TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP Synthesis 2

Low-Floor Transit Buses

A Synthesis of Transit Practice

Transportation Research Board
National Research Council

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Synthesis of Transit Practice 2

Low-Floor Transit Buses

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it

The need for TCRP was originally identified in *TRB Special Report 213--Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration--now the Federal Transit Administration (FTA). A report by the American Public Transit Association (APTA), *Transportation 2000,* also recognized the need for local, problem-solving research TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962 As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended endusers of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U S Department of Transportation

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PREFACE

A vast storehouse of information exists on many subjects of concern to the transit industry. This information has resulted from research and from the successful application of solutions to problems by individuals or organizations. There is a continuing need to provide a systematic means for compiling this information and making it available to the entire transit community in a usable format. The Transit Cooperative Research Program includes a synthesis series designed to search for and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in subject areas of concern to the transit industry.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to transit agency managers; operations, maintenance, and planning managers; and other personnel concerned with the operational experiences of low-floor transit buses in fixed route service and with the viability of this technology in meeting the transit industry's accessibility goals for the future. Information on low-floor transit buses operating in the United States and Canada, including technical specifications as well as status reports on buses manufactured in North America; buses under development; and buses in Europe, obtained from contacts with international organizations is included. It contains descriptions of standard low-floor buses, as well as another smaller bus used primarily in paratransit service.

Administrators, practitioners, and researchers are continually faced with problems on which there is much information, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and or not readily available in the literature, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the problem. In an effort to correct this situation, the Transit Cooperative Research Program (TCRP) Synthesis Project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit problems and synthesizing available information. The synthesis reports from this endeavor constitute a TCRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to a specific problem or closely related problems.

Transit agencies have chosen low-floor buses as a way of providing easier access for *all* passengers. In the United States, the enactment of the Americans with Disabilities Act (ADA) has been a major force in the growing interest in low-floor buses. In Canada, several provinces have taken steps in the form of policy directives and funding incentives to encourage their use. This report of the Transportation Research Board describes, primarily, findings from four transit agencies with standard size, low-floor transit buses in service with respect to passengers, maintenance, operations, drivers, and planning and administration. Additionally, it presents some general insights from transit agencies operating smaller low-floor transit vehicles, and, in particular, describes concerns relative to road clearance, winter operations, operations in high water, and impacts on operating practices. It contains technical specifications from U.S., Canadian, and European manufacturers for all these buses.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, available information was assembled from numerous sources, including a large number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now on hand.

CONTENTS

ACKNOWLEDGMENTS

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Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Michael P. Bolton, Executive Director, Ann Arbor Transportation Authority; Michael Davis, Manager, Victoria Planning, British Columbia Transit; Bart W. Mancini, Mechanical Engineer, Federal Transit Administration; Peter L. Shaw, Public Transportation Specialist, Transportation Research Board; William L. Volk, Managing Director, Champaign-Urbana Mass Transit District; and Bernard W. Walker, Director of Maintenance, Maryland Mass Transit Administration.

The Principal Investigators responsible for the conduct of the synthesis were Sally D. Liff, Manager, Synthesis Studies, and Donna L. Vlasak, Senior Program Officer. This synthesis was edited by Linda S. Mason.

Valuable assistance was provided by W. Campbell Graeub and Gwen Chisholm-Smith, Senior Program Officers, Transit Cooperative Research Program, Transportation Research Board.

Information on current practice was provided by many transit agencies. Their cooperation and assistance were most helpful.

LOW-FLOOR TRANSIT BUSES

SUMMARY Low-floor bus technology is beginning to appear at transit agencies in the United States and Canada. Early in 1992, the first buses arrived at Kitchener Transit in Ontario and the Victoria Regional Transit System in British Columbia. By the end of 1993, 221 low-floor transit buses were in operation at transportation agencies in the United States and Canada, and 490 low-floor buses were on order. Transit agencies have chosen low-floor buses as a way of providing easier and more user-friendly access for all passengers. The reasons for choosing low-floor buses vary from agency to agency. Transit agencies that have chosen the low-floor approach cite the following reasons for this decision:

- To provide easier and more user-friendly access for all passengers,
- To meet the Americans with Disabilities Act (ADA) accessibility requirements using ramp technology,
- To avoid the past high cost and unreliability of wheelchair lifts,
- To provide mobility and access to services for the growing number of elderly people with fixed route service rather than special transportation, and
- To obtain faster boarding and alighting times to reduce stop dwell times.

In the United States, the enactment of the ADA has been a major force in the growing interest in low-floor buses. In Canada, several provinces have taken steps to encourage the use of low-floor buses. These encouragements have taken the form of policy directives and funding incentives.

Low-floor bus technology has had more extensive application in Europe. It began in Germany in the late 1980s, and more than 3,900 low-floor transit buses were sold there between 1988 and 1992. Bus manufacturers in most European countries offer low-floor production models. In Germany, bus manufacturers report that the great majority of transit bus orders are for low-floor models. The pace has been somewhat slower in North America where only three of the eight bus manufacturers have prototype or production models of low-floor buses.

The objectives of this synthesis project were to collect and document the operational experiences of the use of low-floor buses in fixed route service, and to assess the viability of this technology in meeting the transit industry's accessibility goals. The scope of this work did not include costs. A survey of all known transit agencies and bus manufacturers in the United States and Canada experienced with low-floor buses was conducted, including:

- Ann Arbor Transportation Authority, Michigan
- Champaign-Urbana Mass Transit District, Illinois
- Kitchener Transit, Ontario
- Victoria Regional Transit System, British Columbia

- Transit agencies that have Orion II buses
- All standard-size bus manufacturers.

The overall experience with low-floor buses in the United States and Canada has been positive, according to survey responses. Early mechanical and electrical problems with low-floor buses experienced by the four named transit agencies appear to be new bus problems rather than low-floor bus problems. A summary of the significant findings from the four agencies that were interviewed follows:

- Passenger attitude was unanimously positive,
- Low-floor bus boarding and alighting times were faster--an average of about 0.3 seconds for ambulatory adults to 6 seconds for a passenger with a small child,
- Drivers' attitudes were mixed, but the majority see passenger benefits or like the bus in general,
- Drivers liked the eye-level contact with passengers from the higher driver seat position,
- Passengers with disabilities greatly favor the ramp over the lift for boarding and alighting,
- The flip-out ramp was popular with drivers, mechanics, and management,
- Ramp boardings/alightings are much faster than those using a lift for multiple boardings/alightings at a stop because only one ramp cycle is required,
- None of the agencies has had road clearance problems with low-floor buses,
- None of the agencies has had problems with the interior steps that lead to the rear of the bus,
- None of the agencies has had problems with operations in winter conditions or high water, and
- None of the agencies has had problems with the reduced number of seats in the low-floor bus.

More experience is needed in winter operations to determine that there are no problems with winter conditions. The capacity issue is still open for debate. However, as low-floor buses are delivered to larger metropolitan agencies in the coming months, actual operational results will become available. The survey responses indicate that guideline specifications for key technical requirements of low-floor buses would be beneficial to the transit industry. The rapid deployment of low-floor buses in Europe, particularly in Germany, may well have been aided by a consensus on technical specifications. The use of raised platforms at bus stops to provide level boarding with low-floor buses was also suggested.

CHAPTER ONE

INTRODUCTION

BACKGROUND

The emergence of low-floor bus technology in North America has begun. Several transit agencies have chosen this approach as a way of providing more user-friendly access for *all* passengers--adults, people with disabilities, seniors, children, parents with strollers, people with packages. The reasons for choosing low-floor buses vary from agency to agency. Transit agencies who have opted for this approach have given the following reasons:

- To provide easier access for all passengers,
- To meet the Americans with Disabilities Act (ADA) accessibility requirements using ramp technology,
- To avoid the past high cost and unreliability of wheelchair lifts,
- To provide transit services for the growing number of elderly people with fixed route service rather than special transportation, and
- To reduce stop dwell times by achieving faster boarding and alighting times.

As of January 1994, 221 low-floor buses were in service at 12 transportation agencies in the United States and Canada. These agencies are listed in Table One. The growing interest is further substantiated by the 490 low-floor buses on order. Transit agencies that have placed orders for heavy-duty, standard-size, low-floor buses are listed in Table Two.

In the United States, the enactment of the Americans with Disabilities Act (ADA) has been a major force in the growing interest in low-floor buses. In Canada, several provinces have taken steps to encourage the use of low-floor buses,including policy directives and funding incentives.

In Europe, the change to low-floor buses is moving at an even faster pace without regulations or funding incentives, being brought about by market forces. In their search for solutions to mobility and access for persons with disabilities, Europeans have concluded that a low-floor bus with a ramp is a better solution than a bus with a higher floor and a lift. They found that low-floor buses were a better solution for everyone.

Most bus manufacturers in Europe offer low-floor buses. These buses typically have entrance heights of 320 mm (12.6 in.) and an ability to kneel to 250 mm (9.8 in.). In their 1992 Annual Report, the Verband Deutscher Verkehrsunternehmen (VDV), a German transit association, reported that 3,905 low-floor transit buses had been sold to German transit agencies from 1988 to 1992 *(1)*. German bus manufacturers reported that most of their orders

TABLE ONE
TRANSPORTATION AGENCIES WITH HEAVY-DUTY, STANDARD-SIZE, LOW-FLOOR BUSES IN SERVICE*

Transportation Agency/Location	**Number of Buses In Service**
Ann Arbor Transportation Authority, Ann Arbor, MI	10
BC Transit, Kelowna, BC	3
BC Transit, Penticton, BC	5
BC Transit, Victoria, BC	25
Calgary Transit, Calgary, AL	50
Champaign-Urbana Mass Transit District, Urbana, IL	15
City of Kenora, Kenora, MN	1
Edmonton Transit, Edmonton, AL	43
Kitchener Transit, Kitchener, ON	14
Port Authority of New York, New York, NY	48
St. Albert Transit, St. Albert, AL	4
Tillson Transportation, Minneapolis, MN	3
TOTAL	**221**

* As of January 1994

Source: New Flyer Industries

TABLE TWO
AGENCIES WITH HEAVY-DUTY, STANDARD-SIZE, LOW-FLOOR BUSES ON ORDER*

Agency/Location	Maximum Potential Number
Brampton Transit, Brampton, ON	5
BC Transit, Victoria, BC	80
Capital District Transportation Authority, Albany, NY	13
Chicago Transit Authority, Chicago, IL	65
Edmonton Transit, Edmonton, AL	16
Guelph Transportation Commission, Guelph, ON	4
The Hamilton Street Railway Company, Hamilton, ON	25
Keeshin Transportation, Chicago, IL	6
Kingston Transit, Kingston, ON	4
London Transit Commission, London, ON	37
Metropolitan Atlanta Rapid Transit District, Atlanta, GA	51
Mississauga Transit, Mississauga, ON	12
Newmarket Transit, New Market, ON	4
Phoenix Transit System, Phoenix, AZ	71
Roosevelt Island, New York, NY	5
RTC of Clark County, NV	4
Sault Ste Marie Transit Division, Sault Ste Marie, ON	2
Toronto Transit Commission, Toronto, ON	100
Transit Windsor, Windsor, ON	10
Winnipeg Transit, Winnipeg, MN	3
TOTAL	**490**

* As of January 1994

Source: New Flyer Industries and Bus Industries of America

for transit buses in 1993 were for low-floor models; however, regions with less improved roads still order conventional buses.

APPROACH

The synthesis involved the survey of all known transit agencies and bus manufacturers in the United States and Canada experienced with low-floor buses. The intent of the surveys of transit agencies was to collect information on the issues, experiences, and opinions with respect to:

- Passengers,
- Maintenance,
- Operations,
- Drivers, and
- Planning and administration.

Four transit agencies with heavy-duty, standard-size, low-floor buses in service at the time of this inquiry were the primary source of data for this synthesis. They are Ann Arbor Transportation Authority, Ann Arbor, Michigan; Champaign-Urbana Mass Transit District, Urbana, Illinois; Kitchener Transit, Kitchener, Ontario; Victoria Regional Transit System, Victoria, British Columbia.

The data from these agencies were obtained during site visits to each and interviews with staff and passengers. A copy of the interview guide used for the site visits is in Appendix A. In addition, each of the agencies provided internal reports on its planning for and implementation of low-floor bus service.

Transit agencies that operate Orion II buses were another source of information. The Orion II is a heavy-duty, small bus (offered in 22- and 26-ft lengths), primarily developed for paratransit operations. Using a list of these agencies supplied by the manufacturer, a questionnaire was sent to 91 U.S. and Canadian agencies believed to own and operate Orion II buses. The Orion II questionnaire form and the results of the survey are in Appendix B. The goal in this case was to obtain general insight on operation with low-floor vehicles, in particular, concerns relative to road clearance, winter operations, operations in high water, and impacts on operating practices.

The final source of information was manufacturers of heavy-duty, standard-size buses. A questionnaire was sent to eight bus manufacturers in the United States and Canada requesting plans for marketing low-floor buses and technical specifications concerning these buses. A copy of the manufacturers' questionnaire form is in Appendix C. In addition, information was obtained from several European bus manufacturers relative to the technical specification of their low-floor buses.

A brief synthesis cannot convey all of the experiences of the transit agencies operating low-floor buses every day. Also, because low-floor bus developments are rapidly emerging and changing, it is impossible not to be dated in some detail of what bus manufacturers are doing. It is hoped that this synthesis will convey useful information about the "lessons learned" and a view of what low-floor bus technologies are emerging for the transit market.

CHAPTER TWO

LOW-FLOOR BUS STATUS

BACKGROUND

Low-floor buses first appeared as airport apron buses in Europe in 1960 (*2*). Nearly 30 years passed before low-floor buses were used in public transit in Europe. In North America, the initial experiences of transit agencies with low-floor buses began with the Orion II bus introduced in 1984. The first heavy-duty, standard-size buses deployed by U.S. and Canadian transit agencies was the New Flyer D40LF bus, starting in early 1992.

Definition of a Low-Floor Transit Bus

What makes a transit bus a low-floor bus? In a report presented at the International Union of Public Transportation (UITP) 49th International Congress, the following definition of a low-floor bus was proposed (*3*):

> The low-floor bus is a bus which, between doors 1 and 2, has a vehicle floor sufficiently low and level enough to remove the need for steps in the aisle both between these doors, and in the vicinity of the doors

Similar accessibility features are implied in the definition of a low-floor transit bus used for this synthesis and stated as follows:

> A low-floor bus is a bus that shall meet the accessibility requirements of the ADA with a ramp and has a flat floor without a step between the front and rear doors.

A basis issue is how to provide a low, flat floor at entrances and over the axle areas. To provide access to the bus floor without steps at the entrance door, a floor level of 380 mm (15 in.) or less is required. The floor level in the rear of the bus must be higher to clear the rear axle and other drive-train components. To date, two general approaches to the design of a standard-size, low-floor bus have been used. One approach has been to use steps from the low front floor area to an elevated floor area in the rear of the bus.

To Illustrate the principal features of a low-floor bus employing internal steps, sectional views of the New Flyer D40LF are shown in Figure 1. The floor level has been emphasized to show the low levels at the entrance doors and the two steps to the elevated floor level over the rear axle.

The other approach to low-floor buses is to use a ramp in the floor to provide access to the higher floor area over the rear axle. This approach is used by the Bus Industries of America (BIA) in their Orion VI bus, and also is widely used in low-floor buses in Europe. Figure 2 provides sectional views of the BIA Orion VI with the floor level emphasized. The Orion VI bus uses a “drop-center” rear axle to achieve a lower floor over the axle. A sketch of the “drop-center” axle is shown in Figure 3. Currently, “drop-center” axle suitable for transit buses are only manufactured by ZF Friedrichshaften AG in Germany.

The sketch in Figure 4 shows basic differences between a conventional bus and a low-floor bus from a passenger access perspective. The floor of a conventional bus is flat and continuous, and is approximately 890 mm (35 in.) above the street. Access to the floor level is provided by steps at both the front and rear doors. The floor level of a low-floor bus is approximately 380 mm (15 in.) off the street between the front and rear doors. The floor area over the rear axle is elevated and access to this area is either by steps or a ramp in the floor.

LOW-FLOOR BUSES IN NORTH AMERICA

Approximately 640 Orion II buses are operating in the United States and Canada (*4*). A photo of an Orion II is shown in Figure 5. Some of the buses are used in fixed-route service, however, the majority are used in paratransit service.

The Orion II bus was included in this study because it offered the largest body of knowledge on operational issues and experiences could augment the early experiences of North American transit agencies with heavy-duty, standard-size, low-floor buses. A survey was sent to all known Orion II bus owners in the United States and Canada. The results of this survey are in Appendix B.

The only heavy-duty, standard-size, low-floor transit bus in operation in North America at the time of this study was the New Flyer Industries D40LF bus. As of December 1993, 221 of these buses were in service in the United States and Canada. (See Table One for the transit agencies and locations.) A photo of this bus is shown in Figure 6.

While all four transit agencies that were interviewed had the same bus model, there were a few differences in the seating, fare-box mounting, and arrangement of the stanchions. Table Three provides the seating capacities for the buses at each of the agencies. Figures 7 through 11 provide the seating arrangements used at each agency. The approximate placements of the wheelchair securement locations in dotted lines.

STATUS OF LOW-FLOOR BUSES MANUFACTURED IN NORTH AMERICA

Because low-floor bus technology is just emerging and new developments are occurring rapidly in North America, only a “snapshot” of the status as of today can be offered here

All known manufacturers of heavy-duty, standard-size transit buses in the United States and Canada were contacted during this study to learn of their plans and status relative to low-floor buses. Of the eight manufacturers contacted, all responded with information to the questionnaire. A copy of the questionnaire is in Appendix C. As would be expected, all of the manufacturers had some

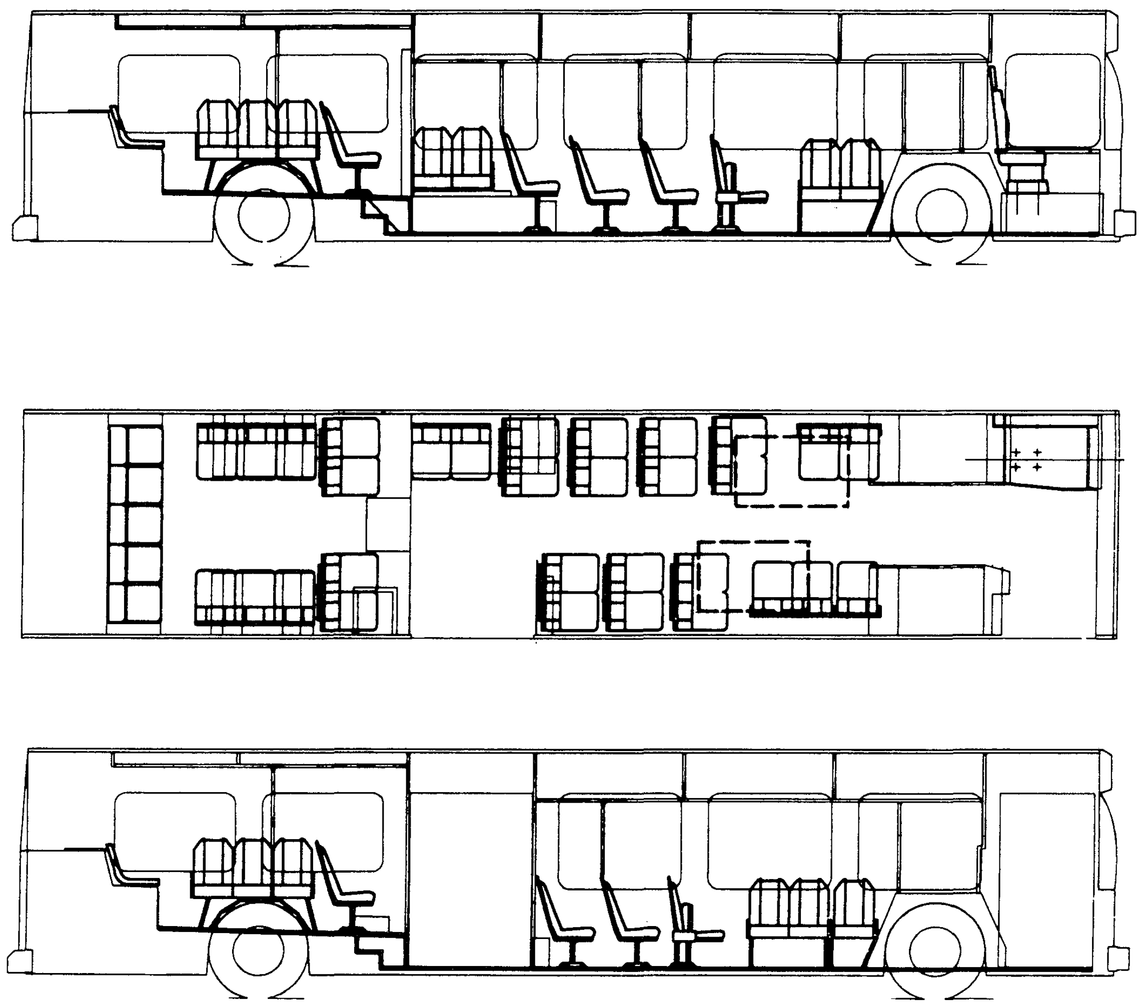


FIGURE 1 Configuration of low-floor bus with internal steps

effort underway with respect to low-floor buses. Some have more aggressive programs than others.

At the time of this synthesis, only New Flyer Industries had a heavy-duty, standard-size, low-floor bus in production. New Flyer Industries plans to develop 10.7-m (35-ft) and articulated low-floor bus models in 1994.

The New Flyer Industries D40FL bus has completed all the tests required by the Federal Transit Administration (FTA) at the bus testing facilities near Altoona, Pennsylvania. It also has been tested at the Transportation Research Center of Ohio for side impact crash worthiness. The side impact test is derived from the Urban Mass Transportation Administration publication, *Baseline Advanced Design Transit Coach Specifications,* commonly called the "White Book," and simulates the impact of a car hitting the side of the bus at 30 mph. The impact of the crash moved the bus about 61 cm (2 ft) to the side, but there was no structural damage to the bus.

The Bus Industries of America (BIA) has developed a prototype heavy-duty, standard-size, low-floor bus, the Orion VI, which was introduced at the American Public Transit Association (APTA) Expo 93 held in New Orleans. BIA plans to begin production of the Orion VI in mid 1994.

Neoplan USA has developed a prototype of a heavy-duty, standard-size, low-floor bus, the AN 440L. This prototype was also introduced at the APTA Expo 93. Neoplan USA also exhibited their MIC (Metroliner In Carbon-Design) carbon fiber, low-floor bus. This bus is called the N8012 in Germany, and is in production there. The MIC bus is expected to be purchased by Houston Metro as part of their Next Generation Bus project.

The Gillig Corporation had the Van Hool A300 low-floor bus on display at the APTA Expo 93. Gillig is surveying the U.S. market relative to the transit agencies' wishes and requirements with respect to low-floor buses. Gillig is considering adapting the Van Hool A300 to the U.S. market.

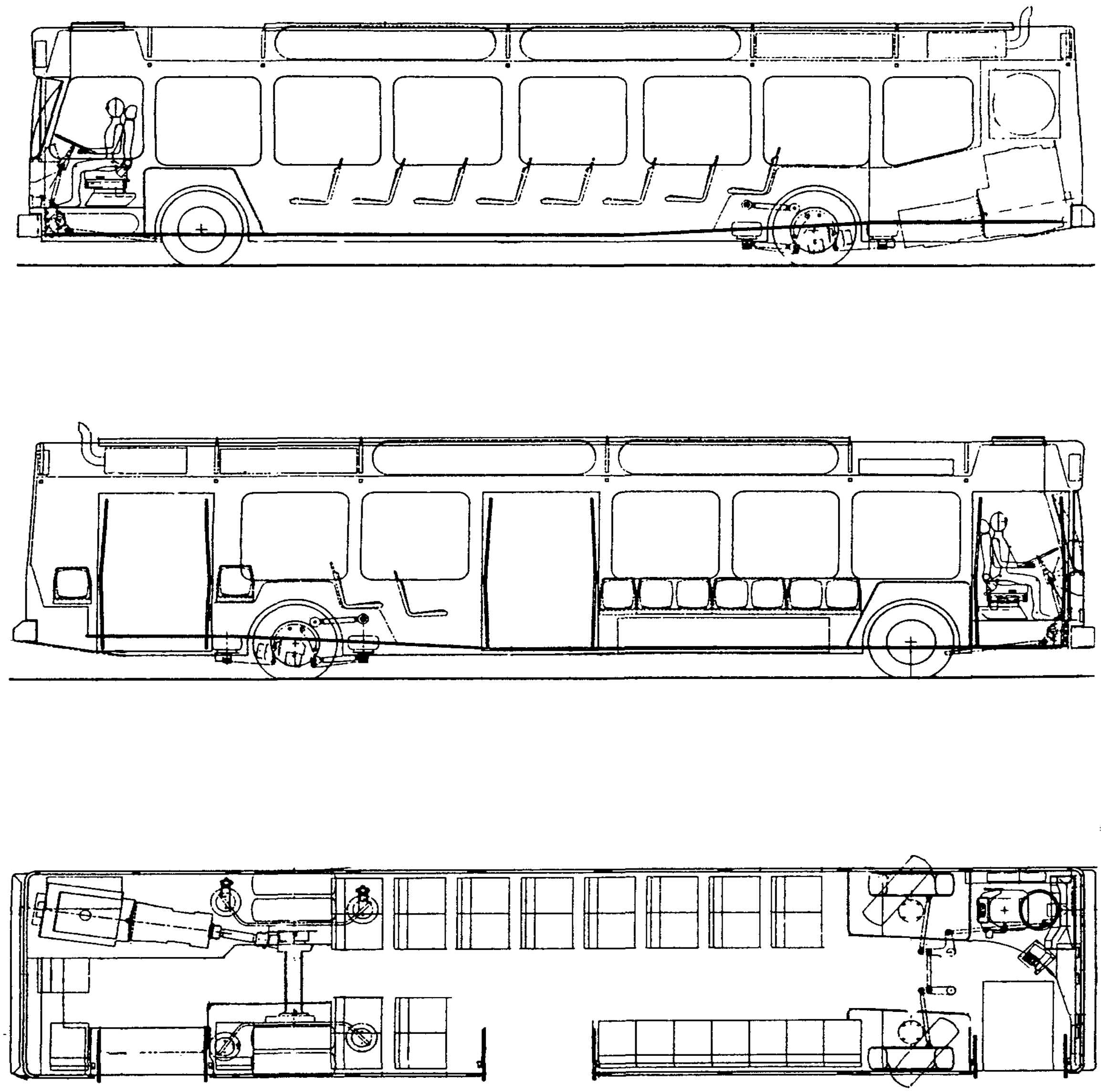


FIGURE 2 Sectional views of the Bus Industries of America Orion VI low-floor bus. (Courtesy of Bus Industries of America)

Nova Bus Corporation provided some preliminary information for its low-floor bus at APTA Expo 93. Nova Bus is planning to adapt a Dutch low-floor bus (den Oudsten) for the Canadian market in the near future. They currently have a den Oudsten bus in Montreal to conduct engineering and operational tests.

An official at Ikarus USA reported that they were monitoring the U.S. transit market to obtain a clearer picture of what will develop relative to low-floor buses. The Ikarus Vehicle Manufacturing Company in Budapest, Hungary, has developed a prototype low-floor bus (the Model 411.02), and provided technical specification information on the prototype. There are no reported plans to enter the European low-floor market in the near future.

The Flxible Corporation has developed concept designs called the "Common Sense Dropped Center" bus *(5).* The center section of this bus design is lower to provide an entrance height of about 190 mm (7.5 in.) (kneeled) at the rear door. Flxible also has a concept design for an articulated model of this bus concept. Flxible estimated that these buses would be in production in 1996.

The Transportation Manufacturing Corporation (TMC) of the Motor Coach Industries is a member of the project team to develop the Advanced Technology Transit Bus. TMC is monitoring the U.S. low-floor bus market, but has no immediate plans to enter the market.

The technical characteristics of low-floor buses in production

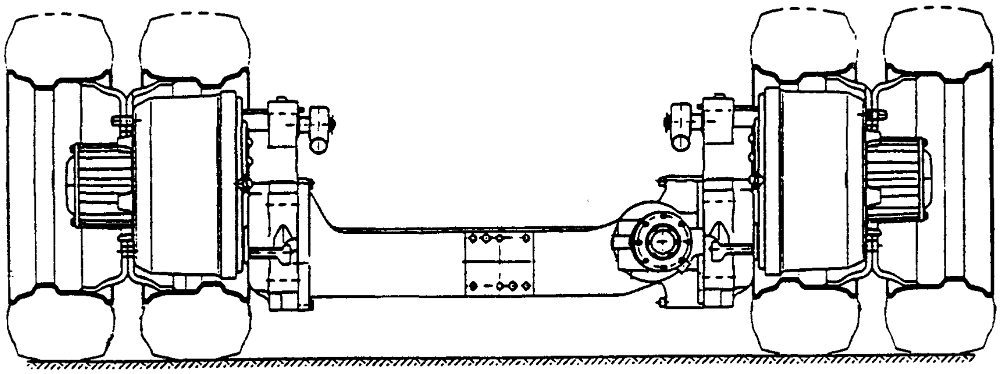
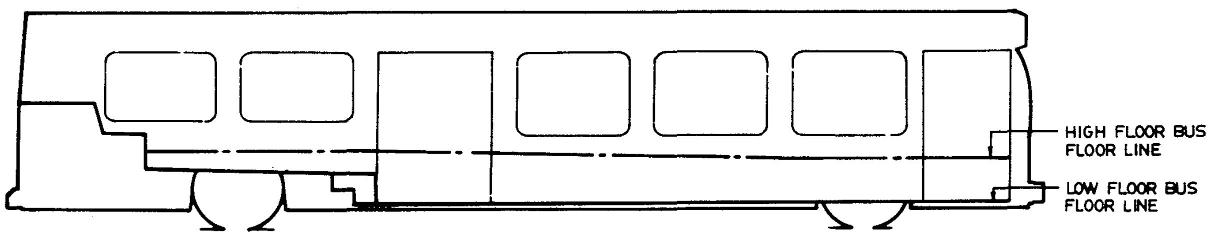


FIGURE 3 A "drop-center" rear axle used in low-floor buses. (Courtesy of ZF of North America)



LOS FLOOR BUS

FIGURE 4 Floor level differences between conventional and low-floor buses.

FIGURE 5 Orion II low-floor small bus.

FIGURE 6 New Flyer Industries, standard-size, low-floor bus.

TABLE THREE
NUMBER OF SEATS ON LOW-FLOOR BUSES

Agency	Number of Seats
Ann Arbor Transportation Authority	36
Champaign-Urbana Mass Transit District	36
Kitchener Transit	37
Victoria Regional Transit System	36 (First Order)
	38 (Second Order)

or at a prototype stage in North America are given in Table Four. Appendix D illustrates road clearance angles described in Table Four.

LOW-FLOOR BUSES UNDER DEVELOPMENT

The FTA has two major projects underway to develop new low-floor buses. Grants have been issued to the Metropolitan Transit Authority of Harris County (Houston Metro) and the Los Angeles County Metropolitan Transportation Authority (LACTATE) for the development of these buses. The Houston Metro grant was $4,488,000 for the entire project, and the LACTATE grant was $3,999,689 for the first phase of their project.

The Houston Metro project *(10)* is called "The Next Generation Bus." The goals of this project include lighter weight, lower floors, wider doors, and low exhaust emissions. In addition, the project will investigate the potential of acheiving cost savings from the use of mass produced truck components. The first phase of the project is preparation of technical specifications for developing the first prototype.

The LACMTA project *(11)* is called the "Advanced Technology Transit Bus" (ATTB). The goals of this project include use of light-weight composite materials, advanced diagnostics and microprocessor controls, low floors, and low exhaust emission propulsion systems. The LACMTA has issued a contract to Northrop to develop design and manufacturing drawings and specifications for the ATTB. The Northrop contract involves three phases: conceptual design, design validation, and prototype fabrication. The conceptual design phase was completed in the fall of 1993.

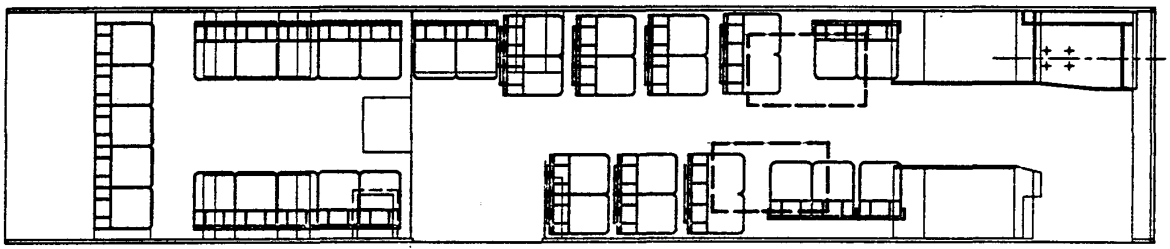


FIGURE 7 Seating arrangement for Ann Arbor Transportation Authority. (Courtesy of New Flyer Industries)

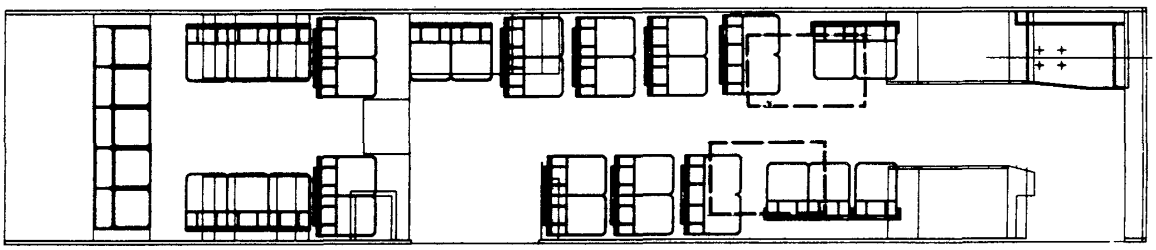


FIGURE 8 Seating arrangement for Champagne-Urbana Mass Transit District. (Courtesy of New Flyer Industries)

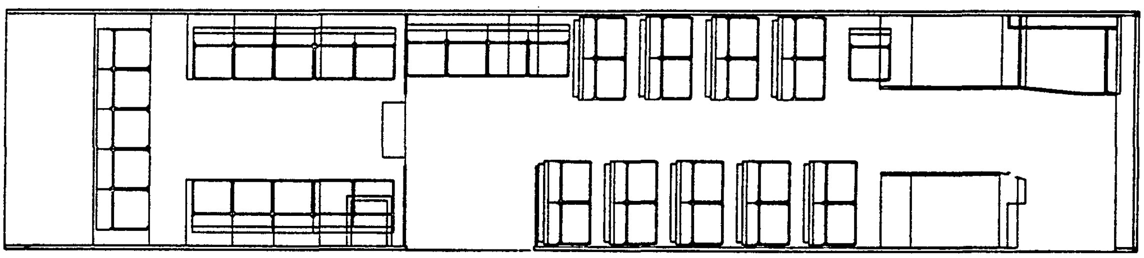


FIGURE 9 Seating arrangement for Kitchner Transit. (Courtesy of New Flyer Industries)

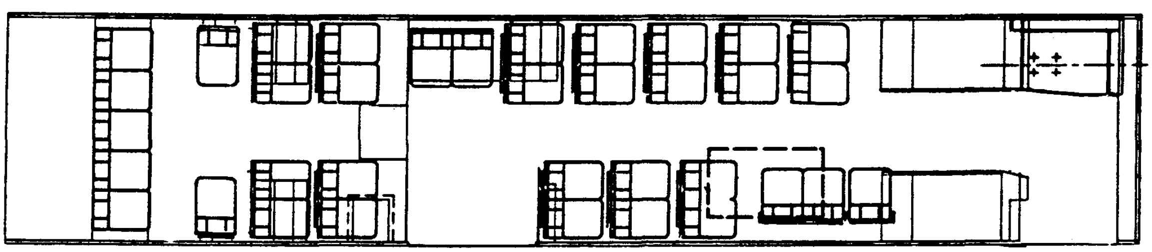


FIGURE 10 Seating arrangement for Victoria Regional Transit (first order). (Courtesy of New Flyer Industries)

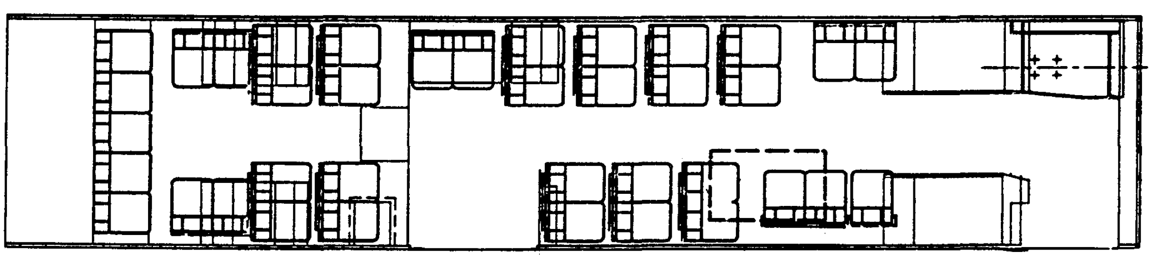


FIGURE 11 Seating arrangement for Victoria Regional Transit System (second order). (Courtesy of New Flyer Industries)

TABLE FOUR
LOW-FLOOR BUS CHARACTERISTICS (PRODUCTION AND PROTOTYPE BUSES)

	Standard-Size			Small		
Manufacturer	**New Flyer**	**BIA**	**Neoplan**	**Neoplan**	**DonManning**	**BIA**
Model	D40LF	Orion VI	AN440L	MIC[a]	No Step Bus	Orion II
Overall length, ft	40	40	40	35	29.5	26
Width, in.	102	102	102	98	98	96
Height, in.	120	118.5	15.5	105	109.5	110
Wheelbase, in.	293	278	274	231	187	236
Turning radius, ft	38	39.6	42	35	30	34
Front overhang, in.	84	85	92.5	104	83	35.5
Rear overhang, in.	109	8	127.5	112.5	82	86 40
†Approach angle, degree	9	9	9	9	9	19
†Departure angle, degree	9	9	10	9	9	20
†Breakover angle, degree	8.3	10	11	9	9	8.5
Entrance height, in.	14.4	14	15	13	13	12
Kneeling height, in.	11.4	11	12	10	9	8 F/4 R
Seats	40[b]	36[b]	41[b]	37	25	24
Standing room	40	54	21	40	25	0
Ramp length, in.	44	44	50	48	36	33 F/15 R
Ramp width, in.	30.5	32	33	30	34	30
Ramp location (front/rear)	F/R	F/R	F/R	R	F	F/R
Front door width, in.	31	44	42	39	48	36
Rear door width, in.	44	44	33	45	--	40
Curb weight, lb	26,500	25,000	25,840	16,500	13,000	14,500

[a] The MIC is called the N8012 in Germany.
[b] Maximum seating with two wheelchair positions.
†See Appendix D for illustration and definition.

Source: *(5-9)*

Phase 2, design validation, was expected to begin in the first quarter of 1994.

Some of the technical characteristics and design goals of low-floor buses in the planning/design stage are presented in Table Five.

LOW-FLOOR BUSES IN EUROPE

Low-floor buses are "sweeping" the market in Central Europe, according to an article in the September/October 1993 issue of *Mass Transit.* All of the manufacturers of city transit buses have either production models or a prototype of a low-floor transit bus. The German bus manufacturers report that the vast majority of their orders for city buses are for low-floor models. Conventional buses are sold only in regions where roads will not permit operation of low-floor buses. Bus manufacturers in Belgium, Denmark, France, and Holland also have production models of low-floor buses.

Low-floor buses first appeared in Europe in 1960 as apron buses at the Frankfurt Airport. Almost 30 years later, low-floor, standard-size buses began to be used in public transit in Germany. The Telebus, a small low-floor bus, had been introduced at the 1979 International Exhibition in Hamburg and later, 50 Telebuses were placed in operation by the Berliner Verkehrs-Betriebe (BVG) in Berlin. The center for development of these low-floor buses took place in Germany at the Gottlob Auwarter GmbH+Co. (Neoplan). Prototypes of standard-size, low-floor buses were tested by several cities in Germany in the late 1980s. The first low-floor, articulated bus was introduced in 1987 in Munich. The Vestische Strassenbahnen GmbH, a 300-bus transit company in Herten, Germany, was the first transit company in Germany to have an entire route served by low-floor buses. The management of Vestische also was the first transit company in Germany to commit to an all low-floor bus fleet (*2*).

From their introduction in 1988, sales of low-floor transit buses have rapidly increased. Sixty-six percent of new sales for transit buses in 1992 in Germany were for low-floor models. By the end of 1992, 3,905 low-floor transit buses were in operation in Germany (*1*).

Historically, transit buses in Europe have had lower floors than what were available in the U.S. and Canadian markets. Some would say that the European buses were "low-aisle" buses rather than low-floor, because the seats were all on platforms, a practice that is generally not used in North America. However, the more recent models of European low-floor transit buses have a flat floor between the first and second doors (some have inclines at doors), and the seats are mounted directly on the floor (no platforms) except for those in wheelhousing areas. An example of a European low-floor bus is shown in Figure 12 along with a typical seating arrangement.

In the UITP report in 1991 (*3*) a low-floor transit bus was defined, and its advantages and disadvantages were discussed. The report concluded that the thrust in Europe was to provide bus designs that offer significant improvements to *all* passengers and to meet the needs of passengers with disabilities and parents with

TABLE FIVE
LOW-FLOOR BUS CHARACTERISTICS (BUSES IN DESIGN)

Manufacturer	Flxible	LACMTA	Houston
Model	Common Sense Dropped Center	ATTB[a]	Next Generation Bus
Overall length, feet	40	40	40
Width, inches	102	102	102
Height, inches	118	114	130 (Max)
Wheelbase, inches	275.5	276.75	TBD
Turning radius, feet	TBD[b]	TBD	39
Road clearance, inches (axle area)	10	10	10
Front overhang, inches	89.5	81.25	TBD
Rear overhang, inches	124	122	TBD
†Approach angle, degree	9.2	10	9
†Departure angle, degree	9.0	10	9
†Breakover angle, degree	8.25	10	10
Entrance height, inches	10[c]	14	14
Kneeled height, inches	7.5[d]	TBD	10
Seats[a]	39	43	39
Standing room	22	29	TBD
Ramp length, inches	96	TBD	TBD
Ramp width, inches	36	TBD	32
Ramp location (front/rear)	R	TBD	TBD
Front door width, inches	36	36	36
Rear door width, inches	44	36	TBD
Curb weight, pounds	29,000	18,000	18,000

[a] Advanced Technology Transit Bus, Northrop Corporation is prime contractor
[b] To be determined
[c] Design goal with two wheelchair locations
[d] Rear door step to ground height

† See Appendix D

Sources: (*5,10,11*)

strollers. The report recognized that it will take some time to develop and produce an optimal low-floor solution. The following goals for future developments were listed in the report *(3)*:

1. Lower floors without steps in the area of the doors and without transverse steps inside the vehicle;
2. Vehicle interior without seat platforms;
3. A greater number of seats; seats which are arranged comfortably for the passenger and easily accessible. Convenience and safety when passengers leave their seats to alight from the vehicle;
4. Smaller wheel arches, i.e., smaller wheels;
5. Low unladen weight so that small wheels with sufficient load capacity can be used;
6. Flat, small, and lightweight components;
7. Environmentally friendly, quiet transmission with low energy requirements;
8. Lightweight, corrosion-free and long-lasting bodywork (12 years minimum);
9. Low overall vehicle noise; and
10. Easily maintainable and economic solutions with vehicle maintenance and checks made from the outside as far as possible.

Perhaps the most important aspect of the UITP report is that it established guideline specifications that all manufacturers could follow. These specifications focused on passenger interface attributes such as maximum entrance heights at the doors, maximum allowable slopes in floor, minimum kneeling capability for bus, maximum seat platform heights, and minimum door widths, and on operational items such as minimum road clearances and safety interlocks. Also, the VDV has developed draft guideline specifications for low-floor transit buses *(12)*. The rapid deployment of low-floor transit buses in Europe, and particularly in Germany,

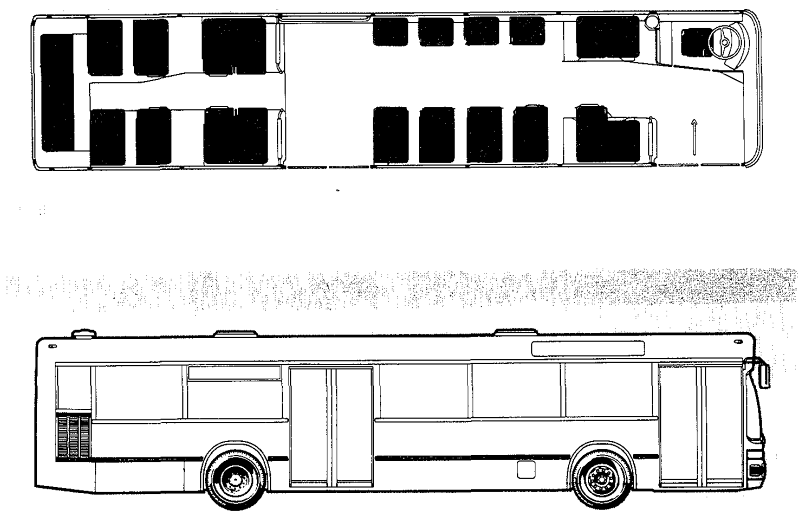


FIGURE 12 MAN NL20 low-floor bus and seating arrangement (Courtesy of MAN)

may well have been aided by a consensus on technical specifications such as these

The low-floor characteristics of several European buses are given in Table Six These examples are only for two-axle buses, articulated low-floor buses are also in production In general, the approach and departure angles on European buses are smaller than those used in North America. Also, the seating practice frequently has rearward facing seats and seats on pedestals--practices not generally used in North America.

TABLE SIX
LOW-FLOOR BUS CHARACTERISTICS (EUROPEAN)

Manufacturer	Kässbohrer	MAN	Mercedes-Benz	Van Hool	Ikarus	Neoplan
Model	S300NC	NL202	0405N	A300	411.02	N4014
Overall length, ft	39.4	38.3	38 4	39.4	36.1	39.4
Width, in.	98.4	98.4	98.4	98 4	98.4	98.4
Height, in.	114 6	113.1	115 5	114.7	113.2	108.2
Wheelbase, in.	233.1	231.2	231.3	236.2	211	237
Front overhang, in.	107.9	102.3	102	96.6	105.9	102.4
Rear overhang, in	131.5	126.0	126.6	137.5	116.1	133.1
Approach angle, degree	7.7	7	7	7.1	7	9
Departure angle, degree	9.5	7	8	7.1	7	8
Entrance height, in	13 4	12.6	12.6	13	13	12 6
Kneeling height, in.	10.2	9.8	9.8	10.2	10.2	9.8
Seats[a]	30	34	43	27	20	44
Standing room	64	70	54	78	82	66
Ramp length, in.	50	43.3	39.4	39.4	39.4	39.4
Ramp width, in.	41 3	42.1	42.1	42.1	42.1	42.1
Ramp location[b]	1/2	1/2	2	2	2	1/2
Front door width, in.	49.2	49.2	49.2	47.3	47.2	53.1
Rear door width, in.	49.2	49.2	49.2	47 3[c]	47.2	53.1

(a) Typical European seat arrangements.

Sources: (*5,13-17*)

(b) Some buses have 3 doors; 1 is for front, 2 is for center, and 3 is for rear.

(c) Has center door of same width

CHAPTER THREE

STATE OF EXISTING PRACTICE AND ISSUES

AGENCIES IN STUDY

Information on existing practice and issues was obtained during field visits to the four transit agencies that had standard-size, low-floor buses in service. All low-floor buses at these agencies were the New Flyer Industries D40LF model. The agencies and the number of low-floor buses in service are given in Table Seven. A capsule overview for each of these agencies is presented in the following sections.

Ann Arbor Transportation Authority

Ann Arbor Transportation Authority (AATA) was the first U.S. agency to use low-floor, standard-size transit buses, beginning their revenue service in January 1993. AATA provides transit service to about 210,000 people throughout Washtenaw County, including the cities of Ann Arbor and Ypsilanti and villages of Dexter, Chelsea, and Saline. With a fleet of 71 buses, AATA provides paratransit services and fixed-route service on 22 routes with an annual ridership of approximately 4,150,000 in 1992. The distribution of passengers for the year ending September 30, 1993, was 10 percent seniors, 6 percent school children, 5 percent people with disabilities, and 79 percent adult.

Champaign-Urbana Mass Transit District

Champaign-Urbana Mass Transit District (C-U MTD) was the first U.S agency to place an order for a low-floor, standard-size transit bus. The low-floor buses were placed in revenue service in June 1993. C-U MTD provides transit service throughout Champaign County, principally the cities of Champaign and Urbana. The population in the service area is about 115,000. With a fleet of 70 buses, C-U MTD provides service on 23 routes throughout the two cities and surrounding areas, and provides four routes for an intra-campus transportation system for the students and staff of the University of Illinois C-U MTD had an annual ridership in 1992 of approximately 7,500,000 The distribution of passengers on all routes for the past year was 8 percent seniors and people with disabilities, 40 percent school children, and 52 percent adult. The distribution of ridership is approximately 69 percent I-Riders (university) and 31 percent community.

Kitchener Transit

Kitchener Transit began receiving its initial order of seven low-floor buses in March of 1992. These buses were placed in regular service in May 1992. A second order of seven low-floor buses was received in November 1992. Kitchener Transit provides transit service to the urbanized area of the cities of Kitchener and Waterloo in Ontario. With a fleet of 108 buses, Kitchener Transit provided service on 17 routes serving a population of about 250,000 with an annual ridership of about 9,000,000. The approximate distribution of passengers in 1992 was 6 percent seniors, 33 percent school children, and 61 percent adult.

Victoria Regional Transit System

The Victoria Regional Transit System (VRTS), a division of BC Transit, began taking delivery of low-floor buses in late December

TABLE SEVEN
FIELD VISITS AND NUMBER OF LOW-FLOOR BUSES

Agency and Location	Number of Low-Floor Buses
Ann Arbor Transportation Authority Ann Arbor, Michigan	10
Champaign-Urbana Mass Transit District Urbana, Illinois	15
Kitchener Transit Kitchener, Ontario	14
Victoria Regional Transit System Victoria, British Columbia	25

1991. During the initial months, the buses were operated on routes throughout the system to gain experience and confidence with these new buses. Then, the initial 9 low-floor buses were placed in regular accessible service in May 1992. A second order of 16 low-floor buses was placed in regular accessible service in February 1993. The VRTS provides transit services throughout Greater Victoria, Sooke, and Sidney in British Columbia. The population in the service area is about 285,000. With a fleet of 147 buses, the VRTS provides service on 38 routes with an annual ridership of approximately 16,500,000. The distribution of passengers for the past year was approximately 59 percent adults, 24 percent seniors and people with disabilities, 14 percent school students, and 3 percent children. The VRTS also operates the handy-DART System, which provides paratransit services with 26 vehicles. The handy-DART System provides door-to-door service to passengers who cannot use conventional transit buses. The total rides by handy-DART is about 131,000 annually

APPROACHES TO INTRODUCING LOW-FLOOR BUSES

The initial deployment of low-floor buses at each of the four agencies was made to best meet the accessible transportation needs of the respective communities. Kitchener Transit choose to introduce the low-floor buses to their riders on all routes rather than selecting specific routes for dedicated low-floor bus service. This choice was made for two reasons Accepting wheelchairs on the low-floor buses was not possible in Ontario because no regulations were in place for that type of service. Perhaps a greater barrier was that many bus stops were not accessible, particularly during inclement winter conditions *(18).* Kitchener Transit provides a shopping charter service for their senior community every Thursday. The low-floor buses have been a big success in this service, and the seniors universally prefer the easy access of the low-floor buses with their shopping carts.

The VRTS evaluated 28 routes with respect to various route-selection criteria and chose two as accessible routes using the low-floor buses. The two routes provided the best combination of activity center coverage, transportation-disabled community coverage, hours of operation, route stability, route connectivity, and scheduling considerations *(19).* With the purchase of 16 additional low-floor buses, another six routes were made into accessible routes. Accessible service is offered only at bus stops clearly marked with the blue international wheelchair symbol. An example is shown in Figure 13. The frequency standard for low-floor buses was set at 25 percent of scheduled trips on those routes with headways of 15 minutes or less, and 50 percent of scheduled trips on routes with headways between 15 minutes and 1 hour. At the accessible bus stops, the "on street" schedule would have a "#" symbol alongside the scheduled arrival time for a low-floor bus. See Figure 14 for an example of the posted "on street" schedule.

Both AATA and C-U MTD had committed to providing accessible buses on all their routes in the mid 1980s. As a result, the concept of having an accessible bus was well known to their passengers. AATA and C-U MTD selected routes for the initial deployment of the low-floor buses that would serve the greatest number of their potential wheelchair passengers. They also used the low-floor bus for special events to maximize the exposure of the low-floor buses to the general public.

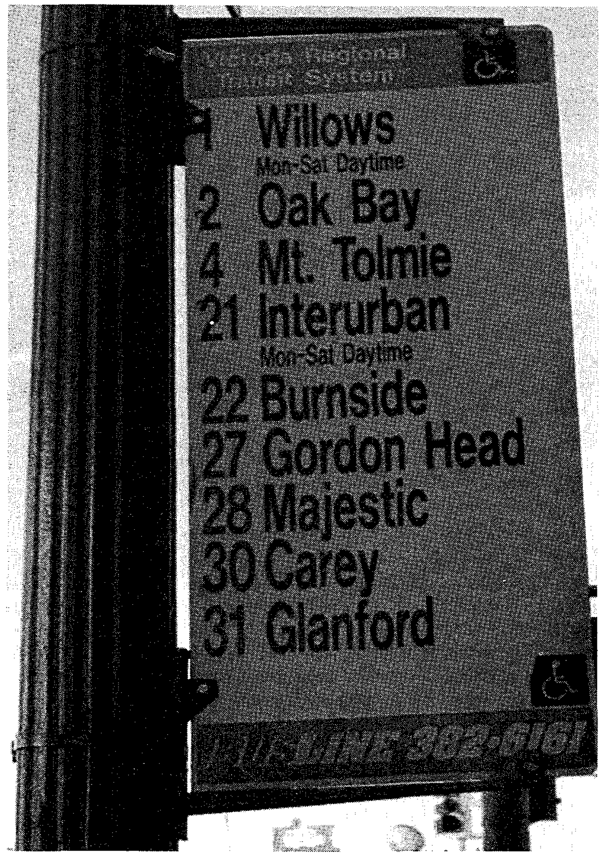


FIGURE 13 Sign for an accessible stop in Victoria

EXISTING PRACTICE AND ISSUES

Field visits to four transit agencies were made to collect information on their operational experiences with the use of low-floor buses in revenue service. Prior to each visit, an interview guide was sent to a contact person at the transit agency to inform them of the information that was desired. The interview guide addressed questions about many aspects of operating low-floor buses, including:

- Passenger issues
- Maintenance issues
- Operations issues
- Driver issues, and
- Planning and administration issues.

A copy of the interview guide is in Appendix A

Passenger Issues and Experiences

Passenger acceptance and attitude toward the low-floor bus was unanimously positive at each of the transit agencies visited. All

ROUTE: 14 UNIVERSITY
DESTINATION: TO UVIC

MON-FRI		SATURDAY		SUN/HOL	
06:29 AM	02:14 PM	07:21 AM#	03:41 PM#	07:45 AM	05:25 PM
06:49 AM	02:26 PM	07:51 AM#	03:56 PM	08:15 AM#	05:45 PM
07:04 AM	02:37 PM#	08:20 AM#	04:11 PM	08:45 AM#	06:05 PM#
07:19 AM	02:50 PM	08:50 AM#	04:26 PM#	09:15 AM	06:25 PM
07:34 AM	03:02 PM#	09:20 AM#	04:41 PM#	09:45 AM#	06:42 PM#
07:46 AM	03:14 PM	09:45 AM#	04:56 PM	10:15 AM#	07:02 PM
07:58 AM	03:28 PM	10:05 AM	05:11 PM	10:45 AM	07:22 PM
08:11 AM	03:44 PM	10:25 AM#	05:28 PM#	11:05 AM	07:45 PM#
08:23 AM	03:54 PM#	10:45 AM	05:45 PM	11:25 AM	08:15 PM#
08:35 AM#	04:06 PM	11:05 AM#	06:05 PM#	11:45 AM	08:45 PM
08:47 AM	04:18 PM	11:26 AM#	06:27 PM#	12:05 PM#	09:15 PM#
09:01 AM	04:33 PM#	11:41 AM	06:47 PM	12:25 PM	09:45 PM#
09:13 AM#	04:42 PM	11:56 AM	07:07 PM#	12:45 PM	10:15 PM
09:25 AM	04:55 PM	12:11 PM#	07:27 PM	01:05 PM#	10:45 PM#
09:38 AM#	05:02 PM#	12:26 PM	07:47 PM#	01:25 PM	11:15 PM#
09:48 AM	05:13 PM	12:41 PM	08:07 PM#	01:45 PM#	
10:01 AM	05:26 PM	12:56 PM#	08:27 PM	02:05 PM	
10:13 AM	05:38 PM	01:11 PM#	08:47 PM#	02:25 PM	
10:25 AM#	05:48 PM	01:26 PM	09:07 PM	02:45 PM#	
10:37 AM	06:02 PM	01:41 PM	09:23 PM#	03:05 PM	
10:51 AM	06:13 PM	01:56 PM#	09:49 PM#	03:25 PM#	
11:01 AM#	06:27 PM#	02:11 PM	10:16 PM	03:45 PM	
11:13 AM	06:47 PM#	02:25 PM	10:45 PM#	04:05 PM	
11:25 AM#	07:07 PM	02:41 PM#	11:15 PM#	04:25 PM#	
11:37 AM	07:27 PM	02:56 PM#	11:45 PM	04:45 PM	
11:49 AM	07:47 PM	03:11 PM	12:13 AM#	05:05 PM#	
12:01 PM	08:06 PM#	03:26 PM			
12:13 PM#	08:26 PM#				
12:25 PM	08:47 PM				
12:37 PM	09:07 PM#				
12:49 PM#	09:21 PM				
01:01 PM	09:49 PM#				
01:14 PM#	10:16 PM#				
01:26 PM	10:52 PM				
01:38 PM	11:15 PM#				
01:50 PM	11:45 PM#				
02:02 PM#	12:18 AM				

NOTE: # TRIPS ARE WHEELCHAIR ACCESSIBLE.

Source: VRTS

FIGURE 14 Example of "on-street" schedule display used by the Victoria Regional Transit System.

four agencies reported a very favorable passenger response to the introduction of low-floor buses in their systems.

None of the agencies reported any complaints from passengers on fewer seats being available. One agency reported that some passengers (very few) had complained about crowding on the low-floor buses. All of the agencies visited have standing loads during peak operations.

There were no passenger complaints of noise with the current low-floor buses. The first production series of the low-floor bus had problems with vibration and high noise in the rear of the bus. These problems have been rectified and the agencies expressed general satisfaction with the interior noise levels that exist today in the buses.

All the agencies reported that the passengers find the lower window view to be "acceptable" to "very satisfactory." There was one driver comment that a passenger had reported "not feeling as secure" while riding in the lower seats. On rainy days, the lower windows do become more covered with spray than on conventional buses.

Three of the agencies provided securement locations for passengers in wheelchairs on their low-floor buses. In all cases, the wheelchair securement locations were in the areas immediately after the front wheelhousings. (See Figures 7 through 11 for the wheelchair locations used.) These locations are close to the entrance door and driver, and appear to be reasonably easy for a passenger in a wheelchair to maneuver into.

Placing wheelchair locations immediately after the front wheelhousings results in a fairly long distance between the wheelhousings and the first rows of transverse seats without vertical stanchions. The distances are about 1.5 to 2 m (approximately 5 to 7 ft), and can present a challenge for the less ambulatory passengers. Horizontal handrails are suspended from the ceiling; however, a short passenger would have difficulty reaching these handrails. The VRTS provided two "strap hangers" from these horizontal handrails on each side of the aisle to alleviate this problem. (These "strap hangers" can be seen in Figure 20.)

Two boardings of wheelchair passengers were observed. In both cases the boarding was fast and the passenger had no difficulty maneuvering to the securement location. The boarding and maneuver time to the securement location was approximately 30 seconds. The securement time was much longer in one case, because four belts were used rather than two. Both of these wheelchair passengers stated that they liked the low-floor bus. The ramp was very easy to use, and they had no problems maneuvering to get to the wheelchair securement locations. There also was a preference for a ramp over a lift.

In a paper by Levine and Torng on "Dwell Time Effects of the Low-Floor Bus Design" (*20),* information on the test results of wheelchair boarding and alighting times at AATA is given, comparing the New Flyer Industries low-floor bus to a conventional bus (TMC RTS). The test was conducted at the AATA facilities using two transit-experienced wheelchair passengers. The test was conducted to simulate two individual boarding and alightings. The results of the test given in Table Eight indicate that the times from wheelchair on sidewalk to wheelchair onboard are shorter for the low-floor bus.

The time to maneuver the wheelchair to the securement location took longer on the low-floor bus. This is an expected result because location of the wheelchair securement location on the conventional bus was directly across from the door, while the wheelchair securement location of the low-floor bus was further in the bus just after the front wheelhousings. The boarding maneuvers of a forward facing wheelchair passenger on the low-floor bus involves a left turn after entering, travel past the wheelhousings, a 180-degree turn, and backing into the securement location. The authors of the paper cautioned the use of the data from these limited trials because they were conducted outside of regular service and under ideal conditions.

St. Albert Transit, Alberta, Canada, reported that the time to board and maneuver the wheelchair to the securement location was 29 seconds, and that 61 seconds were required to secure the wheelchair. Total time to alight of a wheelchair passenger was reported to be 20 seconds (*21*).

A group of individuals experienced in working with seniors and persons with disabilities assessed Kitchener Transit's low-floor bus. The overriding comment of the group was that there was not sufficient space in the low-floor bus for most persons who use walkers, wheelchairs, guide dogs, and other mobility aids to enter and travel down the aisles. Therefore, seats for these passengers would need to be at the front of the bus. Also, the group found that there was not enough space to place guide dogs or walkers out of the footpath of other passengers (*22*). It should be noted that the seating arrangement of the low-floor buses at Kitchener had the highest number of seats, 22, in the area between the doors, and was *not* designed to accommodate passengers in wheelchairs. (See Figure 9 for seating layout.)

Passenger attitudes relative to the boarding and alighting features of the low-floor buses were universally very positive. The ease of boarding and alighting was the most frequent response when passengers were asked what they thought about the low-floor buses. Kitchener Transit provides a Seniors' Shopping Charter each Thursday which provides shuttle service between the seniors'

TABLE EIGHT
WHEELCHAIR BOARDING AND ALIGHTING TIMES (SECONDS) BY BUS TYPES

Segments of Process	Low-Floor Bus		Conventional Bus	
	Passenger 1	Passenger 2	Passenger 1	Passenger 2
Boarding Process				
Door Open (Lift/Ramp Deployed) to Wheelchair On Board	18	26	27	44
On Board to In Securement Position	23	26	10	9
Lift/Ramp Stowed, Bus Unkneeled to Bus Ready to Move	20	19	16	16
Alighting Process				
Door Open (Lift/Ramp Deployed) to Start Releasing	18	16	17	12
Finish Releasing to Wheelchair on Sidewalk	13	16	16	19
Lift/Ramp Stowed, Bus Unkneeled Ready to Move	21	21	21	27

Source: (*20*)

apartment complexes and a local department store. The seniors love the low-floor buses and the ease of boarding and alighting with their shopping carts and sacks of merchandise. Several seniors with their shopping carts are shown as they are about to board the low-floor bus in Figure 15. Kitchener Transit reported that they receive many requests for low-floor buses on charter service.

A major advantage of a ramp over a lift became obvious by observing the seniors using the low-floor bus at Kitchener Transit. As many passengers as required can board or alight with only one deployment and one stowing of the ramp at a stop. The ramp also enabled the seniors to easily pull their shopping carts into the bus.

A young man with arm crutches was observed alighting from a low-floor bus at the University of Victoria bus stop. He alighted the bus without any assistance from the driver (the bus was not kneeled). Afterward, the driver said that the young man had asked that he not kneel the bus because it would embarrass him. It would have been almost impossible for this young man to alight down the two steps of a conventional bus.

FIGURE 15 Senior shoppers about to board low-floor bus with ramp deployed.

Maintenance Issues and Experiences

During field visits, inquires were made to determine the experience with the low-floor buses from a maintenance perspective.

The maintenance issues identified in the Interview Guide (see Appendix A) were discussed with the staff at each agency and their responses are summarized below.

The introduction of low-floor buses at the four transit agencies

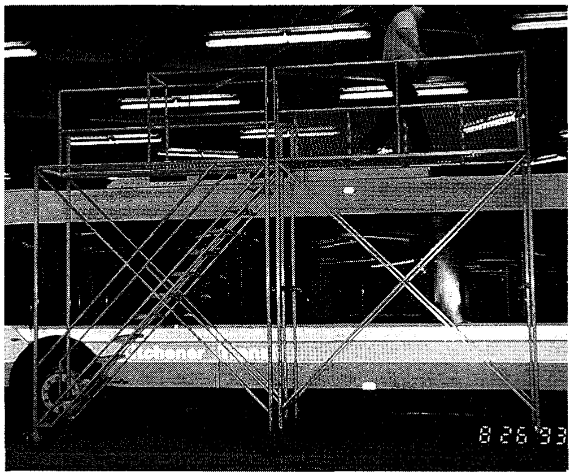


FIGURE 16 Portable stair platform for servicing rooftop air conditioning system

visited had required little or no change of their respective maintenance facilities and equipment. Two agencies reported that modifications had been made to the lift brackets of the bus hoists to accommodate the lifting points of the bus. Kitchener Transit had constructed a portable stair with a platform to perform service on the rooftop air conditioning system. See Figure 16 for a photo of the portable stair. At AATA, small step ladders (2-step) were purchased so mechanics could reach components in the roof area of the low-floor bus from the inside of the bus. In general, bus lifts were preferred over pits for low-floor buses, but either could be used.

Only one agency had added any special equipment to service low-floor buses during a roadcall. The VRTS developed an adapter that attached to the wheel bolts to provide a jacking pad for changing a flat tire during a roadcall. The other agencies reported that they used a low-style hydraulic jack or a wrecker to lift the bus to change a flat tire on the road

The mechanics' rating of the accessibility of components on low-floor buses ranged from "no opinion" to "good." Some liked the accessibility of the T-drive arrangement of the engine, others believed that the engine was less accessible. Because the low-floor bus had some components that were different or were at new locations in the bus, mechanics were asked their opinions of these changes. Their reactions were mixed. Some did not like the changes; however, others didn't seem to mind. One consistent comment was that it was "cleaner" to work on the bus.

While there have been several mechanical and electrical problems with the initial low-floor buses delivered, the problems appear to have been a result of the bus being a "new bus" rather than a "low-floor bus." These problems included such things as excessive vibration and noise in the rear of the bus, loose wheel nuts, door operator problems, and fluid leaks. Through the diligent and cooperative efforts of the manufacturer and agencies' maintenance personnel, these problems appear to have been resolved.

The AATA provided information on the maintenance costs (by maintenance category) for the first year of operations for their 10 bus low-floor fleet. In addition, AATA provided similar data for two Orion II buses purchased in 1992, and three RTS-06 buses purchased in 1987. The total maintenance cost data for each of these three subfleets are given in Table Nine. From these data it would appear that the low-floor buses were incurring maintenance costs similar to other buses in the AATA fleet. The other three agencies generally percieved that maintenance costs of low-floor buses were comparable to the maintenance costs of other vehicles in their fleets. All indicated some increase in inventory costs, mostly because the manufacturer was new to the agency and that some new parts had been added to their inventories.

The low-floor buses all use low-profile radial tires. The tire used on all the buses was the Michelin (XZU-2) 275/70R 22.5. The tire rolling radius is about 76 to 102 mm (3 to 4 in.) smaller than the higher profile tires used on conventional buses, and one would anticipate some reduction in tire life because more rotations would be required to cover the same distance. Mileage for low-floor buses at the four transit agencies is given in Table Ten. Most of the buses at the agencies have less than 80,500 km (about 50,000 mi), so it is a little early to make a definitive assessment of tire life. However, VRTS had nine buses with about 121,000 km (about 75,000 mi) each (as of September 30, 1993), and these buses were still running on the original tires, except for the few replaced because of road hazard damage. The tire life experience was somewhat different at AATA. As of September 1993, the AATA low-floor buses had approximately 55,100 km (about 33,000 mi) on each bus. The tire specialist at AATA estimated that the projected tire life would be about 80,500 km (50,000 mi). No reason for this difference (80,500 km versus 121,000 km) in tire wear was found.

None of the agencies visited had experienced any tire failures from high bead temperatures All of the low-floor buses were equipped with a transmission retarder that could be activated by a brake pedal or an accelerator pedal signal. Some observations of tire bead temperatures taken at AATA as buses pulled into the Blake Transit Center are given in Table Eleven The conventional buses were TMC RTS models and were not equipped with retarders. As noted, Bus Number 315 was equipped with bias-ply tires, all other buses were equipped with radial tires. While these observations are not presented as statistically valid data, they do support the position that retarders can be effective in lowering the tire bead temperatures to a level where radial tires can be used.

Operations Issues and Experiences

In transit industry discussions of low-floor buses, issues of road clearances, winter operations, and operations in high water frequently arise. All four agencies reported that they have had no problems relative to road clearance with their low-floor buses. There had been little or no experience to date with winter operations at the four agencies. However, with the delivery of low-floor buses to Edmonton Transit and Calgary Transit in Alberta, Canada, there should be more information on this issue in the future.

As for operation through high water, none of the four transit agencies had experienced any problems to date. Champaign-Urbana has a railroad that cuts through both cities and there are many underpasses that flood following a heavy rain. This is a problem that occurs 5 to 10 times a year. However, it was not viewed by C-U MTD as a serious problem nor one limited to only the low-floor buses.

Three of the agencies mounted the fare collection box on a small platform, as can be seen in Figure 17. This was primarily to make

TABLE NINE
COMPARISON OF MAINTENANCE COSTS AT AATA FOR 1993

Total Annual Costs of Various Maintenance Categories, In U.S. Dollars							
Fleet	Normal Wear	Rebuild	Warranty	Fuel	Oil	Miles	Average Cost Per Mile
10-D40LF (1993)	$41,833	$0	$31,525	$73,293	$1,470	$461,018	$0.321
2-Orion II (1992)	10,212	0	12,271	8,434	252	85,575	0.364
3-RTS-06 (1987)	203,269	526	10,486	185,654	3,967	1,190,164	0.339

TABLE TEN
TOTAL FLEET MILEAGE FOR LOW-FLOOR BUSES BY AGENCY*

Agency	Fleet Mileage in Miles	Number of Buses in Fleet
Ann Arbor Transportation Authority	394,000	10
Champaign-Urbana Mass Transit District	201,000	15
Kitchener Transit	770,000	14
Victoria Regional Transit System	1,231,000	25
TOTAL	**2,596,000**	

* As of October 1993

TABLE ELEVEN
OBSERVED BRAKE DRUM AND WHEEL BEAD TEMPERATURES IN °F

	Rear Right Side		Rear Left Side	
Bus	Drum	Bead	Drum	Bead
Low-Floor				
Bus No. 356	240	200	210	195
Bus No. 353	210	155	200	175
Conventional				
Bus No. 315[a]	200	140	260	163
Bus No. 340	330	216	410	220

[a]Bus equipped with bias-ply tires.

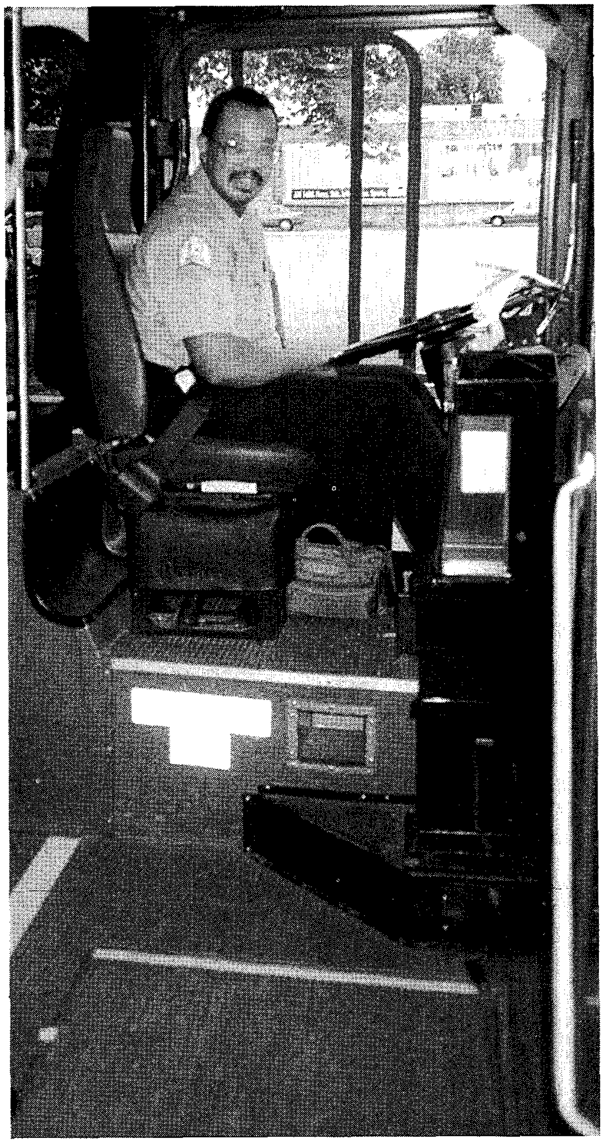


FIGURE 17 Farebox mounted on platform in Champaign-Urbana low-floor buses.

the farebox controls more accessible to the driver. The farebox platform also provides an intermediate step to assist drivers to the seat. VRTS choose to mount the farebox on the floor as is shown in Figure 18. VRTS added a trip pedal activated by the driver's left foot to operate the farebox. Champaign-Urbana also added a dump switch on the driver's panel to clear the farebox plate.

Two perceived safety issues have been postulated concerning low-floor buses. One is the potential safety hazard of the two interior steps to the raised floor area in the rear of the bus. The other is a concern of door safety in that there is no stairwell to keep the passengers from leaning on or being too close to the doors when they open. The concern with the interior steps was that passengers might trip on the steps or a standee on the steps

FIGURE 18 Farebox mounted on floor in Victoria Regional Transit System low-floor buses.

might fall during a high braking effort. The concern with the rear door safety was that a passenger leaning on the door might fall out or a passenger in the door area might be injured when the door opened. All four agencies reported that there have been *no* problems with either of these perceived safety issues. One agency expressed their belief that the flat surface of interior steps was safer to stand on than the sloping surface of a ramp. Figure 19 is a photo taken from the rear of the bus showing interior seating arrangement used by Kitchner Transit. Figure 20 is a photo taken from the front of the bus showing the interior steps, the strap hangers, and the seating arrangement used by VRTS. Because all of the transit agencies basically had the same bus, there is no U.S. or Canadian operational experience to date with low-floor buses with a ramp in the floor to compare with the steps. However, in Europe the use of a ramp in the floor to clear the rear axle is widely used, apparently without serious problems.

Many passengers, particularly younger passengers, seem to prefer the elevated view from the rear of the bus. At all four agencies, there was a noticeable tendency for more passengers to ride in the rear of a low-floor bus than passengers riding conventional buses. Why this occurs is not known, but it could imply that the passengers do not have a safety concern about the interior steps. It was noted on several occasions that even some senior passengers chose to sit in this area. However, at all agencies there was a strong tendency for the senior passengers to choose seats near the front of the bus.

FIGURE 19 Interior of a New Flyer low-floor bus at Champaign-Urbana. (Courtesy of New Flyer Industries)

FIGURE 20 Interior steps of a New Flyer low-floor bus in the Victoria Regional Transit System.

As for the perceived door safety issue, the four transit agencies reported that no door safety problems have been experienced to date. Two of the agencies had placed a vertical stanchion in the area near the rear door to provide standing passengers in the area something on which to hold. All agencies reported that the standee area in the rear door area was improved because the absence of the stepwell created more room.

The four transit agencies reported that the heating, ventilation, and air conditioning on the low-floor buses were satisfactory. Two of the agencies had not experienced winter operations at the time of the field visits. Kitchener Transit reported that a few passengers had complained about cold feet, but these problems were associated with the early operations of the bus and have since been resolved.

All four agencies indicated that the operating range of their low-floor buses was satisfactory. The New Flyer low-floor bus has two diesel fuel tank options--a single tank with a capacity of about 475 liters (about 125 gallons) or two interconnected tanks with a total capacity of about 570 1 (about 150 gal). Since the diesel fuel tank for a low-floor bus is located inside the passenger compartment

TABLE TWELVE
BOARDING AND ALIGHTING TIMES (SECONDS) BY BUS TYPE

Agency (Total in Fleet; Total, Low-Floor Buses)	Low-Floor Bus	Conventional Bus
St. Albert Transit (N/A; 91)		
Single passenger boarding	3.61	4.27
Two passengers boarding	6.15	7.27
Senior passenger boarding	3.88	6.10
Kitchener Transit (108; 14)		
Average passenger boarding	2.23	2.42
Average passenger alighting	1.16	1.49
Ann Arbor Transportation Authority (71; 10)		
Mean boarding time between passengers, no cash transaction, revenue service	1.92	2.22
Mean boarding time, shuttle	1.91	2.26

Sources: (*1820,21*)

envelope, a need for more fuel capacity could further reduce the number of seats that can be made available.

None of the agencies has modified or changed its bus stops to accommodate low-floor buses. One agency reported that a bench was positioned a little farther back from the curb so that passengers rising from the bench would not strike their heads on the right side mirror of the low-floor bus when they stood up. Champaign-Urbana is considering raising the height of the boarding platforms at some bus stops to provide a level-boarding concept similar to that being investigated in Europe.

All four transit agencies reported that boarding and alighting times were faster on low-floor buses. Three reports were found that provide data on measured absolute boarding and alighting times of passengers on low-floor buses and passengers on conventional buses. These data are presented in Table Twelve.

Kitchener Transit completed a survey of boarding and alighting times at two of their heaviest boarding stops in their business district *(18).* As can be seen in Table Twelve, the average boarding time savings was about 0.2 second per boarding passenger for the low-floor buses over the conventional buses. Also, the alighting times were found to be 0.3 second faster for the low-floor buses over conventional buses.

The University of Michigan conducted a study of dwell time impacts as a result of the low-floor bus design *(20).* In this study, they observed boardings of an AATA shuttle service that used both low-floor and conventional buses. Because fare collection was accomplished prior to boarding, the time differences observed were under more controlled conditions than is possible in regular service. As can be noted in Table Twelve, the boarding times for the AATA low-floor buses were 0.35 seconds per passenger shorter as compared to boarding times for conventional buses. These savings were similar to the time savings observed for the "no cash transaction" passengers in regular service.

The faster boarding and alighting times for persons with mobility problems and parents with baby strollers or small children are even more dramatic. Liggett (*21*) reported that observations of boardings at St. Albert Transit found savings of more than two seconds per "senior" passenger and six seconds for a mother with her child.

Driver Issues and Experiences

At each of the four transit agencies visited, discussions were held with drivers who had driven the low-floor buses. While the discussions generally followed the interview guide questions, discussions were informal, and as such, much of the information reported is anecdotal. The drivers' opinions of the buses were mixed; however, they were universally in favor of the low-floor concept. Many of the driver's complaints were about mechanical and electrical problems that had been experienced with the initial production series of the bus. In some instances, the drivers didn't like a change from what was used on other buses in the fleet. Some "loved" the bus, many liked or were favorably inclined toward the bus, and a few didn't like the bus. Summary highlights of the responses from the drivers are given below.

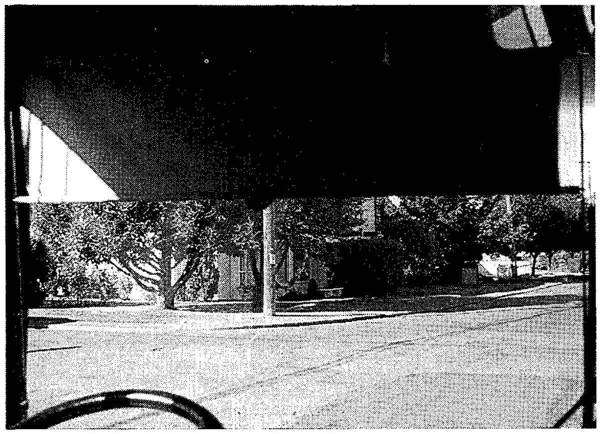


FIGURE 21 Sun visor used by Victoria Regional Transit System

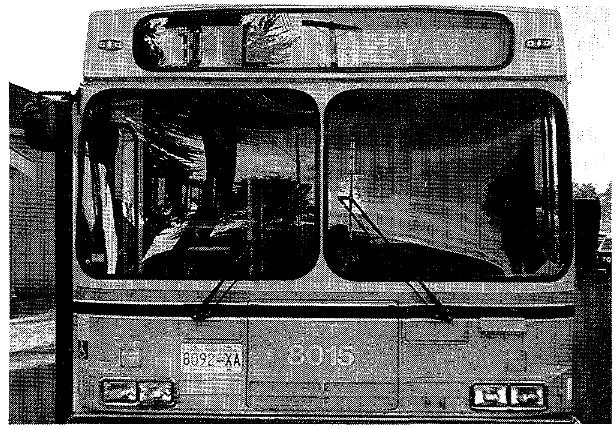


FIGURE 22 Side mirror locations preferred by Victoria Regional Transit System drivers.

Most drivers found access to the low-floor bus work station to be satisfactory. Three agencies had added a step (farebox platform, see Figure 17) to assist drivers to the seat. Some drivers complained about the leg room, and some would like more room to store their personal things while driving.

Driver visibility on low-floor buses was satisfactory or improved over other buses in the fleet. The drivers at VRTS liked the sun visor on their low-floor buses. VRTS has a pull-down shade that can be readily adjusted to the desired height for each driver. A photo of the sun visor used by VRTS is shown in Figure 21.

Sometimes intended improvements can result in complaints. The drivers at Kitchener Transit complained about a blind spot caused by the left side mirror on their low-floor buses. The mirror was much larger than the mirrors used on the rest of the Kitchener Transit fleet. These mirrors were remote-controlled and heated, and were approximately 150 mm (6 in.) wide by 300 mm (12 in.) long. They had been purchased by the agency to improve driver visibility and make it easier to adjust. The mirror provided an excellent view, but also caused a small blind spot in the area to the left front of the bus. A similar mirror was used by VRTS on their low-floor buses with no complaints from their drivers. VRTS had lowered the mounting of the left side mirror about 75 to 100 mm (about 3 to 4 in.) which had reduced the blind spot problem to the point where the drivers were satisfied See Figure 22 for a photo of the VRTS mirror location. AATA and C-U MTD used the same mirrors on their low-floor buses as on the other buses in their fleets, and because there was no change, no comments were received from the drivers concerning the mirrors.

VRTS has their right side mirror mounted high, near the upper corner of the right windshield (see Figure 21). The driver's line of sight to this mirror passes through the area of the windshield that was tinted, causing a vision problem at night. On the second order of buses, VRTS ordered the right windshield untinted, and the problem was eliminated.

Kitchener Transit had a farebox platform built to provide better driver access to the farebox controls. Kitchener reported that this solution was an improvement, but that a remote keypad would be preferred. As reported earlier, all agencies, except VRTS, had the fareboxes mounted on platforms (see Figures 17 and 18). In addition tion to Kitchener, VRTS and C-U MTD had added controls for the driver to more easily operate the farebox.

At all agencies, the drivers liked the simplicity of the flip-out ramp. Only AATA and C-U MTD have had extensive experience with wheelchair lifts to compare with the flip out ramp. Several drivers at AATA and C-U MTD volunteered that the ramp was a major improvement over lifts. The ease of manually deploying or stowing the ramp was the feature drivers most appreciated. The simplicity and the capability of manual operation was also popular with management and maintenance personnel. With the ramp there was little maintenance and no roadcalls because of ramp failure.

Drivers had to be careful not to get too close to a high curb when deploying the ramp and kneeling the bus. The ramp actuator cams protrude outside the normal envelope of the bus when the ramp is deployed. The curb could interfere with the cam when the bus is kneeled. The cam protrudes about 50 mm (about 2 in.) beyond the side of the front bumper and is about 127 mm (5 in.) above street level when the bus is kneeled. The bus should be about 75 mm (3 in.) away from a 150 mm (about 6 in.) or higher curb to prevent interference with the cam operation.

The flip-out ramp has a 51-mm (2-in.) side rail on each side as required by the ADA. The ramp back surface becomes a part of the bus floor when the ramp is stowed (see Figure 18). To stow the ramp flush with the rest of the floor, two grooves are cut into the floor base to accommodate stowing the ramp side rails. Because the ramp is in the front door and all passengers board at this entrance, the ramp floor grooves are in the highest trafficked area. As passengers board, dirt and moisture (from rain and snow) tend to accumulate in these grooves. No problems were reported with these grooves. However, all agencies indicated that the grooves did require some additional cleaning effort.

Most drivers liked the eye-level contact with passengers from the elevated driver seat of the low-floor bus. One reported that he "loved it--especially with kids." Most drivers seemed to like the fact that the passenger seats were located farther back in the bus so they didn't have to contend with a talkative passenger. On this same point, some seniors have complained that there is no seat available close to the driver.

The headroom in the front of the low-floor bus is about 239 cm

(94 in.). While this higher ceiling provides a more open environment for the passengers, it also makes it difficult for a short driver to reach the levers to open the roof vents. In Europe, simple extended handles are provided to make operating roof vents easier.

On balance, the drivers' attitudes toward the low-floor bus were positive. There were driver complaints about things such as leg room, steering stiffness, and mirrors, but there were also plaudits concerning quickness and turning radius, and all drivers recognized the benefit to their customers in the ease of boarding and alighting.

Planning and Administration Issues

A number of planning and administration issues have been raised concerning low-floor buses, but the one that seems to be at the top of everyone's list is capacity. None of the four agencies visited has had a problem with the capacity of low-floor buses. All would like more seats, but their service standards result in passengers standing during peak periods. No operational changes related to capacity have been introduced with low-floor buses. One agency reported that standing room had increased and that the rear exit area "was more inviting" for standees. One reported that they had experienced an increase in crowding on the low-floor buses during peak periods

With the intrusion into the passenger compartment of wheelhousings, the fuel tank, and the engine compartment, the number of seats is lower in low-floor buses compared to conventional buses of similar size. For the transit agencies visited, the number of seats ranged from 36 to 38. Two wheelchairs could be accommodated with both of the 36-seat arrangements, and one wheelchair securement location was available in the 38-seat arrangement at VRTS. The staff at VRTS indicated that two wheelchair securement locations could be accommodated with their 38-seat layout. A typical 12.2-m (40-ft) conventional bus in the United States has 43 to 45 seats, and will accommodate two wheelchair passengers. How critical the loss of 5 to 7 seats would be is unknown. It appears that there may be some compensation in the increase in standing room, because the rear steeple does not exist in the low-floor bus. However, all of the area adjacent to the rear door may not be realized for standees (or be acceptable) at some transit agencies because of safety concerns About all that can be concluded at this time is that capacity is still an open issue.

No perceived increases in capital budgets resulted from low-floor buses at the four transit agencies. It was too early to determine whether or not there were changes in operating costs.

Some transit agencies use automatic passenger counting (APC) systems for monitoring the passenger counts on their routes. These APC systems typically use pads installed on the steps to sense boarding or alighting passengers, or a system of optical beams that sense passenger movement up or down the steps. The steps tend to make passengers travel in a single file, thereby enabling an APC system to obtain an accurate count. Because low-floor buses have no steps and fairly wide doors, the conventional APC systems may not work as reliably as with a conventional bus. The four agencies plan to obtain passenger counts on their low-floor buses in the same way they do with their conventional buses, either by using farebox data or by manual counts. The passenger counting issue for low-floor buses was not an issue at the four agencies interviewed.

All of the agencies had made a strong effort to educate the public about the new low-floor buses. All had press releases and passenger flyers to inform the public about the features of the bus and how to use these features. All have used the low-floor buses at special events such as trade shows, senior charters, art fairs and football games. Some have taken the buses to senior centers or centers for people with disabilities to familiarize them with the boarding ramp and other new features of the low-floor bus. No additional training was required for the low-floor bus beyond what would be required for any other new bus. In Canada, however, the provision of accessible service on fixed-route service is just beginning and both VRTS and Kitchener Transit have provided training programs for their drivers on ambassador training, accessibility training, and special needs/sensitivity training. Similar training is provided for the drivers at AATA and C-U MTD.

CHAPTER FOUR

CONCLUSIONS AND GENERAL RECOMMENDATIONS

OVERVIEW OF STUDY FINDINGS

The emergence of low-floor bus technology in the United States and Canada has begun. The overall experience with the 221 heavy-duty, standard-size, low-floor buses in operation today has been positive.

Low-floor bus technology is widespread Europe, with bus manufacturers in most countries producing low-floor models. In Germany alone, more than 3,900 low-floor transit buses were sold between 1988 and 1992.

The pace has been somewhat slower in the United States and Canada than in Europe. However, three bus manufacturers have production or prototype low-floor models, two manufacturers are considering adapting European low-floor buses to the North American market, and three manufacturers are in the planning stage.

In the deployment of low-floor transit buses, Europe leads both the United States and Canada. Low-floor bus service in Europe began about three years earlier than in North America. The majority of orders for new transit buses in Europe are for low-floor models. The early consensus on technical requirements and willingness to adopt standard specifications for low-floor buses may have contributed to this rapid deployment.

The significant findings from visits to the four transit agencies operating low-floor buses are provided below:

Passengers

- Passengers' attitudes were overwhelmingly positive.
- Boarding/alighting is easier and faster--in particular for the seniors, parents with children, and people with disabilities.
- Wheelchair passengers prefer the ramp to a lift for boarding/alighting the bus.
- The seniors in Kitchener love their Thursday shopping charter with a low-floor bus.

Operations

The agencies have not experienced problems with:

- Road clearance,
- The interior steps,
- Rear door safety,
- Operation in high water,
- Operation in winter, or
- Accommodating low-floor buses at bus stops.

Drivers and Mechanics

- Drivers' attitudes were mixed, but the vast majority of drivers either saw the passenger benefits or liked the bus in general.
- Drivers liked the quickness of the bus, although some complained of stiffness of steering and blind spots.
- Mechanics' attitudes were mixed, but generally favorable; opinion on accessibility of components ranged from no opinion to good.
- Changes to maintenance facilities and equipment were minimal.
- Early electrical/mechanical problems experienced with low-floor buses appear to have resulted from new bus design rather than low-floor bus design.

Planning/Administration

- None of the agencies has had problems with the reduced number of seats in the low-floor bus.
- All four agencies have purchased or plan to purchase more low-floor buses.

POTENTIAL AREAS FOR RESEARCH

Several research areas in low-floor bus technology appear to hold significant potential for improving low-floor bus operations or service:

- Increases in passenger seating capacity,
- Reduction in dwell times, and
- Development of level-boarding systems.

Increasing Passenger Seating Capacity

The loss of passenger seats in low-floor buses continues to be a major concern to the transit community. In the United States and Canada, the practice of having passenger seats facing rearward or seats on pedestals has not been accepted as it is in Europe. As a result, it is not possible to use the areas over the wheelhousings for passenger seats in the current low-floor buses.

Several components of low-floor buses may encroach into the passenger compartment envelope and reduce the useable floor area for passenger seating. These components are:

- Tires and associated wheelhousings,
- Axles and suspension systems,
- Engine and transmission, and
- Fuel tank(s).

To solve these encroachment problems, two basic approaches are used. One is to minimize the size of the encroachment, and the other is to eliminate the encroachment (e.g., move the component).

Bus weight reduction would enable the reduction in size (and weight) of all of the above components, thereby leading to more usable floor area for passenger seating. The use of natural gas fuel and roof-mounted fuel tanks would not only remove the fuel tank from the passenger compartment envelope, but would also facilitate more seating arrangements. The use of hybrid propulsion systems with electric wheelhub motors would also have potential for increasing the useable floor area for seats.

Maximum allowable axle loads also can affect the passenger capacity of a bus. With today's high curb weights of both low-floor and conventional buses, the maximum allowable axle loads may be more of a constraint on bus capacity than useable floor area. This further emphasizes the need for weight reduction.

Reduction In Dwell Times

In a recent TRB paper on "Dwell Time Effects of the Low-Floor Bus Design" (*20*), Levine and Torng reported research findings that boarding and alighting times typically comprised 90.9 percent of the dwell time. Boarding and alighting time included the time spent for boarding, fare collection, and alighting of passengers.

Observations made at the four agencies of boarding times on low-floor buses has led to the subjective conclusion that the time for fare collection substantially adds to the dwell time. In these limited observations, the fare collection process consumed up to two-thirds of the total boarding time. These observations are consistent with the results of a comprehensive study done by Cundill and Watts at the Transport and Road Research Laboratory in England (*23*). This study investigated many operational and equipment factors that impact bus boarding and alighting times. The study found that boarding times ranged from about 1 to 6 seconds per passenger, and that the lowest values found on "one-man" buses, that is those on which the driver collects fares, were for those using prepaid tickets.

To take full advantage of the faster boarding/alighting times of low-floor buses, a speed up of the fare validation/collection process is needed. The European practice in which passengers can board at any door and only need to have "proof of payment" if challenged by an inspector, appears to have potential of taking maximum advantage of the faster boarding/alighting times of the low-floor bus passengers.

Development of Level-Boarding System

The development of low-floor buses provides the opportunity for development of level-boarding systems for buses comparable to those that exist in heavy rail systems (metros). Several cities in Germany and France have constructed demonstration bus stops with raised platforms on their bus routes. The combination of these raised stops and low-floor buses provides a level-boarding system for passengers. A photo of a raised platform bus stop in Germany is shown in Figure 23.

These demonstration bus stops have various configurations, platform heights, and curb designs and are being evaluated to determine which combinations work best. The German cities of Essen and Mannheim are testing guided bus technology, a mechanical guidance system used to steer the bus along a guideway where stop platform heights are the same as the vehicle entrance height.

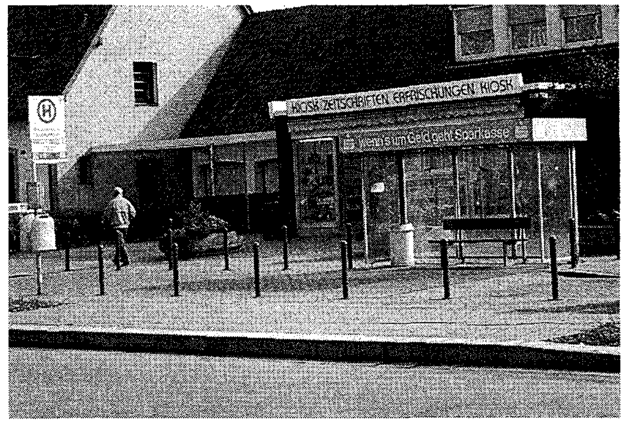


FIGURE 23 Raised platform bus stop in Germany.

FIGURE 24 Guided bus at a stop in Germany

A photograph of the boarding/alighting interface for a guided bus system is shown in Figure 24.

These concepts involve the operation of low-floor buses at bus stops with raised platforms, to reduce the vertical gap between the bus stop platform level and the bus entrance level. To achieve a minimum horizontal gap, the bus must be steered close to the curb. Such an operation can result in damage to the bus if not done carefully. However, when performed properly, the boarding interface (platform and vehicle) is as good as any modern high-platform rail system.

GENERAL RECOMMENDATIONS

Based on the results of this study, the following research topics are recommended for consideration:

- Because experience in winter operations has been modest with the four agencies to date, further study of winter operations is needed. With the deployment of low-floor buses in Edmonton and Calgary and a winter season at Champaign-Urbana and Ann Arbor, there should be adequate information to draw more definitive conclusions on this issue a year from now.

- The capacity issue is still open for debate. Canada is considering a research project to investigate the low-floor bus capacity issue It is recommended that the United States consider joining this effort in some cooperative role. Also, as low-floor buses are delivered to larger metropolitan areas in the coming months, additional operational results regarding capacity will become available. It would be desirable to have these operational results documented and disseminated to the transit community.
- Because low-floor bus technology is emerging and changing rapidly, it is recommended that a study be made to update the available technology in 1 to 2 years.
- From the experience gleaned from Europe, it would appear that establishing guideline specifications for key technical requirements of a low-floor bus would be beneficial to the transit industry. A willingness to agree and standardize could reduce the business risk for the bus manufacturers and should result in lower costs to agencies as there would not be the engineering and development costs associated with custom specifications. It is recommended that the U.S. and Canadian transit community develop guideline specifications in a cooperative effort.
- A research study is recommended to investigate the potential use of different fare collection systems to take maximum advantage of the boarding/alighting times of low-floor buses.
- A research study is recommended to explore the use of raised bus stop platforms along with low-floor buses to provide improved accessibility for all passengers with level-boarding systems.
- A research study of the impact on tire bead temperatures of buses equipped with radial tires and the effectiveness of retarders to lower bead temperatures under heavy loads and various operating cycles is recommended.

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5. Bus Manufacturer Survey Responses, Bus Industries of America, Flxible, Gillig, Ikarus, Neoplan, and New Flyer (September 1993).
6. *Orion II,* sales document, Bus Industries of America.
7. Sales document, D.L. Manning, DLMA Transportation, Inc. (October 1993).
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9. *Neoplan Carbon Fiber Composite,* sales document, Neoplan USA Corporation.
10. Statement of work for *Design and Manufacture of the Next Generation Bus,* preliminary draft, Houston Metro (September 27, 1993).
11. "Advanced Technology Transit Bus," briefing materials presented at the Second Briefing in Washington, D.C. (August 1993).
12. *Rahmenempfehlagen für Niederflurbusse,* Schriften 230 of the Verband Deutscher Verkehrsanternehmen (VDV Germany 1993).
13. *Sentra S300NC Der Neue Niederflurbus,* sales document from Kässbohrer.
14. *0405N Niederflur-Linienomnibus,* sales document from Mercedes-Benz.
15. *MAN Low-Floor Buses,* NM152, NL202, NG272, sales document from MAN.
16. *Neoplan Niederflur Busse anf einen Blick,* sales document from Neoplan.
17. Specifications: A-300 Low-Floor Van Hool, sales document from Gillig.
18. Beck, W.T., "Low-Floor Buses in Kitchener," paper presented at the CUTA Fall Conference in Laval, Quebec (November 1991).
19. *Route Selection for Accessible Low-Floor Transit Service,* Internal Report, Victoria Regional Transit System (no date).
20. Levine, J.C., and G.Torng, "Dwell Time Effects of the Low-Floor Bus Design," paper presented at the Annual Meeting of the Transportation Research Board in Washington, D.C. (January 1994).
21. Light, WD, "Low-Floor Bus--The St. Albert Experience," paper presented at the CUTTER Fall Conference in Laval, Quebec (November 1992).
22. *Assessment of Low-Floor Buses,* Kitchener Transit, Internal Document (April 6, 1993).
23. *Bus Boarding and Alighting Times,* Candela, MA and P.F. Watts, Transport and Road Research Laboratory (TRRL), TRRL Report LR 521 (1973).

GLOSSARY

ATTB	advanced technology transit bus
AATA	Ann Arbor Transportation Authority
ADA	Americans with Disabilities Act
APC	automatic passenger counting
Approach	an angle determined by the front overhang and the lowest clearance height under the front of the bus; whether or not the vehicle is laden must be stipulated.
APTA	American Public Transit Association
BIA	Bus Industries of America
Breakover	included angle determined by wheelbase and clearance height under the vehicle that determines the ability of the vehicle to traverse a humped road surface. Whether or not the vehicle is laden must be stipulated. (From *Dictionary of Automotive Engineering* D. Goodsell, SAE, Butterworth-Heinemann, Ltd.)
BVG	Berliner Verkehrs-Betriebe
cm	centimeter
C-U MTD	Champaign-Urbana Mass Transit District
Departure	an angle determined by the rear overhang and the lowest clearance height under the rear of the bus, whether or not the vehicle is laden must be stipulated.
FTA	Federal Transit Administration
ft	feet
in.	inch
km	kilometer
LACMTA	Los Angeles County Metropolitan Transportation Authority
lbs	pounds
MAN	MAN Nutzfahrzeuge Aktiengesellschaft
m	meter
MIC	Metroliner in Carbon-Design
MINN	Minnesota
mm	millimeter
MN	Manitoba
NFIL	New Flyer Industries, Limited
NGB	Next Generation bus
Orion II	a small (22- or 26-ft) low-floor bus series manufactured by BIA.
RTS	"Rapid Transit System" a transit bus series manufactured by TMC.
TMC	Transit Manufacturing Corporation
TRB	Transportation Research Board
UITP	International Union of Public Transportation
VDV	Verband Deutscher Verkehrsunternehmen
VRTS	Victoria Regional Transit System
"White Book"	*Specifications for the Design of Baseline Advanced Transit Coaches,* Guideline for procurement document for new 35- and 40-ft coach designs. Department of Transportation, Urban Mass Transportation Administration, Washington, D.C. 1978.
ZF	Z F Friedrichshafen AG

APPENDIX A

INTERVIEW GUIDE

1

JUNE 21, 1993

LOW-FLOOR BUS INTERVIEW GUIDE

(STANDARD BUSES)

TRANSIT AGENCY NAME ____________________

CONTACT PERSON ____________ TITLE ________

ADDRESS ____________________ TEL. NO. ________

____________________ FAX NO. ________

(1) DESCRIPTION OF LOW-FLOOR BUS FLEET

MANUFACTURER ____________________

MODEL NO. ____________ NUMBER OF BUSES ________

DATE PLACED IN OPERATION ____________________

SEATING CONFIGURATION (PLEASE PROVIDE COPY OF SEATING DRAWING.)

TECHNICAL DESCRIPTION (PLEASE PROVIDE INFORMATION ON ATTACHED FORM)

(2) DESCRIPTION OF TOTAL SYSTEM

PLEASE PROVIDE SECTION 15 DATA ON ANNUAL BOARDINGS, REVENUE MILES, REVENUE HOURS, AND OTHER INFORMATION THAT IS DESCRIPTIVE OF YOUR OPERATIONS.

PLEASE PROVIDE INFORMATION ON THE DEMOGRAPHICS OF YOUR PASSENGERS, EG. APPROXIMATE PERCENTAGES OF ADULT, SCHOOL CHILDREN, WHEELCHAIR PASSENGERS, ELDERLY, PASSENGERS WITH DISABILITIES, ETC..

(3) TYPE OF SERVICE ROUTES FOR LOW-FLOOR BUSES

(CHECK AS MANY BOXES AS APPROPRIATE)

SUBURB TO CBD [] SUBURB CIRCULATOR [] COMMUTER FROM P&R []

CBD CIRCULATOR [] SUBURB FEEDER TO RAIL [] SUBURB TO CBD (EXP) []

OTHER ____________________

ROUTE MILES SERVED BY LOW-FLOOR BUSES? ____________

NUMBER OF STOPS SERVED BY LOW-FLOOR BUSES? ____________

2

(4) DESCRIPTION OF BUS STOPS

NUMBER OF STOPS IN THE SYSTEM? ________

PERCENT OF STOPS WITH CURBS? ________

AVG. CURB HT. _____ INCHES CURB HT. RANGE _____ IN. TO _____ IN.

ANY STOPS WITH RAISED PASSENGER PLATFORMS? ________

IF SO, HOW HIGH IN INCHES? ________

ARE THERE BUS STOPS IN A TRAFFIC LANE FOR BOARDING? ______

IF YES, WHAT PERCENT OF TOTAL STOPS? ________

(5) LOW-FLOOR BUS RIDERSHIP DATA

PLEASE PROVIDE ANY AVAILABLE RIDERSHIP DATA ON LOW-FLOOR BUSES FOR WEEK DAYS AND WEEKENDS/ HOLIDAYS.

PLEASE PROVIDE INFORMATION ON ANY RIDERSHIP SURVEYS THAT HAVE BEEN DONE ON THE LOW-FLOOR BUSES.

WHAT HAS BEEN THE PUBLIC REACTION TO THE INTRODUCTION OF THE LOW-FLOOR BUSES?

____

____

____

____

____

____

____

(6) PASSENGER ISSUES

DO PASSENGERS HAVE DIFFICULTY IN REACHING THE FAREBOX? ____ IF YES, PLEASE EXPLAIN ____

DO PASSENGERS HAVE DIFFICULTY WITH THE INTERIOR STEPS? ____ IF YES, PLEASE EXPLAIN ____

DO PASSENGERS OBJECT TO REARWARD FACING SEATS? ____________

IS THERE A SEAT AVAILABILITY ISSUE/CONCERN? ____________

DO PASSENGERS HAVE DIFFICULTY IN USING THE SEATS ON PEDESTALS? ____

WHAT HAS BEEN YOUR EXPERIENCE WITH INTERIOR NOISE WITH THE LOW-FLOOR BUSES?____

DO PASSENGERS FIND THE WINDOW VIEW SATISFACTORY? ____________

ARE THE WHEELCHAIR SECUREMENT LOCATIONS SATISFACTORY? ________

PASSENGER ATTITUDES RELATIVE TO BOARDING/ALIGHTING OF A LOW-FLOOR BUS COMPARED TO A CONVENTIONAL BUS? ____________

OTHER COMMENTS

(7) MAINTENANCE ISSUES *(POSSIBLY USE A FOCUS GROUP?)*

HAVE THERE BEEN ANY CHANGES IN THE MAINTENANCE FACILITIES OR PRACTICES TO ACCOMMODATE THE LOW-FLOOR BUSES?

DO YOU NEED ANY SPECIAL TOOLS OR EQUIPMENT TO SERVICE A LOW-FLOOR BUS DURING A ROADCALL? (i.e. CHANGE A FLAT TIRE) ____________

MECHANICS' VIEWPOINTS WITH RESPECT TO THE OVERALL MAINTAINABILITY OF THE LOW-FLOOR BUS. ____________

MECHANICS' VIEWPOINTS ON THE ACCESSIBILITY OF COMPONENTS ON THE LOW-FLOOR BUS. ____________

HAS THERE BEEN ANY IMPACT ON THE PARTS INVENTORY WITH THE LOW-FLOOR BUSES? ____________

PLEASE PROVIDE ANY DATA THAT YOU MIGHT HAVE ON THE MAINTENANCE COST OF THE LOW-FLOOR BUS COMPARED WITH A CONVENTIONAL BUS IN SIMILAR SERVICE. (COSTS PER MILE, MILES BETWEEN ROADCALLS, ETC.)

(8) OPERATIONS ISSUES WITH LOW-FLOOR BUSES

HAVE THERE BEEN ANY ROAD CLEARANCE PROBLEMS? ______ IF YES, PLEASE EXPLAIN ____

HAVE THERE BEEN ANY WINTER OPERATION PROBLEMS? _____ IF YES,PLEASE EXPLAIN ____

HAVE THERE BEEN ANY HIGH WATER OPERATION PROBLEMS? _____ IF YES, PLEASE EXPLAIN ____

HAVE YOU MADE ANY CHANGES IN LOCATION AND/OR METHOD OF FARE COLLECTION? ________ IF YES, PLEASE EXPLAIN ________________

HAVE YOU HAD ANY INCIDENTS CONCERNING THE PROPER/SAFE OPERATION OF THE DOORS? ____

WHAT HAS BEEN YOUR EXPERIENCE WITH THE INTERIOR STEP? __________

HAS THE HEATING, VENTILATION, AND AIR CONDITIONING ON THE LOW-FLOOR BUSES BEEN SATISFACTORY? ________ IF NOT, PLEASE EXPLAIN ________

HAVE THERE BEEN ANY CHANGES CONSIDERED AT THE BUS STOPS TO ACCOMMODATE THE LOW-FLOOR BUSES? (eg. CLEARANCE PROBLEMS)

WHAT HAS BEEN YOUR BOARDING AND ALIGHTING EXPERIENCE WITH THE LOW-FLOOR BUSES?____

PLEASE PROVIDE ANY DATA YOU MAY HAVE ON THE IMPACT OF BOARDING AND ALIGHTING TIMES ARISING FROM THE USE OF LOW-FLOOR BUSES.

OTHER OPERATIONAL IMPACTS:

(9) DRIVER ISSUES *(POSSIBLY USE A FOCUS GROUP?)*

HAS THE ACCESS TO THE DRIVER'S WORK STATION BEEN SATISFACTORY? _____ IF NOT, PLEASE EXPLAIN ____

HAS THE DRIVER'S VISION BEEN IMPACTED IN ANY WAY? PLEASE EXPLAIN

HAS THERE BEEN ANY SIGNIFICANT CHANGE IN CHANGES IN VISIBILITY OR GLARE AND/OR INTERIOR LIGHTING FOR NIGHT DRIVING? _______ PLEASE EXPLAIN

IS THE DRIVER'S ACCESS TO FAREBOX CONTROLS AND MONITORING OF FARE COLLECTION SATISFACTORY? _____ PLEASE EXPLAIN ______________

DESCRIBE THE DRIVER'S ROLE IN ASSISTANCE AND SECUREMENT OF WHEELCHAIR PASSENGERS?

DESCRIBE DRIVER'S ROLE IN THE OPERATION OF THE RAMP? ___________

HAS THERE BEEN ANY SIGNIFICANT CHANGES IN DRIVER/ PASSENGER INTERACTION WITH THE LOW-FLOOR BUSES? (I.E. DRIVER AT HIGHER SEATED LEVEL)

WHAT IS THE DRIVER'S ATTITUDE TOWARD THE LOW-FLOOR BUS? ________

OTHER COMMENTS: ____

(10) PLANNING/ADMINISTRATION ISSUES

HAS THE LOSS OF CAPACITY (SEATS AND STANDEE ROOM) WITH THE LOW-FLOOR BUSES REQUIRED ANY CHANGES IN BUS REQUIREMENTS OR IN OPERATIONS?
IF YES, PLEASE EXPLAIN. ____________________________________

HAS THERE BEEN ANY IMPACTS ON OPERATING OR CAPITAL BUDGETS WITH THE USE OF LOW-FLOOR BUSES? ____________________________________

HOW IS PASSENGER COUNTING ACCOMPLISHED WITH THE LOW-FLOOR BUSES?

WHAT METHODS WERE USED TO EDUCATE THE PUBLIC WITH RESPECT TO THE LOW-FLOOR BUSES?

HOW ARE LOW-FLOOR BUS SERVICES INTEGRATED WITH YOUR PARATRANSIT SERVICES? ____________________________________

HAS THERE BEEN ANY SIGNIFICANT CHANGES IN ANY TRAINING PROGRAMS? ____
IF YES, PLEASE EXPLAIN ____________________________________

OTHER COMMENTS: ____________________________________

LOW-FLOOR TRANSIT BUS
TECHNICAL DESCRIPTION JUNE 21,1993

MANUFACTURER ______________________________

MODEL ______________________________

DIMENSIONS

BODY LENGTH, ft. __________ BODY WIDTH, in. __________
OVERALL HEIGHT, in. __________ WHEELBASE, in. __________

FRONT OVERHANG, in. ________ REAR OVERHANG, in. __________

CLEARANCE

APPROACH ANGLE, deg. ________ DEPARTURE ANGLE,deg. ________

BREAKOVER ANGLE, deg. ________ ROAD CLEARANCE, in. ________

ACCESSIBILITY FEATURES

(NOT KNEELED) ENTRANCE HEIGHT, in. _______ *(NOT KNEELED)* FLOOR HEIGHT, in. ______________

KNEELING CAPABILITY, in. ____ KNEEL FRONT? ___ or RIGHT SIDE? ___

FRONT DOOR WIDTH, in. _______ REAR DOOR WIDTH, in. _________
FRONT DOOR HEIGHT, in. _______ REAR DOOR HEIGHT, in, _________

WHEELCHAIR RAMP? _______ LOCATION(s)? ______________
WIDTH, in. _____ LENGTH, in. ______ LOAD CAPACITY, lbs. _________

INTERIOR HEIGHT CLEARANCE, in. ____________________

WIDTH OF AISLE, in. __________ WIDTH OF AISLES IN THE WHEELHOUSING AREAS - FRONT, in. ______ and REAR, in. ______

FLOOR

FLAT FLOOR? _____ or INTERIOR STEP(s)? _____ or RAMP(s)? ______

IF USED, HEIGHT OF STEP, in. _______ WIDTH OF STEP, in. _________
LOCATIONS? ______________________________

IF USED, SLOPE OF RAMP, percent _____ LOCATION(s) ___________

PASSENGER CAPACITY

NUMBER OF PASSENGER SEATS _______ NUMBER OF STANDEES _____

SEATS ON PEDESTALS? _____ NUMBER OF SEATS ON PEDESTALS _____

SEATS FACING REARWARD? _____ NUMBER OF SUCH SEATS ______

NUMBER OF WHEELCHAIR SECUREMENT POSITIONS _____________

NUMBER FORWARD FACING? _____ NUMBER REARWARD FACING? _____

VEHICLE WEIGHT AND RATING

GVWR, pounds __________ CURB WEIGHT, pounds ___________

APPENDIX B

ORION II SURVEY AND RESULTS

INTRODUCTION

Since 1984, the Bus Industries of America (BIA) has been manufacturing a low-floor bus primarily targeted for small transit systems and demand-responsive operations. This bus, the Orion II, is a heavy-duty small bus, offered in 22-and 26-ft lengths, that can be configured to carry from 16 to 24 passengers, respectively. Approximately 640 Orion II buses are operating in the United States and Canada. A photo of an Orion II is shown in Figure 5.

Because the owners of Orion II buses had the most experience with low-floor buses, a questionnaire was sent to all known owners of Orion II buses in the United States and Canada. Fifty-two agencies out of a total of 91 responded to the questionnaire. Fifty of the responses were from transit agencies, and two were from ambulance agencies. These fifty-two agencies are located in 16 states and 4 provinces as shown in Figure B-1. These agencies operate about 75 percent of the Orion II vehicles in the United States and Canada. The agencies that responded to the questionnaire are listed in Attachment 1. A copy of the questionnaire is in Attachment 2.

Summary of Questionnaire Responses

The primary purpose of the survey was to obtain information on the operating experiences transit agencies had with a small low-floor bus. The questions solicited information on the following issues:

- Road clearance problems,
- Winter operations problems,
- High water operations problems,

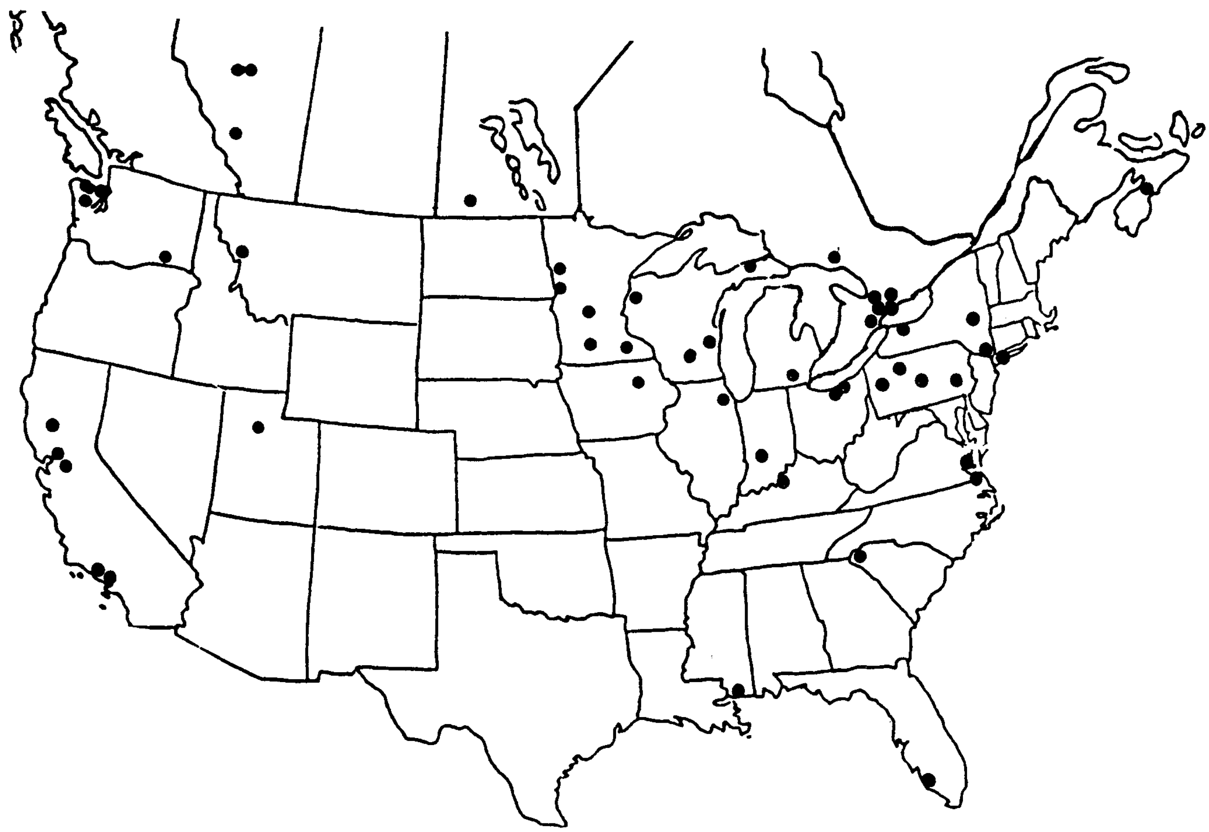


FIGURE B-1 Location of agencies with Orion II fleets that responded to the survey.

- Changes made to bus stops,
- Boarding and alighting experience, and
- Public reaction to the low-floor bus.

Responses from the 50 transit agencies to the questions on operations issues with Orion II buses indicate that 20 transit agencies reported that they had experienced some road clearance problems with the Orion II. Eight agencies reported problems with high crown intersections, railroad crossings, and speed bumps, and five agencies only reported having a road clearance problem. The seven other agencies that reported road clearance problems indicated that these problems only occurred in private areas, such as steep driveways.

Agencies reporting road clearance problems generally described the problem as it "bottoms out" or "scrapes." All of the agencies reporting a road clearance problem have the 26-ft Orion II. The 26-ft Orion II has the same road clearance as the 22-ft Orion II. However, the breakover angle for the 26-ft Orion II is 8.5°, and the breakover angle for the 22-ft Orion II is 10.6°. No transit agency that had only the 22-ft Orion II reported having road clearance problems.

Fifteen of the transit agencies reported some problems in winter operations with their Orion II buses. The winter operation problems reported were mostly loss of traction and difficulties operating in deep snow. Several reported damage to the right lower body panels from snow banks and ice at corners and stops.

Only one agency reported any problem with operation in high water. The problem reported was difficulty in steering.

Three agencies reported that changes had been made to their bus stops. In all cases, the changes were the addition of concrete boarding pads or sidewalk connections to accommodate wheelchair passengers.

There was a very positive response with respect to passenger boarding/alighting experiences and the public reaction. The two unfavorable responses gave comments such as the bus was cold, or the bus was unreliable.

The responses to the other questions in the questionnaire were sparse and fragmentary. Therefore, it was not possible to draw general conclusions from the reported information.

ATTACHMENT 1
RESPONDENTS-ORION II QUESTIONNAIRE

United States

California

- County of Los Angeles
  Dept. of Public Works, Transit Operations Section
  Alhambra, CA
- Eastern Contra Costa Transit Authority (Tri Delta Transit)
  Antioch, CA
- Long Beach Transit
  Long Beach, CA
- Sonoma County Transit
  Santa Rosa, CA
- Stockton Metropolitan Transit District Stockton, CA

Florida

- Lee County Transit (LeeTran)
  Fort Myers, FL

Illinois

- Pace Suburban Bus (Division of RTA)
  Arlington Heights, IL

Indiana

- Bloomington Public Transportation Corporation
  Bloomington, IN

Iowa

- Metropolitan Transit Authority of Black Hawk County
  Waterloo, IA

Kentucky

- Transit Authority of River City (TARC)
  Louisville, KY

Michigan

- Ann Arbor Transportation Authority (AATA)
  Ann Arbor, MI
- Marquette County Transit Authority
  Marquette, MI

Minnesota

- City of Moorhead
  Moorhead, MN
- City of Rochester
  Rochester, MN
- Mankato Heartland Express (City of Mankato)
  Mankato, MN
- St. Cloud Metropolitan Transit Commission
  St. Cloud, MN
- Tri-Valley Heartland Express
  Crookston, MN

Mississippi

- Coast Transit Authority
  Golfport, MS

Montana

- Missoula Urban Transportation District
  Missoula, MT

New York

- Capital District Transportation Authority
  Albany, NY
- Robert Yeager Health Center
  Pomona, NY
- Metropolitan Suburban Bus Authority (MSBA)
  Garden City, NY
- Rochester-Genesee Regional Transportation Authority
  Rochester, NY

Ohio

- LAKETRAN
  Grand River, OH
- Greater Cleveland Regional Transit Authority
  Cleveland, OH

Pennsylvania

- Altoona Metro Transit
  Altoona, PA
- Area Transportation Authority of North Central Pennsylvania
  Johnsonburg, PA
- Lehigh and Northamption Transportation Authority (LANTA)
  Allentown, PA
- Mid-County Transit Authority
  Kittanning, PA
- Westmoreland County Transit Authority
  Greensburg, PA

South Carolina

- Greenville Transit Authority
  Greenville, SC

Virginia

- Peninsula Transportation District Commission (PENTRAN)
  Hampton, VA
- Tidewater Regional Transit (TRT)
  Norfolk, VA

Utah

- Utah Transit Authority
  Salt Lake City, UT

Washington

- Clallam Transit System
  Port Angeles, WA
- Jefferson Transit Authority
  Port Townsend, WA
- Kitsap Transit
  Bremerton, WA
- Valley Transit
  Walla Walla, WA

Wisconsin

- Fond du Lac Area Transit
  Fond du Lac, WI
- Madison Metro Transit System
  Madison, WI
- Rice Lake Transit Authority
  Rice Lake, WI

Canada

Alberta

- Calgary Transit
  Calgary, Alberta
- Emergencey Medical Services
  Edmonton, Alberta
- St. Albert Transit
  St. Albert, Alberta

Manatoba

- City of Brandon
  Brandon, Manatoba

Nova Scotia

- Metro Transit Division
  Dartmouth, Nova Scotia

Ontario

- City of Elliot Lake
  Elloit Lake, Ontario
- Department of Ambulance Services
  Downsview, Ontario
- Oakville Transit
  Oakville, Ontario
- Richmond Hill Transit
  Richmond Hill, Ontario
- Toronto Transit Commission
  Toronto, Ontario
- Transhelp, Region of Peel
  Mississauga, Ontario

ATTACHMENT 2
ORION II QUESTIONNAIRE

1

JUNE 21, 1993

LOW-FLOOR BUS QUESTIONNAIRE
(ORION II)

TRANSIT AGENCY NAME ________________________________

CONTACT PERSON ____________________ TITLE ______________

ADDRESS __________________________ TEL. NO. ____________

__________________________ FAX. NO. ____________

(1) DESCRIPTION OF THE ORION II FLEET

LENGTH,ft. ___ NO. OF BUSES ___ YEAR FIRST PLACED IN OPERATION? ___

LENGTH,ft. ___ NO. OF BUSES ___ YEAR FIRST PLACED IN OPERATION? ___

(2) OPERATIONS ISSUES WITH LOW-FLOOR BUSES

HAVE THERE BEEN ANY ROAD CLEARANCE PROBLEMS? _____ IF YES, PLEASE EXPLAIN ____

HAVE THERE BEEN ANY WINTER OPERATION PROBLEMS? ____ IF YES, PLEASE EXPLAIN ____

HAVE THERE BEEN ANY HIGH WATER PROBLEMS? ______ IF YES, PLEASE EXPLAIN ____

HAVE THERE BEEN ANY CHANGES CONSIDERED AT THE BUS STOPS TO ACCOMMODATE THE LOW-FLOOR BUSES? ______ IF YES, PLEASE EXPLAIN ____

WHAT HAS BEEN YOUR BOARDING AND ALIGHTING EXPERIENCE WITH THE LOW-FLOOR BUSES? ____

PLEASE PROVIDE ANY DATA YOU MAY HAVE ON THE IMPACT OF BOARDING AND ALIGHTING TIMES ARISING FROM THE USE OF LOW-FLOOR BUSES.

2

(3) LOW-FLOOR BUS RIDERSHIP DATA

PLEASE PROVIDE INFORMATION ON THE DEMOGRAPHICS OF YOUR LOW-FLOOR BUS PASSENGERS, *(APPROXIMATE PERCENTAGES)*

ELDERLY ____ PERSONS WITH DISABILITIES ____ SCHOOL CHILDREN ____

OTHER CHILDREN ____ ADULTS ____ OTHERS ______

PLEASE PROVIDE ANY AVAILABLE INFORMATION ON RIDERSHIP ON THE LOW-FLOOR BUSES BY THE ABOVE CATEGORIES.

PLEASE PROVIDE INFORMATION ON ANY RIDERSHIP SURVEYS THAT HAVE BEEN DONE ON THE LOW-FLOOR BUSES.

WHAT HAS BEEN THE PUBLIC REACTION TO YOUR LOW-FLOOR BUSES?
____
____
____
____
____
____

(4) TYPE OF SERVICE PROVIDED BY LOW-FLOOR BUSES

DO YOU USE YOUR LOW-FLOOR BUSES IN FIXED ROUTE SERVICE? YES [] NO []

IF YES, PLEASE COMPLETE THE REST OF THE SURVEY. IF THE LOW-FLOOR BUSES ARE ONLY USED IN A PARATRANSIT SERVICE, YOU MAY IGNORE SECTIONS (5) AND (6) OF THE SURVEY.

(5) TYPE OF SERVICE ROUTES FOR LOW-FLOOR BUSES

(CHECK AS MANY BOXES AS APPROPRIATE)

SUBURB TO CBD [] SUBURB CIRCULATOR [] CBD CIRCULATOR []

OTHER ____
____

ROUTE MILES SERVED BY LOW-FLOOR BUSES? ________________

(6) DESCRIPTION OF BUS STOPS

NUMBER OF STOPS IN THE SYSTEM? ________________

PERCENT OF STOPS WITH CURBS? _________________

AVERAGE CURB HT. ______ INCHES. CURB HT. RANGE ____ in. TO ____in.

(7) OTHER COMMENTS YOU MAY HAVE CONCERNING LOW-FLOOR BUSES.

----

* *

IF YOU HAVE ANY QUESTIONS, PLEASE CONTACT ME.
MY TELEPHONE NUMBER IS (614) 451-4195. IT IS ALSO MY FAX NUMBER.

PLEASE RETURN THIS QUESTIONNAIRE TO:

ROLLAND KING
1266 SOUTHPORT CIRCLE
COLUMBUS, OHIO 43235

APPENDIX C

MANUFACTURERS' QUESTIONNAIRE

1

MANUFACTURERS' QUESTIONNAIRE JUNE 22, 1993
LOW-FLOOR TRANSIT BUS

COMPLETED BY: ____________ TEL. NO. ____________

MANUFACTURER ____________ MODEL ____________

STATUS? *(PLEASE CHECK ONE)*
IN PRODUCTION [] PROTOTYPE STAGE [] DESIGN STAGE []

IF NOT IN PRODUCTION, PLEASE GIVE AN APPROXIMATE DATE OF WHEN PRODUCTION WILL BEGIN. ____________

DIMENSIONS

BODY LENGTHS? 40-FOOT [] 35-FOOT [] 30-FOOT [] 60-FOOT []

OTHER LENGTHS ____________

BODY WIDTHS? 96-INCH [] 102-INCH [] OTHER ____________

OVERALL HEIGHT, in. ______ WHEELBASE in inches ______

IF AN ARTIC, WHEELBASE of SECOND AND THIRD AXLES, in. ______

FRONT OVERHANG, in. ______ REAR OVERHANG, in. ______

CLEARANCES

APPROACH ANGLE, deg. ______ DEPARTURE ANGLE, deg. ______

BREAKOVER ANGLE, deg. ______ GROUND CLEARANCE, in. ______

ACCESSIBILITY FEATURES

(not kneeled)
FLOOR HEIGHT, in. ______
(not kneeled)
ENTRANCE HEIGHT, in. ______

KNEELING CAPABILITY, in. ___ KNEEL FRONT? ___ or RIGHT SIDE? ___

FRONT DOOR WIDTH, in. ______ REAR DOOR WIDTH, in. ______
FRONT DOOR HEIGHT, in. ______ REAR DOOR HEIGHT, in. ______

2

ACCESSIBILITY FEATURES (CONT.)

AISLE WIDTHS IN INCHES?
SEAT AREA ______ WHEELHOUSING AREAS -- FRONT ______ REAR ______

HEADROOM, in. ____________

WHEELCHAIR RAMP? YES [] NO [] LOCATIONS? 1ST DOOR [] 2ND DOOR []
WIDTH, in. ______ LENGTH, in. ______ LOAD CAPACITY, lbs. ______

WHEELCHAIR LIFT? YES [] NO [] LOCATIONS? 1ST DOOR [] 2ND DOOR []
WIDTH, in. ______ LENGTH, in. ______ LOAD CAPACITY, lbs. ______

FLOOR

(CHECK ALL THAT APPLY)
FLAT FLOOR? [] or INTERIOR STEP(s)? [] or INTERIOR RAMP(s) []

IF AN INTERIOR STEP IS USED -- HEIGHT, in. ______ and WIDTH, in. ______

LOCATION OF STEP (s)? ____________

IF AN INTERIOR RAMP IS USED -- SLOPE, percent ______ LOCATIONS? ______
____

PASSENGER CAPACITY

NUMBER OF PASSENGER SEATS ______ NUMBER OF STANDEES ______

SEATS ON PEDESTALS? YES [] NO [] NO. OF SEATS ON PEDESTALS? ______

SEATS FACING REARWARD? YES [] NO [] NO. OF SUCH SEATS? ______

TOTAL NUMBER OF WHEELCHAIR SECUREMENT POSITIONS? ______
NUMBER FORWARD FACING? ______ NUMBER REARWARD FACING? ______

** PLEASE PROVIDE DRAWINGS OF SEATING ARRANGEMENTS, IF AVAILABLE.

POWER TRAIN

ENGINE OPTIONS ____
____

FUEL OPTIONS ____
____

TRANSMISSION OPTIONS ______________________________________
____

AXLES, TIRES, AND SUSPENSION

REAR AXLE ____
DROP CENTER? YES [] NO [] CAPACITY,lbs. ______________

FRONT AXLE ____
CAPACITY, lbs. __________ BEAM TYPE OR INDEPENDENT? ________

TIRE SIZE ________________ NUMBER OF TIRES ______________

TYPE OF SUSPENSION? ______________________________________

VEHICLE WEIGHT AND RATING

CURB WEIGHT, lbs. ______________ GVWR, lbs. ______________

PHOTOGRAPHS AND DOCUMENTATION

PICTURES OF THE BUS THAT COULD BE USED IN THE REPORT AND TECHNICAL BROCHURES WOULD BE GREATLY APPRECIATED.

....

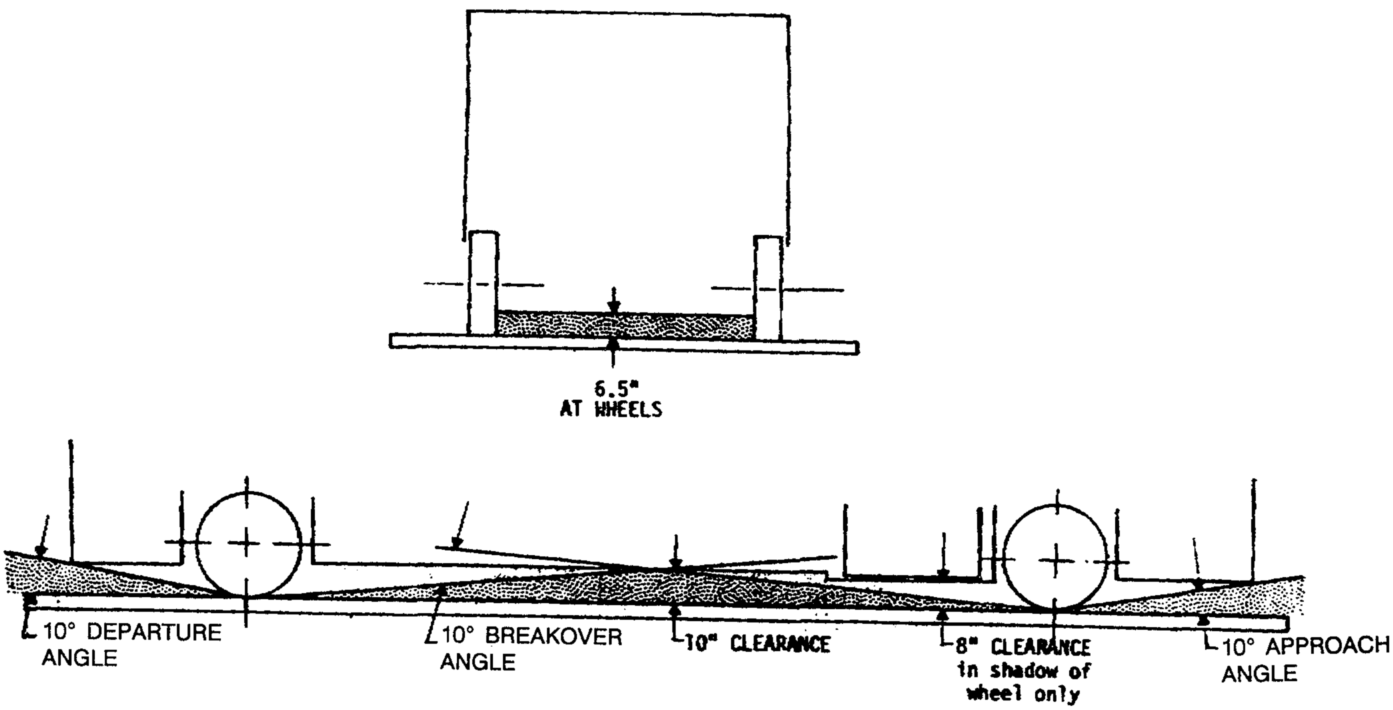
PLEASE RETURN THIS FORM TO:

ROLLAND KING
1266 SOUTHPORT CIRCLE
COLUMBUS, OHIO 43235

TEL. NO. (614) 451-4195
FAX NO. (614) 451-4195

APPENDIX D

ROAD CLEARANCE ANGLES



Small bus minimum road clearance (from *General and Performance Specifications for a Small Urban Transit Bus,* Report No UMTA-IT-06-0074-77-5, December 1976)

Approach — an angle determined by the front overhang and the lowest clearance height under the front of the bus; whether or not the vehicle is laden must be stipulated.

Breakover — included angle determined by wheelbase and clearance height under the vehicle that determines the ability of the vehicle to traverse a humped road surface. Whether or not the vehicle is laden must be stipulated (from *Dictionary of Automotive Engineering* D. Goodsell, SAE, Butterworth-Heinemann, Ltd)

Departure — an angle determined by the rear overhang and the lowest clearance height under the rear of the bus, whether or not the vehicle is laden must be stipulated.

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 It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, 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 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. Robert M.White 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 purposes 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 Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.