4.0 TECHNOLOGY STATUS AND DEVELOPMENTS

4.1 Status of Bus Manufacturers

Currently, there are six manufacturers in North America that are offering heavy-duty, low-floor buses to the transit market. Some of the technical characteristics of the 40-foot, low-floor models by manufacturer are given in Table 4.1. The sizes of low-floor buses that are currently offered or are under development for each manufacturer are identified in Table 4.2. As can be seen in Table 4.2, all manufacturers have a 40-foot model, and four have (or plan to have) a 35-foot model. The various propulsion and fuel options that are available from each manufacturer are identified in Tables 4.3 and 4.4.

4.2 Developments in Technology

There are several projects that could lead to significant advances in body and propulsion technologies that are applicable to future low-floor bus developments. The Advance Technology Transit Bus (ATTB) program was initiated in 1992 with the objective of developing a lightweight, low-floor, low-emission transit bus. There are two programs to develop a fuel cell powered bus, one of which is integrated in a low-floor bus. There are several hybrid electric propulsion system projects that are expected to reach the production stage in the near future. Each of these programs is discussed in the following sections. The last two subsections on developments in technology discuss new approaches under development in Europe. The first discusses innovative approaches to wheelchair securement involving "rear facing protected position" designs that are being adopted in Europe. The last subsection discusses level boarding with low-floor buses, and some of the experiences with level boarding in Europe.

4.2.1 Advanced Technology Transit Bus

The ATTB is a major Federal project to develop a 40-foot transit bus that meets Federal requirements for axle loads, emissions, and accessibility, a maximum unit price of $300,000 (1992 dollars), low operating costs, and can accommodate 43 seated and 29 standee passengers. A layout of an example seating arrangement is given in Figure 4.1.

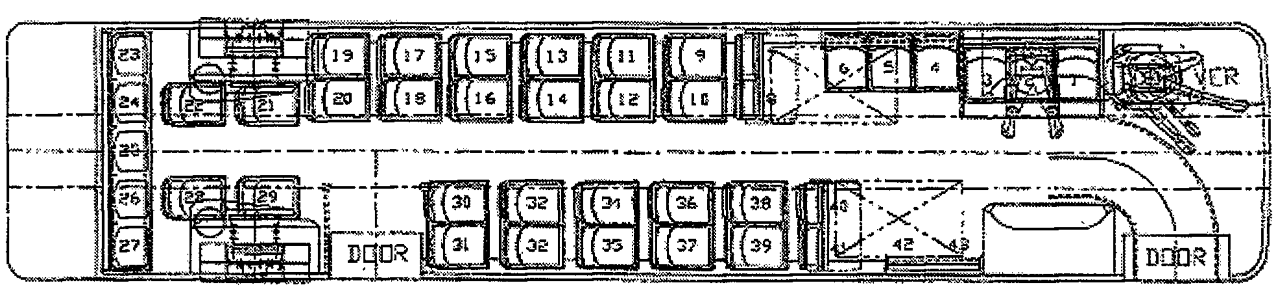

Figure 4.1 Example Seating Layout for the ATTB

Source: Reference 34

Table 4.1 Technical Characteristics of 40-Foot, Low-Floor Buses

Characteristic		Gillig	Neoplan USA	New Flyer Industries	North American Bus Industries	Nova Bus	Orion Bus Industries
Model Identification		Low-Floor Bus	AN440L	D40L	40LFW	LFS	Orion VI
Height, Inches		114.5	115.5[a]	111	114	123[a]	118.5[b]
Wheelbase, Inches		284	274	293	276	244	278
Turning Radius, Feet		42.5	42	44.1	44	41.5	39.6
Approach Angle, Degrees		9	10	9.2	9	9	10
Departure Angle, Degrees		10	9	9.3	9	9	9
Breakover Angle, Degrees		10	10	8.3	10	9.5	10
1st Door Entr. Ht. (Not Kneeled), Inches		12.5[c]	14	14.5	14 - 15[d]	14.6	14.5
2nd Door Exit Ht. (Not Kneeled), Inches		13.75[c]	15	14.5	14 - 15[d]	14.6	14.5[e]
Kneeling Capacity: (in Inches)	Front Door	3	3	3	3	5	3.5
	Rear Door	3	1	3	3+	5	3.5
Ramp Location, Front/Rear Door		F	Both	Both	Both	Both	F
Wheelchair Location, Front/Rear		F	Both	Both	Both	Both	F
Maximum Number of Seats		40	42[f]	39	37	39[f]	35
Maximum Capacity, (GVWR - CW) / 150		87	77	82	77	82	91
GVWR, Pounds		37,920	37,920	39,190	40,600	39,550	41,750
Curb Weight, Pounds		24,800	26,325	26,750	29,000	27,200	28,000

Source: Bus Manufacturers

(a) With roof mounted air conditioning unit.
(b) Over access hatch.
(c) Entrance height with standard profile tires is 15 inches, and the exit height is 16.25 inches.
(d) Entrance and exit heights will depend on the tires used.
(e) Height of exit behind the rear axle is 14.5 inches.
(f) With four rear-facing seats.

Table 4.2 Size of Heavy-Duty, Low-Floor Buses Offered by Manufacturers

Manufacturer	Size of Buses				
	30-Foot	35-Foot	40-Foot	45-Foot	Artics
Gillig Corporation		X	X		
Neoplan USA Corporation		X	X	X	
New Flyer Industries Limited	X	X	X		X
North American Bus Industries		X[a]	X		
Nova Bus Corporation			X		
Orion Bus Industries			X		

Source: Bus Manufacturers

[a] The 35-foot model is under development.

Table 4.3 Propulsion Options Offered by Manufacturers

Manufacturer	Propulsion Option		
	HYB-Elec	Fuel Cell	Trolley
Gillig Corporation	X[a]		
Neoplan USA Corporation			
New Flyer Industries Limited	X[a]	X	X
North American Bus Industries			
Nova Bus Corporation	X[a]	X[a]	
Orion Bus Industries	X		

Source: Bus Manufacturers

[a] Planned or under development.

Table 4.4 Fuel Options Offered by Manufacturers

Manufacturer	Fuel Option		
	Diesel	CNG[a]	LNG[b]
Gillig Corporation	X		
Neoplan USA Corporation	X		
New Flyer Industries Limited	X	X	X
North American Bus Industries	X	X	X
Nova Bus Corporation	X	X	
Orion Bus Industries	X	X	

Source: Bus Manufacturers

[a] Compressed natural gas.
[b] Liquefied natural gas.

The ATTB environmental design goals are the California Air Resources Board (CARB) Low Emission Vehicle (LEV) requirements for urban buses. The program calls for the design and fabrication of six prototypes. Field testing is scheduled through 1998. The physical characteristics of the ATTB are given in Table 4.5.

The first bus is an engineering test bed that is being used to evaluate various subsystems and to validate the design approach. The second bus incorporated design improvements developed with the first unit, and is the durability test bed. Bus number 2 is currently being tested at the Altoona Bus Testing Center. The remaining three units will be used for demonstrations and revenue service tests at several cities throughout the U.S.

4.2.2 Fuel Cell Developments

There are two efforts underway to power a transit bus with fuel cell technology. One is the Federal Transit Administration (FTA) Fuel Cell Transit Bus Program, and the other is the Ballard Fuel Cell which has been integrated in an NFIL D40L bus. While the test bed used in the FTA program is a high-floor bus, if successful the technology could be used in a low-floor bus. The incentives for considering fuel cell technology are a pollution free bus service, use of a non-fossil fuel, and an increase in range over battery technologies.

The FTA program is a joint program with the Department of Energy (DOE), and is managed by the Georgetown University. The program objective is to integrate a phosphoric acid fuel cell in a 40-foot transit bus (RTS). Methanol is fed to a reformer which produces the hydrogen gas used by the phosphoric acid fuel cell to produce electric energy. A prototype is to be delivered in the Summer of 1998 for tests and evaluation.

Ballard Power Systems has installed fuel cell engines in seven NFIL D40L buses. Three of these buses have been sold to the CTA and three to BC Transit Vancouver. The buses were delivered in 1997. The Ballard fuel cell uses hydrogen gas stored in high pressure cylinders, similar to those used for CNG storage. The hydrogen gas is fed into a Proton Exchange Membrane (PEM) fuel cell which through an electrochemical process produces electric power and water vapor. The CTA fuel cell buses will be placed in revenue service by March 1998 on three routes that travel through the downtown area for test and evaluation of the technology.

4.2.3 Hybrid Electric Developments

There are several programs underway to develop a hybrid electric propulsion system for transit buses. One program that will have buses placed in revenue service in the near future is the Orion VI Low-Floor Hybrid-Electric bus. The New Jersey Transit has ordered four buses and they will be delivered in the first quarter of 1998. The NYCT has ten buses on order, and they are scheduled to be delivered in the second quarter of 1998. The bus uses a Lockheed Martin hybrid electric propulsion involving a DDC Series 30 engine, a 110kW generator, and AC traction motor, an advanced lead acid battery pack, and an electric power control system.

The Gillig Corporation is developing a hybrid electric propulsion system for their

Table 4.5 Technical Characteristics of the ATTB

Characteristics	
Length, feet	40
Height, inches	118.4
Wheelbase, inches	301
Turning Radius, feet	42.5
Approach Angle, degrees	10
Departure Angle, degrees	10
1st Door Entrance Height (not kneeled), inches	14
2nd Door Entrance Height (not kneeled), inches	14
Kneeling Capability (in inches) Front Rear	3
Ramp Location, Front/Rear Door	F
Wheelchair Location, Front/Rear	F
Maximum Number of Seats	43
Maximum Capacity, (GVWR - CW)/150	77
Gross Vehicle Weight Rating (GVWR), pounds	31,960
Curb Weight, pounds	20,355
Engine	DDC Series 30 G
Generator	EEMCO AC Induction (200kw)
Wheel Motor	Unique Mobility DC Perm. Mag.
Front Tire	SR275/70R22.5
Rear Tire	SR385/65R22.5

Source: References 34 and 35

buses. The first propulsion system will be tested in a Phantom 40-foot bus that will be delivered to Golden Gate later this year. The Gillig hybrid-electric propulsion system is similar in approach to the Lockheed Martin system, and includes an engine, generator, traction motor, battery pack, and power controller. Gillig plans to use the technology in their low-floor bus, and be in production in 3 to 5 years.

The FTA DUETS program involves the development of an advanced hybrid electric propulsion system for buses. The Nova Bus Corporation is the contractor for the program. The test bed vehicle is an RTS bus that has two small rotary natural gas engines coupled to a generator. Power from the generator flows to the power control unit then to two wheel hub motors. The propulsion system also includes a lead acid battery storage system. A demonstration test of the system is scheduled to begin in 1998.

4.2.4 Protected Position Design for Wheelchair Accommodation

European research and standards development efforts (References 12 and 31) have focused on an innovative approach to accommodating passengers in wheelchairs on low-floor buses, involving a "protected position" on the vehicle. This concept involves two major elements: 1) a clear rectangular floor area of approximately 55 by 28 inches, where a person in a wheelchair can position themselves in a rear-facing position, and 2) a load bearing back and head rest, which protects the passenger in case of rapid deceleration. Flip-up seats are usually provided to be used by other passengers when no passenger in a wheelchair is present. In addition, a vertical aisle stanchion is typically provided to prevent the wheelchair sliding into the aisle during bus turning movements.

Such an approach is reported to provide: the same level of safety afforded to other seated bus passengers; more independence of the passenger in the wheelchair during boarding, riding, and alighting; and a safe wheelchair location without the use of hooks or belts. Further, the approach does not require the assistance of the operator. However, the wheelchair passenger must face to the rear, which is not an issue in Europe, but is more of an issue for North American buses. However, rearfacing seats are common in trains and subways in North America.

This approach appears to offer many advantages and a high level of safety. It has become the widely accepted standard in Europe, and the Canadian Urban Transit Association has been exploring its transferability to Canadian transit systems (Reference 32). As a result, several Canadian transit systems have adopted this approach. Examples of the "protected position" can be seen in Figures 2.5 and 4.2. The "protected position" does not meet the ADA requirement of a 20g deceleration, but studies have shown that even extreme braking on buses rarely exceed 0.5g (References 31 and 33). A waiver would be required to use the "protected position" approach in the United States.

4.2.5 Level Boarding Developments

According to a recent European Community (EC) report (Reference 15), the introduction of low-floor buses should be seen as one step along the path to a more

Figure 4.2 Hamilton Street Railway Low-Floor Bus with Protected Position

Source: Canadian Urban Transit Association

passenger friendly transport system. The next steps that are being proposed are level boarding, improvements in passenger information, and improvements in bus stop facilities. Level access for all customers is regarded as one of the most important features of an attractive and modern means of public transport.

In several cities in France and Germany, level board tests are underway. Level boarding is accomplished by raising the level of the bus stop platform to the level of the low-floor bus entrance. To minimize the horizontal gap between the bus entrance and the bus stop platform, the bus must be consistently brought close to the curb. It is difficult for operators to consistently steer the bus close to the curb without damaging the tire or bus body. In several cities in Germany they are experimenting with special curb stones that are claimed to assist the operators in steering the bus to the curb without damaging the tires. A photo of a "Bus Kap" in Aachen, Germany using this approach is shown in Figure 4.3. In this case, the bus stop was brought out to the traffic lane, and the bus would stop in the traffic lane. Since the honor fare collection system enables all doors to be used to board and alight, and there is no time lost by the bus trying to re-enter the traffic stream, the dwell time is quite short. Another approach used in Caen, France is shown in Figure 4.4. In this case, a steel tube imbedded in the curb is used to protect the tire. In Grenoble, France, experiments are underway to use optical guidance to steer the bus to the stop. In Essen, Germany, a guided bus route uses the median of a four lane highway to Kray. There are three stations located along the route. The route has only low-floor buses operating on the route. The guided bus system operates in this case like a rubber tired rail system. The station platforms are at the same level as the floor level of the guided bus. The interface between vehicle and station platform is as good as any high platform rail system. A photo of a low-floor guided bus stopped at a station is shown in Figure 4.5.

In August 1997, a successful demonstration of full automatic control of two MTA low-floor buses was accomplished. The buses were equipped with both vision and radar sensors to control the bus in both lateral and longitudinal directions. Such technology could also be used to steer a bus close to a bus stop platform.

Figure 4.3 Raised Bus Stop in Aachen, Germany

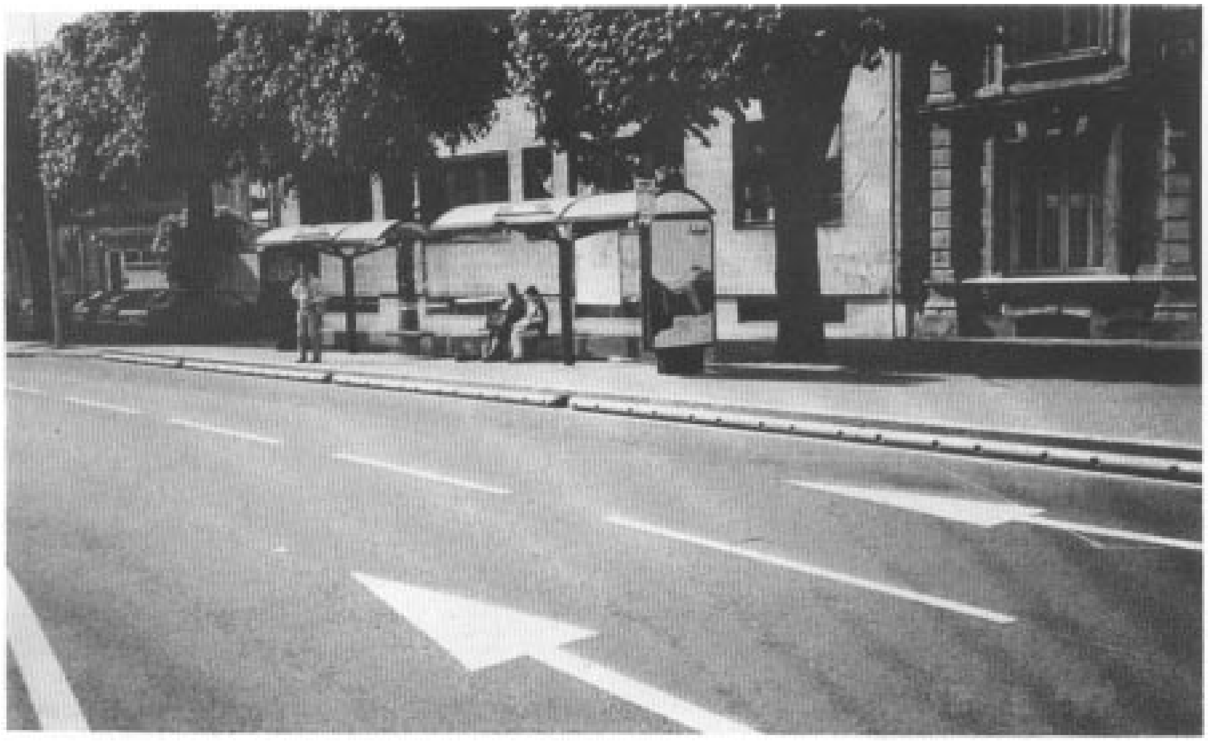

Figure 4.4 Raised Bus Stop in Caen, France

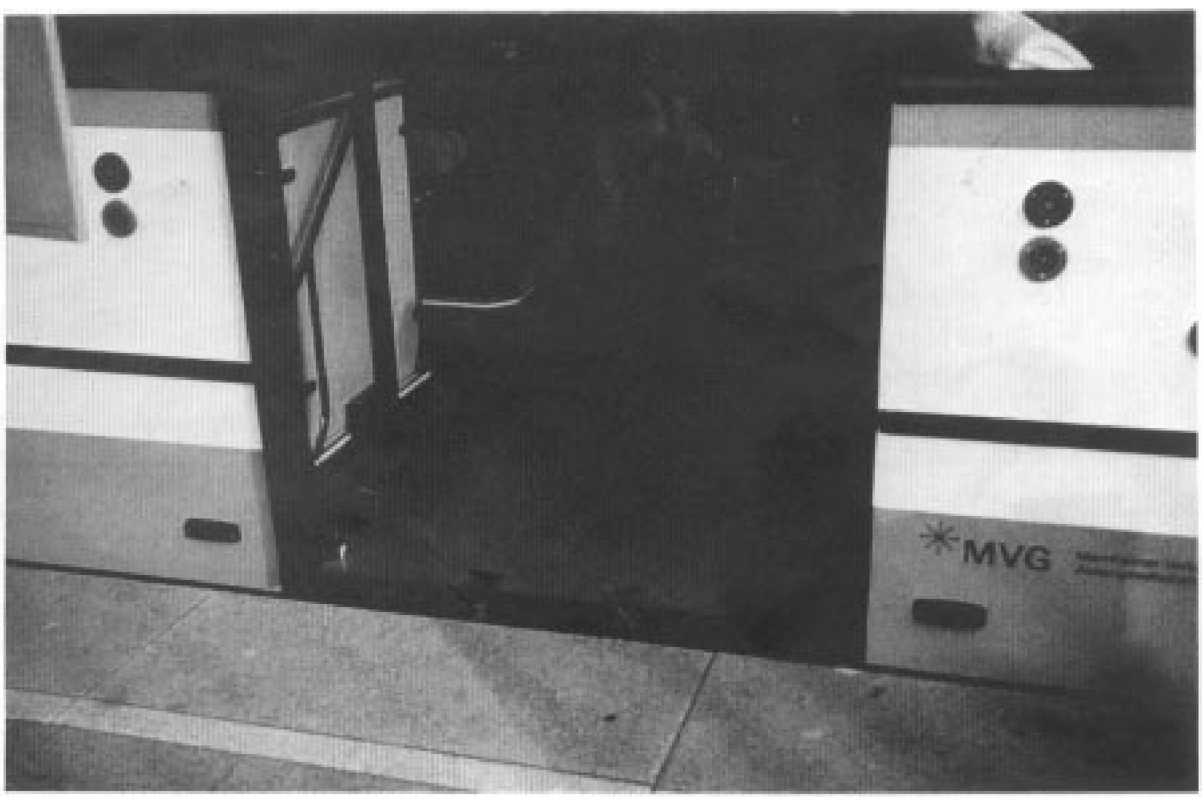

Figure 4.5 Low-Floor Guided Bus at a Station in Essen

5.0 CONCLUSIONS AND RECOMMENDATIONS

Since their first deployment in 1991, low-floor buses have increasingly become the choice of transit agencies in both the United States and Canada. By December 1997, there were over 2,800 low-floor buses in operation and over 2,600 on order in North America. There are six manufacturers that are offering heavy-duty, standard-size, low-floor buses to the transit market.

5.1 Conclusions

The significant findings from interviews with transit agencies operating low-floor buses and discussions with bus manufacturers are provided below:

5.1.1 Customer Satisfaction and Acceptance

- Customers liked the ease of boarding and alighting of the low-floor buses. Seniors and people with disabilities expressed even a stronger preference for low-floor buses. Most wheel-chair passengers preferred a ramp over a lift.
- Other features that customers liked were the ability to see out of the larger windows, the feeling of a spacious environment with the higher ceilings, and places to put packages.
- Customers also had complaints concerning issues such as: lack of seats, crowding, noise and vibration, windows fogged ("can't see out"), concerns about the safety of the steps in the aisle, and a "jerky" ride. Only one transit agency had received many vocal customer complaints about their low-floor buses. The main focus of their complaints was crowding and inability to move freely through the bus, although it should be noted that the average loads of the buses were much higher at this transit agency.
- Six transit agencies had conducted customer surveys. A large majority of customers gave a positive rating of the low-floor bus, and only four to nine percent gave a negative rating for their low-floor bus. One survey found that peak period riders preferred the conventional high-floor bus because the low-floor buses had less seats and lack of room for standees, while the non-peak riders preferred the low-floor bus.

5.1.2 Customer Comfort and Environment

- Overall, the customers were satisfied with the comfort and environment of the low-floor buses.
- Some complaints had also been received:

- During rainy or snowy days, the windows can become obscured with road grime and spray, making it difficult to see out.
- On very cold days, passengers' feet got cold, and some customers were bothered by the noise and/or vibration of the low-floor bus.
- Sudden and unexpected changes in acceleration and deceleration arising from harsh braking or lack of smooth transition in power gave a jerky ride.

The initial low-floor buses had inadequate heating systems. Improvements made in the heating systems are improving the situation, except perhaps for very cold climates. The vibration complaints were usually received with buses powered by four cylinder engines. The noise complaints usually came from passengers seated in the rear of the bus next to the engine compartment.

- Tests conducted by CUTA found that only one of the low-floor buses tested met an ASHRAE Standard for fresh air in the passenger compartment. The test also indicated problems with uneven heat distribution in the passenger compartment.
- Several of the transit agencies reported having dusty buses. The reasons for the higher level of dust intrusion are not fully understood.

5.1.3 Capacity and Ridership

- For the currently available low-floor, 40-foot buses, the maximum number of seats (using only front and aisle-facing) range from 35 to 40, compared with a range of 43 to 45 for high-floor models. If a transit agency's loading standard is to provide a seat for all expected customers, then the loss in capacity on a route would be proportional to the reduction in the number of seats, assuming no changes in schedule speed and headway.
- Most agencies interviewed reported that they had made no changes in their schedules or added buses with the introduction of low-floor buses in their system. Two agencies reported that the lower capacity of their low-floor buses would probably require adding more buses on routes to maintain their service standards. They were experiencing rapid growth in ridership, and buses had been added to routes. They could not say what portion of the need for more buses was due to increase in riders or what portion was caused by the lower capacity of their low-floor buses.
- None of the agencies operated routes with all low-floor buses during the peak periods.
- The CTA reported no changes were required when they introduced the low-floor buses in their system. The CTA uses the same maximum capacity (70) for

their low-floor buses as is used for their high-floor buses when assigning buses to routes.

- The STCUM said that for scheduling purposes their low-floor bus with 39 seats had a "natural" capacity of 65 passengers, compared to a "natural" capacity of 80 for their high-floor buses. However, the STCUM is evaluating a new interior design for their low-floor buses which they feel has a "natural" capacity of 80, which is the same as their high-floor buses. While the new interior design provides an equivalent vehicle capacity, there are 24 percent fewer seats (31 versus 41), and the service quality (measured by the number of seats provided) would be lower.
- Boarding times for an ambulatory passenger on a low-floor bus were reported to be from 0.2 to 0.7 of a second faster. Alighting times for an ambulatory passenger were reported to be from 0.3 to 2.7 seconds faster, and, in one case, 0.3 second slower. The case of the slower alighting time was attributed to a change in how the exit door was activated.
- None of the agencies reported any increases in schedule speed with the introduction of low-floor buses to their fleet though little formal evaluation had been conducted.
- During the Paralympics, the boarding times for athletes in wheelchairs for both low-floor and high-floor buses were measured. The mean boarding times (not including maneuvering inside the bus or securement) for a low-floor bus was about 27.4 seconds, while the mean boarding time for a high-floor bus was about 46.4 seconds. The report also noted that only one deployment of a ramp is required, irrespective of the number of boarding or alighting persons with mobility aids.

5.1.4 Vehicle Operating Experiences

- All agencies were generally satisfied with the road clearance capabilities of the low-floor buses. Some reported that the protective skid for the ramp cam mechanism would occasionally ground on steep ramps, and some reported grounding on some high railroad crossings and large speed bumps.
- The low-floor buses tended to be quicker and had good handling characteristics.
- The CDTA reported some steering problems during a heavy, wet snow storm with their low-floor buses. Slush and ice became packed around the steering linkages, and restricted the operator's ability to steer the bus. The manufacturer has provided a fix that seems to be working.

5.1.5 Impacts on Maintenance

- Transit agencies were generally satisfied with their maintenance experiences. Many of the early problems experienced by the transit agencies appear to be "new bus model" problems, rather than problems intrinsically related to a low-floor bus design. All agencies had a "punch list" of problems that needed to be resolved.
- Three maintenance items that were consistently reported by the transit agencies as being significantly different in comparison with their high-floor buses were:

  - The operating experiences with the ramp have been universally positive. The U.S. transit agencies reported that service interruptions because of ramp failures either did not occur or were rare. Lift failure is a major cause of road calls for many U.S. transit agencies. In addition, the cost of maintaining lifts has been reported to be significantly higher than the cost of maintaining ramps. The costs per bus per year ranged from $50 to $300 for ramps and from $1,500 to $2,400 for lifts.
  - All of the low-floor buses at the transit agencies used a low-profile radial tire, either a 275/70R22.5 or a 305/70R22.5. All indicated that they were getting from 20 to 30 percent less miles with their low profile tires. Also, several agencies reported more wheel damage from hitting curbs with their low-floor buses. The STCUM has noted a higher wear rate on their curb side, dual tires compared with the street side, dual tires. The wear rate difference was thought to have been caused by the right side, dual tires slipping.
  - Problems reported with the brakes were: brake effort balance between front and rear brakes, timing of brake application, and the short life of brake linings. The bus manufacturer conducted a retrofit program and corrected the imbalance and timing problems. The life of brake linings is improving, but for many properties, it is still shorter than desired. The problems with the brakes appear to have resulted because the bus was a new bus design rather than a low-floor design.

5.1.6 Maintenance Facilities Impacts

- The changes needed in the maintenance facilities with the addition of low-floor buses to a fleet have been minimal. No changes had been made to the maintenance pits. Some have fabricated fixtures to adapt their existing hoists to the undercarriage of their low-floor buses.

- To work on roof mounted components, some used step ladders; others used movable work platforms.
- All agencies have purchased some special tooling and adapters largely because it was a new bus in their fleet.
- Several agencies had made adjustments to the height of the brushes on their bus washer. The CTA had fabricated a shim for the tire guide of their bus washer so that the low-floor bus wheel would not contact the curb as it travels through the washer.

5.1.7 Safety Experiences

- All transit agencies were satisfied with their safety experiences with their low-floor buses. However, few had data to support their perceptions.
- Some transit agencies reported that the number of passenger accidents per low-floor bus was higher than the passenger accidents per bus for their high-floor fleet. <u>All</u> of the agencies <u>cautioned against</u> making a simple comparison of the data because of the small amount of data, and the exposure of the low-floor buses (more passengers and more miles per bus) tended to be higher than for their high-floor buses.
- Some agencies felt that the higher frequency of slips and falls of passengers occurring in the front of the low-floor buses could be related to the lack of an adequate number of handholds from the farebox to the first row of seats.
- The steps in the aisle have been perceived as a safety hazard by both transit customers and transit staff, and concerns about the steps were reported in several of the customer surveys. The operating experiences to date do not indicate that the steps represent a safety hazard. All transit agencies that were operating low-floor buses with steps in the aisle reported that they have not had any safety incidents caused by the steps.

5.1.8 Operator and Mechanic Acceptance and Satisfaction

- Overall, operators were satisfied with their low-floor buses. Operators liked the ease of customer boarding, the ease of using the ramp (and the ease of manual operation of the ramp), the quickness and handling of the bus, the improved visibility, and the eye level contact they have with customers. When asked about concerns, a senior operator at CT listed the following: congestion in the front of the bus, the flow of passengers to the rear of the bus, insufficient heat during extremely cold weather, the jerky ride quality, and a blind spot created by the frame of the front door panels.

- Surveys conducted at MARTA and NYCT found that their operators liked the improved visibility, handling, and noise level, but expressed concerns about steps in the aisle and the right side mirror being too low (hazard to passengers).
- The majority of mechanics were satisfied with their low-floor buses. Some mechanics preferred to work on the low-floor buses since everything was cleaner and accessible (many components moved from under the bus to the roof area), while others expressed some concerns about working from ladders and elevated platforms.
- One service person pointed out that the higher ceilings were a little more difficult to clean. However, most agencies felt that there were no significant differences in the cleaning and servicing of the low-floor buses.

5.1.9 Market Status and Trends

- Only Neoplan USA and New Flyer Industries were delivering heavy-duty, low-floor buses from 1991 through 1995. Nova Bus and Orion Bus Industries began delivering low-floor models in 1996 and 1997. Gillig and North American Bus Industries will begin delivery of heavy-duty, low-floor buses in the first quarter of 1998.
- At the end of 1997, bus manufacturers reported that 2,812 low-floor buses had been delivered, and that they had orders for another 2,660.
- With the entry of more manufacturers to the low-floor market, the number of deliveries has grown rapidly. There were 1,185 low-floor buses (35, 40, and 60-foot) delivered in 1997.
- It is estimated that low-floor models were 30 to 40 percent of the 1997 heavy-duty bus market in North America. Three of the manufacturers estimated that their sales of buses in 2000 would be 50 to 90 percent lowfloor models.

5.1.10 Technology Status and Developments

- All six of the manufacturers offer a 40-foot bus to the transit market, and four offer 35-foot models. Only one manufacturer offers 30, 35, 40, and 60-foot models.
- All have low-floor models powered by diesel engines. Four offer the option of compressed natural gas (CNG), and two have options for liquefied natural gas (LNG).
- There are several R&D programs underway that could lead to significant advances in

technologies used in low-floor buses.

- The ATTB is a major FTA program to develop a lightweight, low emission, low operating cost, low-floor bus for the next century. Six prototypes have been fabricated. Testing is underway at the Altoona Bus Testing Center with one of the buses. Three of the prototypes will be demonstrated at various transit agencies during 1998.
- Ballard Power Systems has installed their fuel cell engine in seven New Flyer Industries low-floor buses. Three buses were delivered to both the CTA and the BC Transit-Vancouver for test and evaluation in revenue service.
- The FTA Fuel Cell Transit Bus Program is a cooperative program with the DOE to design a 40-foot bus powered by a fuel cell system. A prototype fuel cell system installed in a Nova Bus RTS will be delivered for demonstration and testing in the summer of 1998.
- A low-floor, hybrid-electric bus is under development by Orion Bus Industries and Lockheed Martin. The initial production models will be delivered to the New Jersey Transit (four buses) and the New York City Transit (ten buses) in the first half of 1998. These buses will be placed in revenue service for test and evaluation.
- The Gillig Corporation is developing a hybrid-electric propulsion system for their buses. The first delivery will be in a Phantom to be delivered to Golden Gate in the spring of 1998. A low-floor bus using this propulsion system is expected to be in production in 3 to 5 years.
- Most European and a number of Canadian transit systems are adopting the rear-facing "protected position" design to accommodate passengers in wheelchairs. This approach uses a backrest to protect the passenger during deceleration. It is extremely attractive because it involves no straps or mechanical devices, no operator involvement, and enhanced passenger independence.
- Several cities in Europe are demonstrating various approaches to level boarding with low-floor buses. To achieve an acceptable horizontal gap between the bus entrance and the station platform, some method of aiding the operator or automatically steering the bus close to the curb is required. Mechanical, optical, and electronic guidance approaches are under evaluation.

5.2 Recommendations

Based upon the insights gained during the course of this study, the following research topics are recommended for consideration:

- **Reduction in Dwell Times.** Low-floor buses enable the faster boarding and alighting of passengers. For ambulatory passengers, the average reported time savings was about 0.5 seconds per passenger, and for passengers with disabilities the average reported time savings was approximately 19 seconds. However, to take advantage of these quicker boarding and alighting times, a faster fare collection process is needed. For example, a "proof of payment" system or "smart card" system where bus passengers can use all doors would significantly shorten dwell times. Facilitating a fast and safe reentry of the bus into the traffic stream would aid in reducing dwell times. Buses in the province of Quebec, and more recently in the State of Washington, are given the right-of-way when they emerge from a bus stop to reenter the traffic stream. Bringing the bus stop adjacent to the traffic lane so that the bus stops in the traffic lane is another approach that has been implemented by some transit agencies.
- **Development of Level Boarding System.** Low-floor buses hold the potential to offer level boarding to bus customers comparable to those that exist for high platform rail systems. Various schemes are being tested in Europe to assist the operator to steer close to the curb of a raised bus stop platform. Automatic guidance approaches are also under development and evaluation. Mechanical guidance has been in use in Germany for over 15 years. Optical and electronic methods are also under development and evaluation. The development of a level boarding system for buses would benefit all customers and would aid in reducing dwell times, thus having beneficial effects on traffic flow and environmental pollution.
- **Improved Passenger Handholds in the Front of the Bus.** A high percentage of passenger slips and falls have occurred in the area between the farebox and the first row of seats. When the wheelchair positions are located in the front of the bus, there are distances of six to eight feet where vertical stanchions are not available for passengers to grasp as they move to the rear of the bus. The horizontal grab bar is too high for some passengers to reach. The straps used by some agencies have helped, but are not a complete solution. The straps do not provide a firm hand hold for the elderly, and some passengers cannot raise their arms to reach the strap. Improvements in passenger

handholds would reduce the passenger slips and falls while on the bus. This might, for example, build on the prototype efforts carried out at Calgary Transit.

REFERENCES

(1) King, R.D., "Low-Floor Buses," TCRP Synthesis 2, (1994).

(2) Schneider, W. And Beechbühl, A., "Defining the Low-Floor Bus: Its Advantages and Disadvantages," Paper presented at the International Union of Public Transport 49th International Congress, Stockholm (August 1991).

(3) Prentice, C. And Kershaw, D., "Low-Floor Bus Design Issues and Guidelines Study," Canadian Urban Transit Association, Report No. RD-94-3, (September 1994).

(4) "Evaluating Transit Operations for Individuals with Disabilities," Final Report (draft), TCRP Project B-1, Multisystems, Inc. & Crain & Associates, Inc., (April 1997).

(5) "Low-Floor Bus Survey," Calgary Transit, (December 1993).

(6) "Low-Floor and Standard Bus Surveys," Chicago Transit Authority, Technical Report SP93-04, (February 1993).

(7) "Low-Floor Bus Surveys," Metropolitan Atlanta Rapid Transit Authority, Planning and Policy Development, (April 1995).

(8) "82 Westheimer Low-Floor Bus Surveys," Metropolitan Transit Authority of Harris County (Internal Memo), (July 1997).

(9) "Customer and Bus Operator Research with the Low-Floor Bus," MTA New York City Transit, Marketing Research and Analysis, (January 1997).

(10) "Hybrid Electric/Low-Floor Bus Research," MTA New York City Transit, Marketing Research and Analysis, (March 1997).

(11) "Customer and Bus Operator Surveys on In-Service Test of New Flyer Low-Floor Bus," MTA New York City Transit Marketing Research and Analysis, (July 1997).

(12) "The Role of Passenger Amenities and Vehicle Characteristics in Building Transit Ridership," TCRP Project B-10, Interim Report, Project for Public Spaces, Inc., (March 1997).

(13) "An Evaluation of Accessible Transit Buses in Vancouver and Victoria," Final Report TP12709E, Transport Canada, (June 1995).

(14) "CTA Service Standards," Service Planning Section, (September 1990).

(15) "COST 322, Low-Floor Buses," Final Report EUR16707EN, European Commission, Directorate-General for Transport, (1995).

(16) "Altoona Bus Testing Reports," the Pennsylvania Transportation Institute, Report Numbers 9201, 9411-13, 9508-20, 9613-08-97, 9617-10-97, and 9708-15-97.

(17) "Kneeling buses take a pounding," News Article, The Globe and Mail, (October 15, 1997).

(18) "Standard Bus Procurement Guidelines, Part 5 - Technical Specifications Baseline Heavy-Duty Transit Bus" (draft), American Public Transit Association, (June 1997).

(19) "Accessible Ridership Report, Memorandum," New York City Transit, Department of Buses, (November 20, 1997).

(20) "Top Twenty Road Calls by Fleet and System-Wide MDBF Report," New York City Transit, Department of Buses, (November 1997).

(21) "Road Calls by Fleet and System-Wide MDBF Report - 1997," New York City Transit, Department of Buses, (January 1998).

(22) ANSI/ASHRAE Standard 62-1989, "Ventilation for Acceptable Indoor Air Quality," American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA. (1990).

(23) ANSI/ASHRAE Standard 55-1992, "Thermal Environmental Conditions for Human Occupancy," American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., Atlanta, GA. (1992).

(24) "Canadian Urban Transit Association Bus Ventilation Study, Phases 1, 2, 3, and 4," Envirotest, Inc. Reports 1, 2, 3, and 4, (November 1993 through June 1996).

(25) Transport Canada Transportation Department Center, "Nova Bus LFS Urban Bus Ventilation System Testing (Phase 5)," Environtest, Inc., Report 5, (May 1996).

(26) Levine, S.C. and G. Torng, "Dwell Time Effects on the Low-Floor Bus Design," Journal of Transportation Engineering, ASCE, Vol. 120, No. 6, (November/December 1994).

(27) Spiller, D. And L. Labell, "Operational Assessment of Paralympics Transit System: Low-Floor Buses, Lift-Equipped Buses, and Signage," Final Report, DOT-VNTSC-FTA-97-1, (February 1997).

(28) Cost Savings from Free Fare for People with Disabilities, AATA Memorandum, (February 1997).

(29) 1997 Transit Fact Book, American Public Transit Association.

(30) Summary of Canadian Transit Statistics, 1996 Data, Canadian Urban Transit Association.

(31) Rutenberg, U., "Urban Transit Bus Accessibility Concerns," Canadian Urban Transit Association, TCRP Report 10 (August 1995).

(32) Rutenberg, U., "Advanced Concepts to Accommodate Mobility Aids on Canadian Low-Floor Buses," Canadian Urban Transit Association, TCRP Report 15, (Forthcoming).

(33) Tests to Determine Regular Service and Emergency Acceleration Forces, Performed by GOTransit, (May 1993).

(34) Technical Developments and Configuration Decisions, Northrop Grumman, Bi-Monthly Report, (March/April, 1995).

(35) Advanced Technology Transit Bus, FY94 Technology Validation Final Report, Volume II Technical Report Updates, Northrop Grumman, (March 1995).

ACRONYMS AND ABBREVIATIONS

Bus Manufacturers

Gillig Corporation	GIL
Flxible Corporation	FLX
Motor Coach Industries International	MCI
Neoplan USA Corporation	NEO
New Flyer Industries Limited	NFIL
North American Bus Industries	NABI
Nova Bus Corporation	NOV
Orion Bus Industries	OBI
Transportation Manufacturing Corporation	TMC

Transit Agencies

Ann Arbor Transportation Authority	AATA
BC Transit - Victoria Regional Transit System	VRTS
Calgary Transit	CT
Capital District Transportation Authority	CDTA
Champaign-Urbana Mass Transit District	MTD
Chicago Transit Authority	CTA
Metropolitan Atlanta Rapid Transit Authority	MARTA
Metropolitan Transit Authority of Harris County	MTA
MTA New York City Transit	NYCT
Milwaukee County Transit System	MCTS
Phoenix Transit System	PTS
Société Transport de la Communauté Urbaine de Montréal	STCUM
Société de Transport de la Rive-Sud de Montréal	STRSM

Government Agencies

Federal Transit Administration	FTA
Transportation Research Board	TRB
Volpe National Transportation Systems Center	VNTSC

Organizations

American Public Transit Association	APTA
Canadian Urban Transit Association	CUTA

APPENDIX A

TECHNICAL DESCRIPTION OF LOW-FLOOR FLEETS

TECHNICAL DESCRIPTION OF LOW-FLOOR FLEETS

A more complete description of the low-floor bus fleets that were included in the study is given in Table A-1.

Table A-1. Information on Low-Floor Fleets

Transit Agency	Fleet		Seats	Fuel	Propulsion System		Tires	HVCA	Manufacturer and Model	
	No.	Size (ft)			Engine	Transmission				
Ann Arbor Transportation Authority	22 15	40 35	36 28	D D	DDC - 6V92 DDC - 6V92	ZF HP500 AL B400R	(M) 275/70R	Roof Sutrac AC-3 Aux. Fl. Ht	New Flyer Industries	D40LF D35LF
BC Transit - Victoria Regional Transit System	36 44	40 40	36 38	D D	DDC - 6V92 DDC 50	VOITH D 863	(B) 275/70R	Roof Sutrac (H/V) Aux. Fl. Ht.	New Flyer Industries	D40LF
Calgary Transit	50 84	40 40	36 39	D D	DDC - 6V92 DDC 50	ZF HP500 AL B400R	(G) 275/70R	Rear Thermo King Aux. Fl. Ht.	New Flyer Industries	D40LF
Champaign-Urbana Mass Transit District	41	40	36	D D	DDC - 6V92 DDC 50	ZF HP49 ZF HP500	(B) 275/70R	Roof Sutrac AC-3 Aux. Fl Ht.	New Flyer Industries	D40LF
Capital District Transportation Authority	21	40	32	D	DDC 50	AL B400R	(B) 305/70R	Roof Thermo King Aux. Fl. Ht	Orion Bus Industries	ORION VI
Chicago Transit Authority	63 2 1	40 40 40	39 39 39	D D H	DDC 50 Cummins 8.3 FUEL CELL	ZF HP590 ZF HP590 - - -	(M) 275/70R (B) 275/70R (M) 275/70R	Roof Thermo King Aux. Fl Ht.	New Flyer Industries	D40LF H40LF
Metropolitan Atlanta Rapid Transit Authority	118 51	40 40	40 39	CNG D	DDC 50G DDC 50	ZF HP500 AL B400R	(M) 275/70R	Rear Thermo King	New Flyer Industries	C40LF D40LF
Milwaukee County Transit System	146	40	39	D	DDC 50	AL B400R	(B) 305/70R	Rear Thermo King Aux. Fl. Ht.	New Flyer Industries	D40LF
Phoenix Transit System	93	40	37	D	DDC 50	AL B400R	(B) 275/70R	Rear Thermo King	New Flyer Industries	D40LF
Sault Ste. Marie Transit	4	40	36	D	DDC 50	AL B400R	(B) 305/70R		Orion Bus Industries	ORION VI
Société de Transport de la Communauté Urbaine de Montréal (STCUM)	270	40	39 (32)[(a)]	D	Cummins 8 3	AL B400R	(M) 305/70R	MCC Heating & Vent.	Nova Bus	LFS
Société de Transport de la Rive-Sud de Montréal (STRSM)	28	40	39 (38)[(b)]	D	Cummins 8.3	AL B400R	(M) 305/70R	MCC Heating & Vent.	Nova Bus	LFS

[(a)] STCUM has a test seating arrangement with less seats to facilitate passenger flow.
[(b)] STRSM replaced two forward facing seats behind the driver with an aisle facing seat.

APPENDIX B

DISCUSSIONS OF FACTORS IMPACTING CAPACITY

DISCUSSIONS OF FACTORS IMPACTING CAPACITY

The theoretical maximum number of passengers that can be carried on a line is a function of the capacity of the buses operating on the line and the average headway between buses on the line. The formula used to calculate the capacity of a line is: $C = B \times 60/H$.

Where:	C =	capacity of the line, usually expressed as passengers per hour per direction (ppdph),
	B =	the capacity of the bus, expressed as the maximum number of passengers the bus can carry, and
	H =	the average operational headway of buses operating on the line, expressed in minutes.

The number of buses required for a line is a function of the length of the line, the average headway between buses, the average operating speed for the line, and the duration of layovers at the ends of the line. The number of buses required for a line can be estimated by the following formula: $TNB = (60 \times LL / S + 2 \times LT) / H$.

Where:	TNB =	the total number of buses,
	LL =	the length of the line in miles,
	S =	the average speed along the line, in miles per hour,
	LT =	the layover time, in minutes, and
	H =	The average operating headway, in minutes.

The average speed, S, along a line is a function of the number of stops along the line, the average dwell time per stop, and the average time that is required to move from stop to stop. Line attributes such as whether or not it is an exclusive bus lane and does a bus have priority at intersections affect the average speed. The average dwell time is a function of the average boarding and alighting times for passengers, method of fare collection (can more than one door be used for boarding), and the average time required to re-enter the traffic stream if the bus is operating in a mixed traffic lane. The following formula (Reference B-1) can be used to approximate the average speed of a bus along a line:

$$S = \frac{D}{T + D/C + C\left(\tfrac{1}{2}a + \tfrac{1}{2}d\right)}$$

Where:	S =	average bus speed,
	T =	average dwell time at stops,
	D =	average distance between stops
	C =	average cruising speed in lane (e.g., 50 kph),
	a =	average rate of acceleration of bus (e.g., 5 kph/sec.), and
	d =	average rate of deceleration of bus (e.g., 6 kph/sec.).

The average speeds of the transit agencies interviewed ranged from 25 to 16 kph (15.5 to 9.9 mph). The minimum headway was reported to be two minutes.

(B-1) Quinby, H.D., "Mass Transportation Characteristics," in Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers, Prentice Hall, New Jersey (1976).

APPENDIX C

INTERVIEW GUIDE AND SURVEY FORM

INTERVIEW GUIDE AND SURVEY FORM

The interview guide that was used for the site visits to the transit agencies and the survey form that was given to all six of the heavy-duty bus manufacturers that are offering low-floor buses to agencies are provided in the following pages.

INTERVIEW GUIDE for TCRP PROJECT ON
"NEW DESIGNS AND OPERATING EXPERIENCES WITH LOW-FLOOR BUSES

PURPOSE: TO GATHER AND SYNTHESIZE INFORMATION AVAILABLE AS TO THE OPERATING EXPERIENCES OF TRANSIT AGENCIES THAT CURRENTLY OPERATE LOW-FLOOR BUSES, INCLUDING USER SATISFACTION AND ACCEPTANCE, SAFETY, NOTABLE FEATURES AND CONCERNS, AND IMPACTS ON RIDERSHIP, MAINTENANCE, AND OPERATIONS.

AGENCY NAME ______________________________ DATE ____________

CONTACT ______________________________ TEL ____________

TITLE ______________________________ FAX ____________

ADDRESS ____
(STREET)

____
(CITY) (STATE) (ZIP)

FLEET INFORMATION

- TOTAL FLEET SIZE: ______ PEAK: AM _____ PM _____ BASE: _____
- LOW-FLOOR FLEET

SIZE	NO.	MANUFACTURER	DELIVERY DATE
40-FOOT			
35-FOOT			
60-FOOT			
≤30-FOOT			

- REASONS FOR PURCHASING LOW-FLOOR BUSES: ______________________
____
- PLANNED FLEET IN 5 YEARS: _____ % LOW-FLOOR
- CAN YOU PROVIDE A COPY OF THE SEATING ARRANGEMENT?

CUSTOMER SATISFACTION/ACCEPTANCE

- DO YOU HAVE ANY SURVEYS/REPORTS ON CUSTOMER SATISFACTION AND ACCEPTANCE OF LOW-FLOOR BUSES? IF YES, CAN COPIES BE PROVIDED?

  DID THESE STUDIES INCLUDE BOTH AMBULATORY, DISABLED, AND SENIOR PASSENGERS, AND DID THE ANALYSIS EXAMINE THE RESPONSES FROM EACH GROUP SEPARATELY?

  DO YOU HAVE OTHER SOURCES OF INFORMATION ON CUSTOMER SATISFACTION OR ACCEPTANCE OF LOW-FLOOR BUSES, SUCH AS: PASSENGER COMPLAINT DATA OR OPERATOR REPORTS?

  TYPES OF CUSTOMER SATISFACTION/ACCEPTANCE INFORMATION SOUGHT INCLUDED:

  - BOARDING/ALIGHTING -- EASE, ENTRANCE/EXIT HEIGHTS, RAMPS
  - PASSENGER COMFORT -- HEATING/VENTILATION, A/C, NOISE, VIBRATION
  - PASSENGER VIEW -- HEIGHT, WINDOWS FOGGING UP, ROAD SPRAY
  - SEATING -- LACK, ARRANGEMENT, PERCEPTION OF INTERIOR SPACE
  - HAND HOLDS/PASSENGER ASSISTS -- LOCATION AND ADEQUACY
  - SAFETY & SECURITY -- INCLUDING PERCEPTIONS
  - FLOOR -- BI LEVEL (INTERIOR STEPS), SLOPES (OVER AXLE)
  - EXIT DOOR BEHIND REAR AXLE
  - LOCATION OF RAMP -- FRONT DOOR VERSUS REAR DOOR
  - OTHER

- HAVE THE LOW-FLOOR BUSES ATTRACTED DIFFERENT CUSTOMERS (e.g. MORE OLDER AND LESS MOBILE PEOPLE)?

OPERATIONAL EXPERIENCES

- WHAT HAVE BEEN YOUR EXPERIENCES WITH OPERATING YOUR LOW-FLOOR BUSES? TYPES OF INFORMATION DESIRED INCLUDE THE FOLLOWING:

  - IMPACTS ON RIDERSHIP
  - CAPACITY ISSUES WITH FEWER SEATS (WAS ADDITIONAL SERVICE ADDED TO COMPENSATE)?
  - DWELL TIME AND SCHEDULE IMPACTS
  - BOARDING/ALIGHTING TIMES - - AMBULATORY, SENIORS, DISABLED
  - MOBILITY DEVICE LOCATION
  - FARE COLLECTION ERGONOMICS
  - EXIT DOOR BEHIND REAR AXLE
  - RIDE QUALITY
  - FLOW OF PASSENGERS (ESPECIALLY BETWEEN FRONT WHEEL HOUSINGS)
  - UNCONVENTIONAL SEATING (e.g. REARWARD FACING, SEATS ON PEDESTALS)
  - OTHER

DO YOU HAVE AVAILABLE REPORTS/DATA ON ANY OF THE ABOVE TOPICS? CAN YOU PROVIDE COPIES?

<u>OPERATIONAL EXPERIENCES</u> (continued)

- HAVE YOU HAD ANY PROBLEMS WITH ANY OF THE FOLLOWING?
  - ROAD CLEARANCES OF THE BUS (damage due to lack of clearances)
  - DRIVING/HANDLING (road conditions: dry, snow, ice, wet)
  - DRIVING IN HIGH WATER
  - WATER OR DUST INTRUSION INSIDE THE BUS
  - WINTER OPERATIONS (e.g. windows fogging up, passenger comfort)
  - DRAINAGE OR BUILD UP OF SNOW OR ICE IN DOOR AREAS
  - PASSENGER VISIBILITY (road spray on windows)
  - OPERATOR VISIBILITY (e.g. road spray on windows/mirrors, glare)
  - NOISE (interior and/or exterior) OR VIBRATION
  - RAMP BOARDING FROM STREET LEVEL (i.e. no curb)
  - RAMP OPERATIONS, FRONT/REAR
  - KNEELING
  - OPERATING RANGE
  - BRAKING
  - TRACTION
  - OPERATION OF ROOF HATCHES (e.g. too high to open/close)
  - EMERGENCY EXIST

ARE REPORTS OR DATA AVAILABLE ON ANY OF THE ABOVE TOPICS?

MAINTENANCE EXPERIENCES

WHAT HAS BEEN YOUR EXPERIENCES WITH THE MAINTENANCE OF THE LOW-FLOOR BUSES? CAN YOU PROVIDE INFORMATION ON ANY OF THE FOLLOWING (including comparison with high-floor bus maintenance experience)?

- MAINTENANCE COSTS
- ROADCALLS (i.e. frequency)
- SERVICING THE LOW-FLOOR BUSES ON THE STREET (i.e. special tools)
- RAMP MAINTENANCE (including comparison with lift maintenance)
- TIRE WEAR OR EXCESSIVE DAMAGE
- SPECIAL TOOLS AND EQUIPMENT
- FACILITIES MODIFICATIONS (i.e. changes to hoists or pits)
- ACCESSIBILITY (i.e. systems and equipment mounted in roof area)
- INDEPENDENT FRONT SUSPENSION OR FRONT AXLES
- BRAKE WEAR
- FLOOR CLEANING

SAFETY EXPERIENCES

WHAT HAS BEEN YOUR EXPERIENCES WITH RESPECT TO SAFETY WITH YOUR LOW-FLOOR BUSES? CAN YOU PROVIDE INFORMATION ON ANY OF THE FOLLOWING?

- SLIPS AND FALLS WHILE BOARDING AND ALIGHTING
- SLIPS AND FALLS ON-BOARD
- INTERIOR STEP INCIDENTS
- RAMP INCIDENTS
- DOOR AND DOOR AREA INCIDENTS
- OTHER

OPERATOR SATISFACTION/ACCEPTANCE EXPERIENCES

WHAT HAS BEEN THE ACCEPTANCE OF YOUR LOW-FLOOR BUSES BY YOUR OPERATORS? HAVE YOU CONDUCTED ANY SURVEYS OF YOUR DRIVERS WITH RESPECT TO THE LOW-FLOOR BUSES?

DO YOU HAVE INFORMATION ON OPERATOR ACCEPTANCE OF ANY OF THE FOLLOWING?

- DRIVEABILITY AND HANDLING
- OPERATOR PLATFORM HEIGHT
- OPERATOR COMFORT - HEATING AND VENTILATION AND A/C
- ADEQUACY OF DEFROSTER SYSTEM
- VISION -- MIRRORS, GLARE, BLIND SPOTS
- SEPARATION OF PASSENGER AREA FROM OPERATOR'S COMPARTMENT
- FARE BOX ACCESSIBILITY
- PASSENGER FLOW

OTHER COMMENTS

BUS MANUFACTURERS' SURVEY
FOR TCRP PROJECT ON

NEW DESIGNS AND OPERATING EXPERIENCES WITH LOW-FLOOR BUSES

PURPOSE: TO GATHER INFORMATION ON HEAVY-DUTY, LOW-FLOOR BUS TECHNOLOGY AND THE MARKET STATUS OF LOW-FLOOR BUSES AVAILABLE TO TRANSIT SYSTEMS IN THE U.S. AND CANADA.

NAME ______________________ DATE ____________

CONTACT ______________________ TEL ____________

TITLE ______________________ FAX ____________

ADDRESS ______________________________________
(STREET)

____
(CITY) (STATE) (ZIP)

STATUS OF LOW-FLOOR TECHNOLOGY

1) WHICH MODELS OF HEAVY-DUTY, LOW-FLOOR BUSES DO YOU OFFER OR PLAN TO OFFER TO THE TRANSIT MARKET? *(PLEASE CHECK ALL THAT APPLY)*

40-FOOT [ ] 35-FOOT [ ] 30-FOOT [ ] ARTICS (55/60') [ ]

2) AT WHAT STAGES OF DEVELOPMENT ARE YOUR LOW-FLOOR BUS MODELS? *(PLEASE CHECK THE STAGE OF DEVELOPMENT FOR EACH MODEL)*

	40-FT	35-FT	30-FT	ARTICS
DESIGN				
PROTOTYPE				
PRODUCTION				

STATUS OF LOW-FLOOR TECHNOLOGY **(continued)**

3) WHICH TYPES OF PROPULSION SYSTEMS ARE AVAILABLE (OR ARE PLANNED TO BE AVAILABLE) FOR YOUR LOW-FLOOR BUSES? *(PLEASE CHECK ALL THAT APPLY)*

MODEL	40-FT		35-FT		30-FT		ARTICS	
PROPULSION OPTIONS	**AV**	**PL**	**AV**	**PL**	**AV**	**PL**	**AV**	**PL**
IC with MECHANICAL POWERTRAIN DIESEL								
CNG								
LNG								
LPG								
METHANOL/ETHANOL								
HYBRID-ELECTRIC POWERTRAIN DIESEL IC with TM [(a)]								
IC with TM [(b)]								
DIESEL IC with WHM [(c)]								
IC with WHM [(d)]								
ELECTRIC POWERTRAIN TROLLEY								
BATTERY								
FUEL CELL								

(a) Diesel engine with an electric traction motor.
(b) Other than diesel engine with an electric traction motor.
(c) Diesel engine with wheel hub motors.
(d) Other than diesel engine with wheel hub motors.

4) PLEASE PROVIDE INFORMATION ON THE TECHNICAL SPECIFICATIONS AND OPTIONS OF YOUR LOW-FLOOR BUSES ON THE FORMS PROVIDED, PAGES 4 AND 5, OR PROVIDE BROCHURES WITH THE INFORMATION.

5) PLEASE PROVIDE A DRAWING(s) OF YOUR MAXIMUM SEATING ARRANGEMENT.

6) PLEASE PROVIDE INFORMATION ON THE TYPE OF ELECTRICAL SYSTEM MULTIPLEX THAT IS USED.

MARKETING STATUS OF LOW-FLOOR BUSES

1) PLEASE PROVIDE THE NUMBER OF HEAVY-DUTY, LOW-FLOOR BUSES (12 YEAR) DELIVERED BY MODEL AND BY YEAR IN THE FOLLOWING TABLE.

YEAR	40-FT	35-FT	30-FT	ARTICS
1991				
1992				
1993				
1994				
1995				
1996				
1997				

2) PLEASE PROVIDE THE NUMBER OF HEAVY-DUTY, LOW-FLOOR BUSES YOU HAVE ON ORDER BY MODEL.

	40-FT	35-FT	30-FT	ARTICS
ON ORDER				

3) WHAT PERCENTAGE OF YOUR TOTAL BUS SALES IN 1996 WAS FOR LOW-FLOOR BUS MODELS? ____ WHAT PERCENTAGE DO YOU ANTICIPATE IT WILL BE IN 2000? ____

4) IS THERE A COST DIFFERENTIAL FOR LOW-FLOOR BUSES OVER COMPARABLE HIGH-FLOOR MODELS? YES [ ] NO [ ]

IF YES, WHAT IS THE TYPICAL DIFFERENTIAL? ________________________

TECHNICAL SPECIFICATIONS OF LOW-FLOOR BUSES

CHARACTERISTICS	40-FT	35-FT	30-FT	ARCTIC
MODEL IDENTIFICATION				
WIDTH, inches				
HEIGHT, inches				
WHEELBASE, inches				
TURNING RADIUS, feet				
MEASURED APPROACH ANGLE, degrees				
MEASURED DEPARTURE ANGLE, degrees				
MEASURED BREAKOVER ANGLE, degrees				
MEASURED CLEARANCE IN AXLE AREA, in.				
1st DOOR ENT. HT. (not kneeled), inches				
2nd DOOR EXIT HT. (not kneeled), inches				
KNEELING CAPABILITY: FRONT DOOR (in inches) REAR DOOR				
TYPE OF KNEELING: FRONT, SIDE, BOTH				
FRONT DOOR WIDTH, inches				
REAR DOOR WIDTH, inches				
RAMP LOCATION, FRONT/REAR DOOR				
WHEELCHAIR LOCATION, FRONT/REAR				
NUMBER OF SEATS [(a)]				
NUMBER OF STANDEES [(b)]				
GVWR, POUNDS				
CURB WEIGHT, POUNDS				

(a) Maximum number of seats with two wheelchair positions (no wheelchair riders on board) using a hip to knee room of approximately 26.5 inches.

(b) Use 1.5 square feet of free floor space per standee.

OPTIONS OFFERED ON LOW-FLOOR BUSES

(PLEASE ADD OTHER OPTIONS OFFERED)

OPTION	YES	NO	ADDITIONAL INFORMATION
AIR CONDITIONING			
ROOF			
REAR OF BUS			
OPENABLE WINDOWS			TYPES?
REAR WINDOW			
FORCED AIR HEATING FOR THE FLOOR AREA			
WARM WALL HEATING			
2ND DOOR LOCATION:			
IN FRONT OF REAR AXLE			
BEHIND REAR AXLE			
NUMBER OF DOORS			2 [ ] 3 [ ]
DOOR WIDTHS			
BUS WIDTH , 96" / 102"			ONLY 102" [ ] ONLY 96" [ ]
ELECTRIC PROPULSION			
ALTERNATIVE FUELED PROPULSION			
PROVIDE LIST OF ENGINE OPTIONS			
PROVIDE LIST OF TRANSMISSION OPTIONS			
PROVIDE LIST OF TIRE OPTIONS			
ELECTRICAL SYSTEM MULTIPLEX OPTIONS			

APPENDIX D

LISTING OF PARTICIPANTS

LISTING OF PARTICIPANTS

The following transit agencies and bus manufacturers participated in this study.

Transit Agencies

Ann Arbor Transportation Authority
BC Transit - Victoria Regional Transit System
Calgary Transit
Champaign-Urbana Mass Transit District
Capital District Transportation Authority
Chicago Transit Authority
Metropolitan Atlanta Rapid Transit Authority
Metropolitan Transit Authority of Harris County
Milwaukee County Transit System
Phoenix Transit System
Sault Ste. Marie Transit
Société de Transport de la Communauté Urbaine de Montréal
Société de Transport de la Rive-Sud de Montréal

Bus Manufacturers

Gillig Corporation
Neoplan USA Corporation
New Flyer Industries Limited
North American Bus Industries
Nova Bus Corporation
Orion Bus Industries

The **Transportation Research Board** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation