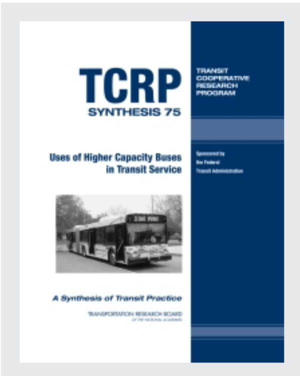

Uses of Higher Capacity Buses in Transit Service

DETAILS

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP SYNTHESIS 75

Uses of Higher Capacity Buses in Transit Service

A Synthesis of Transit Practice

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SUBJECT AREA
Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
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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 Federal Transit Administration (FTA). A report by the American Public Transportation 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.

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Cover figure: Quad articulated bus at student residence hall stop.

FOREWORD

By Staff
Transportation
Research Board

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis explores the use of higher capacity (HC) public transit buses in trunk, express, long-distance commuter, Bus Rapid Transit, and special (e.g., sports and special events) services in North America. For purposes of this study, HC buses included articulated, double-deck, 45-ft, and other buses that have a significant increase in passenger capacity compared with conventional 40-ft buses. This study examined where and how HC buses were being deployed in regular and flexible public transit services and experiences with these buses. It drew on available technical information from APTA, CUTA, HC bus manufacturers, and the Altoona (PA) Bus Testing Center in comparing HC buses with conventional buses with respect to a wide range of planning, operational, and maintenance issues. This synthesis is intended for an audience of transit agency general managers, their operations, planning, maintenance, and procurement staffs, as well as other transit professionals working with them in the deployment of HC buses.

This synthesis contains information derived from survey data collected from selected transit agencies operating distinct HC bus fleets throughout the United States that provided information by e-mail, through telephone interviews, and by assisting in site visits. In addition, this synthesis contains a literature review and, in documenting transit agency surveys, it identifies a number of applications of HC buses. Ad hoc conversations with transit agency staff and experts on specific aspects of the synthesis are also reported, as are more specific findings in three U.S. and Canadian transit agency case studies.

Brendon Hemily, Toronto, Ontario, Canada, and Rolland D. King, Columbus, Ohio, collected and synthesized the information and wrote the report, under the guidance of a panel of experts in the subject area. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

USES OF HIGHER CAPACITY BUSES IN TRANSIT SERVICE

SUMMARY

This study explored the use of higher capacity buses in public transit services in trunk, express, long-distance commuter, Bus Rapid Transit (BRT), and special services (e.g., sports event specials) in North America. What are higher capacity (HC) buses? For this study the following definition has been used:

> Higher capacity buses are motor buses that can transport higher volumes of passengers than can be transported with standard 40-foot buses, with a focus on articulated, double-deck, and 45-ft buses.

A brief history of HC vehicles in North America is provided in the Introduction, beginning with use of double-deck coaches in 1912 to the current status of HC buses as of January 2007. The transit agency participants in this study began using articulated buses in 1975. Survey respondents began using 45-ft composite structure transit buses in 1994 and 45-ft intercity coaches in 1996. At the start of 2007, those totaled approximately 260 and 2,200, respectively. One survey respondent deployed three double-deck buses in 1996, and other participants deployed larger fleets of low-floor double-deck buses (38 and 50) in 2000 and 2005.

Who is using HC buses? For this study it was determined that there were 68 transit agencies of all sizes that use five or more HC buses in their operations: 32 used only articulated buses, 19 used only 45-ft buses, 1 used only double-deck buses, and 16 used multiple types of HC buses. These 68 agencies operate more than 6,200 HC buses, which represented on average 15% of a fleet. A questionnaire about their use and experience with HC buses was sent to these agencies. Responses were received from 32 transit agencies (47%) that operated 41 distinct HC bus fleets, providing information and photographs by e-mail, telephone conversations, and site visits. The U.S. participants included nine large systems (including five of the top ten), nine medium, and seven small transit systems by active fleet size. Of the nine Canadian transit agencies using HC buses, seven participated in the study, four large and three medium-size systems. In terms of HC bus types, 24 of the systems used articulated buses, 3 systems used double-deck buses, and 14 systems used 45-ft buses (all but one using intercity coaches).

As of March 2007, there were only eight bus manufacturers that were identified as potential HC bus suppliers to the North American market. Some of the eight manufacturers offer different types of HC buses; three manufacturers offer articulated buses, one offers double-deck buses, and five offer 45-ft buses. Of the eight North American HC bus manufacturers, three meet the testing requirements of both the Altoona Bus Testing Center and Buy America that are needed for transit agencies planning to use U.S. federal capital grants for the purchase of HC buses.

In what types of services were the HC buses used? The survey found that articulated buses were principally used all day in high-volume trunk service routes and to augment capacity during peak period service. Double-deck buses were principally used in long-distance commuter and on high-volume trunk routes. The 45-ft intercity coaches were focused on long-distance express and commuter services. BRT services with HC buses were predominantly using articulated buses, although one Canadian system was using 45-ft coaches for an

expressway-oriented BRT service. Those with articulated and 45-ft coaches reported using their HC fleets for service to high-demand special events (sports, fireworks, etc.), as backup to their rail services, and for trippers that experience overloads.

What were the reasons these transit agencies chose to use HC buses for these services? The resounding answer received (94%) was to increase seating capacity. Increasing operator productivity (saving labor costs) and reducing peak vehicle requirements (fewer vehicles in the fleet) followed at 69% and 72%, respectively. Enhancing marketing image and increasing passenger comfort were also frequently cited (59% of the participants). The articulated and double-deck fleets were favored by those most interested in increasing service capacity. The improvement of marketing image and passenger comfort were the primary reasons for choosing 45-ft intercity coaches and double-deck buses for long-distance commuter and express services. Various other reasons were also cited for deploying HC buses, among them to address overload situations, to reduce downtown street congestion caused by large numbers of buses, to build ridership along a future rail corridor, etc. In the case of BRT or major new service initiatives for which the vehicle becomes an integral component of the product line, the HC buses may serve to improve the image and recognition of the service.

Did their HC buses meet expectations? The answer was an overwhelming (94%) yes. Only two respondents answered no; one was dissatisfied with the slowness of the wheelchair boarding and the other was unhappy with an underperforming engine in their HC bus. Overall experience with HC buses has been very positive, with some variation with the type of HC vehicle. Agency-reported customer and operator satisfaction and acceptance is high, with articulated fleets receiving slightly lower ratings than those received by the double-deck and 45-ft fleets.

Were there any major issues or concerns raised by the use of HC buses? The capital cost of the HC vehicle was the only significant issue, ranked first or second by approximately one-third of the survey respondents. No other single issue was significant across all HC bus types. However, the cost of all types of HC buses is much more attractive when examined on a cost-per-seat basis. The most dramatic difference using a cost-per-seat basis rather than a cost-per-vehicle basis is for the double-deck bus; all articulated models exhibited significant improvement. Also, it is apparent that the propulsion technologies and the options chosen (i.e., BRT features and passenger amenities) have major impacts on capital costs.

Were facilities or infrastructure modifications made to accommodate HC buses? Because of their length, height, or door locations, HC buses may require modifications to infrastructure or maintenance facilities including: raising garage doors; lengthening stops, maintenance bays, or paint booths; adding three-axle hoists; or making modifications to their wash facilities. However, respondents did not identify the cost of modifications as a significant area of concern; the monetary value of the modifications appeared to be relatively modest, when compared with the capital costs of the vehicles themselves. In many cases, deployment of the articulated buses had been contemplated well in advance of the actual acquisition of the buses, and had been incorporated into the design requirements of new garage facilities. Long-term planning for HC buses greatly reduces the requirement for retrofits to maintenance and storage facilities, and related capital costs.

How has the operating experience with HC buses compared with that of their standard 40-ft buses? Some frustrations appear to exist with the performance and maintenance cost of specific bus models, in particular for articulated buses. Issues cited included acceleration performance, reliability, and maintenance cost. The design of articulated buses, however, includes more components than 40-ft buses, entailing higher maintenance costs. Their fuel economy and acceleration performance are also lower because of their greater weight. However, when an analysis was performed on data from King County Metro Transit (Washington) on a seat-mile basis, their articulated buses proved to be less costly than their 40-ft fleets in both maintenance costs and fuel. For the double-deck buses, only fuel economy was reported as poorer in performance than for 40-ft buses; for the 45-ft coaches it was turning radius. Preliminary findings from the operation of hybrid articulated buses appear very positive in terms of improving acceleration and fuel economy compared with diesel articulated buses. The operation of HC buses does not appear to create significant safety concerns. Two large systems reported that there were no significant differences in the safety experience between their HC buses and their standard 40-ft buses.

Participants did not identify regulatory limitations as an issue, with only four respondents reporting any changes required. However, operation of articulated and double-deck buses may require obtaining exemptions in many jurisdictions.

There were no labor issues reported by any of the study participants. The survey found that 97% of the participants do not pay operators of HC buses at a different wage rate.

Participants handled scheduling in a wide variety of ways; many did not mix HC and 40-ft buses, but some did. Scheduling routes that are dedicated to HC buses (i.e., scheduling at the "block" level) is relatively straightforward. However, to target the deployment of HC buses to address specific overload situations through interlining requires a more sophisticated approach to scheduling, including: working at the "trip" (rather then block) level, the use of optimization modules, as well as detailed data on passenger demand, and on running and deadhead times. It also requires that managerial oversight to ensure planned assignments of HC buses are properly carried out.

Several participants stressed the importance of reducing dwell times. Reducing dwell time to take full advantage of HC buses remains a significant challenge. For articulated buses in particular, the ability of using all doors for simultaneous boarding and exiting is key to shorter dwell times. Because more and wider doors facilitate quick passenger flow, Las Vegas is going to install a second stairway in their double-deck buses to facilitate passenger flow and reduce dwell times. Several respondents are also encouraging more customers to use pre-paid fare media (e.g., day passes, university passes, and smart cards), and one respondent installed off-board ticketing machines. However, the most comprehensive approach is to move to a fare control system based on proof of payment, with random inspection, similar to that used on light rail systems. This is being more actively considered for bus transit, and the synthesis found that proof of payment with off-board fare collection has been deployed on recent BRT systems (e.g., York Region and Lane Transit).

Accommodating wheelchairs on HC buses represents another challenge, especially with respect to the implications on dwell time. The time and effort required to accommodate passengers using wheelchairs represents the most common complaint from transit agencies with 45-ft intercity coaches. Some transit agencies with double-deck or articulated buses have implemented mid-door access and/or rear-facing wheelchair positions as a method for reducing the dwell time of HC buses.

Participants reported that passengers appreciated the amenities offered by many HC buses, with some differences based on the type of the HC bus. Passengers liked the increase in seats and less crowding in the articulated buses. They like the quiet, ride quality, and view from the upper level of the double-deck buses, sometimes waiting for another bus, if a double-deck bus was coming. The most-liked features of the 45-ft coaches were the comfort of the ride and the quality of the passenger compartment with all the amenities.

CHAPTER ONE

INTRODUCTION

BACKGROUND

For more than four decades, the 40-ft bus, operating on fixed-route transit service, has been the workhorse for transit service in North America cities. This standardization to a dominant vehicle type has offered the transit industry several advantages, including:

- Standardization of vehicle characteristics,
- Reasonable capacity for service delivery,
- Standardized parts inventory, and
- Industry-wide enhancements to standard bus technology.

However, one observes a growing acceptance in the transit industry of the concept of "family of services," whereby different types of services or product lines are offered to meet the specific expectations of distinct market segments. In many cases, these different product lines require the deployment of different vehicle technologies, which provide different characteristics in terms of capacity, image, comfort, maneuverability, etc. An initial study by TCRP resulted in the report, *Use of Small Buses in Transit Service* (*1*); examining where and how small buses were being deployed in regular and flexible services, and the experience with these buses. The present study complements the previous report by examining the experience with the other end of the bus spectrum; that is, higher-capacity (HC) buses. For the purposes of this study, HC buses include articulated, double-deck, 45-ft buses, and other buses that have a significant increase in passenger capacity compared with the conventional 40-ft bus.

HISTORICAL PERSPECTIVE

Among the various types of HC buses, articulated buses have a long history of operation. An interview with transit historian William A. Luke provided much of the following discussion of the history of HC buses. The first articulated bus in North America was built by the Twin Coach Company in 1938 for the city of Baltimore and was a 4-axle 47-ft bus that had vertical (but not horizontal) articulation. Remodeled after the war as a "Super Twin" coach, 15 vehicles were built in 1948. However, it was not a huge success; "its major flaw was the inability to bend in the horizontal plane, resulting in an unacceptably large turning radius" (*2*). For the next three decades there was little interest in North America in articulated buses for transit. The situation was quite the contrary in Europe, which saw the development and progressive refinement of articulated bus technologies: "puller"-type articulated buses using under-floor engines; the development of controls to limit jackknifing; and the development of "pusher"-type articulated buses, with the engine located in the rear engine compartment location, similar to 40-ft buses (*3*). Most of the major continental European bus manufacturers (e.g., Ikarus, M.A.N., Mercedes, Scania, Van Hool, and Volvo) offered articulated bus models. The availability of robust articulated bus technology, combined with the productivity benefits such buses offered, led to wide-spread deployment of articulated buses in cities across continental Europe (although Great Britain continued to rely on double-deck buses as their prime HC bus of choice).

During this same period, the transit industry was in serious decline in the United States, with an increasing number of failures of private transit operators. Growing policy concern in the 1960s led to legislation by the U.S. federal government in the 1960s and 1970s, particularly in the areas of federal capital and operating subsidies. This federal support led to the public takeover of failing private transit systems across the United States, enabled massive expansion of transit services, and fueled public expectations. However, during this same period, the transit industry also experienced growing inflationary pressure on operating costs.

One logical response to the increases in operating costs was to explore potential initiatives to increase labor productivity. One such effort in the early 1970s was the creation of the Super Bus Consortium to evaluate the use of HC bus technology, in particular that of the articulated buses commonly used in Europe (*2*). This in turn led to the development of an articulated bus specification, closely reflecting European bus specifications, followed in 1976 by the creation of a Pooled Purchase Consortium. This consortium, led by Seattle Metro and the California Department of Transportation (DOT) (Caltrans), sought to purchase 400 articulated buses to be deployed in a variety of cities. The consortium used an Americanized version of the SuperBus specification, and awarded a contract to a joint venture of AM General Corporation and M.A.N. for 399 buses, which were deployed in several cities including: Seattle, Oakland, Los Angeles, San Diego, Phoenix, Chicago, Pittsburgh, Atlanta, and Washington, D.C. The introduction of these buses was successful, met with positive public acceptance, and improved operator productivity. M.A.N. subsequently opened its own production facility in the early 1980s and continued delivery of articulated buses until 1987.

In a parallel development, Ikarus formed a joint venture with Crown Coach to build and market articulated transit buses in America. Ikarus technology and bodies were used with interiors and drive trains provided by American suppliers. There were 243 Crown–Ikarus Model 286 articulated puller-type buses assembled between 1981 and 1986. The initial deliveries were made to transit systems in Albany, Jacksonville, Honolulu, Houston, Louisville, Milwaukee, Portland, San Diego, and San Mateo. Ikarus also partnered with Orion Bus to market to Canadian systems. The Orion III articulated bus was delivered to transit systems in Ottawa and Toronto. The historical roots of the Ikarus articulated bus were transferred through the corporate structures of Ikarus USA and American Ikarus, and are now in North American Bus Industries. Other European manufacturers (e.g., Breda, Neoplan, Scania, and Volvo) (*3*) also entered the North American market with varying levels of success. Seattle purchased a unique dual-mode articulated bus from Breda for use in their downtown tunnel. In the early 1990s, New Flyer developed a high-floor articulated pusher-type bus, followed later by low-floor articulated bus models.

More recently, the explosion of interest in North America in the concept of Bus Rapid Transit (BRT) has fueled a growing interest in HC buses, in particular BRT-styled articulated buses. The roots of the BRT concept have existed for some time; there have been exclusive right-of-way busways in operation in Pittsburgh and in Ottawa since the late 1970s and early 1980s, and both transit systems rely extensively on the use of articulated buses for these services. In 1996, Vancouver introduced the 99 B-Line, which incorporated uniquely and stylishly branded articulated buses resulting in immediate success and attracting 15,000 passengers a day, 20% who formerly drove (*4*). The B-Line BRT product was further refined with the 98 and 97 B-Lines, which now use low-floor articulated buses. The B-Lines in Vancouver were viewed as one product line in a family of services. The high levels of service and capacity offered by the B-Lines served to grow ridership in these corridors to the point where the 98 B-Line is currently being replaced by the construction of rail transit along the same corridor.

Interest in BRT started to grow in the United States in the late 1990s, promoted in particular by significant initiatives at the Los Angeles County Metropolitan Transportation Authority and the FTA. A federal BRT demonstration program was initiated to research successful deployments around the world (e.g., Curitiba) and develop guidance (*5–8*) for the many transit systems across the United States that were planning HC transit corridors, many of which would use HC buses. These initiatives resulted in extensive research and evaluation concerning the keys to success of BRT systems around the world, including extensive assessments of vehicle alternatives and characteristics (*9–11*). The intensive focus on BRT and the growing number of BRT projects being deployed in North America have created a North American demand for new rail-like stylized HC buses. North American manufacturers have responded to this interest and demand with the development of a new array of BRT-styled buses, typically in a low-floor articulated design, and a new generation of BRT-style HC buses has been deployed, as new BRT systems come on line [e.g., Los Angeles, Las Vegas, and Eugene (Oregon)]. The positive reaction to these vehicles, and their operating characteristics, has renewed interest in the use of HC buses in transit systems across North America.

In terms of other HC buses under consideration in this report, double-deck buses also have historical roots. For example, the Fifth Avenue Coach in New York City used double-deck buses as early as 1912. The open-top double-deck coach actually became synonymous with Fifth Avenue all through the early part of the last century. The design proved both successful and durable, and double-deck buses were operated until 1953 (*12*). However, with a few exceptions and experimentations, North American interest in double-deck buses remained dormant for the next four decades. The interest in double-deck buses was rekindled in British Columbia the late 1990s, when BC Transit (BCT)–Victoria began examining the possibility of acquiring double-deck buses to provide improvements in capacity, customer comfort, and financial performance. BCT and Dennis Specialist Vehicles developed a specification that met their needs. A contract for ten double-deck buses utilizing standard North American components was issued in 1998. The bus subsequently completed the Altoona Bus Testing Center (ABTC) tests, was certified for the North America market, and has been deployed in the cities of Victoria, Kelowna (BC), and Las Vegas.

The 1990s also saw a variety of other HC bus technologies introduced into North America. The largest deployment was that of 45-ft intercity coaches, used in suburban commuter operations. Before 1991, 45-ft buses were prohibited by most jurisdictions. However, the 1991 federal program ISTEA introduced the concept of the National Network (NN) highways, and defined vehicle width and length standards for the NN. In particular, it prohibited states from restricting buses that were 45 ft or less on NN highways, which enabled this new type of HC bus. New 45-ft bus intercity coach models were developed and marketed, and transit systems started taking advantage of this opportunity deploying them on long-distance commuter express services, typically along Interstate highways or expressways, to serve suburban park-and-ride terminals. Today, more than 2,000 such buses, primarily sold by Motor Coach Industries (MCI) Inc., are currently in operation across North America. In addition, in the late 1990s, the North American Bus Industries introduced a low-floor composite-body two-axle 45-ft transit bus to the U.S. market. The Model 45C-LFW CompoBus is deployed in the cities of Los Angeles, Phoenix, and Tempe.

SCOPE

This report will synthesize the current use and experience with HC buses in North America. The scope for this study includes articulated, double-deck, 45-ft, and other buses that provide greater passenger capacity than the conventional 40-ft transit bus. This study draws on transit agencies' experiences and available technical information in comparing HC buses with the use of conventional 40-ft buses, with respect to a wide range of planning, operational, and maintenance issues.

APPROACH

The methodology used to prepare this synthesis involved several elements:

- HC Fleet Data were collected from APTA and the Canadian Urban Transit Association (CUTA). APTA's vehicle fleet databases and CUTA's annual operating data were analyzed to identify those systems that operate HC buses in transit service.
- The literature and Internet were searched for information relating to HC buses and their use.
- A survey of transit agencies using HC buses was sent to all transit systems in the United States and Canada that had reported to APTA or CUTA having a fleet of five or more HC buses. The survey asked questions concerning the types of services where HC buses were used, the primary reasons for implementing HC buses, modifications to facilities and other actions that were made to deploy HC buses, vehicle features, acceptance and operating experience, issues and concerns, etc.
- A survey was conducted of HC bus manufacturers to better understand the range of HC bus vehicles currently available and their relative technological characteristics.
  - APTA's vehicle fleet database and vehicle cost information were obtained from the bus manufacturers for their models of HC buses to identify capital costs of new HC vehicles.
- Vehicle test results were obtained from the ABTC. This supplemented the information obtained from the bus manufacturers and provided a comparable basis for assessing the technical performance of these vehicles in a number of areas (e.g., fuel consumption, acceleration, and noise).
- The survey results helped to identify a number of interesting applications of HC buses. Ad hoc conversations were held with transit staff and experts on specific aspects of the synthesis, and mini-case studies were conducted by telephone or through on-site visits.

The rest of this report discusses the results from these efforts. Chapter two will outline the results from the survey of transit systems. Findings from the case studies are presented in chapter three. In chapter four, there is a discussion of the various aspects related to vehicle technology. Chapter five synthesizes the experience based on the research, and identifies a number of issues emerging from this experience. Finally, chapter six outlines the conclusions of the study and areas for future research.

Copies of the questionnaires sent to transit agencies and to bus manufacturers are included as Appendix A. Appendix B contains a list of the study participants and Appendix C is a survey of the size and weight limits mandated by the federal government and states or provinces.

It should be noted that the terms "standard" and "40-ft" are used interchangeably in the report to mean the conventional 40-ft transit bus.

CHAPTER TWO

USE OF HIGHER CAPACITY BUSES (SURVEY RESULTS)

INVENTORY OF TRANSIT AGENCIES USING HIGHER CAPACITY BUSES

The *APTA 2006 Vehicle Database* (*13*) and CUTA's *Canadian Transit Fact Book: 2005 Operating Data* (*14*) were researched to identify and inventory transit agencies with HC buses. This analysis revealed that 68 North American (approximately 19% of the transit agencies that are members of APTA and/or CUTA and operate five or more HC motorbuses) have HC buses in their fleets. Sixteen of the transit agencies use two types of HC buses in their fleets. No North American transit agency operates three types of HC buses. Table 1 provides a breakdown of the number of transit agencies with HC buses in their fleets by type of HC bus and in parentheses the total number of HC buses. Table 2 shows the number of transit agencies using HC buses in North America by size of the active fleet and by type of HC bus.

For transit agencies using HC buses in the United States, the average HC bus percentage of active fleets was approximately 16%; for Canadian fleets using HC buses the HC bus percentage was approximately 14%. The percentage ranged widely for all sizes of active fleets. For the 16 small agencies (1 to 100 buses) the HC bus percentage ranged from 8% to 100%, with an average of 38%. For the 24 medium-size agencies (101 to 500 buses) the HC bus percentage ranged from 1% to 47%, and the average was 13%. The 19 large agencies (500 or more buses) also exhibited a wide range, 3% to 45% HC buses, with the average HC percentage approximately 15%.

SURVEY RESPONSES

The transit agency questionnaire was sent to 59 U.S. and 9 Canadian agencies; 16 small, 27 medium, and 25 large (*15,16*). The breakdown of these 68 transit agencies by active fleet size and HC bus types is presented in Tables 1 and 2. These transit agencies have sub-fleets of five or more HC buses in their active motorbus fleets, with the size classification based on their active motorbus fleets. Agencies with 100 or fewer buses are labeled small, agencies with 101 to 500 buses are medium, and agencies with more than 500 buses are large. Sixteen U.S. transit agencies use two different types of HC buses. The transit agency questionnaire is provided in Appendix A.

Thirty-two responses were received from these transit agencies, representing a response rate of 47%. The distribution of responses by HC bus type is provided in Table 3.

The remaining sections of this chapter report on the survey's findings from a variety of perspectives, including:

- Type of services using HC buses,
- Reasons for implementing HC buses,
- Deployment dates of HC buses,
- Different wage rates,
- Legislative and regulatory impediments,
- Facilities or infrastructure modifications,
- Local service restrictions,
- Actions taken to reduce dwell time,
- Scheduling procedures for HC buses,
- Approaches to mixed-fleet operations,
- Experience with HC buses,
- Ridership impacts of HC buses,
- Agency-reported customer acceptance of HC buses,
- Agency-reported operator acceptance,
- Issues and concerns with use of HC buses,
- Vehicle features and amenities (including accommodating bicycles),
- Passengers using wheelchairs: equipment and experience,
- Operating experiences with HC buses,
- Spare ratios for HC buses, and
- Future plans for HC buses.

TYPES OF SERVICE USING HIGHER CAPACITY BUSES

Survey respondents were asked to indicate the types of service in which HC buses were used. In most cases, respondents reported multiple applications for the HC buses. The results are presented in Table 4.

All transit agencies reporting the use of HC buses for BRT service used articulated buses, except two that used 45-ft buses. The entire bus fleet of GO Transit (Ontario) consists of intercity coaches (both 40-ft and 45-ft models). They use 85 of their 45-ft coaches on their BRT Highway 407/403 service. The city of Phoenix uses its 45-ft CompoBuses on BRT service routes. The seven other transit agencies use articulated buses for their BRT service.

TABLE 1
NUMBER OF NORTH AMERICAN TRANSIT AGENCIES USING HC BUSES

Country	No. of Transit Agencies with HC Buses* (no. of HC buses operated)						Totals
	Articulated	Double-Deck	45-ft	Articulated and 45-ft	Articulated and Double-Deck	Double-Deck and 45-ft	
United States	25 (1,802)	0	18 (273)	14 (3,321)	1 (156)	1 (22)	59 (5,574)
Canada	7 (463)	1 (38)	1 (167)	0	0	0	9 (668)
Totals	32 (2,265)	1 (38)	19 (440)	14 (3,321)	1 (156)	1 (22)	68 (6,242)

Source: References 13 and 14.
*Only includes transit agencies with more than five HC buses in their fleet.

TABLE 2
NUMBER OF TRANSIT AGENCIES BY SIZE OF ACTIVE FLEET USING HC BUSES

Type of HC Bus	No. of Transit Agencies*[a] (no. of HC buses) by Size of Active Fleets			Totals
	1–100	101–500	501+	
Articulated	3	22	22	47
	(24)	(807)	(3,133)	(3,964)
Double-Deck	1	1	1	3
	(3)	(50)	(38)	(91)
45-ft	13	11	10	34
	(236)	(337)	(1,614)	(2,187)
Total No. of Transit Agencies (including multiple HC fleets)	17	34	33	84[(a)]
Total No. of HC Buses	(263)	(1,194)	(4,785)	(6,242)

Source: References 13 and 14.
*Only includes transit agencies with more than five HC buses in their fleet.
[a]Sixteen transit agencies use two types of HC buses.

TABLE 3
NUMBER OF SURVEY RESPONDENTS BY SIZE OF ACTIVE FLEET AND HC BUS TYPE

Type of HC Bus	Size of Active Fleet			HC Fleet Totals
	Large	Medium	Small	
Articulated Fleets	12	9	3	24
Double-Deck Fleets	1	1	1	3
45-ft Fleets	5	5	4	14
				41[a]
No. of Agencies by Size	13	12	7	32

Source: Transit agency survey responses.
[a]Nine of the respondents were using two types of HC buses.

TABLE 4
USES OF HC BUSES—PERCENTAGE OF SURVEY RESPONSES BY CATEGORY OF USE

Types of Service Where HC Buses Are Used	Percentage of Respondents Citing a Specific Application (for all, and for individual types of HC buses)* All	Articulated	Double-Deck	45-ft
Trunk Service Routes—All Day	56%	83%	67%	7%
Trunk Service Routes—Only in Peak Service	24%	38%		7%
Bus Rapid Transit Routes	22%	29%		14%
Express/Long Distance Commuter Routes	56%	38%	67%	86%
Special Services (e.g., sports event specials)	27%	33%		21%
Other (e.g., special Saturday-only service, supplemental services, emergency service when the rail service goes down)	10%	17%		
No. of Higher Capacity Bus Fleets	41	24	3	14

Source: Transit agency survey responses.
*Respondents could cite more than one application/use for HC buses; therefore, the totals do not add up to 100%. Table reports the percentage of all respondents in each category that cited a given type of use. This provides a relative weighting of each category of use, first for all HC buses as a whole, then broken down according to each type of HC bus operated by respondents.

REASONS FOR IMPLEMENTING HIGHER CAPACITY BUSES

Survey respondents were asked the primary reasons HC buses were used and the results are given in Table 5. The following three tables provide the specific responses by type of HC fleet: articulated buses (Table 6), double-deck fleets (Table 7), and 45-ft fleets (Table 8). The most frequently cited reason for deploying HC buses (94%) was to increase seating capacity, often to alleviate excessive standing on specific routes. This is particularly true for the articulated and double-deck fleets. Marketing image and passenger comfort were cited more often as the primary reason for implementation of the 45-ft fleets.

The distinctions reflected in some of the comments between "increasing seat capacity," "increasing bus operator productivity," and "reducing peak vehicle requirements" are subtle and reflect more a distinction in emphasis than fundamental differences in the reasons driving the deployment of HC buses. For example, one respondent mentioned that the goal was to "address overloads on the system's busiest route, while not increasing peak vehicle requirement or operator needs." Another respondent commented "Reduced vehicles also reduces operator needs." A few respondents were more focused on the savings in labor than the increase in seat capacity per se.

Although the survey wording referred to "increased *seat* capacity," for some systems with high-demand routes in downtown or campus areas, respondents mentioned that increased "total" capacity was the driving motivation.

Other specific operational objectives were also mentioned, including:

- Reducing downtown street congestion caused by large numbers of buses, and
- Building ridership along a future rail corridor.

With respect to this last point, one respondent provided the following comment:

> Both articulated and 45-ft intercity coaches have been a vital part of our fleet. Their use will likely be reduced somewhat in the next 10 years as selected major bus corridors are converted to light rail or commuter rail.

TABLE 5
PRIMARY REASONS FOR IMPLEMENTING HIGHER CAPACITY BUSES FOR ALL RESPONDENTS

Reasons for Implementing HC Buses	Frequency of "Most Important" Ranking* (% of respondents who provided ranking)	No. of Respondents Citing "Important" for Each Reason (% of all survey respondents)
Provide Increased Seating Capacity	15 (60%)	30 (94%)
Reduce Peak Vehicle Requirements	2 (8%)	23 (72%)
Increase Bus Operator Productivity	2 (8%)	22 (69%)
Bus Rapid Transit Service	1 (4%)	9 (28%)
Marketing Image	0	19 (59%)
Passenger Comfort	3 (12%)	19 (59%)
Other (e.g., build ridership along future rail corridor, reduce downtown bus congestion, serve major employer destination)	2 (8%)	3 (9%)

Source: Transit agency survey responses.
*Not all respondents provided rankings. Percentages are calculated based on responses that provided rankings.

TABLE 6
SURVEY RESPONDENTS' PRIMARY REASONS FOR IMPLEMENTING ARTICULATED BUSES

Reasons for Implementing Articulated Buses	Frequency of "Most Important" Ranking* (% of respondents who provided ranking)	No. of Respondents Citing "Important" (% of all respondents with articulated buses)
Provide Increased Seating Capacity	13 (69%)	23 (96%)
Increase Bus Operator Productivity	2 (11%)	17 (71%)
Reduce Peak Vehicle Requirements	1 (5%)	18 (75%)
Bus Rapid Transit Service	1 (5%)	8 (33%)
Marketing Image	1 (5%)	13 (54%)
Passenger Comfort	1 (5%)	14 (58%)
Other	0	2 (8%)

Source: Transit agency survey responses.
*Not all respondents provided rankings. Percentages are calculated based on responses that provided rankings.

TABLE 7
SURVEY RESPONDENTS' PRIMARY REASONS FOR IMPLEMENTING HIGHER CAPACITY DOUBLE-DECK BUSES

Reasons for Implementing Double-Deck Buses	Frequency of "Most Important" Ranking* (% of respondents who provided ranking)	No. of Respondents Citing "Important" (% of all respondents with double-deck buses)
Provide Increased Seating Capacity	1 (50%)	3 (100%)
Increase Bus Operator Productivity	0	2 (67%)
Reduce Peak Vehicle Requirements	1 (50%)	2 (67%)
Bus Rapid Transit Service	0	1 (33%)
Marketing Image	0	2 (67%)
Passenger Comfort	0	1 (33%)
Other	0	0

Source: Transit agency survey responses.
*Not all respondents provided rankings. Percentages are calculated based on responses that provided rankings.

TABLE 8
SURVEY RESPONDENTS' PRIMARY REASONS FOR IMPLEMENTING 45-FT BUSES

Reasons for Implementing 45-ft Buses	Frequency of "Most Important" Ranking* (% of respondents who provided ranking)	No. of Respondents Citing "Important" (% of all respondents with 45-ft buses)
Provide Increased Seating Capacity	6 (55%)	12 (86%)
Increase Bus Operator Productivity	0	8 (57%)
Reduce Peak Vehicle Requirements	0	8 (57%)
Bus Rapid Transit Service	0	1 (7%)
Marketing Image	0	10 (71%)
Passenger Comfort	3 (27%)	9 (64%)
Other:	2 (18%)	2 (14%)

Source: Transit agency survey responses.
*Not all respondents provided rankings. Percentages are calculated based on responses that provided rankings.

Finally, several respondents focused primarily on the marketing image provided by the HC vehicles, typically for BRT applications or 45-ft coaches, or the enhanced customer comfort. Comments included:

- Improves image and makes program more visible;
- Avoids passenger perception of standard bus service;
- Encourages "choice" riders to use the transit option; and
- Makes bus equivalent to car: reclining seats, provide live satellite feed.

DEPLOYMENT DATES OF HIGHER CAPACITY BUSES

As discussed in the section on the historical evolution of HC buses in chapter one, articulated buses have operated in North America for nearly three decades. Among the respondents to the survey operating articulated buses, five (21%) were members of the original Seattle/Caltrans purchase consortium in the late 1970s, and 50% of the respondents deployed their articulated buses more than two decades ago. Twenty-nine percent of respondents have deployed articulated buses in the last 10 years; of these, just under half acquired articulated buses for use in a BRT operation.

The situation is quite different with respect to the deployment of 45-ft buses. As previously mentioned, in 1991, ISTEA introduced the concept of National Network (NN) highways, and defined vehicle width and length standards for the NN. In particular, it prohibited states from restricting buses that were 45 ft or less on NN highways, which enabled this new type of HC bus. New 45-ft bus intercity coach models were developed and marketed, and transit systems started taking advantage of this opportunity to deploy 45-ft coaches on long-distance commuter express services, typically along Interstate highways or expressways, to serve suburban park-and-ride terminals. Among survey respondents, the earliest deployment of 45-ft coaches was in 1994, but it appears to have taken a few years for these vehicles to become more commonplace: 78% of the reported deployments of 45-ft coaches and buses have occurred since the year 2000.

DIFFERENT WAGE RATES

The vast majority of transit agencies, 31 of 32 (97%) do not pay operators of HC buses a different wage rate. The only exception is the Regional Transportation Commission of Southern Nevada, which pays the operators of the MAX (BRT articulated) and The Deuce (double-deck) buses $1 per hour more than their other bus operators. It should also be noted that in the past King County Metro Transit had a wage differential; however, it has since been negotiated out of the labor agreement.

LEGISLATIVE AND REGULATORY IMPEDIMENTS

Survey respondents did not identify regulatory limitations as a significant issue, although some references were made to the limitations created by the regulations for double-deck buses (height and weight) and articulated buses (length). Only four transit agencies reported any legislative or regulatory impediments to the use of their HC buses, and these impediments and the actions taken are listed in Table 9.

FACILITIES OR INFRASTRUCTURE MODIFICATIONS

The survey sought to assess the capital cost of modifications to facilities or infrastructure necessitated by the deployment of HC buses. Respondents reported that the facilities and/or infrastructure modifications ranged from modest amounts to $1,600,000. Only 4 of the 29 respondents reported expenditures between $900,000 and $1,600,000. Table 10 provides a breakdown of the types of modifications that were made. In most situations, required capital modifications appear to be very modest. However, it should be noted that in some cases, planning for HC buses was carried out well in advance and modifications to maintenance facilities were incorporated into the planning and design of new facilities. In addition, many articulated bus fleets were deployed many years ago, and the costs of modifications are a distant memory.

In terms of specific modifications required by the type of HC bus, those agencies using *double-deck bus* fleets cited modifications required as a result of the height of the vehicle. Items mentioned included the removal or modification of

TABLE 9
REPORTED LEGISLATIVE AND REGULATORY IMPEDIMENTS TO USE HC BUSES

Legislative/Regulatory Impediment	Action Taken
Axle Load	Nevada revised statue to increase axle load for public transportation vehicles
Articulated Bus Length	Utah DOT issues an exemption certificate each year to allow 60-ft articulated buses to operate on Utah's highways
Bike Racks on 45-ft Coaches	California revised statute to allow bike racks on coaches
Double-Deck Bus Height	The double-deck buses are over-height and must carry an over-height permit issued by the Province of British Columbia

Source: Transit agency survey responses.

TABLE 10
FACILITIES OR INFRASTRUCTURE MODIFICATIONS IMPLEMENTED

Types of Facilities/Infrastructure Modifications	Percentage of Respondents Citing a Specific Type of Infrastructure Modification (for all, and for individual types of HC buses)*			
	All	Articulated	Double-Deck	45-ft
Maintenance Shops	72%	79%	33%	50%
Bus Stop	50%	62%	0	21%
Terminals/Loops	34%	46%	0	0
Wash Facilities	22%	21%	33%	14%
On-Street Parking	19%	25%	0	0
Fueling Facilities	19%	21%	0	14%
Roadway	6%	4%	33%	0
Other	3%	14%	33%	0
No. of HC Type Fleets	32	24	3	14

Source: Transit agency survey responses.
*Respondents could cite more than one type of facility/infrastructure modification that was implemented when HC buses were deployed; therefore, the totals do not add up to 100%. Table reports the percentage of all respondents in each category that cited a given type of modification that was carried out. This provides a relative weighting for each type of modification, first for all HC buses as a whole, and then broken down according to each type of HC bus operated by respondents.

overhead obstructions along a route, such as low tree limbs or overhead cables; modification to door openings; fuel island modifications; brush wash upgrades; purchase of portable lifts; and the purchase of movable stairs with a work platform to access the roof of the buses, which are approximately 14 ft above ground level.

One respondent indicated that modification costs were as follows:

- Modification to door openings to 14 ft 8 in.—$162,000.
- Fuel island modifications—$10,000 (included in the previous expenditure).
- Paint booth modifications—$68,000.
- Brush wash upgrades—$308,286.
- Portable lifts—$198,000.

Those agencies using *articulated buses* cited modifications that were related to the longer length of the vehicle. Modifications reported for bus stops included bus bays lengthened, street furniture moved to accommodate the three doors, the installation of new bus stop pads (59 ft in length) to accommodate all doors, and the addition of curb space for bus layovers.

As would be expected, the lengthening of a bus stop may result in the removal of some on-street parking. The terminal and loops modifications reported were also related to the vehicles' increased length, and included the lengthening of bus bays, the increase in length of layover positions, and modified loading gates.

Almost 70% of the respondents using articulated buses reported some modifications to their maintenance facilities, including the lengthening bays and inspection pits, installation of three-axle lift sets and in-ground three-post lifts (some adjustable in spacing), and modifications to the exhaust vent system to accommodate the 60-ft three-axle vehicles.

Agencies cited the need to revise their yard-parking configuration or to increase their storage areas to accommodate their articulated buses. The modifications to the wash facilities included the programming of the bus wash cycle for a longer travel path and increasing the length of the steam cleaning bay. The reported modifications to the fueling facilities included the re-alignment of fueling hoses, addition of extra fueling hoses, and changes to vacuum hoses to accommodate the articulated buses.

Agencies using *45-ft buses* reported fewer modifications to facilities or infrastructure, primarily the addition of wheelchair-boarding pads at bus stops.

LOCAL SERVICE RESTRICTIONS

Nine of the transit agencies reported service restrictions for their HC buses. Table 11 summarizes the reported restrictions. Restrictions included limits on bus speed and allowance of standees. Some double-deck buses were not used in high winds.

ACTIONS TAKEN TO REDUCE DWELL TIME

All things being equal, the introduction of HC buses will increase dwell time at bus stops because of the greater number of passengers alighting and boarding. The increased dwell time is further exacerbated if all boarding passengers have to enter through the front door for purposes of fare control by the operator. Some transit agencies have therefore taken actions to reduce dwell time at stops for their HC buses. A summary of the categories of actions taken is given in Table 12. Table 13 lists the specific actions taken by category.

TABLE 11
SUMMARY OF LOCAL SERVICE RESTRICTIONS ON USE OF HC BUSES REPORTED

Type of HC Bus	Local Service Restriction
Articulated	• Passenger loads restricted to 150% seated capacity • Speed limited to 55 mph and interlining with other routes was eliminated • Used only on routes where bus stops and roadway could accommodate
Double-Deck	• No standees allowed on upper deck • Certain routes are restricted because of vertical clearance issues • Do not use during high winds
45-ft	• No standees allowed on coaches on roadways (some transit agencies reported allowing standees on their coaches) • Operator training for 45-ft coaches, in particular for use of tag wheels during winter operations • 45-ft coaches not used on routes that regularly carry persons in wheelchairs • Not allowed on trunk or local lines. 45-ft buses are allowed on supplemental services

Source: Transit agency survey responses.

TABLE 12
SUMMARY OF THE TYPES OF ACTIONS TAKEN TO IMPROVE DWELL TIME

Actions Taken to Reduce Dwell Times at Stops	Percentage of Respondents Citing a Specific Type of Action to Reduce Dwell Time (for all, and for individual types of HC buses)*			
	All	Articulated	Double-Deck	45-ft
Fare Collection Procedures	38%	33%	33%	21%
Wheelchair Accommodations	28%	29%	33%	7%
Bus Stop Design/Signage	19%	17%	33%	7%
Changes to Policies/Procedures	3%	4%	0	0
Other	9%	4%	67%	0
Total No. Types of Action Taken	32	24	3	14

Source: Transit agency survey responses.
*Respondents could cite more than one type of action taken to reduce dwell time at stops; therefore, totals do not add up to 100%. Table reports the percentage of all respondents in each category that cited a given type of dwell-time reduction action. Some respondents use two types of HC buses. This provides a relative weighting for each type of action, first for all HC buses as a whole, and then broken down according to each type of HC bus operated by respondents.

TABLE 13
ACTIONS TAKEN BY CATEGORY TO IMPROVE DWELL TIME

Type of Action	Actions Taken
Bus Stop Design/Signage	• Used three doors • Information tubes were installed on the Las Vegas Strip • Better signage for customer information • Larger stop platform area • Variable message sign at stop indicating departure time of next bus, which encourages passengers to prepare and line up for approaching bus
Fare Collection Procedures	• Encourage use of pre-paid fare media • Outbound PM Express and regional routes pay on exiting • Inbound pay on boarding—Outbound pay upon exiting (all routes) • Introduction of "proof of payment" to encourage all door boarding • Ticket vending machines at stops to sell tickets and day passes • Off-board fare collection—boarding through all doors • Introduction of smart card system that helped to speed boarding • All campus routes are "open" (university pass program))
Wheelchair Accommodations	• Low-floor buses to facilitate easier and faster boarding • Wheelchair strap program that secures straps faster • Bus stop modification to accommodate articulated door spacing • New articulated bus board wheelchairs via ramp in second door • Operator training
Changes to Policies/Procedures	• Honor system for proof of payment. Security personnel conduct random checks to validate fares. Violation fee increased steadily, now at $150 Canadian.
Other	• On double-deck buses a second stairway will be added to speed up boarding and alighting.

Source: Transit agency survey responses.

SCHEDULING PROCEDURES FOR HIGHER CAPACITY BUSES

Forty-seven percent of the transit agencies reported some scheduling procedure changes for their HC buses. One transit agency reported that it did no interlining; therefore, there were no scheduling changes. A summary of comments on scheduling changes and constraints is cited in Table 14.

APPROACHES TO MIXED-FLEET OPERATIONS

Twenty-three percent of respondents dedicate their HC buses to specific routes, at least during peaks and base service, whereas 76% of the transit agencies reported that they have mixed operations with their HC and 40-ft fleets. However, some of the latter respondents indicated that a route is basically dedicated to HC buses; however, capacity is supplemented by 40-ft buses in the peaks. One respondent indicated that it would like to dedicate 45-ft buses to the specific express commuter routes, but lack a sufficient fleet to do so and therefore mix HC 45-ft and 40-ft coaches. Two systems used their HC buses for a BRT or a limited stop service in a corridor, while running parallel local service in the same corridor using standard buses. One respondent noted that the running time had to be increased for the corridor's articulated bus because of its slower acceleration.

One system used the HC buses for a complete route, while using standard buses for a short-turn variation of the same route.

For those agencies operating a mix of HC and standard buses on individual routes, two-thirds try to design the schedule of HC buses based on some assessment of demand by trip, whereas one-third do not take any special actions with respect to scheduling HC buses.

One respondent mentioned that it had tried in the past to adjust headways on specific routes where a mix of HC and standard buses was being operated to reflect the capacity of the bus scheduled for the trip, but abandoned this approach.

EXPERIENCE WITH HIGHER CAPACITY BUSES

Overwhelmingly (94%), transit agencies reported that their HC buses met their expectations. The two transit agencies that believed expectations were not met cited vehicle deficiencies as the cause of their dissatisfaction. The specific vehicle deficiencies reported by the two respondents were:

- Boarding on 45-ft coaches is extremely slow, and
- The specific articulated buses purchased were equipped with under-performing engines.

Table 15 summarizes experiences with the use of the various types of HC buses from the perspectives of the customers, the operators, and the agencies. Experience with HC buses is by and large positive from all perspectives.

TABLE 14
SUMMARY OF SCHEDULING PRACTICES FOR HIGHER CAPACITY BUSES

Operation	Scheduling Practices for HC Buses
Mixed	• Only change was that on some routes the number of buses was lowered when substituting with an articulated bus for a 40-ft bus. • Some additional recovery time for a double-deck bus is provided that will be changed as needed after data are received from the first year of live operations. • Many individual express trips and school trips are targeted during the planning stage to have an artic assignment. In many cases, three standard bus-type trips are collapsed into two artic-type trips. Each of these trips is assigned an artic bus type in the schedule database and the interline scheduling program module is used to connect as many of these trips together to form vehicle blocks. Goal is to maximize the use of articulated buses on as many high-volume trips as possible. Las Vegas Strip schedule was changed to a frequency-based headway service. Two supervisors coordinate the buses on the Las Vegas Strip.
Constrained	• Interlining occurs only with articulated bus routes and trips. Running time is adjusted, if required. • Highest patronage trips are assigned to an HC bus. • Interlining with other routes was restricted owing to bus length as compared with bus stop lengths on other routes. • Certain routes cannot accommodate articulated buses, so the scheduling parameters were adjusted to prohibit some interlining. • Changes were made to interlining to ensure two bus types were not put on same route.
Restricted	• Procedures were changed so that certain types of service could not have an HC bus assigned, thereby limiting interlining opportunities. • Artic buses could not be interlined with other buses. • 45-ft coaches are dedicated to commuter express service only.

Source: Transit agency survey responses.
Artic bus = articulated bus.

TABLE 15
SUMMARY OF THE REPORTED EXPERIENCE WITH THE USE OF HC BUSES

Type of HC Bus (number)	Transit Agency Experience			Agency-Reported Customer Experience			Agency-Reported Operator Experience		
	Very good	Acceptable	Poor	Very good	Acceptable	Poor	Very good	Acceptable	Poor
Articulated (24)	59%	30%	11%	84%	12%	4%	64%	32%	4%
Double-Deck (3)	67%	33%		100%			67%	33%	
45-ft (14)	71%	29%		100%			79%	21%	
All[a]	64%	30%	7%	90%	7%	2%	69%	29%	2%

Source: Transit agency survey responses.
[a]Percentage does not always add to 100 because of rounding.

RIDERSHIP IMPACTS OF HIGHER CAPACITY BUSES

The survey asked what had been the impact on ridership from the use of HC buses. The survey responses do not provide a clear answer, as is shown in Table 16.

Several of those reporting an increase in ridership with the introduction of HC buses provided their insight as to why. The reported reasons were:

- Demand constrained by seat capacity;
- Provides a quality image and a comfortable ride; and
- When passengers feel better about public transit, their word of mouth comments raise awareness and ridership.

For respondents who indicated that the introduction of HC buses resulted in ridership increases, the typical situation appeared to be a capacity-constrained latent demand, frequently on commuter express services to park-and-ride lots. In such cases, the additional seats obtained by deploying double-deck buses or 45-ft coaches are immediately filled, resulting in ridership increases.

This appears to be less apparent with respondents with articulated bus fleets. There may be several explanations. First, as discussed previously, the majority of respondents with articulated buses introduced these vehicles many years ago and any ridership increases that may have resulted directly from their deployment would no longer be apparent. Second, the main benefit from articulated buses, from a customer's point of view, is the reduction of overloads and pass-ups that occur on specific trips. This is a benefit to existing riders, but does not create "new" riders per se; it may, however, encourage retention of existing riders over time, but this is difficult to perceive or measure.

TABLE 16
AGENCY-REPORTED RIDERSHIP IMPACTS BY INTRODUCTION OF HIGHER CAPACITY VEHICLES

Types of HC Vehicles (no. of fleets)	Have Observed Measurably Increased Ridership		
	Yes	No	Unknown
Articulated (24)	8 (33%)	10 (42%)	6 (25%)
Double-Deck (3)	2 (67%)	1 (33%)	
45-ft (14)	6 (43%)	6 (43%)	2 (14%)
All Three (32)	13 (41%)	12 (38%)	7 (22%)

Source: Transit agency survey responses.
Note: The summation by types of HC bus does not equal the "All" number because there are fleets with more than one type of HC vehicle in use.

Several respondents had difficulty distinguishing the ridership effects of the vehicles. One typical response was, "Ridership has increased, but we cannot attribute that to introducing coach-type buses per se." This is equally true with new BRT systems; they introduce an integrated package of service enhancements, and although most report sizable increases in corridor ridership, it is extremely difficult to isolate the impact of any single factor, such as the use of enhanced HC buses.

AGENCY-REPORTED CUSTOMER ACCEPTANCE OF HIGHER CAPACITY BUSES

Survey respondents were asked to assess customer acceptance with respect to HC buses. Table 16 indicates that the transit agency respondents perceive that customers' acceptance of HC bus service is very high. The respondents were also asked to identify the features that customers most like and dislike. Table 17 provides a summary of these cited features.

With respect to articulated buses, customers like the reduction of crowding that accompanies the deployment of articulated buses. The design of the interior of the articulation is one of the unique issues: some systems include seats and others hip-rests. Some customers do not like the seats in the articulation because of the turning movement and the difficulty of seeing outside. Double-deck bus customers greatly appreciate the better view available from the upper deck and these seats fill quickly on long-distance runs, although some customers do not like negotiating the stairwell. With respect to 45-ft coaches, these vehicles typically include enhanced customer amenities and provide a more comfortable ride; these features are believed to be highly appreciated by customers, resulting in a high level of agency-reported customer acceptance. A few respondents commented, however, that some customers dislike the steep stairs and narrow aisles.

TABLE 17
AGENCY-REPORTED CUSTOMER MOST LIKED AND MOST DISLIKED FEATURES OF HIGHER CAPACITY SERVICE

Type of HC Bus	Most Liked	Most Disliked
Articulated	• More seats—less standing • Less overcrowding • More space • Ability to carry more passengers, no one left at the stop • Novelty of articulated joint • Smooth ride • Comfortable interior	• Bounce and movement of rear seats at highway speeds • Low-floor bus ride not as smooth • Seats in articulated joint • Road dust entering passenger com partment • Longer wait times[a] • As a HC commuter bus[b]
Double-Deck	• Comfort and quiet of upper deck • View from the upper deck	• Having to negotiate tight stairwell
45-ft	• Ride quality • Comfort of bus for long distance trips • Quality of passenger compartment • Amenities • Image	• Narrow aisle ways • Steeper stairwell • Longer boarding time • Longer boarding time can in turn have a possible repercussion on the dwell time of other buses sharing the bus stop

Source: Transit agency survey responses.
[a]When bus is substituted for 40-ft buses.
[b]When equipped with transit seating and no amenities.

AGENCY-REPORTED OPERATOR ACCEPTANCE

Similar to the previously discussed customer acceptance, survey respondents reported that operators generally like HC buses. This is believed to be especially true for operators of double-deck and 45-ft buses; as one respondent with both double-deck and 45-ft buses mentioned, operators appreciate the recognition that accompanies being the operator of a very recognizable vehicle. In Victoria, senior operators primarily choose the runs with the double-deck buses and so it is very difficult for junior operators to sign up for these runs.

Several respondents indicated that operators appreciate the 45-ft coaches for various reasons, including the smooth ride and operation on highways; effective heating, ventilation, and air conditioning system; better line of sight from the high driver platform; dependability, etc. Some respondents mentioned that operators appreciate the tight turning radius of articulated buses.

In terms of features disliked by operators, the most frequently mentioned issue for operators of articulated buses concerned poor acceleration, which is the main factor explaining the difference between customer and operator acceptance (see Table 15). In addition, a few respondents mentioned that operators were sometimes concerned with operating articulated buses in snow.

Two features were disliked by operators of 45-ft coaches. The first concerned the difficulty and time involved in boarding and securing customers using wheelchairs. As explained by one respondent:

> [T]he wheelchair lift requires two bench seats to be moved forward for each wheelchair: bus can accommodate up to 2 wheelchairs. The seats are difficult to slide due to their limited use. The operator has to exit the bus and operate the lift from outside the bus and away from the driver console; he/she may have to stand in poor weather and does not have access to the radio or other fixed device communications on the bus.

Several respondents mentioned the time involved for this procedure. The second feature about 45-ft coaches that was disliked by operators concerns its large turning radius that results from its long wheelbase; one comment was that "the swinging tag axle leads to more corner damage."

ISSUES OR CONCERNS RAISED WITH USE OF HIGHER CAPACITY BUSES

Transit agencies were asked to identify any major issues or concerns that were raised by their use of HC buses. They were also asked to rank these issues and concerns. Table 18 provides a summary of the major issues and concerns that were reported. The transit agencies were asked to indicate the type of HC bus and to rank the major issue/concern, with "1" indicating the most important.

The following tables identify the major issues/concerns reported by survey respondents by type of HC bus: articulated buses (Table 19), double-deck buses (Table 20), and 45-ft buses (Table 21).

When reviewing these tables, the one common major issue or concern for all HC buses mentioned by several respondents is the capital cost of the vehicles.

In terms of issues that are specific to types of HC buses, the articulated buses stimulated various comments. Some respondents expressed concern about the capital cost of retrofitting facilities, although several admitted that new garage facilities had been planned with articulated buses in mind and, therefore, did not create any costs for retrofitting. In addition, a few respondents expressed considerable concern over the maintenance and/or operating costs for articulated buses, ranking

TABLE 18
SUMMARY OF MAJOR ISSUES AND CONCERNS RAISED BY USE OF HIGHER CAPACITY BUSES

Major Issues and Concerns Raised	Frequency of "Importance" Ranking* (% of all respondents with HC Buses)	
	Ranked "1" or "2"	Any Ranking
Capital Cost of Vehicles	10 (32%)	15 (48%)
Facility Retrofit Costs	6 (19%)	7 (23%)
Operating Costs (labor, fuel)	4 (13%)	9 (29%)
Maintenance Costs	4 (13%)	12 (39%)
Dwell Time/Fare Collection	2 (6%)	6 (19%)
Accommodation of Wheelchairs	2 (6%)	4 (13%)
Accommodation of Bicycles	1 (3%)	2 (6%)
Safety and Security	0	2 (6%)
Vehicle Reliability	1 (3%)	8 (26%)
Winter Operations	2 (6%)	10 (32%)
Operating Constraints	0	3 (10%)
Other (e.g., tail swing when exiting stop)	1 (3%)	1 (3%)

Source: Transit agency survey responses.
*The numbers in parentheses are the number of ranking citations as a percentage of all respondents with HC buses; they do not add up to 100%.

this either first or second, and more than 50% had some level of concern with respect to maintenance costs. It is difficult to determine to what extent this is related to individual bus model design, or inherent to the concept of articulated buses. In addition, a few respondents also mentioned being concerned about the operation of articulated buses in snow conditions, and the risk of jackknifing.

VEHICLE FEATURES AND AMENITIES

The responses to the questions concerning vehicle features and amenities (e.g., accommodating bicycles) are summarized in Table 22. The five transit agencies that reported having enhanced passenger amenities on their articulated buses (e.g., enhanced seats, reading lights, and storage areas) were using those buses in either BRT or commuter and express services.

Of the 16 transit agencies that reported having security features on their HC buses all had recording security cameras. In addition, one had a silent alarm and two cited the use of a vehicle location system as security equipment. The double-deck buses have a TV monitor that allows the operator to monitor passenger activity upstairs.

TABLE 19
MAJOR ISSUES AND CONCERNS RANKED 1 OR 2 FOR ARTICULATED BUSES

Major Issue/Concern Raised	Frequency of "Importance" Ranking* (% of all respondents with articulated buses)	
	Ranked "1" or "2"	Any Ranking
Capital Cost of Vehicles	5 (22%)	10 (43%)
Facility Retrofit Costs	5 (22%)	6 (26%)
Operating Costs (labor, fuel)	4 (17%)	9 (39%)
Maintenance Costs	6 (26%)	12 (52%)
Dwell Time/Fare Collection	0	2 (9%)
Accommodation of Wheelchairs	0	0
Accommodation of Bicycles	0	1 (4%)
Safety and Security	0	1 (4%)
Vehicle Reliability	3 (13%)	8 (35%)
Winter Operations	1 (4%)	8 (35%)
Operating Constraints	0	3 (13%)
Other (e.g., tail swing when exiting stop)	1 (4%)	1 (4%)
No. of Articulated Bus Fleets (23)		

Source: Transit agency survey responses.
*The numbers in parentheses are the number of ranking citations as a percentage of all respondents with articulated buses; they do not add up to 100%.

TABLE 20
MAJOR ISSUES AND CONCERNS RANKED 1 OR 2 FOR DOUBLE-DECK BUSES

Major Issue/Concern Raised	Frequency of "Importance" Ranking* (% of all respondents with Double-Deck Buses) Ranked "1" or "2"	Any Ranking
Capital Cost of Vehicles	1 (33%)	1 (33%)
Facility Retrofit Costs	0	0
Operating Costs (labor, fuel)	0	0
Maintenance Costs	0	0
Dwell Time/Fare Collection	1 (33%)	1 (33%)
Accommodation of Wheelchairs	0	0
Accommodation of Bicycles	0	0
Safety and Security	1 (33%)	1 (33%)
Vehicle Reliability	0	0
Winter Operations	1 (33%)	1 (33%)
Operating Constraints	0	0
Other (tail swing when exiting stop)	0	0
No. of Double-Deck Bus Fleets (3)		

Source: Transit agency survey responses.
*The numbers in parentheses are the number of ranking citations as a percentage of all respondents with double-deck buses; they do not add up to 100%.

TABLE 21
MAJOR ISSUES AND CONCERNS RANKED 1 OR 2 FOR 45-FT BUSES

Major Issue/Concern Raised	Frequency of "Importance" Ranking* (% of all respondents with 45-ft Buses) Ranked "1" or "2"	Any Ranking
Capital Cost of Vehicles	4 (29%)	4 (29%)
Facility Retrofit Costs	1 (7%)	1 (7%)
Operating Costs (labor, fuel)	0	0
Maintenance Costs	0	0
Dwell Time/Fare Collection	1 (7%)	3 (21%)
Accommodation of Wheelchairs	2 (14%)	4 (29%)
Accommodation of Bicycles	1 (7%)	1 (7%)
Safety and Security	0	0
Vehicle Reliability	0	0
Winter Operations	0	1 (7%)
Operating Constraints	0	0
Other (tail swing when exiting stop)	0	0
No. of 45-ft Bus Fleets (14)		

Source: Transit agency survey responses.
*The numbers in parentheses are the number of ranking citations as a percentage of all respondents with 45-ft buses; they do not add up to 100%.

TABLE 22
HIGHER CAPACITY VEHICLE FEATURES AND AMENITIES

Vehicle Feature or Amenity	Percentage of Respondents Citing a Specific Type of Vehicle Feature or Amenity (for all, and for individual types of HC buses)* All	Articulated	Double-Deck	45-ft
Security Features	44%	50%	67%	43%
Enhanced Passenger Amenities	54%	21%	100%	100%
Transported Bicycles	80%	88%	67%	71%
No. of Survey Responses	41	24	3	14

Source: Transit agency survey responses.
*Respondents could cite more than one type of vehicle feature; therefore, totals do not add up to 100%. Table reports the percentage of all respondents in each category that cited a given type of vehicle feature. This provides a relative weighting for each type of feature, first for all HC buses as a whole, and then broken down according to each type of HC bus operated by respondents.

A large majority of respondents provided means for transporting bicycles for their riders. A breakdown of how respondents transported bicycles by HC bus type is given in Table 23.

WHEELCHAIR EQUIPMENT AND PASSENGER EXPERIENCE

The equipment for boarding passengers using wheelchairs for articulated and double-deck buses was for the most part located in the first door, which is typical for most standard buses in the North America. The exceptions for the articulated fleets were for some BRT vehicles and for the articulated buses designed and manufactured in Europe. For the double-deck fleets, one had ramps in both first and second doors, one had only the first door, and one had only the second door. Five respondents (15%) (four in Canada and AC Transit in the United States) used the rear-facing compartment design with padded backrest for accommodating wheelchairs. Of these five systems, three used a combination of one forward plus one rear-facing position, whereas two Canadian systems used two rear-facing positions.

The 45-ft fleets using the intercity coaches all had a second access door, used only for wheelchair boarding with a lift. The fleet using the 45-ft composite transit bus had the ramp in the second door with three forward-facing positions.

In terms of experience with respect to the transporting of passengers using wheelchairs, the survey responses indicated a dichotomy of experiences with HC buses. The articulated fleets overwhelmingly reported that the experience was the same as with standard 40-ft buses (95%), with only one respondent reporting an inferior experience. One respondent indicated that its articulated buses were well used and very crowded, and a possible difficulty of passengers using wheelchairs reaching the wheelchair positions. The double-deck bus fleets reported that experience was either the same or better.

However, the response from respondents with 45-ft bus fleets was significantly different: more than half (57%) reported that the experience of transporting passengers with wheelchairs was poorer than on 40-ft buses. In further analysis of the responses, this experience was found to be related more to the use of the lifts versus ramps than to HC bus types. The vast majority of the 45-ft buses used were high-deck intercity coaches, and all of those reporting a "poorer" experience were comparing it with their experience with low-floor 40-ft buses. The 45-ft fleets that reported the same experience were comparing with their high-floor 40-ft transit buses or intercity coaches. Table 24 provides a breakdown of the experiences with transporting passengers in wheelchairs.

An examination of the following comments of the 45-ft fleets sheds some additional insight on the issue.

- Location of lift mid-bus versus at entrance well, seating loss of eight positions as seats needed to be slid in tracks and folded before boarding, instead of quick flip-up seats, lift versus ramp on low floors, full boarding requiring 8 min more that standard stairwell lift and 12 min more than low-floor ramp.
- Longer boarding time required for a wheelchair on 45-ft bus.
- Takes two to three times as long to board as a standard 40-ft bus.
- Intercity wheelchair lift is very slow, with a long loading time.
- Poorer with wheelchairs, requiring moving seats and 5 min to deploy lifts.
- Longer time to load as a result of having to move the ambulatory seats out of the way.

The dissatisfaction stems from the longer time it takes to board and secure a passenger using a wheelchair. The longer time is inherent to the elevation of the vehicle from the ground causing a greater amount of vertical travel; the preparation of a wheelchair position also takes more effort and time. There may also be additional issue time required when two wheelchair users are on the bus, depending on their respective exit stop. It may be necessary to offload the first

TABLE 23
ACCOMMODATION OF BICYCLES ON HIGHER CAPACITY BUSES (by HC bus type)

HC Bus Type	Means of Accommodations
Articulated	• 19 respondents used a front bike rack that would accommodate two bicycles • Two BRT systems provide racks inside the vehicle for bicycles • One respondent is going to front bike racks that would accommodate three bicycles
Double-Deck	• Two respondents use a front bike rack that will accommodate two bicycles
45-ft Intercity Coach	• Three respondents transport bicycles in the under floor storage bays. Two indicated that a maximum of two bicycles could be accommodated • One respondent used a front bike rack that would accommodate two bicycles • Five respondents did not indicate how bicycles were accommodated, but reported that they were
45-ft Transit Bus	• One respondent used a front bike rack that would accommodate two bicycles

Source: Transit agency survey responses.

TABLE 24
REPORTED EXPERIENCE WITH TRANSPORTING PASSENGERS IN WHEELCHAIRS

Type of HC Bus	Wheelchair Passenger Experience			No. of Fleets
	Better	Same	Poorer	
Articulated		18 (95%)	1 (5%)	19
Double-Deck	1 (33%)	2 (67%)		3
45-ft		6 (43%)[a]	8 (57%)	14

Source: Transit agency survey responses.
[a]Two fleets only have 40-ft intercity coaches for comparison, and the other four fleets have high floor 40-ft buses for comparison.

wheelchair passenger, before boarding the second one, and then re-board the first one.

The repercussion of 45-ft bus dwell time on other buses sharing the same bus bay or curbside stop is all the more significant if a wheelchair user needs to board or exit the bus at the shared stop.

OPERATING EXPERIENCES WITH HIGHER CAPACITY BUSES

Respondents were asked to compare the performance of their HC vehicles with that of their standard 40-ft buses for several performance measures. The transit agency responses to the survey questions for each of the three types of HC vehicles are presented in Tables 25–27.

The operation and maintenance of articulated buses was an area where a number of respondents reported poorer performance in comparison with standard buses. Approximately one-half of the transit agencies reported poorer acceleration (50%) and grade climbing (54%) capability with their articulated buses compared with their 40-ft buses. A little more than one-half (52%) of the transit agencies reported better maneuverability, and a large majority (83%) reported poorer fuel economy with their articulated fleets. Most transit agencies (87%) reported the same experience with road clearance with their articulated fleets. The reported experiences with reliability, availability, and road calls were evenly divided between "the same" and "poorer."

However, these responses need to be put in perspective. Some respondents reported that fleet age and manufacturer resulted in the differences in rating these performance measures. One maintenance manager observed that in comparison with standard 40-ft buses, "articulated buses had one or two more doors, one additional axle, two more brakes, four more tires, and an articulated joint; one would expect the maintenance to be proportionally higher." The same manager suggested that operating costs such as fuel and maintenance costs should be measured on a passenger capacity basis (e.g., number of seats).

SPARE RATIOS FOR HIGHER CAPACITY BUSES

All except two of the respondents provided information on the spare ratios for their HC fleets. The agencies were asked to compare the spare ratio for their HC buses with that of their 40-ft buses. Table 28 provides a summary of the responses. Although there are a few exceptions and despite some of the maintenance problems mentioned by respondents with their

TABLE 25
VEHICLE OPERATING EXPERIENCES REPORTED FOR ARTICULATED BUSES

	Operating Experience Compared with Standard 40-ft Bus			
Performance Measure	Better	Same	Poorer	Unknown
Acceleration[a]	2 (8%)	10 (42%)	12 (50%)	0
Grade Climbing[a]	2 (8%)	9 (38%)	13 (54%)	0
Road Clearance	1 (4%)	20 (87%)	2 (9%)	0
Turning Maneuverability	12 (52%)	8 (35%)	3 (13%)	0
Fuel Economy	0	4 (17%)	19 (83%)	0
Range	1 (4%)	13 (56%)	6 (26%)	3 (13%)
Reliability	1 (4%)	11 (48%)	10 (43%)	1 (5%)
Availability	0	11 (48%)	10 (43%)	2 (9%)
Road Calls	1 (4%)	11 (48%)	11 (48%)	0
Other				

Source: Transit agency survey responses.
[a]One transit agency had multiple fleets of articulated buses and reported different acceleration and grade climbing experiences with their different sub-fleets.

TABLE 26
VEHICLE OPERATING EXPERIENCES REPORTED FOR DOUBLE-DECK BUSES

	Operating Experience Compared with Standard 40-ft Bus			
Performance Measure	Better	Same	Poorer	Unknown
Acceleration	1 (33%)	2 (67%)		
Grade Climbing	1 (33%)	2 (67%)		
Road Clearance		3 (100%)		
Turning Maneuverability	1 (33%)	2 (67%)		
Fuel Economy		1 (33%)	2 (67%)	
Range	1 (33%)	1 (33%)	1 (33%)	
Reliability	1 (33%)	2 (67%)		
Availability	1 (33%)	2 (67%)		
Road Calls	1 (33%)	1 (33%)	1 (33%)	
Other				

Source: Transit agency survey responses.

TABLE 27
VEHICLE OPERATING EXPERIENCES REPORTED FOR 45-FT BUSES

Performance Measure	Operating Experience Compared with Standard 40-ft Bus			
	Better	Same	Poorer	Unknown
Acceleration	6 (46%)	7 (54%)		
Grade Climbing	7 (54%)	5 (38%)	1 (7%)	
Road Clearance	3 (23%)	7 (54%)	3 (23%)	
Turning Maneuverability	2 (15%)	3 (23%)	8 (62%)	
Fuel Economy	4 (31%)	6 (46%)	2 (15%)	1 (7%)
Range	7 (54%)	4 (31%)		2 (15%)
Reliability	6 (46%)	4 (31%)	1 (7%)	2 (15%)
Availability	6 (46%)	6 (46%)		1 (7%)
Road Calls	8 (62%)	3 (23%)	1 (7%)	1 (7%)
Other				

Source: Transit agency survey responses.
Based on 13 fleets, because one transit agency did not have standard 40-ft buses for comparison.

TABLE 28
SPARE RATIOS FOR HIGHER CAPACITY BUS FLEETS

Type of HC Bus	Spare Ratio		
	Higher	Same	Lower
Articulated	19%	54%	27%
Double-Deck		67%	33%
45-ft	8%	50%	42%

Source: Transit agency survey responses.

articulated buses, there has not been a widespread need to have a larger spare ratio than the norm.

The six agencies reporting a higher spare ratio for their HC buses provided the following reasons:

- Three were for BRT applications and a small number of vehicles in the fleet, and
- Three were for reliability and maintenance needs of their particular HC sub-fleet.

The agencies reporting a lower spare ratio for their double-deck and 45-ft buses also reported better maintenance and reliability experiences with their HC buses. Those agencies reporting a lower spare ratio for their articulated fleets generally report the same maintenance and reliability experiences with their articulated fleets. One agency indicated that the spare ratio depended on the particular sub-fleet.

FUTURE PLANS FOR HIGHER CAPACITY BUSES

The transit agencies provided some insight into their plans for future operations with HC buses, which are summarized in Table 29. Overall, it is clear that respondents valued the contribution of HC buses: 61% planned to expand their existing HC fleets with more of the same type of vehicle, and 35% had plans to deploy a new type of HC bus to their overall fleet.

TABLE 29
PLANS FOR FUTURE HIGHER CAPACITY OPERATIONS

Expansion/Deployment	Have Plans			Type of HC Vehicle		
	Yes	No	Unknown	Articulated	Double-Deck	45-ft
More of the Same Type of HC Bus	19	7	5	10[a]	2	8
Plans to Add a New Type of HC Bus	11	14	6	6[a]	3	1

Source: Transit agency survey responses.
[a]One transit agency has plans for using articulated trolleybuses.

CHAPTER THREE

HIGHER CAPACITY BUSES IN VARIOUS APPLICATIONS

Three case studies will illustrate the use of HC buses in different contexts:

- Denver, Colorado—Regional Transportation District.
- Victoria, British Columbia—Victoria Regional Transit System/BC Transit.
- Champaign–Urbana, Illinois—Champaign–Urbana Mass Transit District.

REGIONAL TRANSPORTATION DISTRICT (DENVER, COLORADO): HIGHER CAPACITY BUSES AS A COMPONENT OF A FAMILY OF SERVICES

The Regional Transportation District (RTD) was created in 1969 by the Colorado General Assembly to plan and build a public transportation system for a six county area. Over the years, the RTD has grown to become a large multi-modal public transportation provider serving a service area population of approximately 2.5 million and an area of 2,327 square miles. The RTD serves 38 cities in the six counties and two city/county jurisdictions. RTD operates 1,071 total buses, of which 311 are HC vehicles (about 28% of the active fleet). The RTD operates three types of HC buses: articulated, 45-ft, and a special purpose 45-ft mall-shuttle vehicle. The RTD deployed M.A.N. articulated buses in 1983, and began using 45-ft coaches in 1997. Bus service is provided on 174 fixed routes, which are divided into Local, Express, Regional, Limited, skyRide, and Circulator service classifications. Three center of city stations, Market Street, Civic Center, and Union Stations, are the hubs for all HC buses with stops in downtown Denver. An HC shuttle tying together the Market Street and Civic Center stations provides mobility in the Denver downtown area. These stations are under street level reducing street congestion and have off-board ticketing to facilitate quick boarding. All Local route buses remain at street level.

Why Higher Capacity Buses and How Are They Used

The three primary reasons why RTD uses HC buses are to increase the seating capacity for the higher volume services, save labor costs through increased operator productivity, and reduce vehicle requirements during peak service periods.

The articulated buses are primarily used on RTD's Limited stop routes and for Express routes with high volumes. The 45-ft coaches are used on Regional and skyRide routes. All HC buses are also used for special services at sports events, such as Broncos Ride.

How Regional Transportation District Uses Higher Capacity Buses

Several of the bus corridors have medium to high ridership and the RTD provides a combination of Local and Limited service for the same route path. Forty-foot buses are used for the all-stop Local service and articulated buses are used for the Limited stop service. There is a companion Local route for every Limited route. The 15 Limited is an example; its route map is shown in Figure 1. A 15 L articulated bus is shown in Figure 2. This integration of types of buses allows the slower accelerating articulated buses to maintain schedule speeds because the Limited stops are spaced farther apart. For the lower volume Local/Limited route combinations, RTD uses 40-ft buses for both services. For the original M.A.N. articulated buses, RTD added 10% longer running times for schedule planning compared with their 40-ft buses.

Another use of articulated buses at RTD is Express service. Many Express routes are characterized by inbound morning service with a few local stops in outlying communities or at park-and-ride lots, and then continuing nonstop (some have exception stop service) to one of the stations in downtown Denver. The afternoon service is essentially the reverse.

A few Express routes (e.g., the 120X) have high volumes throughout the day. These routes provide 10-min to 15-min frequency service during peaks and 30-min service off peak between one of the downtown stations and various outlying municipality terminals or park-and-ride lots. A map for Route 120X is given in Figure 3 showing both the exception stop and the high-occupancy vehicle sections that facilitate shorter running times. Also, note that the 120X inbound has an exception stop at Union Station. Figure 4 shows an RTD articulated bus at the Wagon Road Terminal as a passenger loads a bike.

One of the principal applications for using 45-ft buses is for Regional route services. Before federal legislation in the 1990s enabled the use of 45-ft buses on NN highways, RTD used a 40-ft intercity coach for the Regional route services.

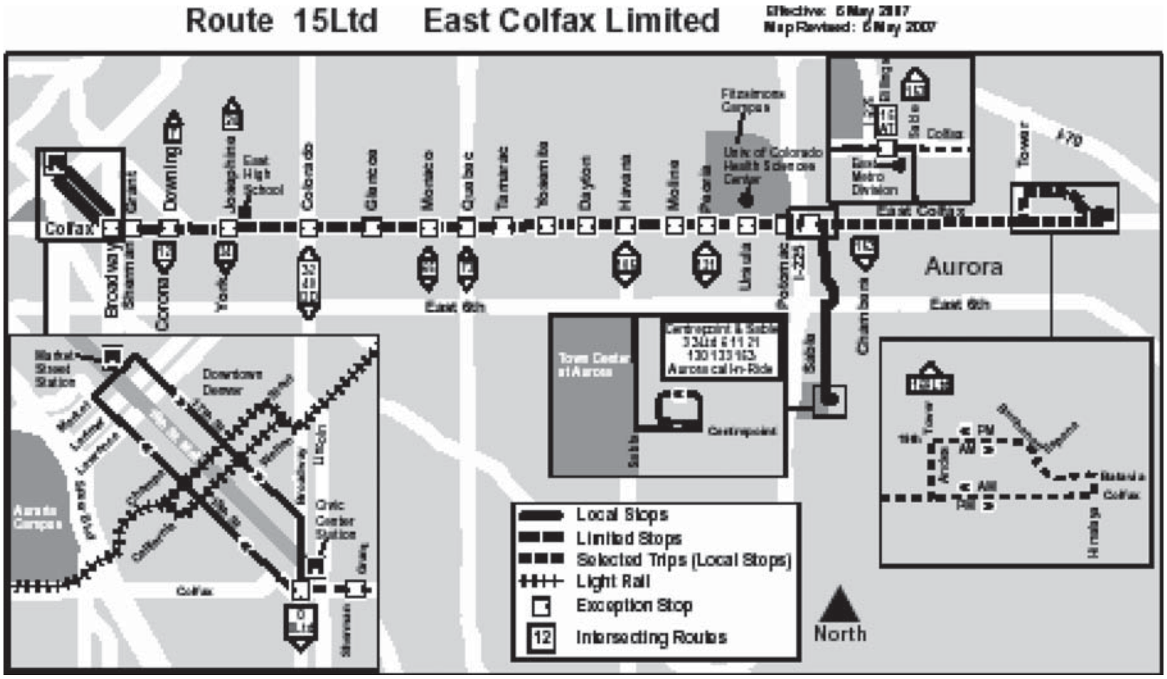

FIGURE 1 Map of East Colfax Limited, Route 15L.

There are 18 Regional routes providing high quality service from the larger municipalities in the RTD service area to a downtown Denver station. Some of the Regional routes are designed to provide service between these outlying cities and various employment centers, with service generally operating only on weekdays. The schedule frequencies are typically 30 min, with service only provided during the morning and afternoon peaks. One of the Regional routes is extended to a ski resort during the period of November through April. The 45-ft intercity bus cargo bays are ideal for transporting ski equipment and luggage.

FIGURE 2 Articulated bus on 15 Limited route.

RTD's most popular Regional service is the Boulder B or BX service, which is an exception stop service over the same route. The route map for the Bolder Regional is shown in Figure 5 and the Regional B bus is shown in Figure 6.

RTD's second use of 45-ft buses is on the six skyRide routes. These routes operate between the larger RTD Park-n-Ride lots to the Denver International Airport (DIA), as illustrated in Figure 7. One, the AF Route, has a scheduled stop at the Market Street Station on the way to DIA. Scheduled service begins as early as 3:07 a.m. and runs to 12:07 a.m. The service hours were chosen to meet the needs of airport employees as well as airline customers. The marketing for skyRide service stresses the frequency, ease, comfort, and low cost transport to DIA for Denver area residents. The large cargo bays of the 45-ft buses offer easy transport of baggage. Three of the skyRide routes stop at the Airport Boulevard/40th Avenue Park-n-Ride as a last stop, and serve as a shuttle for those using the Park-n-Ride to the DIA terminal. RTD's Park-n-Ride lots are free and provide an alternative to airport parking for local residents.

Modification of Facilities and General Operational Information

RTD uses mostly far side bus stops, with not much modification done to the bus stops other than ensuring adequate length for the articulated buses. The two downtown underground stations were built after articulated buses were in service and were designed to accommodate 45-ft buses in ten of the bays and articulated buses at the two end bays. The RTD has seven bus maintenance facilities. RTD employees use

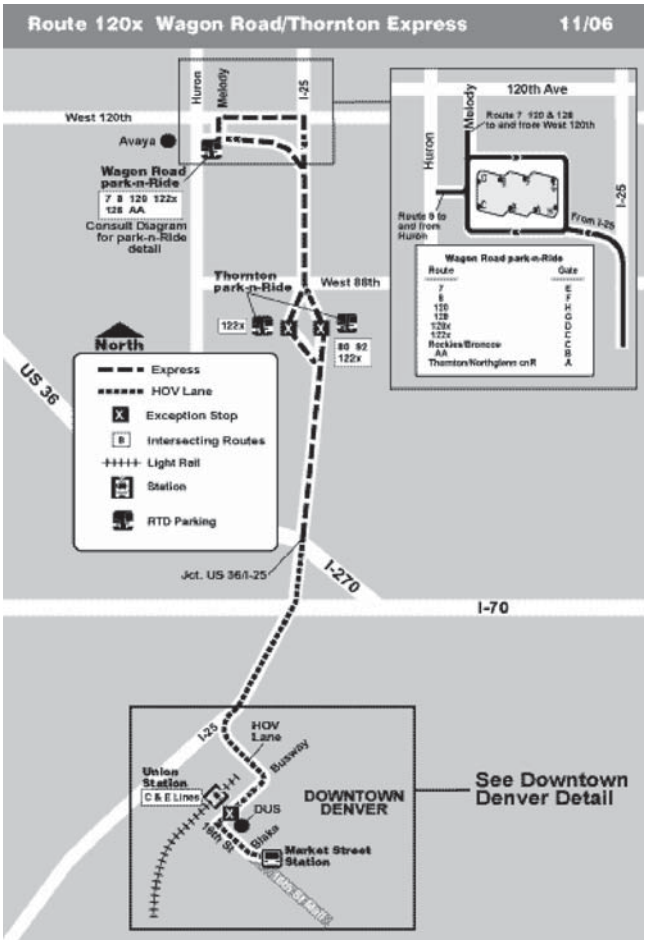

FIGURE 3 Wagon Road/Thornton Express, Route 120X.

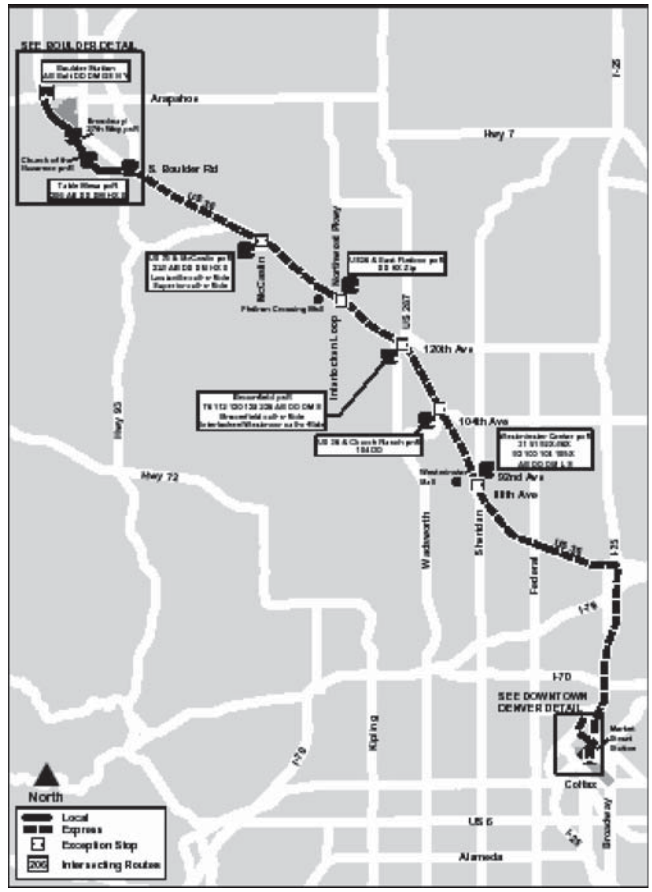

FIGURE 5 Map of the Boulder Regional, Routes B and BX.

three, and three RTD contractors use the other four. Only RTD employees operate HC buses. Because RTD has been operating HC buses for more than 23 years, there were no available records of the costs of any modifications to maintenance facilities that were made to accommodate HC buses.

RTD has no special training for articulated or 45-ft coach operators, except in-bus practice of entering the two downtown (Market and Civic Center) stations, which are at the ends of the MallRide Shuttle. A Route 120X articulated bus operator commented that driving in the stations was easy. The operator, who had about 20 years of driving experience, said that the articulated buses handled well, but possessed slow acceleration capability. Apparently, a

FIGURE 4 RTD articulated bus at Wagon Road Terminal.

FIGURE 6 An RTD 45-ft Boulder Regional bus.

FIGURE 7 An RTD 45-ft skyRide bus at Denver International Airport.

required environmental engine adjustment had resulted in lower performance.

RTD does not have any wage differential for operating HC buses. They did not experience any legislative or regulatory impediments to the use of HC buses. RTD has no service restrictions, such as standees, on any of their HC buses.

The wheelchair accommodations for the articulated buses are a lift in the first door and two forward-facing wheelchair securement positions in the front of the bus. The 45-ft coaches have a lift in a second door and two forward-facing securement positions. RTD's experience with the transport of passengers using wheelchairs was reported as the same as with their 40-ft bus fleet. However, the 45-ft coach lift was reported to be very slow, resulting in long loading times. Front bicycle racks are used on the articulated buses (see Figure 4), and on the 45-ft intercity coaches (see Figure 6).

Several of the survey responses commented on the difficulty of operating articulated buses in snow conditions. The RTD regularly uses snow tires on the drive axle of its articulated buses during the winter months. In December 2006, three large snowstorms struck the Denver area. All service was temporarily halted, but HC buses, including articulated buses, were equally deployed as service was restored.

The articulated fleet is equipped with recording security cameras. The 45-ft intercity coaches have reclining seats, luggage racks, and reading lights. A summary of some of the features of RTD's current HC fleets is given in Table 30.

Both articulated and 45-ft intercity coaches have been a vital part of the RTD fleet. The use of these types of buses will likely be reduced over the next decade as selected major bus corridors are converted to light rail or commuter rail service.

TABLE 30
SUMMARY OF THE RTD HC BUSES

Year	Type	Model	Passenger Seats	No. of Buses	Floor Height
1997	45-ft	102D3	55	71	High
2000	Articulated	436	63	119	High
2001	45-ft	AN 345/3	55	85	High

Source: Survey responses and Reference 1.

Free MallRide Shuttle

A unique feature of RTD's downtown transportation network is the MallRide shuttle. MallRide provides mobility between all three downtown stations (Market Street, Civic Center, and Union Station), as well as an easy (and free) transport system to downtown offices and retail stores.

The MallRide shuttle is a special purpose 45-ft HC bus, with three wide doors, low-floor entrance, and a capacity for 116 passengers. Average weekday boardings are approximately 64,000 passengers. The shuttle is powered by an environmentally friendly hybrid propulsion system [compressed natural gas (CNG), electric]. It has a wheelchair ramp to enable passengers with disabilities to board and exit with greater speed and ease. As the shuttle travels the 16th Street Mall, it provides connections for all bus routes entering the downtown as well as the D Line light rail at Stout and California Streets and the C Line light rail at Union Station. Figure 8 shows the MallRide shuttle at the Market Street station.

VICTORIA REGIONAL TRANSIT SYSTEM/BC TRANSIT: SEARCH FOR HIGHER CAPACITY IN AN OLDER CITY CONTEXT

The city of Victoria is located on Vancouver Island in British Columbia and has a population of 340,000. Transit service at the Victoria Regional Transit System is provided by BC Transit, a provincial Crown corporation. Victoria Regional transit has a fleet of 211 conventional buses. In addition to providing the transit service in Victoria, BC Transit plays a prominent role in transit in the small communities across the province

FIGURE 8 RTD's MallRide Shuttle at the Market Street station stop.

(excluding the Vancouver region); among its various activities, it coordinates and funds the procurement of a province-wide municipal fleet, and provides planning and marketing assistance to the small transit systems in the province.

BC Transit enjoys a reputation of being one of the most progressive and innovative transit systems in Canada. In 1991, it was the first transit system in North America to introduce low-floor accessible 40-ft transit buses, paving the way for a wave of interest across Canada. It has been also been at the forefront of introducing various ridership-building initiatives including Transportation Demand Management, employer-based commuter transportation options, and employer- and university-based special transit pass programs (e.g., Eco Pass and U-Pass).

Background

The city of Victoria has deep historical roots. Founded as a trading post in 1843, its population rose dramatically after gold was discovered in British Columbia in 1858, becoming the base supply port and outfitting center for miners. In 1871, it became the provincial capital when British Columbia joined the confederation, and enjoyed a large real estate boom just before World War I that left a large legacy of historical buildings downtown. Victoria is also a geographically constrained city as shown in Figure 9, squeezed on narrow strips of land and peninsulas that are sandwiched between mountains and the surrounding sea and inlets.

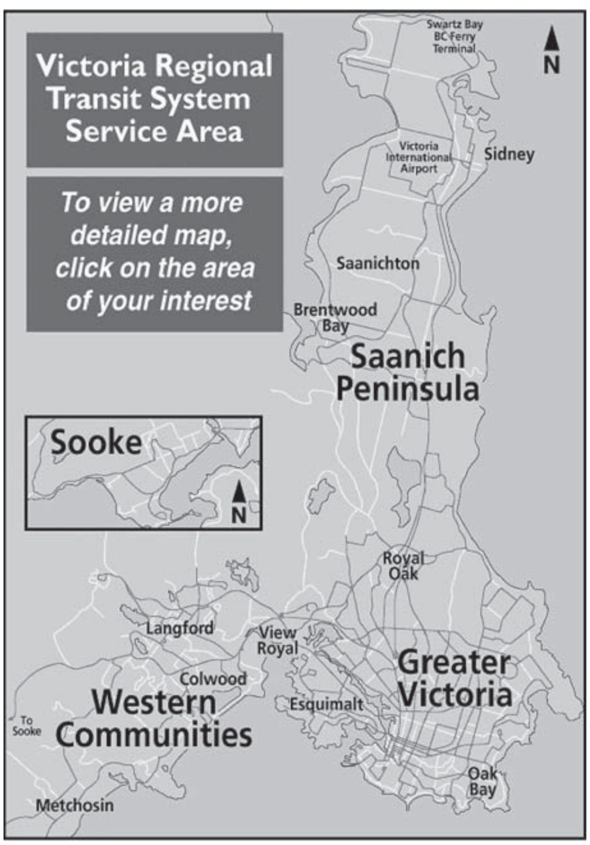

FIGURE 9 Victoria Regional Transit System service area.

The geographic constraints and historical evolution of the city have resulted in a very dense network of operation for the region's transit routes. Transit operates on relatively few arterials (Figure 10), mostly radially feeding into a downtown core, which consists of typically narrow streets, with short blocks and a high concentration of pedestrian and traffic activity in a very limited area (Figure 11).

In the mid-1990s, BC Transit management sought options for increasing vehicle capacity, especially on certain heavily used long-distance routes on which ridership was growing and had periodically experienced overload situations. The use of HC buses could alleviate the overload conditions while providing capacity for growth. Articulated buses represented a significant operational challenge in the downtown core given the levels of traffic, pedestrian congestion, and the great competition for curb space caused by the street layout. Management had contemplated double-deck buses as an option, but existing double-deck bus models were not compatible with the agency's policy of full accessibility; the agency was particularly proud of having been the first transit system in Canada to deploy low-floor accessible buses.

Justification

In 1997, a major order of more than 1,000 low-floor double-deck buses was delivered to Hong Kong, which convinced senior management at BC Transit that the concept of a low-floor double-deck bus was technically feasible. Staff explored with various manufacturers of low-floor double-deck buses the possibility of developing a vehicle for their North American market with the minimum size of fleet that would be mutually acceptable. One manufacturer expressed interest in the concept.

An agency report was prepared in May 1998 by BC Transit staff to review options for deploying HC buses, which assessed both double-deck and articulated buses, in terms of capacity, cost, and other factors. The assessment concluded that in Victoria's context, there was considerable merit to recommending deployment of double-deck buses for BC Transit. In particular, double-deck buses had the following advantages:

- The shorter length of the double-deck bus more closely matches the shorter street block length within the Downtown Core. The longer articulated bus would add to congestion within the Downtown Core and reduce the efficiency of major downtown bus stops.
- The double-deck bus has a higher passenger carrying capacity than the articulated bus (120 versus 108) and also provides seating for the majority of the customers (90 for a double-deck versus 54 in an articulated bus). This provides improved passenger comfort, particularly on the intended routes which have relatively long travel times (*18*).

In addition, the financial assessment of the vehicle appeared quite positive. The estimated cost of purchasing the 11 vehicles

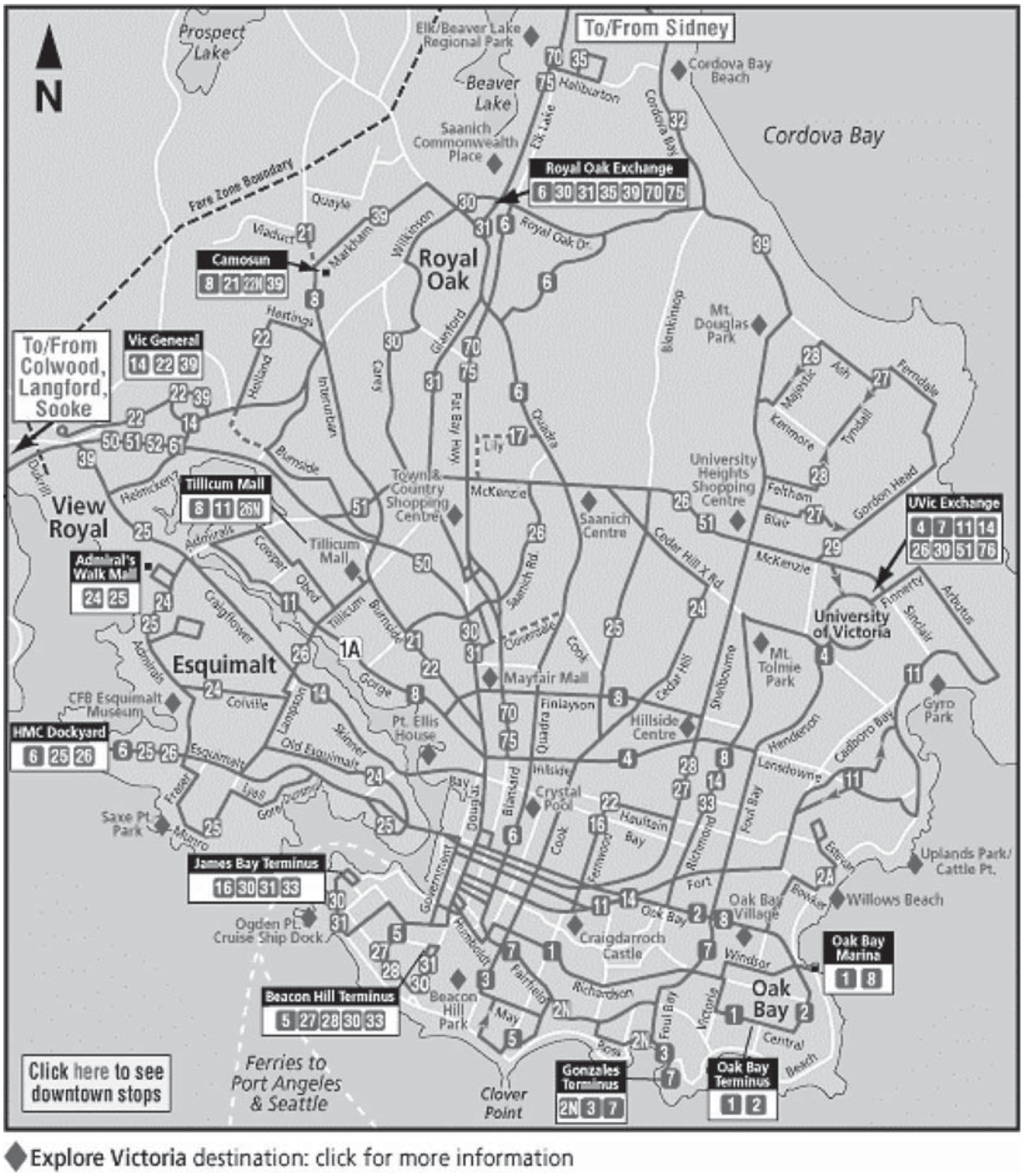

FIGURE 10 Transit service in Victoria.

was $6.5 million [Canadian (Cdn)] and the report estimated that 11 double-deck buses would provide the same level of service as 16 standard buses. This would eliminate the need to purchase and operate five buses, reducing annual operating costs by $300,000 Cdn. The net present value savings would be $2 million Cdn over the service life of these vehicles.

As a result, BC Transit Management recommended that the Victoria Regional Transit Commission acquire 11 low-floor double-deck buses stating the following key benefits:

> Double-deck buses improve operating and service quality in three ways, namely:
> - elimination of the need to dispatch a second "overload" bus when peak loads exceed the passenger carrying capacity of the regularly scheduled buses,
> - introduction of high capacity buses enables transit to increase the carrying capacity of the route with little increase in the cost of service, and
> - double-deck buses increase capacity by increasing seating rather than standing capacity (*18*).

The report also identified a detailed deployment plan based on the following logic:

> The fleet of double-deck buses provides an opportunity to attract a growing market without increases in operating costs through the provision of additional capacity. The buses are most suitable to longer trips where passengers are on-board the bus for longer time periods. These trips also provide the best opportunity to increase service efficiency.
>
> Suburban locations such as Sooke and Sidney are well suited to the use of double-deck vehicles as the passengers tend to be collected at a relatively few stops and travel to a limited number of destinations (for example, Western Exchange or Downtown Victoria). This travel pattern minimizes the number of "ons and offs" experienced at stops along the route and provides the most suitable target market for double-deck buses . . .

FIGURE 11 Downtown Victoria: Street layout and transit service.

> The first eleven double-deck buses would be focused on providing EXPRESS service to the Western Communities and Saanich Peninsula during peak hours. In addition, trips will be scheduled to reduce the need for "overload" buses to post-secondary institutions during the late AM peak and early PM peak and to accommodate growing demand and reduce overload requirements for service to BC Ferries throughout the day and weekends (*18*).

The recommendation was accepted, and staff proceeded to negotiate the procurement of these buses, which were introduced into service in June 2000.

Preparation for Deployment

There were three key aspects to preparing for the deployment of double-deck buses:

- Development of a North American version of the vehicle,
- Pre-deployment planning, and
- Required modifications for vehicle maintenance.

Development of a North American Version of the Vehicle

This was the first deployment of an accessible low-floor double-deck bus for transit service in North America. As a result, BC Transit staff had to work closely with the manufacturer to develop a vehicle specification that would allow it to be certified in Canada (and subsequently in the United States), and be equipped with standard North American components to facilitate servicing and maintenance.

Figure 12 is an exterior picture of the bus, and Figure 13 is an interior photo of the upper deck. The lack of intrusions (e.g., doors and wheelchair securement positions) allows for a large number of seats (i.e., 53), which explains the high total seat capacity of 81 seats for the bus, as illustrated in the floor plans for the bus (see Figures 14 and 15). The double-deck bus also incorporates some special customer amenities such as reading lights and a quiet the upper deck, which are highly appreciated by passengers.

Pre-Deployment Planning

The 1998 report had included an implementation plan that identified the initial routes where the double-deck buses would be deployed. These consisted of a number of long-distance peak express routes, as well as specific trips experiencing overload situations on a regular basis (e.g., to the University and to the Swartz Bay Ferry Terminal with ferry service to the mainland).

The second requirement for deploying the vehicles was to work with the provincial regulatory authorities to obtain a provincial over-height exemption. The relationship between BC Transit and the provincial regulatory agency was excellent, and staff from the two agencies worked closely together to obtain the exemption certification (which must be carried in the vehicle). It should be noted that the manufacturer has subsequently re-engineered the HVAC system, moving some of the ductwork to the walls, allowing a reduction of the height by a two inches (from 14 ft 2 in. to 14 ft 0 in.).

FIGURE 12 Low-floor double-deck bus of the Victoria Regional Transit System. (*Source*: BC Transit.)

FIGURE 13 Interior of the upper deck of the double-deck bus. (*Source*: BC Transit.)

Third, staff had to check the height along the six double-deck bus routes; this was carried out by attaching a 14-ft stick to a supervisor's vehicle to measure height clearance. This process identified a number of utility structures that were not in compliance with clearance requirements, and these were communicated to the utility companies. Although a few streets had to be avoided by the buses because they included historic trees with low canopies, planted as a war memorial, it did not cause any significant problem. It should be noted that the vehicle incorporates a "tree-guard" in the front at the roof line, which provides some additional protection against low branches.

The only significant problem identified was the identification of one rail overpass where the bridge needed to be lifted at a cost of $125,000 Cdn. This was the only significant cost item for accommodating the double-deck buses.

Street furniture and stops also needed to be assessed. The double-deck bus has a shorter wheel base (224 in.), compared with that of standard 40-ft buses (285 in.), resulting in a sweep that is considerably greater. The former clear zone requirement for the 40-ft bus on the sidewalk had been 18 in., but the double-deck bus requires a clear zone of 27 in. As a consequence, street furniture needed to be relocated. It should be noted however that the 27 in. clearance is now also required by the 30-ft buses operated by BC Transit because of their short wheel base.

Required Modifications for Vehicle Maintenance

The garage facilities had sufficient height clearance to accommodate the double-deck bus height, and had occasionally been used for maintenance of private tourist-style double-deck buses. The only modifications required were:

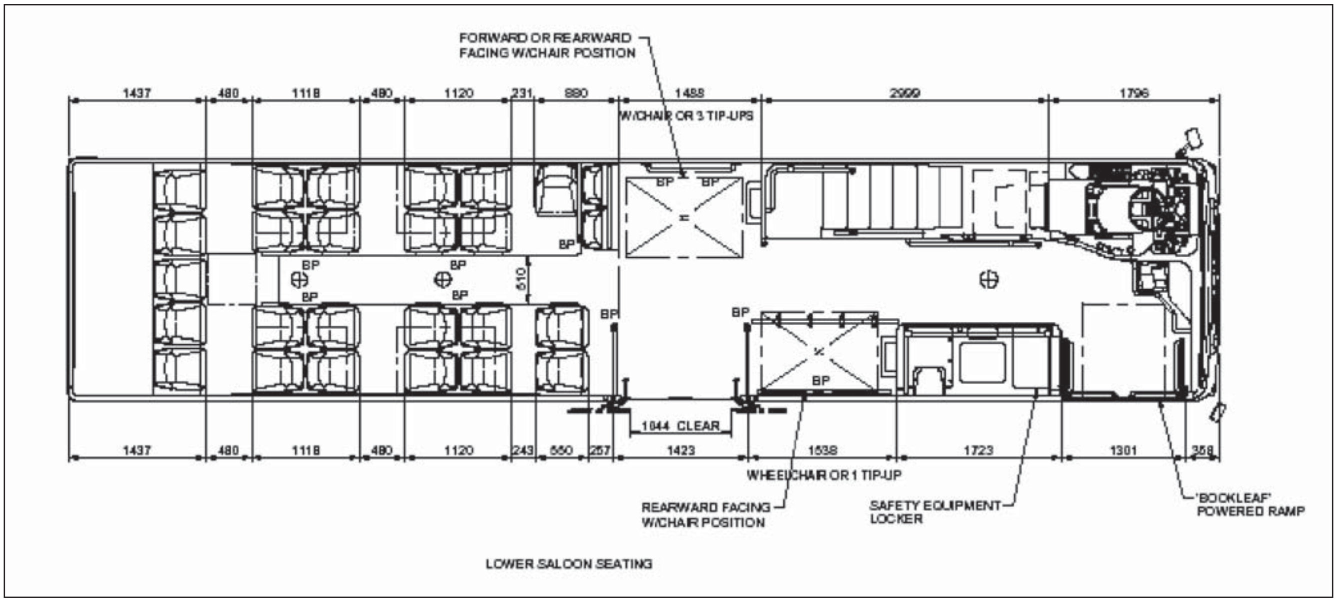

FIGURE 14 Floor plan of lower deck of Victoria's double-deck bus. (*Source*: Alexander Dennis.)

- The acquisition of a 6-post hoist,
- A scissors-lift work platform for mechanics to access to the roof area for maintenance, and
- A modification to the vacuum system.

Bus wash height is also a consideration. However, a new bus wash had previously been installed that could handle the vehicle's height.

Deployment

As outlined in the implementation plan, the initial deployment was as follows:

- Service from Sooke and Western Communities (a.m. and p.m. Commuter Peak Express): These routes are characterized by increasing demand. Most passengers are collected in relatively small areas and travel to concentrated destinations. On-board times are considerable (one hour from Sooke, 40 min from CanWest Mall) and frequency of service to these areas is six to seven buses per hour.
- a.m. and p.m. peak buses to Saanich Peninsula (Routes 70—Pat Bay, 72—Sidney, and 75—C. Saanich): These routes are also characterized by increasing demand and longer travel times (travel from Sidney in the a.m. peak is approximately 45 min. Frequency of service is 12 buses per hour in the peak periods on the 70 or 72 routes. Figure 16 provides the details of Route 70, which serves the Saanich Peninsula and the Swartz Bay Ferry Terminal.

In addition to the long-distance commuter express services, the double-deck buses were also deployed on specific trips characterized as follows:

- Peak shoulder period service to post-secondary institutions: After the a.m. peak trips and before the p.m. peak

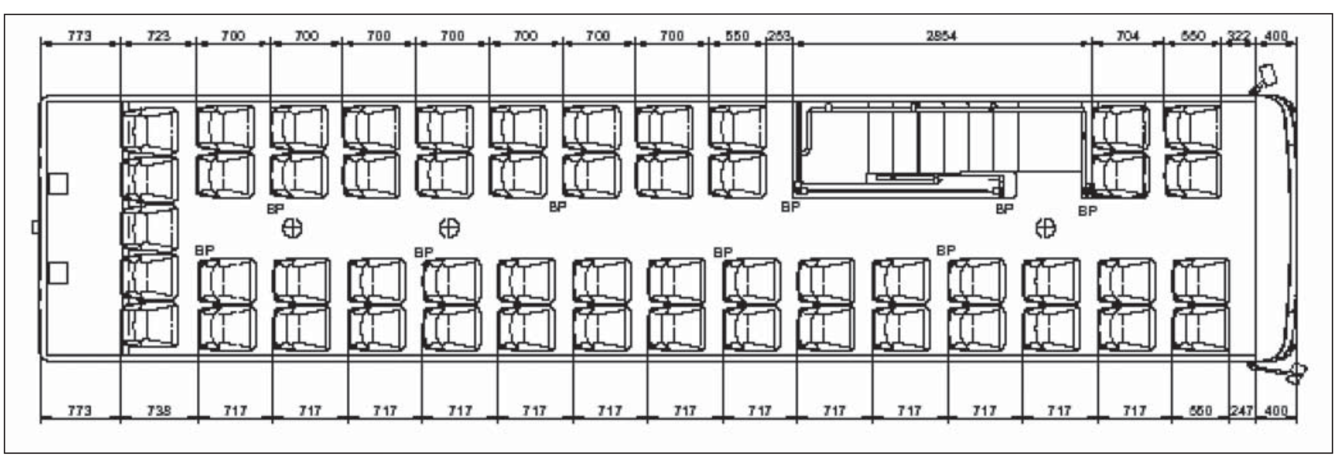

FIGURE 15 Floor plan of upper deck of Victoria's double-deck bus. (*Source*: Alexander Dennis.)

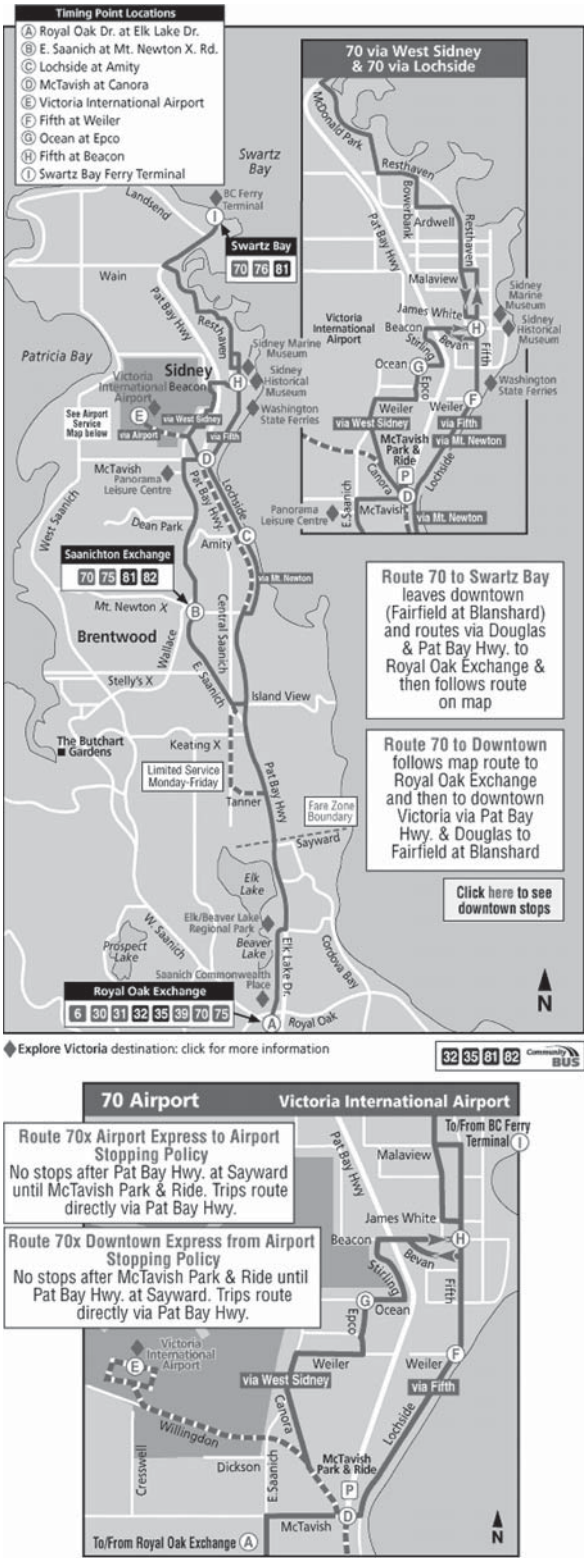

FIGURE 16 Route 70 serving Saanich Peninsula and BC ferry terminal.

trips from downtown to suburban destinations, the double-deck buses were deployed to increase efficiency and accommodate the growing demand to post-secondary institutions (University of Victoria and Camosun College). Buses were generally provided through overtime. Using the HC vehicles in these busy periods helped eliminate the need for "overload" trippers.

- Off-peak service to Swartz Bay Ferry Terminal and Butchart Gardens: Demand for service to these two important destinations was growing. At times, three buses were also deployed to provide sufficient off-peak capacity to meet the demand for travel from the Ferry Terminal or the Gardens.

A typical pattern for use of the double-deck buses in the initial deployment might have been as follows:

- Early peak: Inbound express commuter trips.
- Late morning peak and mid-day: University route.
- 2:30 to 3:30 p.m.: School tripper with overloads.
- Afternoon peak: Outbound commuter trips.

Ten buses were eventually acquired and deployed as outlined previously. The deployment of these first buses was so successful that a subsequent 29 buses were acquired, with more to be acquired in the future. Three of the double-deck buses operate in the city of Kelowna in central British Columbia, a city of just over 100,000, with a fleet of 47 conventional buses.

In Victoria, half of the current fleet is operated in Express commuter service and half is now operated in base trunk urban service. Figure 17 illustrates an example of a heavy demand urban route serving major demand generators (e.g., both the University of Victoria and Camosun College), where double-deck buses have been successfully deployed.

Experience

The experience in Victoria with double-deck buses has been overwhelmingly successful. Examples mentioned by interviewees include:

- Regular customers and tourists truly appreciate the view from the upper deck and the quiet; these seats always fill up.
- During the introduction of double-deck buses, customers would let regular buses pass so that they might ride on a double-deck bus.
- There continues to be a "wow" effect, even six years after their initial deployment, and staff still receives positive comments from customers.
- Although no formal measurement of ridership impact has been undertaken, staff is convinced that it has had a positive effect.
- The introduction of HC buses facilitated the implementation of BC Transit's U-Pass programs; the deployment of HC buses to the routes serving the University and College has enabled BC Transit to accommodate the increased ridership stimulated by the U-Pass Program.

FIGURE 17 Route 4 University—Example of trunk urban service operated with double-deck buses.

- These buses are highly desired by operators, because of the quality of the ride and handling offered by the vehicles, as well as because of the recognition factor associated with the unique buses; senior operators always sign up for these runs first.

The following sections discuss a few specific issues related to the deployment of double-deck buses by BC Transit.

Scheduling

Staff was somewhat concerned about the scheduling of the double-deck buses, and decided at the outset to add some additional recovery time at the end of the runs, whenever double-deck buses were introduced to a route. The experience has been that the vehicle's acceleration is no different than standard low-floor buses; however, dwell time can be higher, merely because of the increased vehicle capacity. This is somewhat mitigated by a tendency of passengers on double-deck buses to pre-position themselves in advance of their stop (i.e., to initiate their descent from the upper deck at the stop preceding theirs). The Automatic Passenger Counting (APC) system tracks schedule adherence in addition to passenger activity and is used by staff to continuously monitor running times. These data enable staff to reduce, as warranted, any additional recovery time that has been added when the double-deck buses are introduced.

Safety and Security

Safety of passengers ascending and descending the internal staircase is an obvious area of concern. BC Transit's experience has been that this has not turned out to be an issue. The staircase is narrow and has sufficient handholds and stanchions as can be seen in Figures 18 and 19, and standees are not allowed on the upper deck.

There appears to be an informal self-sorting among passengers; those few passengers who may have concerns tend to stay on the lower deck. In addition, it has been observed that passengers prepare to exit the bus well in advance of the stop, and this has taken place without any information campaign by the agency. Interviewed staff indicates that no significant accidents have occurred, and there are fewer passenger incidents inside double-deck buses than for passengers exiting the second door on any bus (standard or double-deck).

To ensure the security of passengers on the upper deck, closed circuit television cameras have been installed, with a

FIGURE 18 Internal double-deck staircase as seen from above. (*Source*: BC Transit.)

FIGURE 19 Internal double-deck staircase as seen from below. (*Source*: BC Transit.)

monitor provided to the operator; this replaces the periscope mirror that was traditional in older generation Route Master double-deck buses.

Vehicle Performance

The performance of the vehicle has generally been positive. Acceleration, grade climbing, turning maneuverability, and range were ranked in the survey response as superior to that of their standard 40-ft buses, and reliability was ranked as the same.

One interesting aspect was an initial concern that staff had about the potential leaning or tipping of the bus, which might create a feeling of sway for customers on the upper deck. The experience has been that, despite its height, the double-deck bus has a suspension system that maintains its vertical to a higher degree than do standard buses, and there is no perceived sway on the upper deck.

Snow Operation

Another issue concerned vehicle performance in snow conditions, because the initial order of buses experienced poor traction in snow conditions. The bus manufacturer, working with BC Transit staff, identified an engineering solution to reduce this problem. A manual switch was installed, which can be activated by the operator when required. When activated, some air is bled off from the suspension of the tag axle so that the weight is more focused on the drive axle, providing better traction. After the bus gets going, the air bag fills up automatically again. With this modification, the performance of double-deck buses in snow conditions is equivalent to that of the standard buses.

Accommodation of Wheelchairs

As mentioned, BC Transit has been one of the leaders in promoting accessibility of transit service and was the first transit system to introduce low-floor accessible 40-ft buses in North America. When these buses were introduced in 1992, BC Transit developed its own version of a practical forward-facing securement system. The introduction of the double-deck buses, in parallel with that of a new fleet of 30-ft buses, provided an opportunity to reexamine the securement system in use. Although rear-facing wheelchair position was the norm in the United Kingdom and some transit systems in Canada had also moved in that direction, there had not been any standardized approach. BC Transit staff actively participated in the development of a Canadian Standards Association standard (*18*), and explored alternative configurations that would meet the needs for the BC Transit fleet.

The resulting designs are discussed in detail in a previous TCRP synthesis report (*19*), but a standard approach emerged from these efforts. Figure 20 illustrates this standard approach as it appears on the current generation of low-floor double-deck buses. There are two wheelchair positions:

- A roadside "combi design" position where the wheelchair can be positioned in either a forward-facing or a rear-facing direction, and
- A curbside rear-facing position.

The rear-facing position includes a padded backrest and a wall-mounted retractable belt to prevent tipping of the wheelchair. The rear-facing position provides more independence to customers in wheelchairs, provides a more rapid positioning of the wheelchair, and is generally preferred by customers. The rear-facing wheelchair position has been valuable in reducing dwell time and maintaining schedule on the double-deck buses.

CHAMPAIGN–URBANA (ILLINOIS) MASS TRANSIT DISTRICT: SMALL SYSTEMS CAN EFFECTIVELY USE HIGHER CAPACITY BUSES

The twin cities of Champaign and Urbana have a combined population of approximately 110,700 and are the home of a large university, the University of Illinois, with a student population of more than 42,700. The combined population of faculty, staff, and students of approximately 53,700 makes the campus area a busy and challenging transportation issue to solve. Buses began operating on the streets of the small twin cities as early as 1925. National City Lines, which operated the system through World War II, was later sold to Westover Transit Management, which suffered the familiar decline in public transit ridership in the years after the war. A referendum to create a mass transit district was overwhelmingly approved

FIGURE 20 Wheelchair positions on BC Transit low-floor double-deck buses: Combi system roadside and rear-facing system curbside. Note: Both wheelchair positions have backrests with flip-down seats.

in November 1970, and the Champaign–Urbana Mass Transit District (MTD) began operations in August 1971 (*20,21*).

A 1993 trade journal article listing reasons and conditions when transit agencies should consider articulated buses prompted MTD's interest in articulated buses. Because the MTD met all of the needed conditions, a search began. Owing to limited capital funds, new buses were not feasible, and 13 1981 Crown Ikarus articulated buses were purchased from the Transit Authority of Northern Kentucky. One bus was cannibalized for parts, and the remaining 12 were placed in revenue service on July 1, 1994. The Crown Ikarus vehicles were replaced with new low-floor diesel-powered articulated buses in 2001.

The MTD in 2007 operates a fleet of 100 buses of which 12 are articulated buses. The ridership in 2006 was approximately 9.6 million. The total service area is about 30 square miles, and there are 24 week-day day-time routes, which are divided into community service (18 routes) and campus service (6 routes).

Why Higher Capacity Buses and How They Are Used

The primary reason MTD chose the articulated bus was to save on labor costs. Because operator cost is approximately 70% of total operating costs, the HC articulated bus appeared to be an obvious choice. A secondary reason for using articulated buses was to reduce street congestion. The articulated buses are used on two campus and two community routes.

The major use of the articulated buses is to handle the heavy campus loads on the 21 Quad and the 26 Pack routes. On each route, four articulated buses replaced eight 40-ft buses. During peaks, an articulated bus and a 40-ft bus are used in mixed-vehicle service on the 13 Silver route, which provides service from an off-campus housing and commercial area to the main campus. One articulated bus is used in an afternoon supplemental service on the 7 Grey route. Two articulated buses are held in reserve and for scheduled maintenance.

Reasons Higher Capacity Buses Work So Well: Fare Collection and Short Dwell Times

All University of Illinois students, faculty, and staff have unlimited access to all MTD routes and services at all times by presenting a valid I-card to the operator. All campus routes are "open" service; that is, no fare is collected, enabling all three wide doors to be used for boarding and exiting, minimizing dwell times. Many of the community service routes intersect with campus routes, which provide excellent connectivity for the students with community services and for commuting by the faculty and staff. Fares are collected on community routes and boarding is limited to the first door. About 87% of the community routes fares are prepaid. As a result, about 92% of all fares are prepaid for MTD.

Campus Service Operations

The 22 Quad and the 26 Pack are similar campus routes that provide access from large student residence halls to the main campus buildings. Both provide 5-min headway service from 7:30 a.m. to 4:30 p.m. and 7-min headway service from 4:30 p.m. to 7:17 p.m.. The weekday passenger ridership for 21 Quad is 5,700 and 5,200 for 26 Pack. MTD experiences peak periods throughout the day (approximately 20 min before and after the hour), with loads of 129 per bus on 21 Quad and 118 per bus on 26 Pack. A typical peak-period dwell time is approximately 34 s. Figure 21 shows a map for the 21 Quad.

The route is approximately 4 miles in length and average travel time for the route is approximately 15 min. The buses have brief layovers at the student residence halls.

The 13 Silver route provides transportation for students from an off-campus residential community to the main campus. This route is assigned one articulated bus, and one 40-ft bus is added during peak periods. During weekdays, a 30-min scheduled service is provided in both directions from 6:30 a.m. to 6:30 p.m..

MTD currently has STOPwatch passenger information displays at 14 major stops. Six are in the Champaign and Urbana communities and eight are located along campus routes. The STOPwatch sign displays the minutes to a bus departure in real time (integrated with an automatic vehicle location system) for the routes using that particular bus stop. The display is essentially a countdown to the next bus departure for a given route. MTD also has STOPwatch Plus at two locations, the Illinois Terminal and the Lincoln Residence Halls, that display time and date, and messages for re-route and safety information.

The information displayed on STOPwatch is available in a number of ways: cell phones, PDAs, and laptops may access the information through a wireless application protocol, or by text messaging to the MTD number or by widget.web using a browser. Figure 22 shows a STOPwatch display at a stop served by all campus and several community routes.

Mass Transit District Articulated Bus: High Loads and Short Dwell Times

The buses are equipped with 47 seats and hip rests in the articulated joint. The decision to use of hip rests versus seats

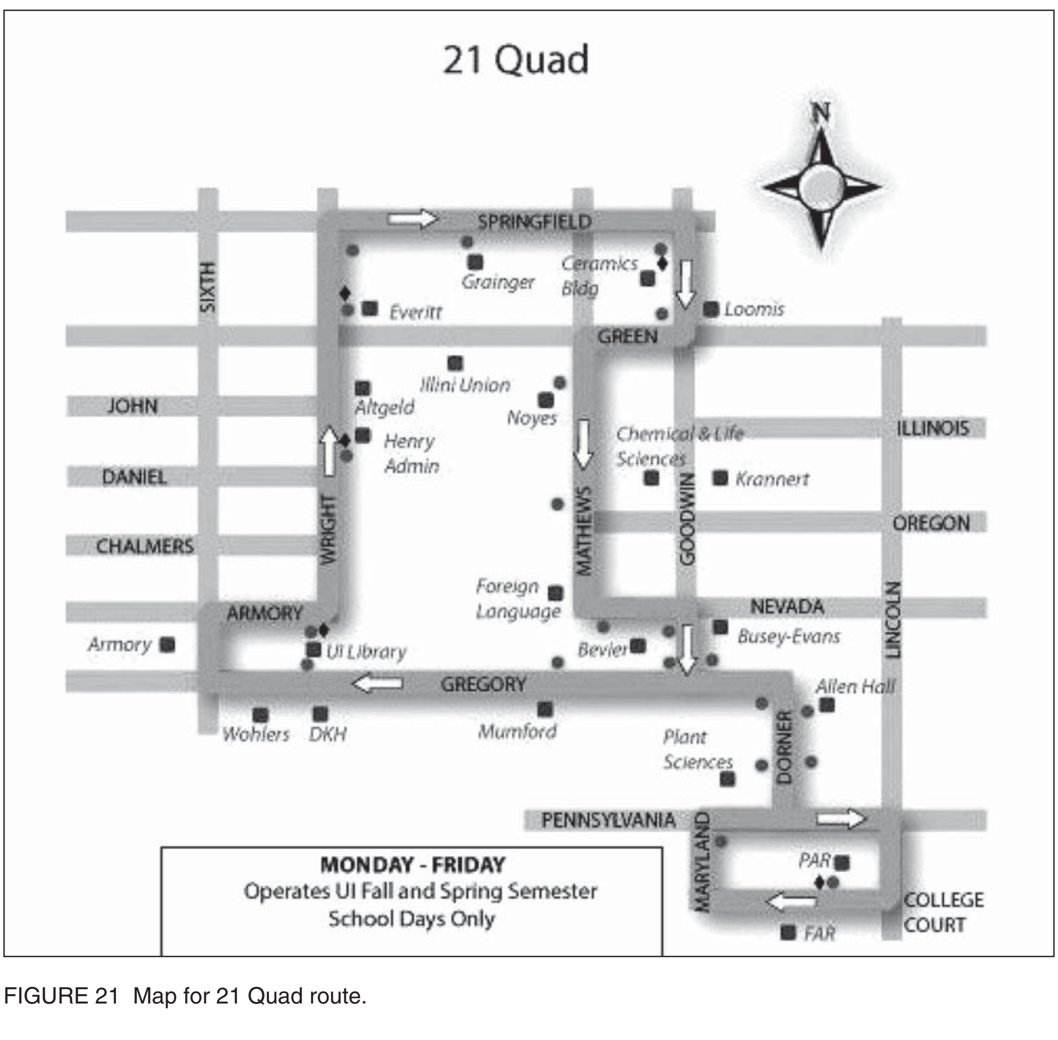

FIGURE 21 Map for 21 Quad route.

FIGURE 22 STOPwatch display at Wright Street stop.

was to accommodate more passengers. The hip rests are shown in Figure 23. Eight passengers can easily use the hip rests compared with two double seats, which would accommodate only four. Because trips are short, having a majority as standees is not a problem. The buses have three doors; the second and third doors are extra wide (44 in.) to facilitate shorter dwell times. The entire right (curb) side of the articulated bus kneels to facilitate quicker dwell times. Crush loads as high as 130 have been observed on the buses.

The wheelchair ramp is installed in the first door so that the operators can observe the operation without leaving their seat and, if assistance is requested, the operator would not have to work through a crowded interior to get to a second door.

The articulated buses used by MTD are New Flyer D60LF equipped with Cummins ISL330 engines and Voith transmissions. MTD uses a 5% blend of bio-diesel with their low sulfur diesel fuel. MTD buses have eight closed circuit television cameras installed in the bus: one for each doorway,

FIGURE 23 Hip rests used in MTD articulated buses.

FIGURE 24 21 Quad articulated bus at student residence hall stop.

four looking forward and aft covering the entire interior, and one looking forward through the windshield. The buses have two or three (articulated has three) strobe lights (light emitting diodes) on each side of the bus that flash when the left or right turn signal or 4-ways flashers are on. The reason for the flashing lights is to alert motorists and pedestrians that the bus will be turning and to reduce incidents at intersections. MTD buses are also equipped with an audio "beep" signal that is activated when the right turn signal is on to alert pedestrians that the bus is making a right turn. The capital cost of the bus was $425,000. MTD articulated buses are shown in Figures 24 and 25. In Figure 24, a 21 Quad bus is waiting at the residence halls stop with all doors open for boarding. Figure 25 is a 13 Silver bus at the Illini Union stop with side strobes flashing. Passengers are only boarding at the first door because this is a community service bus.

Mass Transit District Maintenance Facilities

At the time articulated buses were being considered, MTD was constructing a new maintenance facility that was designed to accommodate MTD 30- to 60-ft vehicles. MTD has one pit that is 60 ft in length and equipped with a mov-

FIGURE 25 13 Silver articulated bus at the Illini Union stop.

able axle jack. They also have one three-post in-ground hoist. The two end posts are movable and can accommodate vehicles of 30 to 60 ft in length. MTD hoist equipment is shown in Figure 26.

Modifications Made to Accommodate Articulated Buses

Only a few modifications were done after the facility was built. One was to extend the paint booth approximately 6 ft to accommodate the articulated buses. All MTD buses are stored in a garage. The only change implemented to accommodate the articulated bus was to relocate the air hose drops for the three rows assigned to these buses. Four articulated buses require the same length that six 40-ft buses require; therefore, the entire garage space is utilized. MTD maintains a full air charge on all buses in storage. This reduces operator time for pull out by approximately 4 to 6 min (the time it would take the bus air compressor to fully charge the bus air system).

FIGURE 26 MTD hoist equipment for articulated buses.

With the addition of articulated buses to the fleet, some bus stop zones and layovers were lengthened to accommodate the added length of the articulated bus. For some stops this required the loss of some on-street parking. The maneuverability of the articulated bus was equal to the 40-ft bus, so no roadway modifications were required.

Mass Transit District Operating and Maintenance Costs

Overall, MTD is pleased with the performance of their articulated buses. On a vehicle-mile basis, the maintenance expenses compared with that for a 40-ft bus are higher. However, that is to be expected because there is more equipment (e.g., door, axle, brakes, and tires) to be maintained on an articulated bus. MTD articulated buses had traveled approximately 79,700 miles; however, there had not been any brake maintenance required, because of the effectiveness of the retarder. Table 31 provides a summary of operating and maintenance costs for MTD articulated and 40-ft buses on a vehicle-mile basis. The total costs include all operational costs except for the operator costs. Because MTD has been able to replace two 40-ft buses with one articulated bus, the articulated bus operating and maintenance costs on a passenger transported basis look good.

TABLE 31
MTD OPERATING AND MAINTENANCE EXPERIENCE WITH ARTICULATED BUSES

Bus Type	Fuel Consumption (mpg)	Maintenance Parts Cost ($/vehicle-mile)	Total Operating and Maintenance Cost ($/vehicle-mile)
Articulated	2.58	$0.27	$1.05
40-ft	4.04	$0.11	$0.60

Source: MTD.

CHAPTER FOUR

HIGHER CAPACITY BUS TECHNOLOGIES

MANUFACTURERS OF HIGHER CAPACITY BUSES AND BUSES OFFERED

The databases of APTA and CUTA were examined to identify which bus manufacturers made the HC buses used by the 68 transit agencies. The results of that effort identified 16 manufacturers. Over the years, there have been changes in the corporate structures, ownership of bus manufacturers, and brand names. Some manufacturers have left the North American market, although 6 of these 16 continue to market HC buses. Additional potential bus manufacturers were identified from APTA and CUTA membership directories and a review of trade magazines that feature information on motorbus transportation. At the time of this report, eight bus manufacturers were identified as currently marketing HC buses in North America to either the public or private transportation sectors. These eight manufacturers, along with the type of HC buses being marketed, are provided in Table 32.

The bus manufacturers' questionnaire (see Appendix A) was sent to the eight identified HC bus manufacturers. Responses were received from seven manufacturers. The interest, type, and cost range information that was provided in the responses is presented in Table 32. Tables 33 and 34 contain technical descriptions of the HC models that the responding bus manufacturers reported to be marketing to North American transit agencies

OPERATING PERFORMANCE OF CURRENT HIGHER CAPACITY BUSES

From the transit agency survey responses, several HC bus performance issues were reported. In the following sections, test data on acceleration, fuel economy, and noise performance of HC buses are presented to provide some quantification with respect to these performance areas.

Acceleration and Fuel Economy of Higher Capacity Buses

The survey asked respondents about their operating experiences with HC buses. The intent of the related survey question was to gather information on how transit agencies perceived the performance of their HC vehicles compared with their standard 40-ft buses for several performance measures. The transit agency responses to the survey question were presented in chapter two for each of the three types of HC vehicle.

To examine three of the performance measures in more detail, recent reports from 2001 to 2005 of the ABTC were reviewed for all three types of HC buses and for 40-ft buses. Six reports on articulated buses, one on double-deck buses, four on 45-ft buses, and six on 40-ft buses were reviewed. The performance measures of acceleration, grade climbing, and fuel economy were examined and the results are given in Table 35.

The Altoona data support the perceptions reported by transit agencies of the performance of their diesel-powered articulated and/or 45-ft buses on both acceleration and gradability measures. Both the articulated and the double-deck buses tested were slower compared with the 40-ft buses tested. This is an expected result because the four articulated buses were approximately 50% heavier than the 40-ft buses tested. Information on the installed horsepower was not provided. However, based on the engine model information provided, it is estimated that the installed horsepower for the articulated and double-deck buses tested was about 20% to 25% higher than for the 40-ft buses. The acceleration of the 45-ft intercity coaches was better compared with the 40-ft buses tested.

The Altoona data also support the reported performance relative to fuel economy for articulated and double-deck buses; that is, 30% to 35% poorer fuel economy overall when compared with 40-ft buses. The reported same or better performance on fuel economy of their 45-ft buses is most likely attributed to the type of service (express and/or commuter) because the ABTC-measured overall fuel economy was 26% poorer than that of the 40-ft buses.

An emerging technology for transit buses is the use of hybrid propulsion systems, which result in significant improvements in acceleration and fuel economy. The available Altoona test reports for buses using hybrid technology were examined for the effects on bus performance. Table 36 contains the acceleration, gradability, and fuel economy data for an articulated bus equipped with hybrid propulsion technology compared with five articulated buses, four equipped with diesel engines and one with a CNG engine. The performances of the diesel and CNG buses were averaged for all tests except the fuel economy test, which is the average of the four diesel buses.

The data in Table 36 illustrate the potential for hybrid technology in overcoming two of the common concerns of using

TABLE 32
LIST OF POTENTIAL SUPPLIERS OF HIGHER CAPACITY BUSES AS OF JANUARY 2007

Possible HC Bus Manufacturers	Model ID	HC Vehicle Type	Max. Pass. Seats[a]	Unit Cost (U.S. dollars in thousands)	Market US/Canada	Altoona Tests Completed	Meets Buy America	Meets Canada Motor Vehicle Regulations
Alexander Dennis	E500	Double-deck	81	600	U.S. & Can	yes	no	yes
DamilerChrysler Comm. Buses NA	S 417	45-ft coach	58	450	U.S. & Can	no	no	yes
Motor Coach Industries	D 4500	45-ft coach	57	450 to 500	U.S. & Can	yes	yes	yes
New Flyer	D60LF	Articulated	64	550 to 675	U.S. & Can	yes	yes	yes
	DE60LF[b]	Articulated—Hybrid	64	755 to 1,000	U.S. & Can	yes	yes	yes
	DE60LFR[b]	Articulated—Hybrid	64	760 to 1,000	U.S. & Can	yes	yes	yes
	DE60LFA[b]	Articulated—Hybrid	64	765 to 1,000	U.S. & Can	yes	yes	yes
North American Bus Industries	Exp. 4500	45-ft coach	54	inp	U.S.	yes	yes	inp
	436[c]	Articulated	65	500 to 700	U.S.	yes	yes	unknown
	60-LFW[c]	Articulated	61	500 to 700	U.S.	yes	yes	unknown
	60-BRT[c]	Articulated BRT	58	650 to 850	U.S.	yes	yes	unknown
	65-BRT[c]	Articulated BRT	67	700 to 900	U.S.	no	yes	unknown
Nova Bus	Nova LFS	Articulated	inp	inp	Can	no	no	yes
Prevost Car	X3-45	45-ft Coach	inp	inp	U.S. & Can	no	no	yes
Van Hool	AG300	Articulated	43	Mid 400s	U.S. & Can	no	no	yes
	AGG300	Double Articulated	61	Low 600s	U.S.	no	no	inp
	C2045 P&R	45-ft Coach	57	TBD	U.S.	no	no	inp

Sources: HC Bus Manufacturers S urvey responses and References 22 and 23.
[a]Actual number of seats depends on customer specifications.
[b]The “R” identifies a Restyle model, an “A” identifies an advanced style BRT model, and no letter after LF identifies a traditional model.
[c]The “LFW” identifies a low-floor model, the “C” identifies a composite model, the “BRT” identifies a BRT model, and “436” identifies a standard floor model.
inp = Information was not provided or available in literature; TBD = to be determined.

TABLE 33
TECHNICAL DESCRIPTION OF HIGH CAPACITY BUSES (Articulated models)

Technical Description	Model Identification					Model Identification (BRT)[a]		
	NF D60LF	NF[b] DE60LF (R)	NABI 436	NABI 60LFW	VH AG300	NF DE60LFA	NABI 60 BRT	NABI 65 BRT
Length, Not Including Bumpers (ft)	60.7	61.7	59	60	59.75	62.7	60	65
Width, Not Including Mirrors (in.)	102	102	102	102	102	102	102	102
Height (in.)	121	132	118	116	134	136	137	137
Approach Angle (deg)	9.01	9.01	9	9	9	8.5	9	9
Departure Angle (deg)	8.76	8.76	9	9	9	8.76	9	9
Breakover Angle (deg)	8.35	8.35	11/11	9/10.5	inp	8.35	8.7/10.2	8.7/8.1
Turning Radius, Outside (ft)	38.8	38.6	44	44	39.3	38.6	44	46
No. of Passenger Doors	2,3	2,3	2,3	2,3	3,4	3,4,5	2,3	2,3
Option for Passenger Doors on Left Side	no	yes	no	no	inp	yes	yes	yes
Entrance/Exit Height at Doors (in.)	16	16	15	15	14.2	16	15	15
No. Steps to Enter/Exit	1	1	3	1	1	1	1	1
Wheelchair Equipment (lift or ramp)	R	R	L	R	R	R	R	R
Lift/Ramp Door Locations	all	all	1	1	2	all	1	1
Maximum Number of Seats	64	64	65	61	43	64	58	67
Maximum Number of Standees	57	53	inp	inp	57	53	inp	inp
Gross Vehicle Weight Rating (lb)	63,880[b]	63,880	66,000	66,000	inp	68,000	66,000	66,000
Propulsion Options[c]	D, N	D, N, H	D, N, H	D, N, H	D & F	D, N, H	D, N, H	D, N, H
Powered Axle (two or three)	3	3	3	3	2	3	3	3

Source: Manufacturer survey responses and Reference 24.
[a]BRT models have body streamlining features.
[b]Both the DE60LF and the DE60LFR were reported to have the same technical description information.
[c]Propulsion codes: D = diesel, N = natural gas, H = hybrid (either diesel or gasoline), and F = fuel cell.
Manufacturer codes: NF = New Flyer, NABI = North American Bus Industries, NB = Nova Bus, VH = Van Hool.
inp = Information was not provided or available in literature

TABLE 34
TECHNICAL DESCRIPTION OF HIGHER CAPACITY BUSES (Double-deck and 45-ft models)

Technical Description	Double-Deck Models			45-ft Models			
	AD E500	AD E500i 42’	AD E500H	DC S417	MCI D4500	NABI Exp 4500	VH C2045
Length, Not Including Bumpers (ft)	40	42	42	45	45	45	45
Width, Not Including Mirrors (in.)	102	102	102	102	102	102	102
Height (in.)	168	168	168	144	138	143	138
Approach Angle (deg)	8	8	8	inp	9.8	9	inp
Departure Angle (deg)	9	8	8	inp	8.3	10	inp
Breakover Angle (deg)	8	7	7	inp	5[a]	8	inp
Turning Radius, Outside (ft)	39	41	41	40	47	43	40.3
No. of Passenger Doors	2	2	2	1	1	1	1
Option for Passenger Doors on Left Side	no	no	no	no	no	no	no
Entrance/Exit Height at Doors (in.)	13.4/12.5[b]	inp	inp	6[c]	15.6[b]	16[b]	inp
No. Steps to Enter/Exit	1	1	1	6	4[b]	4	inp
Wheelchair Equipment (lift or ramp)	R	R	R	L	L	L	L
Lift/Ramp Door Locations	2	2	2	rear	center	rear	center/rear
Maximum Number of Seats	81	89	79	58	57	53–57[d]	57–65[d]
Maximum Number of Standees	10	2	15	0	a	inp	inp
Gross Vehicle Weight Rating (lb)	52,000	52,000	52,000	50,516	48,000	52,000	50,700
Propulsion Options[e]	D	D	H	D	D, H	D	D

Source: Manufacturer survey responses and References 25 and 26.
[a]Respondent stated that standees vary by state regulations.
[b]Information obtained from Altoona test reports for model.
[c]Kneeled.
[d]Number varied depending on seating selected.
[e]Propulsion codes: D = diesel, N = natural gas, H = hybrid (either diesel or gasoline), and F = fuel cell.
Manufacturer codes: AD = Alexander Dennis; DC = DaimlerChrysler Commercial Buses, NA; MCI = Motor Coach Industries, NABI = North American Bus Industries, VH = Van Hool.
inp. = information not provided.

TABLE 35
TESTING RESULTS OF HC BUSES COMPARED WITH 40-FT BUSES
(All buses—Diesel propulsion)

Test Speeds (mph)	Articulated	Double-Deck	45-ft Inter-City Coach	40-ft
	Average Times to Reach Test Speeds, in seconds (percent difference of time—HC bus compared with 40-ft bus)			
10	4.7 (–6%)	6.2 (24%)	4.0 (–20%)	5.0
20	9.1 (5%)	10.4 (20%)	7.4 (–8%)	8.7
30	14.8 (11%)	16.4 (23%)	11.6 (–13%)	13.3
40	24.7 (18%)	25.8 (23%)	17.6 (–11%)	21.0
50	43.3 (30%)	43.6 (31%)	27.1 (–18%)	33.2
	Average Calculated Sustainable Grade at Test Speeds, in percent (percent difference of sustainable grade—HC bus compared with 40-ft bus)			
10	10.8 (–4%)	9.2 (–18%)	13.0 (16%)	11.2
40	3.9 (–23%)	3.8 (–28%)	6.5 (23%)	5.3
Test Cycle[a]	Average Fuel Economy for Test Cycle, in mpg (percent difference of mpg—HC bus compared with 40-ft bus)			
CBD	2.4 (–31%)	2.3 (–34%)	2.5 (–28%)	3.5
Arterial	2.9 (–29%)	2.6 (–36%)	3.0 (–27%)	4.1
Commuter	5.3 (–27%)	4.6 (–37%)	5.9 (–19%)	7.3
Overall	3.0 (–30%)	2.8 (–35%)	3.2 (–26%)	4.3

Source: References 24–27.
[a]Reference 28, Section 5.12(20) Design Operating Profile.

articulated buses, namely acceleration capability and fuel economy. All tests were conducted at seated load weight. The hybrid articulated bus test weight was 49,880 lb. The average seated load weight of the five diesel/CNG articulated buses was 51,288 lb. Although the hybrid articulated bus was lighter by approximately 3% (1,400 lb), which undoubtedly helped its performance, buses equipped with hybrid technology could provide significant improvement in acceleration and fuel economy performance compared with similar buses equipped with conventional internal combustion engines.

Another comment received was that the articulated buses could not operate all day on a single tank of fuel. The hybrid articulated was equipped with a 167-gallon fuel tank. That size tank would provide a range capability of 718 miles, assuming the bus was operating on the Design Operating Profile test cycle. The four diesel articulated buses were equipped with fuel tanks with capacity of from 120 to 140 gallons. The calculated ranges would be 360 to 420 miles, again assuming that the buses were operating on the Design Operating Profile test cycle. The lowest fuel economy for the test buses was 2.2 mpg (Central Business District cycle) for a bus equipped with a 140-gallon fuel tank, which results in a computed maximum range of 308 miles. The fuel economy data appear to indicate that articulated buses should be able to operate all day without requiring refueling in most situations. Most certainly, the hybrid articulated bus that was tested had the capability of operating all day.

Operating Performance Comparison of King County Metro Transit Fleets

Over the years, Metro Transit has tested its different motor bus fleets for acceleration and grade climbing capability. Of particular interest in recent tests was evaluating the capability of its new hybrid articulated buses. In Table 37, the times to reach various speeds for various grades are presented for the articulated and 40-ft fleets. All buses were tested at 130% of seated load weight, with the air-conditioning system off. The test grades are typical of Metro Transit's hilly routes. The test weight of the bus is also given in this table.

The Metro Transit test results clearly show the improvement in performance with the hybrid technology. The diesel–electric hybrid articulated bus was the only articulated sub-fleet that met all of Metro Transit's performance specifications. On a level road the diesel–electric hybrid was nearly as quick as the much lighter weight 40-ft bus, which should facilitate interchangeability when assigning buses to routes.

The articulated buses of the 2800 fleet are identical to the buses in the 2600 fleet (hybrid) except for the propulsion

TABLE 36
ALTOONA BUS TESTING RESULTS: DIESEL VERSUS HYBRID PROPULSION TECHNOLOGY

Test Speeds (mph)	Test Results: Diesel/CNG	Test Results: Hybrid	Hybrid Articulated Compared with Diesel/CNG Articulated (in percent difference)
	Calculated Times to Speeds (in seconds)		
10	4.0	3.8	5% better
20	9.1	8.6	5% better
30	15.9	14.7	8% better
40	25.9	23.1	11% better
50	42.3	35.2	17% better
	Calculated Sustainable Grade at Test Speed		
10	10.8%	10.8%	same
40	3.7%	4.6%	24 % better
	Calculated Acceleration, (in ft/s/s)		
1	4.1	4.1	same
5	3.7	3.8	3% better
10	3.3	3.5	6% better
15	2.9	3.1	7% better
20	2.5	2.7	9% better
	Fuel Economy for Test Cycle (in mpg[a])		
Test Cycle[b]			
CBD	2.4	3.7	54% better
Arterial	2.9	4.2	45% better
Commuter	5.3	6.6	25% better
Overall	3.0	4.4	47% better

Source: References 24 and 27.
[a]Fuel economy data are the average of four diesel articulated buses.
[b]Reference 28, Section 5.12(20) Design Operating Profile.

technology. When comparing the test performance between these two fleets, the improvement with the hybrid technology is as follows:

- 0–20 Level Road Test—hybrid is 13% better.
- 0–45 Level Road Test—hybrid is 15% better.
- 0–20 5% Grade Test—hybrid is 17% better.
- 0–10 9% Grade Test—hybrid is 6% better.
- Highest Maintainable Speed on 5% Grade Test— hybrid is 1% better.

To make use of the low emissions of hybrid technology, the hybrid articulated buses will replace the dual-propulsion articulated buses that were used for routes servicing the downtown tunnel. In the tunnel, the hybrid articulated buses are operated using a special computer program that limits

TABLE 37
PERFORMANCE TEST COMPARISONS OF KING COUNTY METRO TRANSIT FLEETS

Test	40-ft	Articulated Buses: Diesel HF	Diesel DM	Diesel LF	Hybrid LF	Metro Spec.
Metro Fleet Identification	3200	2300	5000	2800	2600	
Test Weight (lb)	39,050	56,560	65,550	56,118	57,753	130% SLW
Passenger Seats	42	64	58	58	58	
0–20 mph—Level Road (sec)	7.91	9.74	9.84	9.09	7.94	9
0–45 mph—Level Road (sec)	30.61	38.32	46.28	40.12	34.10	36
0–20 mph—5% Grade (sec)	11.86	21.65	18.13	15.76	13.05	14
0–10 mph—9% Grade (sec)	5.39	6.32	7.83	6.43	6.02	9
Highest Maintainable Speed on 5% Grade (mph)	Pass	Pass	N/A	43.4	43.1	43

Notes: SLW = seated load weight, mph = miles per hour, HF = high floor, LF = low floor, DM = dual mode, N/A = not available.
Source: King County Metro Transit.

horsepower to approximately 100. This is enough power to operate the bus electrical loads and run in the tunnel using the battery. In the 1.3 miles inside the tunnel, the fuel consumed is about 1.5 cups, and there are essentially no emissions and no odor (J. Boon, King County Metro Transit, personal communication, March 4, 2007).

Internal Sound Levels for Higher Capacity Buses

Internal sound levels are a growing concern for the transit industry in general. Data from the noise tests conducted at ABTC were reviewed to obtain data on the performance of HC and 40-ft buses. All tests are conducted with the bus at seated load weight. Two internal sound level tests are conducted.

1. With doors and windows closed and the engine and all accessories off, the external surface of the left side of the bus is exposed to a 80 decibel [dB(A)] uniform pressure level using a white noise generator. The noise transmitted to the interior is measured at six locations, five in the center aisle at 48 inches in height (nominal ear height of seated passenger) and one at the driver seat at ear height.
2. With all openings closed and all accessories on, the bus is accelerated at full throttle from zero to 35 mph. The internal sound levels are measured at four locations in the center aisle at 48 inches in height.

The sound levels are measured on a logarithmic scale, and some example perceptions of the change of sound levels are listed here:

- A 1-db(A) change is an imperceptible change,
- A 3-db(A) change is barely perceptible, and
- A 10-db(A) increase is perceived as twice as loud.

To place a sound level in perspective, a 40 dB(A) sound level would be similar to that of a quiet library or home (*29*).

Internal noise test data for 10 HC buses are given in Table 38. Data for the average of four 40-ft diesel buses are also included for comparison purposes.

As shown in the table, the passenger compartments of the 45-ft intercity and the double-deck buses are considerably quieter than the other bus types. The elevation from the roadway and engine would tend to make the upper deck of the double-deck and the 45-ft intercity buses quieter.

A LOOK AT THE FUTURE

Some hints of changes in HC vehicle technologies are beginning to emerge. The change to a hybrid propulsion technology appears to be increasingly accepted. The significant improvement in vehicle performance (acceleration and gradability), along with improved fuel economy make hybrid propulsion increasingly attractive, in spite of the higher initial capital costs. Transit agencies in Europe are increasingly using 15-m buses for their intercity and regional routes because of the higher seat capacities and improved operator productivity. Figure 27 shows a low-floor 15-m bus operating in Zeven, Germany.

There are a few transit agencies in Europe and South America that are using double (or bi) articulated buses that provide very high capacities. These 24-m vehicles usually operate in bus lanes or exclusive busways. Recent French INRETS (Institut National de Recherche sur les Transports et leur Sécurité) research on super-high capacity buses was presented at a 2006 BRT conference in France (*30*). Bordeaux, in France, operated a line with 10 megabuses from 1988 to 2004, when they were replaced by light-rail transit (LRT). There have been high-floor bi-articulated buses in operation in Curitiba and Sao Paolo since 1992, and there are bi-articulated buses either in operation, or planned, in Utrecht (The Netherlands), Aachen, Wuppertal, Goteborg, and Hamburg (Germany). The Wuppertal bus is shown in Figure 28.

A recent U.S. innovation of attempting to produce lighter-weight transit buses using composite technology was not a

TABLE 38
INTERNAL AND EXTERNAL NOISE TEST DATA FOR HC BUSES

	Interior Sound Levels in dB(A)				APTA Guidelines	
	80 dB(A) External Noise Source		0 to 35 Acceleration		80 dB(A) Test	0–35 Test
Bus Type	Average	Peak	Average	Peak	Less than	Less Than
Articulated—Diesel[a]	57.0[a]	64.6	75.7[a]	86.6	65	83
Articulated—Hybrid D/E	54.2	58.7	79.2	82.2	65	83
Double-Deck—Diesel						
Lower Deck	44.6	45.5	76.4	77.5	65	83
Upper Deck	40.4	41.4	64.4	66.6	65	83
45-ft Intercity—Diesel[b]	39.0[b]	46.3	69.9[b]	79.6	65	83
45-ft Compo—CNG	50.8	55.9	76.6	79.9	65	83
40-ft—Diesel[c]	52.0[c]	63.2	77.1[c]	83.2	65	83

D/E = diesel/electric; CNG = compressed natural gas.
Source: References 24–27.
[a]The average measurements are for the average of four articulated buses.
[b]The average measurements are for the average of three 45-ft intercity coaches.
[c]The average measurements are for the average of four 40-ft buses.

FIGURE 27 A 15-m low-floor EVB Linenbuse.

FIGURE 28 Wuppertal, Germany, 24-m bi-articulated bus. [*Source*: Soulas (*30*)].

marketing success. One composite model was an HC bus, the 45C-LFW, which has a maximum capacity of 47 seats. The concept was to take advantage of the lighter body weight (estimated at 7,000 lb) to design a longer-body, low-floor two-axle bus and recapture seats that had been lost with the low-floor design that could be powered by CNG. A two-part article in *Metro Magazine* provides some insight into the business and regulatory issues that contributed to the demise of the innovation (*31*). Fleets of the 45C-LFW are currently operating at three transit agencies.

CAPITAL COSTS OF HIGHER CAPACITY BUSES

Fifty-one percent of the survey respondents cited capital cost of an HC bus as a major concern or issue. To explore this issue further, the *APTA 2006 Transit Vehicle Database* (*13*) was reviewed for cost data on recent purchases of HC buses. Fourteen transit agencies reported on their purchases of 428 HC buses (all types) in 2005 and 2006, and a summary of the reported cost data is presented in Table 39. Because many of the bus-type combinations involve only a few procurements, which can result in a wide variation in cost-per-seat data, the number of agencies involved is provided along with the total number of buses purchased.

Because the propulsion technology used is a significant cost factor, the data are presented by propulsion technologies. The number of seats on a bus model can vary significantly, and has a direct impact on the bus capital cost-per-seat metric. The maximum number of seats is affected by bus design (standard versus low-floor models), and the actual number is determined by the seating arrangements chosen by the transit system. The impact of the number of seats can be observed from the data in Table 39. A summary comparison of HC and 40-ft buses using similar technologies and bus designs is given in Table 40.

TABLE 39
CAPITAL COSTS OF RECENTLY PURCHASED HC BUSES

HC Bus Type	Propulsion	No. of Buses (agencies)	Cost Range	Seats per Bus	Cost per Seat Range
Articulated	Diesel	76 (4)	$435,693–$508,976	43–61	$7,142–$10,995
Articulated[a]	Diesel	40 (2)	$476,411–$498,000	63–68	$7,324–$7,562
Articulated[b]	CNG	200 (1)	$644,000	57	$11,298
Articulated	Diesel/Electric	12 (1)	$650,000	57	$11,404
Double-Deck	Diesel	50 (1)	$583,963	80	$7,300
45-ft[c]	Diesel	50 (5)	$422,156–$496,257	57	$7,406–$8,706
40-ft Bus Type	**Propulsion**	**No. of Buses (agencies)**	**Average Costs**	**Seats per Bus (average)**	**Average Cost per Seat**
40-ft	Diesel	1,635 (45)	$339,023	38.9	$8,715
40-ft[a]	Diesel	28 (4)	$298,699	38.7	$7,718
40-ft	CNG	354 (6)	$363,033	40.3	$9,008
40-ft	Diesel/Electric	128 (10)	$456,674	38.5	$11,862

Source: Reference 13.
[a]Standard floor vehicles.
[b]BRT vehicle with special features.
[c]Standard high-deck intercity coaches.

TABLE 40
COMPARISON OF HC VERSUS 40-FT CAPITAL COST FOR SIMILAR TECHNOLOGIES

HC Type vs. 40-ft Comparison (floor height and propulsion—for both)	Capital Cost Percent Difference HC Compared with Average 40-ft (in percent)	
	On bus basis	On seat basis
Articulated vs. 40-ft (LF and diesel)	28% to 50%	17% to 26%
Articulated vs. 40-ft (HF and diesel)	59% to 68%	–2% to –5%
Articulated vs. 40-ft (LF and CNG)[a]	77%	25%
Articulated vs. 40-ft (LF and diesel/electric)	42%	–4%
Double-Deck vs. 40-ft (LF and diesel)	72%	–16%

LF = low floor, HF = high floor, CNG = compressed natural gas.
[a]Articulated CNG bus had BRT features and the 40-ft buses did not.

The cost of all types of HC buses is much more attractive when examined on a cost-per-seat basis. The most dramatic difference using a cost-per-seat basis rather than a cost-per-vehicle basis is for the double-deck bus, and all articulated models exhibited significant improvement. It is also apparent that the propulsion technologies used and the options chosen (i.e., BRT features and passenger amenities) have major impacts on capital costs.

CHAPTER FIVE

EXPERIENCES WITH HIGHER CAPACITY BUSES

WHY AND WHERE ARE THEY USED (DRIVING FACTORS IN DECISIONS)?

Higher capacity buses are used in a variety of applications, as was discussed in chapter two, but certain patterns are apparent, depending on the type of HC bus being considered:

- Articulated buses are predominantly deployed in all-day heavy-demand trunk (or BRT) services, but are also used to a lesser extent in various other types of services, including peak-only service on trunk routes, commuter express services to park-and-ride lots, trippers that experience overloads, replacement service for rail shutdowns, and high-demand special events.
- Only three systems have deployed double-deck buses (although several others are planning to), and deployment has been for long-distance commuter express services (e.g., Victoria Regional Transit), and also on heavy-demand trunk routes (e.g., Las Vegas and Victoria).
- Forty-five-foot intercity coaches are the most focused in their application, because they are overwhelmingly used in long-distance express commuter services. They are occasionally also used to serve special high-demand sports events or in emergencies. Phoenix Transit uses its 45-ft Compo buses for BRT express service. GO Transit (Orlando, Florida) also uses 45-ft coaches for their suburban circumferential BRT service; however, this is an unusual configuration for BRT, because it is almost entirely used along expressways, and stop distance is much greater than is typical for BRT service.
- Some respondents mentioned that HC buses were being used to increase ridership along a future rail corridor (LRT or commuter rail).

EXPERIENCE WITH HIGHER CAPACITY BUSES

Overall Findings with Respect to Higher Capacity Buses

In terms of experience, two general conclusions can be made from the synthesis findings. First, there is no evidence that ridership is directly affected by the introduction of HC buses. Respondents were evenly divided between those who thought that measurable ridership increases could be attributed to the introduction of HC buses and those who did not. Where ridership increases were apparent, it appeared to be more of a result of other factors than the mere increase in capacity, including an increase in the level of service through the introduction of a BRT, introduction of attractive new transit pass programs (e.g., university U-Pass programs), and enhancement of customer amenities on vehicles (although there remains little understanding of how this affects ridership behavior).

The second general finding is that experience with HC buses has generally been positive, with some variation by type of vehicle. The overall positive experience is evident from various indicators:

- Respondents reported overwhelmingly that HC buses had met their expectations.
- Respondents rated their experience with HC buses as very good (59% to 71%).
- Agency-reported customer acceptance was noted as being positive (64% to 79% ranked customer experience as very good).
- Agency-reported operator acceptance was noted as being positive (64% to 79% ranked operator experience as very good).
- In terms of vehicle performance, survey respondents ranked the performance of 45-ft and double-deck buses as the same or better than that of their standard buses.
- Spare ratios for all HC buses were the same or lower than for standard buses.

The most common area of concern for all transit systems with HC buses was the capital cost of the vehicle, ranked as the most, or second most, significant concern by approximately one-third of survey respondents. No other single issue was significant across all HC buses.

Experience and Issues Related to Specific Vehicle Types

A number of vehicle-specific areas of concern were mentioned for the various types of buses.

Forty-Five-Foot Buses

In general, 45-ft buses ranked high in performance, ride quality and comfort, amenities, and respondent experience, but suffered in four specific areas:

- A majority of respondents mentioned that the turning maneuverability of 45-ft buses was poorer than that of the standard bus. This is explained by the longer wheelbase of the vehicle, which increases ride comfort, but constrains its use on routes with tight turns.
- Several respondents mentioned that the wheelchair lift and securement system was a considerable constraint because of the disruption it caused and the time required for operation; at least one respondent mentioned that they would avoid using 45-ft buses on routes with regular wheelchair patrons.
- Several respondents mentioned that the steep steps and the narrow aisle were a limitation for some customers.
- The dwell time of 45-ft buses at stops, caused by passengers boarding up the steep stairs, can have a repercussion on the dwell time of other buses sharing the same stop or bus bay, and becomes even more pronounced if wheelchair passengers need to board or exit the bus.

Double-Deck Bus

The double-deck bus ranked high with respect to seat capacity, turning maneuverability, and attractiveness of the vehicle to both customers and operators; the upper deck in particular is very popular because of the view it offers and the quietness of the ride. Issues of concern included:

- Winter operation (although that has now been mitigated by the addition of a control to temporarily decrease the load on the tag axle).
- Passenger movement in the tight stairwell and related potential for safety concerns (although no negative experience was actually reported).
- Dwell time (Las Vegas has opted to acquire a bus with two stairwells to improve passenger interior flow).

Interestingly, none of the respondents operating double-deck buses viewed the infrastructure modification cost as significant.

Articulated Buses

Respondents with articulated buses were much more divided in their opinions concerning experience with the vehicle. The only area where a majority of respondents believed that the articulated bus was superior in performance to standard buses concerned turning maneuverability. This finding is not surprising because of the shorter wheelbase of the front section of the articulated bus.

However, more than half of respondents perceived that the performance of articulated buses was less than that of standard 40-ft buses, in three areas in particular:

- Fuel economy,
- Grade climbing, and
- Acceleration.

Historically, acceleration, caused by underpowered engines, appears to be a common problem in articulated buses. One possible explanation may be the inability to fit a larger engine in the engine compartment. Although the problem appears to have been significant with older articulated bus models, and may be eliminated in the future through the deployment of hybrid articulated buses (discussed in chapter four), it was a commonly reported area of concern. One respondent mentioned that the poor acceleration resulted in different running times than for a standard bus in the same corridor.

In addition to the above-mentioned issues related to the HC vehicles, only those operating articulated buses cited maintenance costs as a major issue or concern (12 of 23, or 52%), and a somewhat smaller percentage (10 of 23, or 43%) reported articulated bus reliability to be lower than their 40-ft buses. On a vehicle basis, articulated buses have more components to fail and repair (an extra axle; additional tires, brakes, and doors; the articulated joint; etc.); therefore, those survey responses may be in question. However, none of the other HC vehicle types (except the 45-ft Compo bus) reported poorer reliability or maintenance costs as an issue or concern.

King County Metro Transit Maintenance Experience with Articulated Buses

To explore the issue of articulated bus maintenance cost in more detail, the experience of King Country Metro was examined. King County Metro in Seattle, Washington, was a member of the original Super-Bus Consortium and has operated articulated buses since 1978. Over the years, it has operated a wide range of articulated buses, including dual-mode articulated buses and most recently a significant fleet of diesel–electric hybrid articulated buses.

Approximately one-half of Metro Transit's active fleet is articulated vehicles and as of January 2007 Metro Transit had 517 articulated motor buses in revenue service as shown in Table 41. Composition of the Metro Transit 40-ft sub-fleet is shown in Table 42.

Metro Transit uses approximately 57% of the motor bus articulated buses for its CORE service, 35% for Express service, and 8% for other high ridership routes (mixed articulated and 40-ft service). The 40-ft buses are used primarily on the CORE service routes; however, some are used on lower

TABLE 41
KING COUNTY METRO TRANSIT ARTICULATED BUS SUB-FLEET

Fleet ID	Model	Propulsion	Year	No.
2600	DE60LF	Diesel–electric hybrid	2004	214[a]
2800	D60LF	Diesel	2004	30
2300	D60HF	Diesel	1998–2000	273

[a]Includes the prototype bus.

TABLE 42
KING COUNTY METRO TRANSIT 40-FT BUS SUB-FLEET

Fleet ID	Model	Propulsion	Year	No.
3600	D40LF	Diesel	2003	100
9000	Phantom 40	Diesel	1999	6
3200	Phantom 40	Diesel	1997	210

ridership Express routes. The average age for the articulated fleet buses is 5.5 years and for the 40-ft fleet buses 8.1 years.

Maintenance data for 2006 were obtained for both the articulated and 40-ft fleets. The annual miles traveled per bus ranges from 35,000 to 37,000 (see Table 43).

The loss of passenger seats when changing from standard floor to low-floor bus design is apparent in Table 43. For the seating arrangement chosen by Metro Transit, one low-floor articulated bus is equal to approximately 1.6 low-floor 40-ft buses on a passenger seat basis. Comparing the standard floor models, the factor would be 1.5. The weighted average for all sub-fleets is one articulated bus is equal to 1.57 40-ft buses on a seat basis. If one applies those factors to the operational data in Table 43, an operational cost on a passenger seat basis is obtained and the results are given in Table 44.

On a seat-mile basis, the articulated fleets are less costly than the 40-ft fleets in both maintenance costs and fuel. Any comparisons of the road call experience is complicated because the average age of the total articulated fleet is approximately 2.5 years less than the total 40-ft fleet.

The National Renewable Energy Laboratory (NREL) using Metro Transit's newest low-floor articulated buses, conducted a recent evaluation of hybrid technology (*32*). The buses were identical except for the propulsion system; the test fleet was made up of 20 hybrid articulated buses and the control fleet 20 diesel articulated buses. The test period was 12 months, and the service routes and vehicle-miles of the test and control fleets were similar. A summary of the evaluation results is given in Table 45.

The evaluation results show a significant improvement in fuel cost (17 cents per mile) with only a small increase in the maintenance cost of the hybrid propulsion system (1 cent per mile) when compared with the diesel control fleet.

These findings, in combination with the findings in chapter four, indicate that hybrid propulsion technologies offer a promising approach to overcoming some of the concerns expressed with respect to articulated buses, in particular, with respect to the issues of acceleration and fuel economy in frequent stop-and-go types of operations.

SAFETY ISSUES

Safety Considerations Related to Higher Capacity Buses

The operation of HC buses does not appear to create significant safety concerns. However, two considerations related to safety were identified. The first concerned double-deck buses and the potential safety concern created by the interior

TABLE 43
KING COUNTY METRO TRANSIT OPERATIONAL DATA FOR ARTICULATED AND 40-FT BUS SUB-FLEETS

Fleet ID	Propulsion	Seats	Maintenance Cost ($/vehicle-mile)	Miles Between Road Calls	Fuel Economy (mpg)
2600—Articulated	Hybrid	58	0.7103	5,628	3.5
2800—Articulated	Diesel	58	0.7198	4,424	2.4
2300—Articulated	Diesel	64	0.8352	4,123	3.4
Weighted Average		61.2	0.7768	4,763	3.4
3600—40-ft	Diesel	35	0.5846	5,069	4.1
9000—40-ft	Diesel	42	0.3829	9,552	5.1
3200—40-ft	Diesel	42	0.6000	6,494	4.5
Weighted Average		38.9	0.5775	7,539	4.5

Source: King County Metro Transit.

TABLE 44
OPERATIONAL DATA COMPARED ON A SEAT-MILE BASIS FOR METRO TRANSIT SUB-FLEETS

Fleet ID	Propulsion	Seats	Maintenance Cost ($/seat-mile)	Seat-Miles Between Road Calls	Fuel Economy (seat-miles/gal.)
2600—Articulated	Hybrid	58	0.0122		203
2800—Articulated	Diesel	58	0.0124		139
2300—Articulated	Diesel	64	0.0130		218
Weighted Average		61.2	0.0126	7,478	207
3600—40-ft	Diesel	35	0.0167		143
9000—40-ft	Diesel	42	0.0091		214
3200—40-ft	Diesel	42	0.0143		189
Weighted Average		38.9	0.0142	7,539	182

TABLE 45
SUMMARY OF EVALUATION RESULTS OF METRO TRANSIT'S HYBRID AND DIESEL ARTICULATED BUSES

Evaluation Item	Diesel Ryerson Base	Hybrid Atlantic Base	Difference Hybrid vs. Diesel
Monthly Average Miles per Bus	2,949	3,096	+5%
Fuel Economy (mpg)	2.50	3.17	+27%
Fuel Cost per Mile ($): Diesel at $1.98/gal.	0.79	0.62	–22%
Total Maintenance Cost per Mile ($)	0.46	0.44	–4%
Propulsion—Only Maintenance Costs per Mile ($)	0.12	0.13	+8%
Total Operating Cost per Mile ($)	1.25	1.06	–15%
Miles Between All Road Calls	5,896	4,954	–16%
Miles Between Propulsion Road Calls	12,199	10,616	–13%

Source: Reference 32.

stairwell. The interior design has focused special attention to stanchions and hand holds, and a restriction has been established that prohibits standees on the upper deck. Interviews with staff at BC Transit indicated that there had been no serious accidents as a result of the interior stairwell.

The second issue mentioned by survey respondents related to articulated buses: the left rear corner of some articulated buses may swing out when turning corners or departing from bus bays, which may cause accidents. This problem was more common in the past with "puller-type" articulated buses. An incursion of the right side of the second section can occur with "pusher-type" articulated buses. The major difference between these problems is that the operator can observe the right side incursion; however, the operator cannot observe the left rear corner excursion. Performing safe turns at intersections is a concern for all types of buses.

To communicate to motorists and pedestrians that a bus is about to turn, the Champaign–Urbana MTD has installed strobe lights on the sides of its buses (two on 40-ft and three on articulated) that flash when the turn signals are activated. An audio signal (beeping) is activated when the bus is making a right turn to warn pedestrians of the maneuver.

One respondent expressed concern about the safety of passengers using the third or fourth door of an articulated bus, and how difficult it is for operators to observe passengers in those doors. This respondent is investigating the use of different mirrors and the possible use of an ultrasonic sensor on those doors.

One interesting issue concerns winter conditions (snow). A little more than one-third of agencies reported some level of concern with winter operations with their articulated fleets. Only one rated this as their highest major concern. The Denver RTD routinely equips its articulated fleet with snow tires on the drive axle, and reports no special problems with operating in snow conditions. Anecdotal evidence suggests that jackknifing of articulated buses can still occur; however, it does not appear to be a serious concern for many.

King County Metro Transit Safety Experience with Articulated Buses

To better understand any potential concerns with articulated buses, safety statistics were obtained from Metro Transit for motor bus collisions for 2005. There were four bus groups: articulated buses (573), 40-ft buses (568), trolleybuses (161), and small buses (130). The collision statistics for the articulated and 40-ft fleets are given in Table 46.

The articulated and 40-ft fleets operate in similar traffic environments and have similar mileage. The percentages of collisions are consistent with the percentages of the total fleet. There is no significant difference in the average cost per collision for the two fleets. The Metro Transit safety staff concluded that the collision safety record of the articulated buses is similar to that of the 40-ft buses. There does not appear to be any difference in risk between the two fleets based on collision statistics.

INFRASTRUCTURE ISSUES

The costs of modifications were not identified by respondents as a significant area of concern, and the monetary value of the modifications appeared relatively modest, certainly in comparison with the capital cost of the vehicles themselves.

TABLE 46
COLLISION STATISTICS FOR ARTICULATED AND 40-FT MOTOR BUSES IN 2005

Fleet Type	No. of Collisions	Percent of All Collisions	No. of Buses	Percent of Total Fleet	Total Cost of All Collisions	Average Cost per Collision
Articulated	684	39.09	573	40.00	$281,257	$411
40-ft	700	40.00	568	39.66	$296,027	$423

Source: King County Metro Transit.

The survey discussion in chapter two identified a number of infrastructure modifications that may need to be carried out to deploy HC buses.

With respect to 45-ft intercity coaches, the location of the wheelchair lift toward the mid-section or rear of the bus may require the modification of concrete pads at bus stops. This modification would be applicable for any bus with a lift or ramp in a location other than the first door.

The length of articulated buses may lead to a number of potential modifications to stops in terms of removed parking spots or lengthened concrete pads (depending on whether the bus has a third door). Articulated buses may also require modifications to maintenance pits and hoists, paint booths, wash facilities, location of air hoses, striping of parking areas, etc. However, survey respondents did not identify these modifications as particularly onerous.

In many cases, deployment of the articulated buses had been contemplated well in advance of the actual acquisition of the buses and had been incorporated into the design requirements of garage facilities. For example, the Champaign–Urbana MTD had designed their garage to have storage rows that were 240 ft in length, which allowed them to store six 40-ft buses or four 60-ft articulated buses. Long-term planning for HC buses that can be incorporated into maintenance facility design greatly reduces the requirement for retrofits to maintenance and storage facilities.

With respect to double-deck buses, the vehicle's height is the obvious factor in possibly requiring infrastructure modifications, which might lead to modifications of garage doors, maintenance bays, paint booths, bus wash equipment, service islands, etc. It will also require the acquisition of a work platform to access the roof for maintenance.

The height clearance of the double-deck bus along planned routes will need to be carefully assessed, as will clearance for adjacent power poles, in particular where there is pronounced crowning of the roadway. However, the Victoria case study indicates that this can be achieved simply and did not involve many modifications.

As discussed in the Victoria case study, the smaller turning radius of the double-deck bus may also require relocation of street furniture at stops because of the vehicle's overhang sweep.

LEGISLATIVE AND REGULATORY IMPEDIMENTS

Survey respondents did not identify regulatory limitations as a significant issue, although some references were made to the limitations created by the regulations for double-deck buses (height and weight) and articulated buses (length).

To assess this issue in more detail, regulations on vehicle size and weight were reviewed, and the findings are detailed in Appendix C.

The latest configuration of the double-deck bus measures 14 ft in height and the articulated bus models are 60 to 65 ft in length. The review of state and provincial regulations indicates that the double-deck buses meet the height limits of 21 states, and the 60-ft articulated buses meet the length limits of 17 states. Exemption certificates may be needed in the other states and in all Canadian provinces, as was done in Victoria and Kelowna, British Columbia.

The federal regulation on weight (CFR 658.17 Weight) was changed in February 2007 to extend the exception for buses of a single axle limit of 24,000 lb on the NN until October 2009. The tandem axle limit remains at 34,000 lb.

OTHER OPERATIONAL ISSUES

Labor Issues

There were no labor issues of significance related to the operation of HC buses. The survey found that 97% of transit agencies do not pay operators of HC buses a different wage rate.

In terms of training, little special training is provided for operating HC buses. Some transit agencies provide operators with training concerning the tag axle on 45-ft intercity coaches. Others provide in-vehicle training for operators to become familiar with the driving of an HC bus; an example was the Denver RTD, which has two underground terminals in the downtown area that are very busy with articulated and 45-ft buses. The training is essentially practice to become familiar with the set up and turning queues necessary to negotiate the circular path and docking properly in the bay.

Scheduling

The survey found that less than one-third of respondents dedicate their HC buses to specific routes, whereas more than two-thirds mix HC and standard operations along single routes. Mixed operations can however take many forms:

- Trunk service operated by HC buses, with added trips at the peak provided by standard buses (or vice versa).
- BRT or limited stop service operated along a corridor using HC buses, with local service operated along the same corridor with standard buses (or vice versa).
- Mixed operation along a route resulting from an inadequate number of HC buses, etc.

If a route is built specifically for HC buses, then specifying HC buses at the block level can be handled by most scheduling packages. This is also the situation if the different services in a given corridor (e.g., BRT and local) are treated, and blocked, separately. From a scheduling perspective, express services are often treated as a separate system altogether, which allows optimization while ensuring use of dedicated intercity coaches. However, to fully mix HC and standard buses into a given route schedule requires working at the "trip" (rather than "block") level, and this in turn requires a special-purpose optimization module for vehicle blocking, as well as considerable on-street supervision (J. Pappas, personal communication, Feb. 14, 2007). One transit agency reported trying to manage the headways of different capacity vehicles on the same route, based on the individual capacity of the vehicles, but abandoned this approach. One-third of the systems using mixed operations made no attempt to deploy the HC buses based on demand.

Beyond routes that are dedicated (and blocked) for HC buses, many respondents indicated that their HC buses were used to address specific overload situations, such as school trips. There are two approaches. In the first approach, a transit agency may simply deploy HC buses to the entire route experiencing the overload situation. This ensures that the overload trip is accommodated, but may provide excess capacity for the rest of the block, and might be viewed as an underutilization of the capacity of the HC bus. This may occur because the agency does not have the internal scheduling expertise or tools, or because it is easier to obtain "capital" funding to acquire HC buses than the "operational" funding required to add trippers for individual overload situations.

The second approach would require working at the trip level, and might involve the use of interlining if minimizing peak bus requirements was an agency objective.

OC Transpo in Ottawa is one agency that traditionally has had an aggressive objective of using the scheduling system to minimize peak bus requirements through the use of interlining, and this applies as well to their articulated buses (J. Koffman, OC Transpo, personal communication, Feb. 11, 2007). Of OC Transpo's approximately 160 articulated buses available on a daily basis, about 85% (135) of these buses are required for base service and are blocked for routes designed for articulated buses (i.e., transitway core routes and a small number of trunk arterial routes). The remaining 25 or so articulated buses are available for interlining.

The objective is to maximize the efficient use of the articulated buses by stringing together as many individual trips that have heavy demand, while minimizing the overall number of peak buses required. Having extensive data is an important ingredient for schedule optimization. For example, OC Transpo has been using a very sophisticated APC system for more than two decades. Its APC system provides them with extensive data on passenger loads by trip (to determine where articulated buses would be valuable). It also measures running times for in-service and deadhead trips (which is required for trip-based scheduling and interline optimization).

In addition, to enable the most efficient interline optimization, the transit agency has worked aggressively with local school boards to encourage different school start times and to shift them away from the commuter peak. This cooperation between OC Transpo and the schools has worked very well, and start times of schools now vary considerably (e.g., 8:00 a.m., 9:00 a.m., 9:15 a.m., etc.). This permits considerable efficiency in the interlining of buses; for example, an interlined articulated bus might have a block that links:

- An early school trip starting at 7 a.m., finishing at 7:30 (for a 7:45 school start), to
- An express commuter trip downtown from 7:45 to 8:15 a.m., and to
- Another school trip to arrive for a 9:15 a.m. school start time.

The overall process for interlining buses (including articulated buses) is schematically as follows:

- The Service Planning Department develops a service plan, specifically taking into account HC buses, and the Scheduling Department has the responsibility of implementing the service plan.
- The scheduling system is used to efficiently block the majority of service.
- An interline network is assembled with a variety of trips including express trips, school trips, counterflow trips, industrial park trips, etc.
- Each trip is assigned a vehicle option (40-ft low-floor default, 60-ft, etc.).
- An enhanced vehicle blocker module (Hastus Minibus) is used to optimize the interline network, based on a wide range of cost penalties, with the objective of minimizing the number of buses required to deliver service to the peak interline network.
- The module uses a variety of criteria (expressed as cost penalties) as part of its optimization process; examples include the total number of buses, vehicle-specific designation, layover requirement, and length of block. OC Transpo also allows for trip shifting (i.e., varying the start and end time of a trip by a few minutes) to increase the efficiency of the optimization. Applying cost penalties controls the degree of shifting.
- The process is carried out iteratively, examining each solution proposed by Hastus Minibus, and involves continuous consultation with the Service Planning Department staff to arrive at the best possible compromise

However, as important as the sophistication of the scheduling process is, the day-to-day operational management concerning bus assignments is critical to ensure that the articulated buses actually end up on the designated runs. The best plan for articulated buses will only be as good as its execution. To this purpose, OC Transpo has automated the assignment process to assist the "bus starter" in assigning the right bus to the right run. However, because errors can happen, they manually check the assignments each day to see how each garage performs. When performance begins to fall off, the Fleet Department is notified immediately. The ongoing daily monitoring of the articulated assignments (and other bus type-specific assignments, such as low floor, bike racks, APCs, etc.) is in the process of being automated so that both the Planning and Fleet Departments can immediately identify weaknesses in the chain.

Such a process requires considerable access to data, sophisticated scheduling tools, staff expertise, and management oversight, but enables an optimization process that makes best use of limited resources, such as HC buses and operators, and results in higher efficiency and revenue-cost performance.

Reducing Dwell Time

The use of HC buses increases individual vehicle capacity, which can be used to increase overall route capacity, expressed in passengers per hour. However, the increased number of passengers boarding and alighting will also increase dwell time at stops, which will increase overall running time, and therefore negates the route capacity increase provided by HC buses. Some agencies have therefore sought to reduce dwell time to maximize the benefit derived from the deployment of HC buses. Survey respondents cited the following efforts to reduce boarding and alighting times:

- Specify vehicles with three doors (e.g., Vancouver and Champaign–Urbana MTD) and/or extra-wide doors (44 in.) at Champaign–Urbana MTD.
- Add and/or lengthen concrete pads at bus stops so that all doors can be used to exit.
- Install variable message sign indicating departure time of next bus for BRT routes [e.g., Los Angeles Metro Rapid and York Region Transit Viva (Richmond Hill, Ontario, Canada)] or on heavy demand routes (e.g., Champaign–Urbana MTD); this encourages passengers to prepare themselves in advance of bus arrival at stop.
- Install better signage at stop to reduce questions to operator.
- Specify rear-facing wheelchair position to significantly reduce time required by passenger in wheelchair to position and secure themselves (e.g., Victoria and York Region Transit).
- Move access of wheelchair to second (and wider) door [e.g., AC Transit (Alameda and Contra Costa Counties, California) and York Region Transit].
- Implement wheelchair strap program that enables wheelchair passengers to secure straps more quickly (e.g., AC Transit).
- Include a second stairway for double-deck buses to speed up boarding and alighting (e.g., Las Vegas).
- Address fare collection procedures.

Fare Collection Issues

Significant reduction in the dwell time of HC buses can be achieved through fare collection system initiatives. A first level of effort is to encourage a higher proportion of passengers to use pre-paid media.

- Smart cards allow for more rapid boarding than cash fares or magnetic media: SouthWest Transit (Eden Prairie, Minnesota) found the use of smart cards helped to speed boarding on their 45-ft coaches.
- Day passes sold by ticket vending machines at stops: Las Vegas Regional Transportation Commission sells a 24-h pass for $5.00.
- Existence of a university pass program that enables the operator to open all doors at university stops: I-Card used at Champaign–Urban a MTD.

A second approach is to vary the fare control point based on passenger flows.

- Outbound PM Express and Regional routes pay on exiting.
- Inbound pay on boarding and outbound pay on exiting (e.g., King County Metro Transit); this is sometimes associated with a downtown fare-free zone.

The most efficient fare collection strategy reducing HC bus dwell time is the use of proof of payment (POP) control. In such systems, passengers are responsible for having or purchasing a valid fare title. Fare control is carried out on a random basis by roving fare inspectors. Although this has been in existence a long time on LRT, it has recently become increasingly popular in conjunction with the recent interest and deployment of BRT systems. Its advantage is that it allows operators of LRT or HC buses to open all doors, which minimizes alighting and boarding times.

Two basic approaches have been identified through this research.

The first approach is *POP, with all-door access for pass customers only*. This has been used by OC Transpo since its deployment of articulated buses on the transitway in 1983 (J. Koffman, OC Transpo, personal communication, Feb. 14, 2007). To achieve the maximum efficiency of the three-door articulated buses being used on routes with high levels of off-and-on movement, a POP approach to fare control was instituted. Passengers with monthly or day passes can enter through any door; passengers with tickets or cash need to pass by the operator, deposit their payment into the farebox, and receive a transfer that serves as a POP receipt. It requires no platform fare vending equipment and works well in an environment where an extremely high proportion of passengers use passes. It is used by OC Transpo on all routes with articulated buses, but the operator has the discretion of whether to open the back doors.

The second approach is *POP, with off-board fare collection*. This is the approach that all LRT systems have been using for the last two decades, and has now been adopted by recent BRT systems [e.g., York Region Transit Viva and Lane Transit EmX (Eugene, Oregon)]. It has proven to be a critical component of the York Region Transit Viva system, not only in terms of speeding up passenger movement and reducing dwell time, but also in terms of enhancing the image of the BRT system (D. Roberts, ITrans Consulting, personal communication, Feb. 9, 2007). Every BRT stop or station is equipped with one or more piece of ticket vending and/or validating equipment. Passengers are responsible for having a valid fare title (monthly or day pass), for validating a ticket, or for purchasing a one-ride fare. The receipt serves as their POP. This approach allows for all-door entry for all passengers, removes fare control responsibility from the operator, and reduces dwell time, but also requires a significant capital investment as well as active random enforcement.

Experience in Transporting Wheelchair Users

As was discussed in chapter two, transporting wheelchair users represents one of the most significant negative aspects for survey respondents operating 45-ft intercity coaches. Wheelchairs are difficult to accommodate (they require the moving of seats), disruptive to the operator, and require significant time to operate the lift.

The survey found that some transit agencies with articulated or double-deck buses are using the rear-facing approach for wheelchairs (e.g., AC Transit, Victoria and Kelowna, and York Region) and/or access by the second door (e.g., AC Transit and York Region). Both approaches significantly reduce dwell time for boarding, positioning, and securing wheelchairs).

TRADE-OFFS IN USING HIGHER CAPACITY BUSES

The survey and case studies indicate certain trade-offs in using HC buses. Although high-volume short-trip applications can easily be served by using the articulated bus design with its intrinsic potential for shorter dwell times, double-deck buses have also been successfully deployed for this type of route. If seats are a high priority and roadway height clearance is not a problem, then the double-deck bus design offers the highest capacity, with a quiet upper-deck ride, and superior views. If one is trying to provide a premium quality ride for the long-distance commuter customers, then the 45-ft intercity coach design with its long wheelbase, quiet ride, and passenger amenities will likely continue to dominate this service application, assuming wheelchair passengers are few.

When should a transit agency consider an HC vehicle, and which type is most suitable? These are the two questions that

TABLE 47
HC VEHICLE ATTRIBUTES—PROS AND CONS

HC Type	Pros	Cons
Articulated	• 3 or 4 doors available for exiting. Also for boarding if pre-paid fare collection is used. Shorter dwell times. • Turning radius comparable to 40-ft buses. • Available in low-floor design, which facilitates boarding and exiting. • Wheelchair access and transport similar to 40-ft buses.	• Larger roadway foot print. • Longer bus stop zones required. • May have slower acceleration capability. • Low-floor results in higher passenger compartment road noise. • Some passengers do not like the articulated joint to ride in—cannot see out and it moves. • State regulations on length may be an impediment.
Double-Deck	• Capable of more seats per bus than other HC types. • Upper deck very quiet. • Excellent views from upper deck. • Smallest of HC types in roadway footprint. • Available in low-floor design, which facilitates boarding/exiting. • Ramp wheelchair access.	• Longer time to exit from upper deck. • Access to upper deck requires climbing stairwell. • Requires highest roadway height clearance (at least 14 ft) and may limit routing. • Some state regulations on height may be impediment. • Possible procurement issues for U.S. transit agencies.
45-ft	• Longer wheelbase provides smoother ride. • High-deck floor reduces passenger compartment noise. • Good acceleration capability. • Passenger amenities available; reclining seats, individual lights/vents, tables. • Storage for luggage and cargo in storage bays.	• Longer wheelbase leads to larger turning radius. • One door entry/exit leads to longer dwell times. • Has 3–5 step entrance/exit. • Narrowest of aisle widths, causes slower boarding/exiting and difficulty with packages and bags. • High-deck floor and lift leads to longer wheelchair boarding/exiting times. • Longer boarding time can in turn have a repercussion on the dwell time of other buses sharing the bus stop.

transit managers frequently ask. The information that was gathered during this study provides some insights with respect to current practices and has been used to develop a table of pros and cons that provides an overview of current choices and applications (Table 47).

VEHICLE DESIGN ISSUES

At the time of the preparation of this report (March 2007), transit agencies that wished to deploy HC buses faced a decision tree with three main branches: articulated bus, double-deck bus, or 45-ft intercity coach. Each of these branches has many sub-branches with respect to the specific design parameters of the vehicle with respect to propulsion, fuel, doors, seating type and arrangements, passenger amenities (trays, vents, lights, electrical power, wireless access, etc.), climate control system, wheelchair accommodations and accommodations for other passengers with disabilities, and a multitude of other decisions.

The previous section discussed the rationale for the selection of HC buses based on service attributes, along with the advantages and disadvantages for each type. The information received from the transit agencies also helps to highlight vehicle design choices, and these are presented in Table 48.

TABLE 48
HC VEHICLE DESIGN ISSUES

HC Type	Vehicle Design Issue	Choices to be Made
Articulated	Passenger accommodations in articulated joint	• Placing seats in the joint will increase the number of seats in bus. Using hip rests in the joints will increase capacity of bus. Factors to consider—length of trip and mobility of passengers.
	Door number and side	• More and wider doors can facilitate shorter dwell times. Additional doors will reduce the number of seats. Choosing to have doors on both sides will reduce seats but enable use of center street stations. • The ability to shorten dwell time will depend on the fare collection practice used. A proof of payment approach will allow the use of all doors for boarding/exiting and result in the shortest dwell times.
	Advanced features and styling	• Streamlined styling for BRT services. The bullet nose improves operator mirror vision by reducing blind spots. Increases the length of bus. Improves marketing image.
	Propulsion/fuel	• Geographic location may dictate low emissions alternative fuel. Alternative fuel increases vehicle curb weight and may limit capacity. Hybrid technology improves performance and fuel economy. Also, capital cost is increased.
Double-Deck	Propulsion	• Hybrid technology requires a 2 ft longer vehicle. Weight increases 650 lb. Loss of 3 seats and an increase of 5 standees.
	Addition of second stairway	• Improves passenger circulation between decks and shortens dwell time. Loss of 4 seats plus one flip-up seat in wheelchair position.
All	Strobes on sides	• Light-emitting diode strobe lights flash when turn signal is activated and warn motorist and pedestrians of intention of bus maneuver.

CHAPTER SIX

CONCLUSIONS

This synthesis explored the use of higher capacity (HC) buses in the transit industry. For the purposes of this study, HC buses included articulated, double-deck, 45-ft coaches, and buses that have a significant increase in passenger capacity compared with the conventional 40-ft bus. The study involved several tasks, including a survey of transit agencies in North America using HC buses; a survey of bus manufacturers; reviews of documents and websites; follow-up communications with transit managers, staff, and experts; and three case studies. Conclusions drawn from the research are briefly outlined here.

- Approximately 19% of the transit agencies that are members of APTA and the Canadian Urban Transit Association and operate five or more motorbuses have HC buses in their fleets.
- HC buses represent on average 18% of the fleet of those agencies that operate HC buses.
- The significance of HC buses, as a percentage of the fleet, does not show any particular pattern according to agency size. HC buses represent on average 20% of the fleet for the largest transit agencies, those with more than 1,000 buses; 11% to 13% for transit agencies with fleets between 101 and 1,000 buses; and an average of 38% for the smallest transit agencies with fleets of fewer than 100 buses. The high percentage for small transit agencies is partially explained by a number of small commuter operations with fleets composed entirely of 45-ft intercity coaches.
- As of March 2007, there were only eight bus manufacturers identified as potential HC bus suppliers to the North American market. Some of the eight manufacturers offer different types of HC buses; three offer articulated buses, one offers double-deck buses, and five offer 45-ft buses. Of the eight North American HC bus manufacturers, three meet the testing requirements of both the Altoona Bus Testing Center and Buy America that are needed for transit agencies planning to use U.S. federal capital grants to purchase HC buses.
- The most predominant rationale (94% of respondents) for purchasing HC buses (all types) was to provide increased seating capacity. Other important rationales were to reduce peak vehicle requirements (72%) or to increase bus operator productivity (69%). All HC bus types were similar in the ranking of purchasing reasons; however, marketing image was frequently cited as an important reason for 45-ft coach and double-deck buses (71% and 67%, respectively).
- Various other reasons were also cited for deploying HC buses including to address overload situations, reduce downtown street congestion caused by large numbers of buses, and to build ridership along a future rail corridor. In the case of Bus Rapid Transit (BRT) or major new service initiatives for which the vehicle becomes an integral component of the product line, HC buses may serve to improve the image and recognition of the service.
- HC buses are used in a variety of applications; however, certain patterns are apparent depending on the type of HC bus being considered.
  - Articulated buses are predominantly deployed in all-day heavy-demand trunk (or BRT) services, but are also used to a lesser extent in various other types of services, including peak-only service on trunk routes, commuter express services to park-and-ride lots, trippers that experience overloads, replacement service for rail shut-downs, and high-demand special events. Articulated buses were the most frequent HC type used for BRT.
  - Double-deck buses are being used not only in long-distance commuter express services, but also on heavy-demand trunk routes (e.g., Las Vegas and Victoria).
  - Forty-five foot intercity coaches are the most focused in their application because they are overwhelmingly used in long-distance express commuter services. However, one respondent uses its 45-ft coaches for transportation service to the airport from park & ride lots and terminals for both airport employees and passengers. The storage bays provide ample and easy transport of luggage. The agency also extended one route to a ski lodge during the winter season using its 45-ft coaches with storage bays for transport of sports equipment and luggage.
- The history of HC bus deployment varies considerably by type of HC bus:
  - Of the respondents with articulated buses, 50% deployed them more than two decades ago.
  - Forty-five-foot coaches were made legal in 1991, but did not really become deployed in transit until after 2000 (78% of respondents).
  - Double-deck buses have been deployed only in the last decade.
- Overwhelmingly (94%), respondents reported that their HC buses met their expectations. Dissatisfaction with the slowness of wheelchair boarding and an under-

performing engine were given as the reasons for the HC vehicles not meeting original expectations.

- Overall experience with HC buses has generally been positive, with some variation by type of vehicle. Agency-reported customer and operator acceptance of HC buses is high. The articulated fleets received slightly lower ratings than those for the double-deck and 45-ft fleets.
- The most common area of concern for all transit systems with HC buses was the capital cost of the vehicle. It ranked as the most, or second most, significant concern by approximately one-third of survey respondents; there was no other single issue that was significant across all HC buses.
- However, when comparisons of capital costs are made on a per-seat basis, all types of HC buses are much more attractive and some are even less expensive than their 40-ft equivalents (standard floor articulated, hybrid articulated, and double-deck diesel buses).
- Because of their length, height, or door locations, HC buses may require modifications to infrastructure or maintenance facilities. However, the cost of modifications was not identified by respondents as a significant area of concern and appeared relatively modest in comparison with the capital cost of the vehicles themselves.
- In many cases, deployment of the articulated buses had been contemplated well in advance of actual acquisition of the buses and had been incorporated into the design requirements of new garage facilities. Long-term planning for HC buses greatly reduces the requirement for retrofits to maintenance and storage facilities.
- Some frustrations appear to exist with the performance and maintenance cost of specific bus models, in particular for articulated buses. Issues cited include acceleration performance, reliability, and maintenance cost. The design of articulated buses however includes more components than 40-ft buses and therefore entails higher maintenance costs. Their fuel economy and acceleration performance are also lower largely because of their greater weight. However, when an analysis was performed on data on a seat-mile basis, the articulated buses proved to be less costly than the 40-ft fleets in both maintenance and fuel costs.
- Preliminary findings from the operation of hybrid articulated buses appear positive in terms of improving acceleration and fuel economy compared with diesel articulated buses.
- The operation of HC buses does not appear to create significant safety concerns.
- Survey respondents did not identify regulatory limitations as a significant issue. However, operation of articulated and double-deck buses may require obtaining exemptions in many jurisdictions.
- There were no labor issues of significance related to the operation of HC buses. The survey found that 97% of transit agencies do not pay operators of HC buses a different wage rate.
- Scheduling routes that are dedicated to HC buses (i.e., scheduling at the "block" level) is relatively straightforward. However, to target the deployment of HC buses to address specific overload situations through interlining requires a more sophisticated approach to scheduling, including working at the "trip" (rather then block) level, the use of optimization modules, as well as detailed data on passenger demand and running and deadhead times. It also requires managerial oversight to ensure that planned assignments of HC buses are properly carried out.
- Reducing dwell time to take full advantage of HC buses remains a significant challenge. For articulated buses in particular, the ability to use all doors for simultaneous boarding and exiting is key to shorter dwell times. Because more and wider doors facilitate quick passenger flow, Las Vegas will install a second stairway in the double-deck buses to facilitate passenger flow from the upper deck and reduce dwell times. Several respondents are also encouraging more customers to use pre-paid fare media (e.g., day passes, university passes, and smart cards), and one respondent installed off-board ticketing machines. However, the most comprehensive approach is to move to a fare control system based on Proof of Payment (POP) with random inspection, similar to that used on light rail systems. This is being more actively considered for bus transit, and the synthesis found that POP with off-board fare collection has been deployed on recent BRT systems.
- Accommodating wheelchairs on HC buses represents another challenge, especially with respect to the implications on dwell time. The time and effort required to accommodate wheelchairs represents the most common complaint from transit agencies with 45-ft intercity coaches. Some transit agencies with double-deck or articulated buses have implemented mid-door access and/or rear-facing wheelchair positions as a method for reducing the dwell time of HC buses.
- Agencies reported that passengers' most-liked feature of HC buses varied depending on type. Passengers appreciated the increase in the number of seats and less crowding of articulated buses. They liked the upper level's quiet, ride quality, and view of the double-deck buses, and sometimes would let another bus pass if they saw a double-deck bus coming. The most liked features of the 45-ft coaches were the comfort of the ride and the quality of the passenger compartment with all the amenities and image.

Four areas for future research have been identified.

- The impact of vehicle amenities (e.g., seat quality, ride comfort, reading lights, reduced interior noise, writing tables, and Wi-Fi access) on ridership is poorly understood. "Passenger comfort" is not included as a variable in demand forecast models, was not identified as a factor in the TCRP Traveler Response research, and is rarely assessed. A better understanding of this issue would help to identify which features and amenities of HC buses are likely to increase transit ridership.

- According to survey respondents, one of the main objectives in deploying HC buses was to address "overload" and "pass-up" situations. Considerable research has been carried out over the years concerning service reliability as a determinant of mode choice. However, little understanding exists on the potential benefits from addressing overloads and pass-ups on potential transit ridership retention rates.
- Some transit agencies are using POP fare control for HC buses and the concept is becoming increasingly important for new BRT systems. Research would be valuable to document existing experience and to develop best practice guidelines related to the application of POP-based fare control, with or without off-board fare collection equipment.
- Europeans use a wider range of HC buses including 15-m three-axle transit buses, in particular in Germany, as well as bi-articulated buses. The 15-m bus was implemented to compensate for seating capacity that was lost by the move to low-floor buses. It would be useful to explore European experience with the 15-m and bi-articulated buses, and assess the potential issues affecting the transferability of such HC buses to the North American context.

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APPENDIX A

Surveys of Transit Agencies and Bus Manufacturers

November 2006

USE OF HIGHER CAPACITY BUSES IN TRANSIT SERVICE
TCRP SYNTHESIS TOPIC SA-16
QUESTIONNAIRE FOR TRANSIT AGENCIES USING HIGHER CAPACITY BUSES

Purpose: The purpose of this survey is to gather information on ***the use of higher capacity (HC) buses in transit service****, as part of a Synthesis of Practice being prepared for the Transportation Research Board. For the purposes of this study, HC buses are defined as vehicles used in public transit service, such as articulated, double-decker, 45-foot, and others that are higher capacity than the standard 40-foot bus.*

Please note that some transit systems operate more than one type of HC bus.

Transit Agency: ________________________________ Date: ________________________________

Contact Name: ________________________________ Title: ________________________________

Telephone: ________________________________ E-Mail: ________________________________

Size of total active (Non-ADA) fleet ______________

Size of Higher Capacity (HC) Fleet(s)

Artics _______ *Double Decker* _______ *45'* _______

MOTIVATION FOR USE OF HC BUSES

Types of Services Using Higher Capacity (HC) Buses:

Please check all that apply	**Name of Service (if any)**	**No. of HC Buses (& type: Artic, DD, 45')**
[ ] Trunk service routes—all day		
[ ] Trunk service—use only in peak service		
[ ] Bus Rapid Transit (BRT) routes		
[ ] Express/long distance commuter routes		
[ ] Special services (e.g., sports event specials)		
[ ] Other:		

What were the primary reasons for implementing HC buses for the above services?

Please rank (*with 1= most important reason*) — ***Please add any comments***

[ ] Provide increased seating capacity ________________________________

[ ] Increase bus operator productivity ________________________________

[ ] Reduce peak vehicle requirements ________________________________

[ ] Bus Rapid Transit (BRT) service ________________________________

[ ] Marketing image ________________________________

[ ] Passenger comfort ________________________________

[ ] Other (*Please explain*): ________________________________

DEPLOYING HC BUSES

In **what year** were HC buses first deployed into the active fleet of your transit system?

Type of HC bus (Artic, DD, 45'): ____________ Year first deployed: ____________

Type of HC bus (if more than one type in fleet): __________ Year first deployed: __________

Do you have **different wage rates** for operating **HC** buses? [ ] Yes [ ] No

Is the wage differential significant? ________________________________

Were **facilities or infrastructure modifications made to accommodate your HC buses**?

Please check all that apply HC Bus Type (A, DD, 45') Modifications

[ ] Bus stop dimensions [ ] ______
[ ] ______
[ ] On-street parking [ ] ______
[ ] ______
[ ] Roadway [ ] ______
[ ] ______
[ ] Terminals/loops [ ] ______
[ ] ______
[ ] Maintenance shops [ ] ______
[ ] ______
[ ] Wash facilities [ ] ______
[ ] ______
[ ] Fueling facilities [ ] ______
[ ] ______
[ ] Other: [ ] ______
[ ] ______

What was approximate **capital cost of modifications**? ______

Were there any **legislative/regulatory impediments to the use of HC buses**? ______

______

What actions were taken? ______

______

Are there any **internal service restrictions to the use of HC buses** (e.g., no standees)? ______

______

Were **actions taken to improve dwell time at stops** in order to take advantage of higher capacity buses?
Bus stop design/signage ______
Fare collection procedures ______
Wheelchair accommodation ______
Changes to policies/procedures ______
Other: ______

Were changes made to **scheduling procedures** (e.g., rules, interlining, modifications to scheduling software, etc.)?
Please explain: ______

______

Do you **operate a mix of HC buses and standard 40-foot buses on a single route**?
Yes [ ] No [ ]
If so, what approach is taken to the headway design when using buses with different passenger capacities?

______

______

______

VEHICLE FEATURES

Are your HC vehicles equipped with **special security features** (e.g., real-time CCTV monitors for operators)?

____

Do your HC vehicles have **special passenger amenities** (e.g., Internet access, reclining seats, or luggage racks)?
(Please specify type of HC buses and amenities): ____

____

Are your HC vehicles equipped with **bike racks**? [ ] Yes [ ] No
Restrictions on their use? ____

How are your HC vehicles equipped for **passengers with physical disabilities**?
Type of HC buses (Artic, DD, 45'): ____________
Features (check)
Ramp/lift location: [ ] 1st Door [ ] 2nd Door [ ] Other:
Wheelchair positions: [ ] 2 Forward-facing [ ] 1 Rear-facing + 1 forward position

Type of HC buses (if more than one type in fleet): __________________
Features (check)
Ramp/lift locations: [ ] 1st Door [ ] 2nd Door [ ] Other:
Wheelchair positions: [ ] 2 Forward-facing [ ] 1 Rear-facing + 1 forward position

EXPERIENCE WITH HC BUSES

Has your experience met your expectations with respect to the above primary objectives?
[ ] Yes [ ] No
If not, please specify type of HC bus and explain: ____

____

Has your **overall experience with the use of HC buses** been?
[ ] Very Good [ ] Acceptable [ ] Poor
If poor, please specify type of HC bus and explain: ____

____

Has **customer acceptance** of the HC buses been:

[ ] Very Good [ ] Acceptable [ ] Poor

Type of HC bus and features they most like? ____

____

Type of HC bus and features they most dislike? ____

____

Has **ridership been measurably increased** by the introduction of HC vehicles [ ] Yes [ ] No
(excluding any increases in service hours)? ____

Has **operator acceptance** of the HC buses been:

[ ] Very Good [ ] Acceptable [ ] Poor

Type of HC bus and features they most like? ____

____

Type of HC bus and features they most dislike? ____

____

How has the **vehicle operating experience** with your HC buses compared to that with your standard 40-foot buses (specify type of HC vehicle)?

	Type of HC Bus (Artic, DD, 45'): ______				**Type of HC Bus**: ______			
Performance Item	Better	Same	Poorer	Unknown	Better	Same	Poorer	Unknown
Acceleration/ Grade Climbing	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Road Clearance	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Turning Maneuverability	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Fuel Economy	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Range	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Reliability	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Availability	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Roadcalls	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

How does the HC fleet **spare ratio** compare to that for 40' buses?

		Higher	Same	Lower
Type of HC Bus (Artic, DD, 45'):	______________	[ ]	[ ]	[ ]
Type of HC Bus:	______________	[ ]	[ ]	[ ]

What has been your **experience in transporting passengers using wheelchairs** with your HC buses compared to your standard 40-foot buses? [ ] Better [ ] Same [ ] Poorer
Please explain differences: ____

Have there been **any major issues or concerns** raised by your use of HC buses?
(Please indicate type of HC vehicle for which issue applies: A-Artics, DD-Double-deckers, 45')

Please rank (with 1 = most important reason) ***Please add any comments***

[ ] Capital cost of vehicles ____
[ ] Facility retrofit costs ____
[ ] Operating costs (labor, fuel) ____
[ ] Maintenance costs ____
[ ] Dwell time/fare collection ____
[ ] Accommodation of wheelchairs ____
[ ] Accommodation of bicycles ____
[ ] Safety and security ____
[ ] Vehicle reliability ____
[ ] Winter operations ____
[ ] Operating constraints ____
[ ] Other: ______________ ____

AVAILABLE INFORMATION ON HIGHER CAPACITY BUS OPERATIONS:

Do you track the operations/costs of the HC bus operations separately?
[ ] Yes [ ] No

Can you provide data on your HC bus operations? (*Please check all that apply*)
[ ] Ridership impacts attributable to HC buses
[ ] Maintenance/fuel costs per vehicle hour or mile
[ ] Safety experience
[ ] Road calls

Did you conduct any pre-deployment feasibility study/business case analysis?
[ ] Yes [ ] No

Have you conducted any post-deployment evaluations concerning your HC buses?
[ ] Yes [ ] No

Could you make the above information available for this study?
[ ] Yes [ ] No

FUTURE PLANS FOR HIGH CAPACITY BUSES

Do you have **plans to expand** the existing HC Bus fleet: [ ] Yes [ ] No

Number/type of buses: ____________________________

Do you have **plans to deploy a new type of HC bus**: [ ] Yes [ ] No

Type of HC bus? Number of buses? Type of service? ____

____

OTHER COMMENTS:

____

____

____

If you have any questions, please contact Rolland King at (614) 439-8843 or by e-mail at
Rolland D. King: azrdk@yahoo.com.

Please return this survey by **November 30th** to:

Rolland D. King
E-mail: azrdk@yahoo.com

Thank you in advance for your cooperation and participation in this study

USE OF HIGHER CAPACITY BUSES IN TRANSIT SERVICE
TCRP SYNTHESIS TOPIC SA-16

QUESTIONNAIRE FOR MANUFACTURERS OF HIGHER CAPACITY BUSES

Purpose: The purpose of this survey is to gather information on the use of higher capacity (HC) buses in transit service in North America, as part of a Synthesis of Practice being prepared for the Transportation Research Board. For the purposes of this study, HC buses are defined as vehicles used in public transit service, such as articulated, double-decker, and 45-foot buses.

Manufacturer: ______________________________ Date: ______________

Contact Name: ______________________________ Title: ______________

E-Mail: ____________________ Tel.: ____________ Fax: ____________

Do you manufacture HC buses for the North American transit market? [ ] Yes [ ] No
Are you planning to manufacture HC buses for the North American transit market? [ ] Yes [ ] No
If "yes" for either question, please complete the remainder of the survey. If "no" for both questions, please return the survey with this information.

For each of your HC bus models that are or will be marketed to transit agencies in North America, please provide the information requested in Tables 1 and 2.

TABLE 1
PURCHASING STATUS FOR U.S. TRANSIT MARKET

Bus Model	Altoona Bus Tests Completed (Yes or No)	Meets "Buy America" Requirements (Yes or No)	Unit Cost Range# (in U.S. dollars)

#Do not include costs such as spare parts, delivery, or training.

TABLE 2
PURCHASING STATUS FOR CANADIAN TRANSIT MARKET

Bus Model	Meets Canada Motor Vehicle Regulations (Yes or No)	Unit Cost Range# (in Canadian dollars)

#Do not include costs, such as spare parts, delivery, or training.

Please provide the information requested in Table 3 for all of your HC buses that are offered to transit agencies. Sales/marketing brochures that contain the requested information may be provided in lieu of filling out Table 3.

TABLE 3
TECHNICAL DESCRIPTION OF HIGHER CAPACITY BUSES

Technical Description	Model Identification			
Length, not including bumpers (ft)#				
Width, not including mirrors (in.)#				
Height (in.)#				
Approach angle (deg.)				
Departure angle (deg.)				
Breakover angle (deg.)				
Turning radius, outside (ft)#				
Number of passenger doors (1, 2, 3, …)				
Entrance/exit height at doors (in.)#+				
Number of steps to enter/exit (e.g., 1, 2, …)				
Wheelchair equipment (ramp or lift)				
Door location(s) of wheel chair equip. (1, 2, …)				
Maximum number of seats				
Maximum number of standees				
Gross vehicle weight rating (lb)#				
Curb weight (lb)#				
Propulsion options, list all*				
Engine options (manufacturer and model)				

#Please indicate if units are in metric.
+Please indicate if heights differ for multiple doors.
*Diesel (D), Compressed Natural Gas (CNG), Liquid Natural Gas (LNG), Gasoline (G), Hybrid (H), Electric Trolley (ET), or Other (O), please explain.

Please provide information on the models that offer additional features (*e.g., Bus Rapid Transit features*) *mentioned in Table 4.*

TABLE 4
BUS RAPID TRANSIT OPTIONS

Technology Description	Model Identification	
Passenger doors on either side (yes or no)		
Body streamlining (e.g., large curved window, fender skirts, etc.)		
Bus guidance technology (yes or no)		
WiFi technology (yes or no)		
Blind spot sensors (yes or no)		
Other, please explain:		

If you have any questions, please contact Rolland King at (614) 439-8848 or azrdk@yahoo.com.
Please return the completed questionnaire and marketing material by December 8 to:
Rolland King
10020 Sandstone Drive
Sun City, AZ 85351
or forward by e-mail to azrdk@yahoo.com or by FAX to (623) 977-7563.

Thank you in advance for your time and cooperation by participating in this study.

APPENDIX B

Study Participants

PARTICIPATING TRANSIT AGENCIES

The following transit agencies participated in this study:

- Alameda–Contra Costa Transit District
- Anoka County Transit
- Antelope Valley Transit Authority
- BC Transit (Victoria)
- Champaign–Urbana Mass Transit District
- Chicago Transit Authority
- City of Everett Transportation Services/Everett Transit
- City of Phoenix Public Transportation District
- Coast Mountain Bus Company
- Connecticut Transit
- Edmonton Transit System
- Fairfield/Suisun Transit
- Golden Gate Bridge, Highway & Transportation District
- GO Transit
- King County Department of Transportation/Metro Transit
- Lane Transit District
- Miami–Dade Transit
- Mississauga Transit
- Nashville Metropolitan Transit Authority
- New Jersey Transit Corporation
- OC Transpo, City of Ottawa
- Potomac & Rappahannock Transportation Commission/ OmniRide
- Regional Transportation Commission of Southern Nevada
- Regional Transportation District—Denver
- San Mateo County Transit District
- San Diego Metropolitan Transit System
- Santa Clara Valley Transportation Authority
- Snohomish County Public Transportation Benefit Area Corporation
- Southwest Metro Transit
- Utah Transit Authority
- Washington Metropolitan Area Transit Authority
- York Region Transit

BUS MANUFACTURERS AND OTHER ORGANIZATIONS

The following organizations participated in this study:

- ABC Companies
- Alexander Dennis Inc.
- Altoona Bus Testing Center
- American Public Transportation Association
- Canadian Urban Transit Association
- DaimlerChrysler Commercial Buses, NA
- Motor Coach Industries
- New Flyer
- North American Bus Industries, Inc.
- Nova Bus, A Division of Prevost Cara

APPENDIX C

Regulations on Vehicle Size and Weight

In the United States, federal law governs the weight of vehicles traveling on the Interstate System and vehicle width and length on the National Network, the Interstate System, and designated federal-aid primary highways (*C1*). The states regulate vehicle height on all highways in the state, and the weight limits on all highways not included in the National Network. In Canada, the provinces regulate height and weight limits on roads.

FEDERAL REGULATIONS ON VEHICLE SIZE AND WEIGHT

The specifics of these regulations are found in the *Code of Federal Regulations* (CFR) Part 658: Truck Size and Weight, Route Designations—Length, Width, and Weight Limitations (*C2*). The applicable sections of CFR Part 658 are excerpted here.

§658.13 Length.

(d) No State shall impose a limit of less than 45 feet on the length of any bus on the National Network.

§658.15 Width.

(a) No State shall impose a width limitation of more or less than 102 inches, or its approximate metric equivalent, 2.6 meters (102.36 inches) on a vehicle operating on the National Network, except for the State of Hawaii, which is allowed to keep the State's 108-inch width maximum by virtue of section 416(a) of the STAA.

§658.17 Weight.

(a) The provisions of the section are applicable to the National System of Interstate and Defense Highways and reasonable access thereto.

(b) The maximum gross vehicle weight shall be 80,000 pounds except where lower gross vehicle weight is dictated by the bridge formula.

(c) The maximum gross weight upon any one axle, including any one axle of a group of axles, or a vehicle is 20,000 pounds.

(d) The maximum gross weight on tandem axles is 34,000 pounds.

(e) No vehicle or combination of vehicles shall be moved or operated on any Interstate highway when the gross weight on two or more consecutive axles exceeds the limitations prescribed by the following formula, referred to as the Bridge Gross Weight Formula:

(k) Any over-the-road bus, or any vehicle which is regularly and exclusively used as an intrastate public agency transit passenger bus, is excluded from the axle weight limits in paragraphs (c) through (e) of this section until October 1, 2009. Any State that has enforced, in the period beginning October 6, 1992, and ending November 30, 2005, a single axle weight limitation of 20,000 pounds or greater but less than 24,000 pounds may not enforce a single axle weight limit on these vehicles of less than 24,000 lbs. (Effective as of March 22, 2007.)

STATE REGULATIONS ON MOTOR BUS SIZE

Two sources for the following information were used. One is the Rand McNally Motor Carriers' Road Atlas '07 (*C3*), and the second was the motor vehicle codes and regulations that were available from the websites of the 50 states and the District of Columbia. The motor carrier height limits by state are given in Table C1. The height exceptions that were found for motor buses are given in brackets.

The maximum motor bus lengths allowed by states on highways controlled by the state are given in Table C2. Motor buses of at least 45 ft must be allowed to operate on the National Network by federal regulations. Limits in brackets are for straight truck, and motor bus limits may differ.

There are seven states that have a smaller width than the federal National Network width of 102 inches. The maximum widths for motor buses by state are given in Table C3. Where the width limit for motor buses was not found, the limits for straight trucks are given in brackets.

PROVINCIAL REGULATIONS ON MOTOR CARRIER SIZE

The information presented below was obtained from Reference 17 for commercial carriers, and there may be exceptions for motor buses. Information is given only for the southern provinces. The size limits are given in Table C4.

REFERENCES

C1. *Title 23 USC, 127*, Federal Statute on Interstate Vehicle Weight.
C2. 23 CFR Part 658, *Code of Federal Regulations*, Federal Size Regulations for Commercial Motor Vehicles.
C3. *Motor Carriers' Road Atlas '07*, Rand McNally & Company, Skokie, Ill., 2007.

TABLE C1
MAXIMUM MOTOR CARRIER [BUS EXCEPTIONS] HEIGHT LIMITATIONS BY STATES

State	Height (in feet)	State	Height (in feet)	State	Height (in feet)
Alabama	13.5	Kentucky	13.5	North Dakota	14
Alaska	14	Louisiana	13.5	Ohio	13.5
Arizona	14[a]	Maine	13.5	Oklahoma	13.5
Arkansas	13.5	Maryland	13.5	Oregon	14
California	[14.25]	Massachusetts	13.5	Pennsylvania	[14.5][e]
Colorado	[14.5][b]	Michigan	13.5	Rhode Island	13.5
Connecticut	13.5[c]	Minnesota	[14][d]	South Carolina	13.5
Delaware	13.5	Mississippi	13.5	South Dakota	14
District of Columbia	13.5	Missouri	13.6	Tennessee	13.5
Florida	13.5	Montana	14	Texas	14
Georgia	13.5	Nebraska	14.5	Utah	14
Hawaii	14	Nevada	14	Vermont	13.5
Idaho	14	New Hampshire	13.5	Virginia	13.5
Illinois	13.5	New Jersey	13.5	Washington	14
Indiana	13.5	New Mexico	14	West Virginia	13.5
Iowa	13.5	New York	13.5	Wisconsin	[14.5][f]
Kansas	14	North Carolina	13.5	Wyoming	14

[a]With permit, otherwise 13.5 ft.
[b]On designated highways, otherwise 13.5 ft.
[c]Commissioner of Transportation can grant permit for greater height.
[d]For double-deck bus, otherwise 13.5 ft.
[e]Bus exception.
[f]With approval for double-deck buses, speeds limited to 45 mph.

TABLE C2
MAXIMUM MOTOR CARRIER [BUS EXCEPTIONS] LENGTH LIMITS ON STATE HIGHWAY SYSTEMS

State	Length (in feet)	State	Length (in feet)	State	Length (in feet)
Alabama	40	Kentucky	45	North Dakota	[60]
Alaska	[65]**	Louisiana	45	Ohio	[60]*
Arizona	[65]*	Maine	45	Oklahoma	45
Arkansas	40	Maryland	[60][b]	Oregon	40[c]
California	[60]	Massachusetts	[60]*	Pennsylvania	[60]*
Colorado	[60][a]	Michigan	[65]*	Rhode Island	40[d]
Connecticut	45	Minnesota	[61]*	South Carolina	45[e]
Delaware	45	Mississippi	40	South Dakota	[45]
Dist. of Columbia	40[#]	Missouri	45	Tennessee	45[f]
Florida	[50][#]	Montana	55	Texas	45[#]
Georgia	[ND]	Nebraska	40	Utah	45[g]
Hawaii	[65]	Nevada	[65]*	Vermont	46
Idaho	45	New Hampshire	45	Virginia	40[h]
Illinois	[60]*	New Jersey	40	Washington	[61]***
Indiana	[65]	New Mexico	40	West Virginia	40
Iowa	[61]*	New York	[62]*	Wisconsin	[65]*
Kansas	45	North Carolina	40	Wyoming	60

*Articulated bus, other buses 45 ft.
**Articulated bus, other buses 50 ft.
***Articulated bus, other buses 46 ft.
[#]Articulated buses operate in state, exception not found.
[a]Designated highways only.
[b]For articulated buses, otherwise 45 ft on state primary system, otherwise 41 ft.
[c]Size limits do not apply to mass transit district vehicles that are approved by road authority, 267.01-39.
[d]Articulated buses are exempt from length limit, if owned by Rhode Island Transit Authority.
[e]Bus lengths as approved by Department of Public Safety.
[f]Bus length and weight exempt from limits for cities between 400,000 and 800,000 population.
[g]Permit can be obtained for articulated buses.
[h]Virginia Code 46.2-1147 permits articulated buses to be used, length was not specified.
[ND] = Length limit not designated.

TABLE C3
MAXIMUM MOTOR CARRIER [BUS EXCEPTION] WIDTH LIMITS BY STATES

State	Width (inches)	State	Width (inches)	State	Width (inches)
Alabama	102	Kentucky	102	North Dakota	102
Alaska	102	Louisiana	[102]	Ohio	[104]
Arizona	102	Maine	102	Oklahoma	102
Arkansas	102	Maryland	102[c]	Oregon	102
California	102[a]	Massachusetts	102	Pennsylvania	102
Colorado	102	Michigan	102	Rhode Island	102
Connecticut	102	Minnesota	[108]	South Carolina	102
Delaware	102	Mississippi	102	South Dakota	102
District of Columbia	[102]	Missouri	96[c]	Tennessee	102
Florida	102[b]	Montana	102	Texas	102
Georgia	102[b]	Nebraska	102	Utah	102
Hawaii	108	Nevada	102	Vermont	102
Idaho	102	New Hampshire	102	Virginia	102
Illinois	102	New Jersey	96[c]	Washington	102
Indiana	102	New Mexico	102	West Virginia	102
Iowa	102	New York	[d]	Wisconsin	102
Kansas	102	North Carolina	102	Wyoming	102

[a]Up to 104 with Public Utilities Commission permission.
[b]On lanes less than 12 ft, 96 in.
[c]On designated highways/routes, 102 in.
[d]On designated truck access highways and on highways outside New York City with 10 ft or more lane widths, 102 in.; elsewhere 96 in.

TABLE C4
CANADIAN PROVINCIAL SIZE LIMITS
FOR COMMERCIAL CARRIERS

Province	Width (meters[b])	Length[a] (meters[b])	Height (meters[b])
Alberta	2.6	12.5	4.15
British Columbia	2.6	12.5	4.15
Manitoba	2.6	12.5	4.15
New Brunswick	2.6	12.5	4.15
Nova Scotia	2.6	12.5	4.15
Ontario	2.6	12.5	4.15
Québec	2.6	12.5	4.15
Saskatchewan	2.6	12.5	4.15

Source: Reference 41.
[a]Length is for straight trucks.
[b]Metric conversion: 2.6 m = 102.4 in.; 12.5 m = 41 ft; 4.15 m = 13.62 ft

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation