keng, Lisa Colbert, William Hathaway, Joseph Koziol, and Ronald Kangas.

Budget Data: Actual expenditures on program areas were obtained from annual reports of Congressional Budget Hearings. Budget requests for each year are accompanied by the actual expendutures of the prior year.

TO FIND OUT MORE

New volumes of information are being digitized and websites are being expanded each year. The best way to start is with the FTA's **National Transit Library** at www.fta.dot.gov/ntl/index.html. It provides links to the other most useful resources, including other transportation libraries, transit associations, research centers, other transit document search engines, transit agencies, and other government sites.

Some of its most useful links are: **TRIS Online** (a comprehensive searchable database of technical reports, articles, and books on transit), the **American Public Transportation Association (APTA)** website (provides links to transit equipment manufacturers, contractors and consultants), .the **Transportation Research Board Bookstore (TRB)** (lists digests of research results and other publications available from TRB. The **National Technical Information Service (NTIS)** website lists technical reports and Project Directories online that have been entered since 1990. Earlier reports may be identified on TRIS and ordered by phone or mail. Note that from FY 1972 through 1983 Project Directories are titled: "Innovation in Public Transportation."

Current information on **FTA's Research and Technology Program** is available on the FTA internet website: www.fta.dot.gov/research/index/htm.

A comprehensive report on existing and proposed advanced transit systems can be found on the **Innovative Transportation Technology** website at http://faculty.washington.edu~jbs/itrans/