Transbus

An Overview of Technical, Operational, and Economic Characteristics

The MITRE Corporation

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Preface

The Transbus program had its genesis in a study conducted by the National Academy of Sciences in 1968 which suggested improvements, such as low floors, in existing bus design. Two years later, in December 1970, the Urban Mass Transportation Administration announced its Transbus program. In May 1979, no American or foreign manufacturers were prepared to submit a bid to make buses with the specifications that had been developed through that program.

The Secretary of Transportation called for an independent technical review of the procurement requirements and associated issues to assist him in establishing policies and guidelines for future uses of federal funds for bus procurement. The technical review will be conducted by a special panel of the National Research Council's Commission on Socio-Technical Systems. The purpose of this report is to present an independent assessment of the technical, operational, and economic factors involved, and some options that should be considered by the DOT and the special panel.

The reader should keep in mind the constraints placed on MITRE by the limited time (approximately six weeks) allowed for our work.

1. The report is not a review of the decision to mandate a bus with a 22-inch floor height. It is an assessment of the technical feasibility of building such a bus, and its economic and operational performance relative to other, currently available buses.

2. The report does not address whether transportation service for the handicapped could be provided more economically by other means.

3. The report assumes that the recently issued regulations implementing Section 504 of the Rehabilitation Act of 1973 will remain in effect during the time-span (fifteen years) covered by the report, specifically ". . . all buses must be wheelchair accessible."

Also, within the time available, it has not been possible to conduct independent analyses of technical problems which are critical to the success of the Transbus program. Fortunately, the data available from the extensive Transbus development program has proved to be adequate for our purposes. One objective of this report has been to separate the facts from the rhetoric which has surrounded the Transbus program since its inception, and present the facts in a way that will help the panel make decisions.

The study has been conducted by the Systems Development Division of The MITRE Corporation, under the direction of Mr. William F. Mason, Technical Director. Task Leaders were Dr. James L. Milner, Associate Department Head, Ground Transportation Systems (Technical Review); Mr. Peter Wood, Department Head, Urban Systems (Performance Analysis); and Dr. Marcel Zobrak, Associate Department Head, Urban Systems (Cost Analysis). Other members of the MITRE staff who contributed to this final report include Anthony Chambliss, Lawrence Deibel, Fred Holland, Tom LaManna, Jack Ludwick, Dave Muhlenberg, Denis O'Sullivan, Virgil Thurlow, Warren McCabe, and Andy Wetzel. Karen Dimsdale assisted in data collection.

The study team would like to acknowledge the assistance rendered by members of the Urban Mass Transportation Administration; the bus manufacturing industry; the transit operators; the American Public Transit Association; and Booz-Allen Applied Research, program manager for the Transbus program. Without their cooperation this study would not have been done in the six weeks allowed.

The authors are aware that decisions concerning Transbus involve social, political, and business issues that are broader than those considered "technical, operational and economic." In fact, these broader issues exert such force that they may cause decisions to be made without regard for technical, operational, or economic feasibility.

We have not addressed the broader issues but have alluded to some of them when it has been necessary to put our assessments in context.

We believe a full evaluation of the options presented here should include formal consideration of all the issues, even though they cannot be quantified.

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Contents

Contents (Continued)

List of Figures

List of Tables

List of Tables (Continued)

Synopsis

1. The Transbus program has been an innovative attempt to upgrade bus design at a time when bus ridership was declining and there was little incentive for manufacturers to invest in new designs.
2. The Transbus Procurement Requirements (TPR) define a vehicle that could, by and large, be developed and manufactured within the time frame called for at an acceptable level of *technical* risk. At least one of the three Transbus prototype manufacturers was ready in 1975 to accept orders for a tandem axle Transbus with a twenty-two inch floor and ramp. All three stated that the bus was technically feasible.
3. Most of the stated reasons now cited by the manufacturers for declining to bid on the 1979 consortium procurement were technical. However, the fundamental corporate reasons involved the requirements that they assume all the technical and *financial* risk; absorb the investments they had made in the Advanced Design Buses (ADB) as a result of the previous UMTA decision to delay Transbus; and face a possible change in the DOT Transbus mandate and a market that may exert considerable pressure to introduce yet another bus design, or even revert to New Look buses.* The manufacturers also claim to be concerned that their companies bear the ultimate responsibility for the acceptability of the product, and they will not produce a bus that will be unpopular, regardless of the price incentive. Our conversations with GM and GFC suggest that these factors led the manufacturers to limit their technical approach to how their current ADB and production facilities could be adapted to meet the TPR. We found no evidence that they have considered what a completely new design could achieve.
4. From the government's viewpoint, Transbus has been demonstrated as a desirable, buildable bus. About $28 million has been invested in its development; the basic technologies involved are available, but further subsystem development cannot be done effectively without a major bus procurement. (The component manufacturers prefer to fund their own product development for the marketplace.)
5. MITRE believes that considerable financial risk would be involved in accepting a fixed-price contract to provide the specified Transbus with its tandem axles, smaller tires, and the warranties required by transit operators. Four companies have withdrawn from transit vehicle manufacturing in recent years, partly because of losses sustained as a result of this type of procurement.
6. Transbus would represent a major advance over the New Look buses in passenger comfort, convenience, accessibility, safety, effective operating speed, and environmental impact. Compared to the Advanced Design Buses that are now being produced and equipped with a wheelchair lift, Transbus will offer some improvements in accessibility (two steps instead of three), effective operating speed, and the option to utilize a ramp. The value of a ramp over a lift is a matter of judgment. However, compared to the ADB, Transbus as specified has one or two fewer seats, is about 2 percent less fuel efficient, costs 15 to 20 percent more to buy and about 3 percent more to operate and maintain—primarily because of the tandem axle required by the TPR.
7. If the requirement for a tandem rear axle were dropped, the principal Transbus features (low floor and wide door) could be achieved in the time frame specified in the TPR. Such a version of Transbus would cost about 15 percent more than an ADB.
8. It has not been proved that a tandem axle is required to meet the Transbus goals without exceeding federal axle load limits. It is definitely possible to build a lighter bus than the present ADBs. Recently procured New Look buses are 2,000 pounds lighter than the ADBs or the Transbuses specified in the TPR, and they provide more seats. European experience indicates that a single rear axle bus can be built with at least a low entrance and center aisle (seats on raised floor sections), wide doors and within U.S. axle load limits with a full seated load. The DeLorean Motor Company of New York City proposed to the U.S. DOT in July 1979 to build a single rear axle Transbus in the U.S. They would retain all the other Transbus features, and use a completely new design to reduce weight. Minor exceptions to the TPR would be needed. The estimated price is significantly lower than GM and GFC estimates provided to MITRE. Admittedly, these examples do not prove that a single rear axle bus can otherwise meet Transbus goals, but they do suggest that the tandem axle requirement in the TPR may be replaced by an axle load limitation.
9. Conclusions and Options:

A. The Transbus design specified in the TPR could be built in the required five-year time frame. More than the usual number of reliability problems can reasonably be expected in the first year of operation. The increased cost of Transbus relative to ADB (after amortization of special facilities development, tooling and training) would be slightly higher than the 10 to 18 percent estimated by the government.

B. GFC's and GM's decisions not to bid were reasonable, understandable business judgments. They were conditioned by appropriate business

*New Look buses were built by GM and GFC from 1959 until around the middle of 1978, and are still being built in Canada. They now provide over 95 percent of bus service in urban areas.

perspectives of companies that have only recently made heavy investments in the ADB, and are sensitive to a history of changing UMTA decisions. In particular, after being encouraged by UMTA to begin ADB production, they are disturbed to see that federal funds are being used to purchase New Look buses from Canada.

C. Because of these business perspectives, it is highly unlikely that the bus defined in the TPR could be procured with modest changes in the technical clauses and terms and conditions of the TPR.

D. The goals of the Transbus program can still be achieved with some modifications to the TPR as indicated in the options below. However, in view of the continuing and deepening concern with energy problems, it would be wise to reassess and redefine the goals to reflect more emphasis on fuel economy, cost, increased seating capacity and reliability. Enforcement of the Transbus mandate should be delayed until this reassessment has been completed.* It would also be desirable to consider a legislative, rather than an administrative, mandate to encourage a more stable market.

E. Options for Consideration

MITRE has examined a large number of technical and procurement options, and selected five which it recommends should be evaluated in more detail.

Option 1. Procure Transbus as presently defined.

The existing Transbus Procurement Requirements should be modified as suggested in Appendix A1.

Provisions will have to be made for further prototype development. Time must be allowed after an initial production run for test, evaluation, and debugging. There are two ways to do this.

Option 1a: A two-step procurement process would be adopted in which 100 buses would be purchased from each of two manufacturers. After operational evaluation, an additional 1,000 would be purchased on a fixed-price basis. UMTA would reserve the option to split the procurement between the two manufacturers.

This option has the advantage of ensuring some production tooling and process development.

Option 1b: A similar two-step procurement process would be adopted in which ten buses would be purchased with R&D funds on a cost-plus-fixed-fee (CPFF) basis from each of at least two manufacturers. Following a rigorous test program and demonstration of sastisfactory performance in actual operational conditions, a further 1,000 buses would be purchased on a fixed-price basis. UMTA would reserve the option to split the procurement between two manufacturers.

Option 2. Develop and procure an improved Transbus.

The Transbus Procurement Requirements would be changed to eliminate design requirements and to accent performance specifications. Under this option, we would hope to see a completely new bus, designed to meet rear axle load limitations without the tandem axle. Incentives would be added for fuel efficiency, weight reduction, and improved maintainability and reliability.

Technical proposals would be solicited, and technical negotiations would be conducted individually with interested companies before cost proposals were requested. This option could also be implemented in two ways.

Option 2a: Similar to Option 1a. Initially 100 buses would be bought on a fixed-price basis.

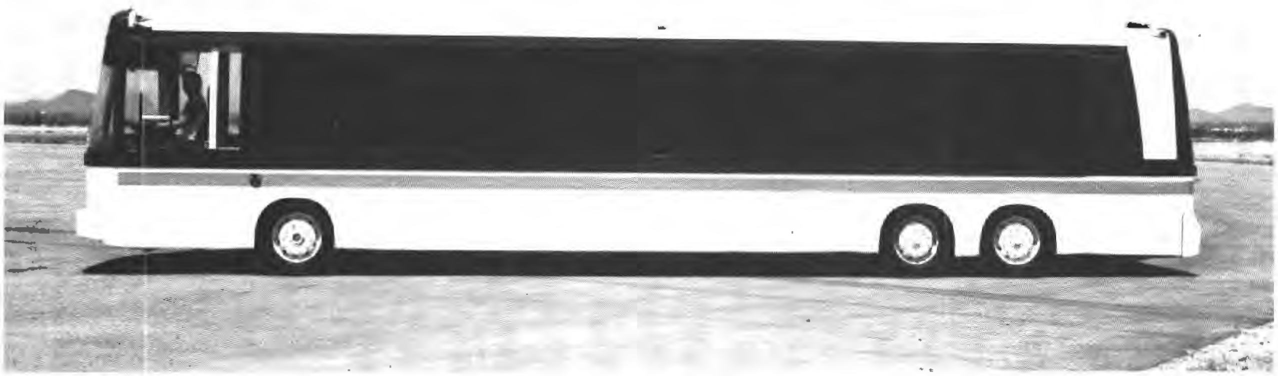
Option 2b: Similar to Option 1b. Initially ten buses would be bought on a CPFF basis.

Option 3. Improve the Advanced Design Bus now and continue R&D on a future Transbus.

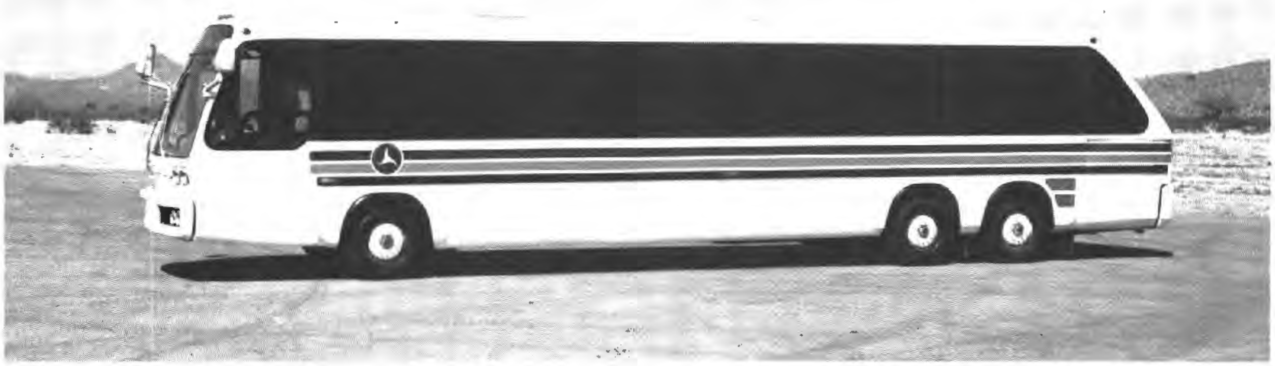
The present mandate would be modified to require ADBs with a 24 inch floor at the front door (kneeled), and a wide (38 inch clear) front door. Incentives would be set for better fuel economy. Current requirements for a lift would remain unchanged. The mandate would require all buses ordered *after* a certain date (possibly 1982) to conform to the new requirements. This would allow enough time to overcome current problems with the ADB, and design and test the necessary modifications. An initial production order for 1,000 buses (500 from each manufacturer) would be awarded.

Selection of Option 3 does not exclude further Transbus development. UMTA could announce its continued willingness to award a sole-source contract on a fixed-price basis to a manufacturer willing to supply a bus which met Transbus specifications at a later date.

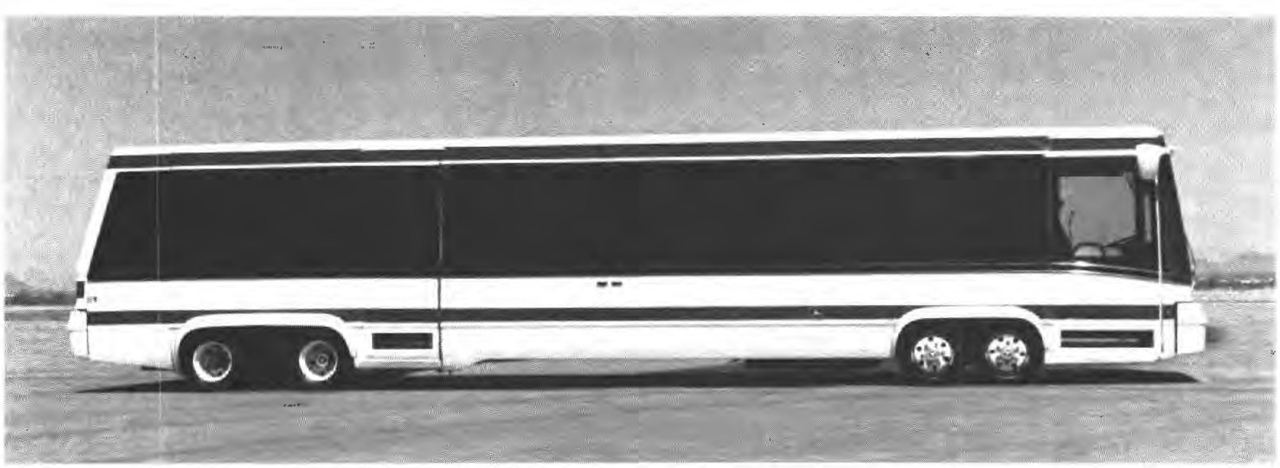
*The Transbus mandate of May 19, 1977 requires that conventional 35-foot to 40-foot transit buses purchased with federal funds after September 30, 1979 satisfy the TPR document.



AM General Corporation



General Motors Corporation



Rohr Industries

Introduction

In 1964, the Congress of the United States determined that:

(1) The predominant part of the Nation's population is located in its rapidly expanding metropolitan and other urban areas, which generally cross the boundary lines of local jurisdictions and often extend into two or more states.
(2) The welfare and viability of urban areas, the satisfactory movement of people and goods within such areas, and the effectiveness of housing, urban renewal, highway and other federally aided programs are being jeopardized by the deterioration or inadequate provision of urban transportation facilities and services, the intensification of traffic congestion, and the lack of coordinated transportaion and other development planning in a comprehensive and continuing basis.
(3) Federal financial assistance for the development of efficient and coordinated mass transporation systems is essential to the solution of urban transportation problems.

As a result, Congress passed the Urban Mass Transportation Act of 1964.[1] For the first time the federal government became directly involved in planning and financing local transportation systems.

The purposes of the 1964 Act were to:

(1) assist in the development of improved mass transportation facilities, equipment, techniques, and methods, with the cooperation of mass transportation companies, both public and private.
(2) Encourage the planning and establishment of area wide urban mass transportation systems needed for economical and desirable urban development, with the cooperation of mass transportation companies, both public and private.
(3) Provide assistance to state and local governments and their instrumentalities in financing such systems, to be operated by public or private transportation companies, as determined by local needs.[1]

Funding was provided under the act to support capital projects (Section 3), research, development, and demonstration (Section 6), technical studies (Section 9), management training (Section 10), and university research and training (Section 11).

The 1964 Act was subsequently modified by the Urban Mass Transportation Assistance Act of 1970,[2] the National Mass Transportation Assistance Act of 1974,[3] and the Surface Transportation Assistance Act of 1978.[4] One key change that was introduced in the 1974 Act was the provision, for the first time, of federal funds that could be used by local jurisdictions to offset part of their operating deficits (Section 5).

One of the earliest studies supported under the Urban Mass Transportation Administration's (UMTA) research and development program was performed by the National Academy of Engineering. This study, "Design and Performance Criteria for Improved Nonrail Urban Mass Transit Vehicles and Related Urban Transportation Systems," became the basis for the Transbus program.[5]

The program, which became UMTA's major research and development effort in bus design, began in 1971. In 1979, eight years later, no bids were received in response to a procurement of 530 buses to the Transbus specification, issued by a consortium of three transit properties, Los Angeles, Miami, and Philadelphia.[6,7]

The Secretary of Transportation has called for an independent technical review of the procurement requirements and the associated issues to help him establish policies for future uses of federal funds for bus procurement. This report provides an analysis of technical, operational, and economic factors relating to Transbus. It presents a number of options relating to the technical and performance aspects of buses to be purchased in the future with federal funds, and the methods by which buses which utilize advanced techniques can be brought into service.

This section of the report continues with a description of current bus utilization, the potential market for new buses, and a summary of the chronology and technical aspects of the Transbus program. The section concludes with a statement of the critical issues that must be addressed.

The second section is devoted to a technical feasibility analysis of Transbus and the specifications prepared for the Transbus procurement, with amplifications and amendments contained in the consortium addendum.

The third section compares the projected operational implications of Transbus with the current performance of the Advanced Design Bus (ADB) manufactured by General Motors Corporation and Grumman Flxible Corporation, and supplied to the ADB specification.[8] Comparisons are also made with the buses supplied by two Canadian manufacturers, Flyer Industries Ltd. and General Motors of Canada.

The fourth section is an analysis of Transbus costs, including one-time (start-up and tooling), and an estimate of production costs, based upon the supply of 4,000 buses per year.

The fifth section reviews several alternative courses of action, and discusses the impact of each. Possible financing procedures for innovative bus technologies are covered.

The appendix to this report contains supporting material used in the analysis and trade offs.

Contemporary Bus Operations

Many of the technical requirements in the Transbus specifications were based upon the need for Transbus to meet current operating conditions. This section provides background information on the environment in which Transbus would be manufactured and operated.

Operations

The diesel engined bus is the mainstay of public transportation in the United States, with over 1,000 of the 1,034 operating transit systems providing bus service. Motor bus services carry three-quarters of all transit passengers and generate 60 percent of total operating revenues. Motor buses comprise 77 percent of all passenger vehicles owned and leased by mass transit systems in the United States.[9]

Mass transit ridership declined from a peak of 19 billion in 1945 to a low of 5.25 billion in 1972, and has subsequently recovered to more than 5.7 billion (Table 1-1). The latest figures indicate that this trend will continue; the ridership during the first four months of 1979 was 4.8 percent higher than the corresponding figure in 1978.[10] Bus ridership has increased as a proportionate share of the market from 44 percent in 1945 to 74 percent in 1977.

Table 1-1
Mass Transit Ridership

Year	Total Rides (Millions)	Bus Rides (Millions)	Percent Bus
1945	18,981.9	8,334.7	44
1950	13,845.0	7,681.0	55
1955	9,189.0	5,734.0	62
1960	7,521.0	5,069.0	67
1961	7,242.0	4,834.0	66
1962	7,122.0	4,773.0	67
1963	6,915.0	4,752.0	68
1964	6,854.0	4,729.0	68
1965	6,798.0	4,730.0	69
1966	6,671.0	4,702.0	70
1967	6,616.0	4,663.0	70
1968	6,491.0	4,524.5	69
1969	6,310.3	4,335.3	68
1970	5,931.7	4,058.7	68
1971	5,497.0	3,734.8	67
1972	5,253.3	3,560.8	67
1973	5,293.9	3,652.8	69
1974	5,605.9	3,997.6	71
1975	5,643.4	4,094.9	72
1976	5,673.1	4,168.0	73
1977	5,722.7	4,246.5	74

Source: Reference 9.
Note: All transfer rides are excluded.

Bus ridership declined from 5 billion in 1960 to a low of 3.56 billion in 1972 (recovering to 4.2 billion in 1978), but both the number of vehicles in operation and the total vehicle miles traveled by motor bus has remained relatively stable (Table 1-2). This apparent anomaly can be attributed to the change from urban to suburban population patterns since World War II; as population has moved from urban areas to the developing suburbs it has been necessary to extend bus routes to these new areas. An early (1971) study showed that, in a representative group of cities, route mileage (the combined length of all bus routes) increased by as much as 60 percent, while the total number of miles operated remained constant.[11] That is, the transit systems were providing less frequent services on longer routes.

These changes, in turn, have affected the operating profile required from a bus. Instead of frequent accelerations and decelerations with a low cruising speed, buses are required to accelerate to arterial and freeway speeds and maintain them. Buses operating in downtown city streets maintain average speeds of eight miles per hour or less; buses operating on suburban routes maintain average speeds in excess of sixteen miles per hour.[12] Bus requirements have reflected this trend. In 1960, virtually all buses were equipped with six-cylinder engines; by 1980, 75 percent of all buses will be ordered with the more powerful V-8 engine.[13]

These differences in operating needs are reflected in the Transbus Specification, which provides for a low power option with a top speed of 50 miles per hour, compared to the 60 miles per hour top speed of the standard Transbus.

Transit buses cover an average of 30,000 miles each year. However, different operating conditions cause wide variations and on some systems average annual mileage exceeds 40,000 miles per year.[14] The actual miles accrued each year by a bus varies about the average. For example, in one transit system the average mileage for one-year-old buses was more than 46,000 miles; for buses at the end of normal operating life, the average fell to 26,000 miles.[15] The average total mileage was 660,000, but it is not unknown for buses to exceed one million miles, particularly where the transit system has an active program of performance monitoring and preventive maintenance. These figures support the service life performance requirements for Transbus.

The Bus Market

For many years there has been a discrepancy between projections of potential demand for buses and the actual number of buses delivered. Table 1-3 lists the buses fitted with forty to fifty-two seats (encompassing the thirty-five and forty foot long buses that are the options permitted by the Transbus specification) delivered since 1964.

Table 1-2
Bus Operations

Year	Total Motor Buses	Total Vehicle Miles (millions)	Average Vehicle Miles (Thousands)
1945	49,670	1,722.3	34
1950	56,820	1,895.4	33
1955	52,400	1,709.9	32
1960	49,600	1,576.4	31
1961	49,000	1,529.7	31
1962	48,800	1,515.2	31
1963	49,400	1,523.1	30
1964	49,200	1,527.9	31
1965	49,600	1,528.3	30
1966	50,130	1,521.7	30
1967	50,180	1,526.0	30
1968	50,000	1,508.2	30
1969	49,600	1,478.3	29
1970	49,700	1,409.3	28
1971	49,150	1,375.5	27
1972	49,075	1,308.0	26
1973	48,286	1,370.4	28
1974	48,700	1,431.0	29
1975	50,811	1,526.0	30
1976	52,382	1,581.4	30
1977	51,968	1,623.3	31

Source: Reference 9.

Table 1-3
Seating Capacity

Capacity	Number of Buses	Percent of Total Number of Buses
Less Than 40	2,624	6.6
40	200	0.5
41	830	2.0
42	944	2.3
43	2,729	6.9
44	488	1.2
45	4,087	10.3
46	2,863	7.2
47	2,714	6.8
48	2,416	6.1
49	3,064	7.7
50	4,278	10.8
51	7,576	19.1
52	1,078	2.7
More Than 52	3,649	9.2
Total	39,540	99.4

Note: Because of rounding totals do not equal 100 percent.
Source. Transit Passenger Vehicle Fleet Inventory, Volume One.

In the last fifteen years, 46,656 buses have been delivered, of which 40,317 were in the thirty-five to forty foot range (86 percent). From 1973 to 1976, an average of 4,500 buses per year were delivered; rather lower than the 5,000 to 6,000 projected by UMTA Administrator Villareal in 1972 (Table 1-4).

Projections published by the American Public Transit Association in January, 1979 estimate a six year average of between 4,561 and 5,973, of which between 4,125 and 5,293 would be for thirty-five and forty foot coaches.[13] However, these figures estimated between 6,642 and 9,079 (5,822 and 7,964) for 1978.* In fact, the actual deliveries for that year were 3,795 and 2,741. Replacing the estimated with the actual deliveries gives an adjusted six year average of 4,086 to 5,092 for all buses, and 3,610 to 4,423 for thirty-five and forty foot buses. These estimates were derived by accumulating transit company procurement estimates.

A study prepared in 1974 by Frost and Sullivan Incorporated projected a demand for urban buses of 6,200 in 1975 (actual deliveries were 4,714), 12,000 in 1980, 20,000 in 1985, and 23,000 in 1990.[16] These estimates appear high in view of current trends. However, the American Public Transit Association believes that orders for buses have been limited by the level of funding available, rather than by demand. If increased funding is provided (such as the $10 billion proposed by the President in his speech on July 15 1979) they expect the demand to increase to between 9,000 and 15,000 buses per year to cover replacement and expansion.[17]

With a total fleet of 40,000 vehicles, 35 and 40 feet long, and an assumed average life of fifteen years, an average of 2,667 buses per year is required for replacements. In the past five years, bus ridership has increased an average of 3.8 percent per year. During this time, bus inventory has increased by only 1.8 percent. If it is assumed that excess capacity has by

*For thirty-five and forty foot coaches.

Table 1-4
Bus Deliveries

Year	35 and 40 Foot	Total
1964	2,331	2,500
1965	2,679	3,000
1966	2,752	3,100
1967	2,208	2,500
1968	1,994	2,228
1969	2,002	2,230
1970	1,274	1,424
1971	2,349	2,514
1972	2,581	2,904
1973	2,701	3,200
1974	4,222	4,818
1975	4,714	5,261
1976	4,099	4,745
1977	1,580	2,437
1978	2,741	3,795

Source: Transit Fact Book, 1977-1978 Edition[9] *and testimony presented to the Subcommittee on Public Works and Transportation* now been absorbed, and that ridership trends are maintained, it is reasonable to project a 3-to-4 percent per year increase in demand for buses to meet the increased loading (from 1,200 to 1,600 additional buses per year). This would put the projected market for 35 and 40 foot buses in the range of 3,800 to 4,300 per year—very close to the adjusted figures obtained from APTA projections. An annual production of 4,000 buses to Transbus specifications has been used in the cost estimation section of this report. Unless a single type of bus is mandated, it is apparent that not all buses in the 35 and 40 foot range will be purchased to the Transbus (or ADB) Specifications. Small transit systems that are expanding, or partially replacing, their bus fleet are reluctant to break away from an existing design. (New Look buses of different manufacturers have many components in common.) Some larger systems are reluctant to sacrifice the four or five seats that are lost when moving from a New Look bus to an ADB. While some estimates of New Look bus procurements are as high as 500 per year, this is not considered large enough to have a major impact on the potential market for Transbus.

Chronology of Transbus

1964 The Urban Mass Transportation Administration established within the Department of Housing and Urban Development.

1968 "Design and Urban Performance Criteria for Improved Nonrail Urban Mass Transit Vehicles and Related Transportation Systems" described requirements for new buses.

Urban Mass Transportation Administration transferred to newly formed Department of Transportation.

1970 UMTA announced Transbus program.

1971 Transbus program initiated by UMTA, which called for development of prototype followed by purchase of 100 pre-production models.

Booz-Allen Applied Research awarded contract as Systems Manager.

Transbus specification developed.

Proposals received for Transbus.

1972 Contracts for development of prototypes awarded to AM General Corporation, General Motors Corporation, and Rohr Industries.

1974 - Transbus prototype delivered.

1975 Transbus prototypes demonstrated in New York, Miami, Kansas City, and Seattle.

1975 "Policy for Introducing Transbus into Nationwide Service" issued by Administrator. This called for a performance oriented specification requiring low floor and ramp or lift to be developed.

Interim procurement of high floor improved buses (ADB) approved.

Transbus goes to subsystem development program.

4/1976 Transbus Procurement Requirement (TPR) first issued.

5/1976 Administrator conducts public hearing concerning Transbus.

7/1976 UMTA policy announced requiring 24 inch "effective" floor height in buses bid after February 15, 1977.

2/1977 Effective date of 24 inch effective floor height delayed to May 27, 1977.

3/1977 Public hearing on Transbus policy conducted by the Secretary of Transportation.

5/1977 The Secretary issued Transbus mandate requiring full size buses bid after September 30, 1979 to comply with Transbus specification (18 inch effective floor height).

6/1977 Transbus Procurement Requirements revised to reflect mandate.

10/1977 First Transbus purchasing consortium formed.

3/1978 TPR re-issued with single rear axle configuration.

8/1978 TPR revised and re-issued to reflect tandem rear axles and an option of a lift or a ramp for wheelchair access.

9/1978 Administrator reaffirms Transbus mandate.

1/2/1979 Transbus invitation to bid issued. Opening date set at March 30, 1979.

1/25/1979 Bidders briefing

2/22/79 Request from Grumman Flxible to extend bid opening date to April 27. Bid opening extended to May 2, 1979.

5/2/79 Bid opening—no bids received.

5/31/79 Regulations issued requiring all buses ordered after July 2, 1979 to be accessible to handicapped persons, including wheelchair users.

Key Issues

The purpose of this report is to critically examine the technical and economic characteristics of Transbus and factors relating to its procurement. The report addresses the following questions.

- Do Transbus specifications represent as bus design that can be built using currently available technology? If not, what subsystems require development? When would proven designs be available?
- It is possible to amend the specifications or procurement terms for Transbus to attract interest in building it without compromising the basic rationale for the Transbus?
- How do the performance and costs of buying and operating Transbus compare to the performance and costs of Advanced Design Buses and the New Look bus?
- How would the first investment costs involved in producing Transbus be reflected in its price?
- What options should be considered now that U.S. bus manufacturers have declined to bid on the Transbus procurement package?

MITRE was asked to consider Transbus as specified, and to suggest some alternatives. The options that are presented in Section 5 are:

1. Transbus as specified (minor adjustments to specs)
2. Transbus with a performance specification allowing a lighter bus with a single rear axle instead of present specification (tandem axle)
3. ADB with 24 inch floor height and 38 inch clear width front door

Variations on these options were considered and rejected:

- elimination of a wide front door
  — would adversely affect productivity
- high floor Transbus
  — would offer little advantage over an ADB
- relocation of wheelchair lift on Transbus
  — possibility with all options. Policy decision
- ADB with 22 inch floor height
  — possible candidate for Option 2. Problem is weight reduction (or tandem axle)
- ADB with 24 inch floor height and 44 inches wide front door
  — more design problems than with 38 inches clear width front door, without commensurate benefits

References

[1] Urban Mass Transportation Act of 1964, PL88-365.78, Stat 302, 49 USC 1601 et seq.

[2] Urban Mass Transportation Assistance Act of 1970, PL91-453, 84 Stat 962.

[3] National Mass Transportation Assistance Act of 1974, PL93-503, 88 Stat 1565.

[4] Surface Transportation Assistance Act of 1978, PL95-599, 92 Stat 2689.

[5] National Academy of Engineering, *Design Performance Criteria and Improved Nonrail Urban Mass Transit Vehicles*, Washington, D.C.: May 1968.

[6] U.S. Department of Transportation, Urban Mass Transportation Administration, *Transbus Procurement Requirements*, Washington, D.C.: GPO, August 1978.

[7] Southeastern Pennsylvania Transportation Authority, *Addendum to Transbus Procurement Requirements*, Philadelphia, Pennsylvania: August 1978.

[8] U.S. Department of Transportation, Urban Mass Transportation Administration, *Baseline Advanced Design Transit Coach Specification*, Washington, D.C.: April 4, 1977.

[9] *Transit Fact Book*, 1977-1978 Edition, Washington, D.C.: American Public Transit Association, May 1978.

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[14] V.S. Thurlow, "Capital Grant Guidelines for Bus Replacement," WP-10527, McLean, Virginia: The MITRE Corporation, February 1974.

[15] V.S. Thurlow, "Bus Repair Cost Profile: Southern California Rapid Transit District," WP-10579, McLean, Virginia: The MITRE Corporation, May 1975.

[16] Frost and Sullivan, *Transportation Market in the USA to 1990*, New York: November 1974.

[17] American Public Transit Association, *Emergency Bus Needs Summary*, 1979 Special Survey Number 1, June 21, 1979.

Introduction and Background

This section addresses the question of whether it is technically feasible to produce Transbus as it is specified in the Transbus Procurement Requirements (TPR). The assessment also considers whether the design specified in the TPR is reasonable in the time frame required. Terms and conditions, including warranty provisions, are considered which might have influenced the bus manufacturers in making their decisions about bidding on the procurement.

The Transbus Procurement Requirements were reviewed with both the history of the document and the positions of the U.S. bus manufacturers before and after the procurement solicitation in mind.

Meetings were held with some of the key people who were directly involved in the procurement process. These included representatives of Booz-Allen Applied Research, who prepared the original specification from UMTA, and representatives of component and bus manufacturers. These sources could only be pursued for information within the limited time allotted to MITRE for the study. A complete list of the persons interviewed, and their affiliation, is presented in Appendix E.

Technical Review and Assessment

The following questions were the focus of MITRE's investigations.

1. (a) Can the bus be built to meet the technical specifications?
   (b) Are the terms and conditions, including warranty requirements, consistent with reasonable business practice for producing a new product? In addition, did the terms and conditions affect the no-bid decisions of the U.S. bus manufacturers?
2. What changes to the TPR are needed to procure a bus that meets the requirements of the Secretary's Mandate?

Details of the review and assessment are presented below.

The TPR requires that Transbus have a low, 22 inch floor, with a kneeling feature to reduce the floor height to 18 inches while picking up or discharging passengers. As a direct result of this requirement, various technical complexities are added to the bus design which are not present in existing ADB or New Look buses.

Although vehicle productivity for the general population is not significantly increased by a low floor, it is perceived to be of definite value to the elderly and handicapped, while providing more convenient access for all transit users, and is necessary to acommodate a ramp with an acceptable slope. Furthermore, increasing the 22 inch floor height to 23 or 24 inches would slightly worsen the boarding and alighting problem for the elderly and handicapped, without alleviating the technical problems described in the following sections.

For the low floor, new developments and design are required for rear axles, tires, brakes, front doors, windshield, and seating arrangements. In addition, maintenance for all underbody systems is made more difficult since space is reduced under the floor, which limits access to components for maintenance and repairs.

A second consideration is the weight of the bus. The Transbus curb weight allowed in the TPR is 26,000 pounds. At this weight, with a full load of seated passengers, the bus must have tandem rear axles to comply with federal axle load limits.

Careful examination of the existing ADB at the separate manufacturing facilities leads us to conclude that the weight of major bus subsystems cannot be substantially reduced, using available components or established component design philosophies. Second, the lighter of the two ADBs, the Grumman Flxible 870, weighs about 24,800 pounds, without a lift.* A weight reduction of approximately 2,400 pounds would be required before this bus could meet axle load limits with a full seated load. Such a reduction does not appear feasible, since the bus design already utilizes lightweight structural construction techniques and materials.

Although a complete new bus design has been proposed, which would be significantly lighter and therefore would permit a single rear axle with dual tires, MITRE does not have sufficient information to judge whether the claims for this design can be achieved.

It is axiomatic that development of a lighter weight bus should be encouraged. Therefore, a performance specification which would allow a single rear axle to be used if the bus met federal axle load limits would be appropriate.

Tandem Axles

As discussed above, the 26,000 pound weight of Transbus dictated that tandem axles be used at the rear of the bus. In addition, in order to achieve sufficient traction, both axles must be driven.

Both Rockwell and the bus manufacturers estimate that development of a tandem drive axle will require approximately four years, including the extensive operational testing necessary to derive warranty information. Rockwell estimates the development program will cost $1.5 million, and that tooling costs for the tandem axle will be between $10-$20 million.

*Weights vary somewhat with particular procurement requirements.

Such a program is necessary because (1) a new differential with a smaller ring gear is required, and (2) the differential must be floor mounted, which requires swing axles with more bearings and U-joints. The new, floor-mounted differential must fit under the low floor with 6½ inch ground clearance.

Although there is an established procedure for axle design based on years of truck axle manufacturing experience, scaling may be complicated by dynamic interaction among the drive train components. Also, since bus axles are only a small part of axle manufacturing, there is little financial incentive to encourage new development for a limited production item.

As previously stated, maintenance will be more difficult for this underbody component. Not only is space limited, but the added mechanical complexity of the driven rear axles will require additional maintenance. A weight penalty of at least 400 pounds is also incurred. Purchase cost of the tandem axle, including inter-axle differential and swing axles, is estimated at $12,000 per bus, as opposed to slightly less than $4,000 for a conventional single axle.

Tires

The low floor and tandem axle requirements make a new low profile tire necessary. This tire, approximately 35 inches in diameter, is the highest risk development item in the Transbus concept, because no commercially available, warranted tire can meet the load and temperature requirements. In current operations, temperatures often exceed 250°F at the tire bead-wheel rim interface in transit operations with the ADB. At these temperatures, tire life is drastically reduced, and tire blow-outs are potential safety hazards.

A MITRE analysis concludes that the bead temperature can probably be reduced to approximately 250°F on the Transbus tire (using an extra brake retarder discussed in the next section); up to four years for development and testing will be required.

The cost of the Transbus tire will be higher than an ADB tire since the tire cannot be regrooved and the wear rate will be higher due to reduced tire diameter. While the reduced amount of rubber in the tire may lower its initial cost, it is likely that the overall tire costs will be approximately double that of ADB tires.

In conclusion, both tire manufacturers state that a satisfactory low profile tire can be built, but they will not commit to a warranty until operational testing on a Transbus has been conducted. Firestone estimates a cost of approximately $4 million for fully developing a satisfactory low profile tire. Goodyear estimates that a radial tire (presently limited to 200°F bead temperature) can be developed for approximately $2 million.

Brakes

Along with the tandem axle and tires, additional development is required for brakes for the small Transbus wheels. Smaller wheels will have smaller diameter brake drums, so the brake shoes will be smaller in diameter. However, because the shoe is wider and there will be six brakes (instead of four as on the ADB), there will be sufficient brake area. Since brakes are a major cost and maintenance problem on existing buses (partially due to FMVSS121 requirements), brake retarders will most likely be adopted for all future buses.

Brake retarders are virtually state-of-the-art technology. Electromagnetic retarders are now being marketed by Telma. A new hydraulic retarder, being developed by Detroit Diesel Allison, is expected to be available with a warranty within four years. One version of this retarder, the MT 600 Output Retarder, is a separate driveline connected hydraulic retarder with an integral friction clutch. Another version will be incorporated into the V730 transmission, adding 3½ inches to the length of the transmission. Allison states that the retarder will weigh approximately 140 pounds and cost approximately $2,500. It is expected to appreciably reduce brake wear and maintenance.

Another promising development is the oil-cooled disk brake. This brake was used by GM on their Transbus prototype, but development has presently stopped. Such a brake would alleviate the tire temperature problem; it could be available within four or five years if sufficient financial incentive could be obtained, according to GM.

Design Considerations at Front of Bus

The combination of the 22 inch floor height, 10° approach angle, 44 inch wide front door, and 4 inch limit on front door protrusion presents a design problem to the bus manufacturer. Not only geometric problems are involved; mechanical components for the ramp/lift must also be integrated into the wide door, and satisfactory ramps and lifts are not yet available.

It appears that neither GM nor GFC can meet the above design parameters with incremental changes to their ADB design. However, a new design can provide all the desired features if some minor compromises are allowed.

For example, a slightly narrower front door may significantly reduce the geometric limits required to achieve a 10° approach angle. It will also improve streamlining and bus front styling, and reduce windshield reflection. Basically, a 38 inch wide front door opening is adequate for two-way bus entry and exit (a desirable productivity feature discussed in Appendix B). If less than 3 inches per door side is allowed for grab rails, the total front door width may be reduced to perhaps 42 inches.

In another example, the approach angle may be reduced slightly from 10° without appreciable detriment to bus front impact with potholes, curbs, and steep grades.

Nevertheless, design problems will remain with items such as windshields, which will be subject to reflection from the higher illumination required for the Transbus interior. This problem will be no worse than in the ADB, and a design concept has been proposed which may solve the problem. This concept utilizes an "elliptic" contoured windshield that will focus reflection vectors on a door panel. (See U.S. Letters Patent No. 2,833,590.)

As previously mentioned, design problems have not yet been solved for ramps and lifts. These components will require special tools, parts, and framing, and will also be more susceptible to impact damage because of their vulnerable position at the front of the bus. Obviously, maintenance costs will be incurred for these mechanical devices.

Seating Capacity

Layouts in Appendix B indicate that the specified forty-six seats can be provided, but no flexibility in specifying seat pitch will be allowed. That is, only with the minimum hip-to-knee room (27 inches) and minimum seat back thickness (½ inch) can forty-six seats be fitted into the available space.

With respect to the provision for wheelchair positions, we note that at least one seat is permanently eliminated to provide each wheelchair position. When the position is in use, at least two additional seats must be folded up to make room for the wheelchair passenger. Of these two additional seats only one is actually lost, since the other folded seat is replaced by the wheelchair.

Transbus Feasibility

Manufacturing Considerations

MITRE concludes that Transbus can be built in accordance with the Transbus specifications and the terms and conditions of the TPR, including the Consortium Addendum, *with the following exceptions*.

First, certain wording in the Transbus specifications should be changed to relieve unduly restrictive terminology which was presumably not intended by the specification writers. These items, discussed in detail in Appendix A-1, correct an error made by UMTA in the specification for bus drivers' visibility of the curb. They also relieve restrictive terminology pertaining to Bus Design Operating Profile, Bus Maintenance, Handicapped Passenger Loading System, and Electrical System General Requirements.

Second, wording of the specification should be modified in certain instances to clarify requirements which are the source of legitimate objections on the part of the U.S. bus manufacturers. These clarifications are also discussed in Appendix A-1.

Warranty Considerations

Under the provisions of the TPR, warranties are to be provided for six subsystems or components, some of which will not be manufactured by the bus manufacturer but which will be purchased separately from other suppliers. For the bus manufacturer to warrant the entire bus, it is necessary that the warranty provisions be imposed upon his supplier. As discussed earlier, tandem axles, tires, and brakes are components which are not presently available. They must be developed over a period of time. In normal industry practice, warranties on such items are not furnished until a new product has undergone testing in actual field service to the satisfaction of both the customer and the supplier, and the design is finalized. The extent of the warranty can be established only after such testing. The provisions of the TPR and the normal industry practice are in conflict, and excessive costs may be incurred by the manufactuer.

MITRE concludes that the terms and conditions, including warranty requirements, were not reasonable, and were a signficant factor affecting the no-bid decisions of the U.S. bus manufacturers.

Allowances for Exceptions and Waivers and Technical Alternatives

Two basic changes to the TPR would relieve some technical and economic problems in the TPR and yet not affect the real objectives of the Transbus mandate.

Change 1—the TPR should allow exceptions and waivers.

The TPR did not allow any exceptions to be taken to the specifications. The pertinent sentences appearing in Part I, Solicitations, Offer and Award Contractual Provisions, Par. 1.1.12, Bidder Review Procedures are:

> This (TPR) has been issued . . . after numerous consultations with transit coach manufacturers and operators. Therefore neither the Procuring Agency nor UMTA will accept requests for review or protests of the baseline specification used with this procurement.

Paragraph 1.1.1.6, Bid Rejection , states:

> Conditional bids, or those which take exception to the specifications, will be considered nonresponsive and will be rejected.

MITRE recognizes that identical language appears in procurement documents for ADBs and that buses are being routinely procured under the ADB specification. However, the crucial distinction is that

- the ADB design is known, and uses off-the-shelf, warranted components
- the Transbus procurement required new components to be designed, developed, tested, and warranted

Under the low-bid, fixed-price procurement policy mandated by the Office of the Secretary of Transportation there was no easy alternative to restricting bidders to the particular specification requirements with no exception. Although potential bidders did have previous opportunities to present their objections to the baseline specifications, which were the Transbus specifications that existed before the Consortium added its Addendum, the TPR does not make adequate allowances for designing, manufacturing, and testing new hardware. The TPR should allow exceptions that would not seriously affect its objectives.

In addition, the TPR does not address the possibility of waivers. Certain documents relating to the history of Transbus suggest that UMTA had in mind the possibility of extending waivers to the manufacturers. However, the present version of the

TPR, upon which the bus manufacturers were required to submit bids, contains no such provision, nor are any procedures for obtaining waivers described. The TPR should be changed to allow waivers.

Change 2—The TPR should allow more design flexibility.

The specification does not take into account the design and performance trade-offs which are necessary when systems and components are being developed. Bids which may meet the intent of the specifications but not the letter should not be disallowed. An example of a potentially valuable deviation is illustrated by Part II, Paragraph 3.2.1 of the specifications. This paragraph requires that the bus be driven by a tandem rear axle. Discussions with the authors of the specifications (Booz-Allen) indicate that the requirement for tandem drive axles was included to assure that the bus did not violate either federal or state axle loading requirements. Thus, a bus design light enough to require only a single axle to remain within the limits of the law could not have been proposed. Such a proposal would have been determined to be nonresponsive and rejected.

Specification Part II, Paragraph 3.2.1 should be modified to state that the axle loading shall be within the federal axle load limit. This permits the contractor to perform design trade-offs between such elements as overall bus weight, the number of drive axles required, fuel efficiency, maintainability, and reliability.

(Appendix A-2 presents technical details of the three development programs that will be required if it proves necessary to meet federal axle load requirements by using a tandem rear axle.)

Two additional items that would benefit from alternatives, the Bus Front End Design and Steering Force, are discussed in Appendix A-3.

The specifications do provide (Part I, Paragraphs 2.13 and 2.14) for weight reduction and seating capacity incentives and for weight penalties if curb weights exceed the specified amount. This allows the contractor to determine the value of each pound of weight on each bus and permits trade-offs whenever weight is a factor. This philosophy of incentives and penalties should be extended to allow a performance trade-off for fuel economy.

Specification Part II, Paragraph 3.1.1.6 should be modified to specify a fuel consumption of no less than four miles per gallon, with cost incentives for exceeding this figure and cost penalties for poorer performance.

UMTA's Transbus program was designed to achieve the most advanced bus design practicable within the state-of-the-art. The particular areas of improvement identified were: comfort and ride quality; improved safety for passengers, pedestrians, and occupants of other vehicles; reduced maintenance; and lower floor and better access and interior arrangements which accommodate elderly and handicapped riders.[1]

This section compares Transbus with the operational performance of other buses readily available on the U.S. market; the Advanced Design Buses (RTS-II manufactured by General Motors Corporation, and 870 by Grumman Flxible Corporation), and the New Look buses manufactured by Flyer Industries, Limited, and General Motors of Canada. Table 3-1 provides comparative data for each of the buses. Specific aspects covered are:

- accessibility
- productivity
- performance
- maintainability
- reliability

Complete details of the analysis of operational performance are given in Appendix B.

Two issues arise at this point. First, we are comparing the performance of buses that have been produced in their basic form for twenty years, with two bus designs that have been in operation for less than two years, and with a yet-to-be-built bus whose

Table 3-1
Bus Specifications

Specified Item	Transbus[1]	Flyer	GMCL	GMC RTS-II	GFC 870
A. Technical					
1. Dimensional					
Ground to 1st Step					
- Entrance	14" max	13.5"	13.5"	13.0"	14.0"
- Exit	15" max	14.0"	15.7"	15.7"	15.0"
First to 2nd Step & 2nd to Floor					
- Entrance	8" (1st to floor)	10.7"	10.0"	9.6"	8.0"
- Exit	9½ (1st to floor)	10.7"	9.6"	10.0" est.	10.2"
Floor Height at Front	22" max	34.9"	33.2"	32.0"	30.0"
- Kneeled	18"	30.9"	29.2"	27.0"	24.0"
Door Clearance					
- Entrance	38" min	38.0"	44-48"[2]	30.0"	36.0"
- Exit	24" min	26.5" (push)	26.5" (push)	44.0"	30.0" (push)
Aisle Width	20" min	25.0"	26.0"	22.5"	26.0"
2. Suspension	Automatic Height Control	Air Suspension & Height Control	Air Suspension & Height Control	Air Suspension & Height Control	Air Suspension & Height Control
3. Axle					
- Front	Single	Single, Rockwell Reverse Elliot Type	Single, Rockwell Reverse Elliot Type	Single	Single, Rockwell
- Rear	Tandem	Single, Rockwell 63° Drive Angle	Single, Rockwell 63° Drive Angle	Single, 63° Drive Angle	Single, Rockwell
4. Brakes	Air Actuated	Air Actuated: 14.5"x5" Front 14.5"x10" Rear	Air Actuated: 14.5"x5" Front 14.5"x10" Rear	Air Actuated: 15"x6" Front; 15"x10" Rear	Air Actuated: 14.5"x6" Front; 14.5"x10" Rear
5. Wheels	Compatible with Tires	22.5"x8.25"-10 Stud		22.5"x8.25"	22.5"x8.25"
- Dual Wheel Spacing	Not Applicable	13¼"	13¼"		
6. Tires	Suitable for Conditions	6-11:00x22.5" 43.5" OD&11" Width	6-11.5x20"	6-12.5x22.5	6-11:00x22.5"

Continued on next page.

Table 3-1 (Concluded)
Bus Specifications

Specified Item	Transbus[1]	Flyer	GMCL	GMC RTS-II	GFC 870
7. Engine	DD8V71, 6V71 or Equivalent	DD6V71 Cum. VTB-903	DD8V71 / 6V71	DD8V71 / 6V71	DD8V71 / 6V71
8. Transmission	Allison 730 (Automatic)	Allison 730 (Automatic)	Allison 730 (Automatic)	Allison 730 (Automatic)	Allison 730 (Automatic)
9. Electrical System	12 or 24V / Generator	12V / Alternator	12V / Generator	24-12V / Generator	12V / Alternator
10. Odometer		Yes	Yes		
11. Body Construction	Durable, Exterior Surface Free of Fasteners	Steel Structure & Aluminum Panels	Monocque	Unitized Construction	Semi-Monocque
12. Windows	Fixed	Slides at Side Fixed at Rear	Slides at Side Fixed at Rear	Fixed Acrylic	Fixed Acrylic
14. W/C Lift Available	Yes (or Ramp)	Yes	Yes[2]	Yes (Rear Door)	Yes
B. Operations					
Capacity, Seats	46 min	51 nom.	51 nom.	47	48
Curb Weight, lbs.[3]	25,300 max	22,900[5]	22,000[2]	26,000[4]	24,800[9]
Seated Load Weight, lbs.[3]		30,500	30,000	33,100	32,100
- SLW Front Axle	20,000 max[8]	8,800	8,500	11,900	10,500
- SLW Rear Axle	34,000 max[8]	21,700	21,500	21,200[4]	21,600
Gross Vehicle Weight, lbs.[3] (Number of Passengers)		35,300(80)	34,200 (80)	38,000 (80)	36,800 (80)
Rear Axle (estimated)		23,500	23,700	23,600	24,000

[1]*Design Specifications*
[2]*Information from GMCL.*
[3]*Without wheelchair lift*
[4]*Information from GMC. Weights can vary depending upon equipment. Bus has A/C*
[5]*Information from Flyer: Axle load = 6,350 (front) & 16 050 (rear) for curb weight.*
[6]*Front axle load = 42% of total passengers.*
[7]*WMATA bid from GFC*
[8]*Federal Interstate Specifications.*
[9]*Information from GFC. Bus has A/C.*
[10]*With low profile tires. 26.0" with standard tires.*

specifications are based on nine experimental vehicles. Naturally, much of the data have been adjusted to compensate for the inevitable problems arising from the introduction of new vehicles, or have had to be estimated (guessed) because firm numbers were not available. Wherever possible, the source of the original data has been identified, and any adjustments or modifications made by MITRE have been explained.

Second, much of this analysis is based on service offered by the transit system rather than on service used by the public. This is particularly important when dealing with productivity and fuel efficiency. For example, while it is straightforward to compute fuel consumption in terms of seat-miles, an attempt to provide a comparison in terms of passenger-miles introduces a variable, i.e., load factor. This variable depends on a number of factors, including the extent to which a particular design of bus can attract additional ridership.

Any bus that meets the objectives of decreased trip-time, increased passenger convenience, comfort, safety, and greater aesthetic appeal will tend to attract more riders from their automobiles, and (at other than crush load times) operate at a higher load factor. As one paper states, "there is unquestionably a strong association between perceived system attributes and modal choice."[2] Perceived system attributes include comfort, convenience, ease of use, and vehicular and personal safety. Unfortunately, no data exist that would allow one to determine the modal split resulting from the introduction of Transbus.

Accessibility

Probably no issues of the Transbus design are as critical or as controversial as those associated with accessibility, specifically:

- floor (step) height
- wheelchair access
- ramp

The requirement for accessibility is defined in the regulations published in the *Federal Register* dated May 31, 1979.[3] Paragraph 27.85, subsection (b) states:

> New vehicles. New fixed route buses of any size for which solicitations are issued after the effective date of this part shall be accessible to handicapped persons, including wheelchair users.

With respect to new, standard, full size urban transit buses, this requirement remains in effect until such time as solicitations for these buses must use UMTA's bid package entitled, *Transbus Procurement Requirements*.

This regulation was introduced to ensure compliance with the requirements of Section 16 of the Urban Mass Transportation Act (as amended) and Section 504 of the Rehabilitation Act.

The Transbus concept has always assumed easier access for the general public and for the transportation of handicapped people.

Specifically transportation handicapped people are those who:

1. Experienced general problems in the past twelve months such as visual, hearing, mechanical aids, wheelchair or other problems (i.e., walking/going more than one block, waiting/standing; going up and down stairs, etc.);
2. Perceive they have more difficulty in using public transporation than persons without their general problems; and
3. Are not homebound (go/can go outside home) at least once a week with or without the help of another person.[4]

A survey showed that approximately 5 percent of urban residents classed themselves as transportation handicapped.

The original Transbus specification called for the provision of an extending ramp. Subsequently a wheelchair lift was permitted as an alternative. The value of a ramp over a lift is a matter of judgement. The ramp is quicker to deploy and stow, and can be used by all passengers and not just those in wheelchairs, including some ambulatory handicapped who cannot climb stairs. However, the ramp angles that are practical with Transbus are more than twice those generally considered acceptible. Tests have shown that some wheelchair users cannot use the ramp.

As a result of the recently published regulation, all Advanced Design Buses and New Look buses now being purchased will have to be fitted with wheelchair lifts. On June 29, 1979, the American Public Transit Association filed suit to stop the new regulation from going into effect. However, all the comparisons in this report assume that wheelchair lifts are installed.

Floor (Step) Height

The relevant sections in the Transbus Procurement Requirements state:

2.1.5.1 Height
Height of the floor above the street shall be no more than 22 inches measured at the centerline of the front door with the coach at curb weight. At this weight, the height of the floor above the street shall be no more than 24 inches, measured at the centerline of the rear door. The floor may be inclined only along the longitude areas of the coach. The floor incline shall be less than 1 degree of the horizontal.

2.1.6.1 Steps
A maximum of two steps shall be required for passenger ingress and egress. . . . At the front door, the first step up from the street level shall not exceed 14 inches with the coach at curb weight, and the second step riser height to coach floor level shall be no more than 8 inches. At the rear door, the interior step down shall not exceed 8 and ½ inches, and the second step to street level shall not exceed 15 inches with the coach at curb weight.

A related section states:

3.3.2.2 Kneeling
A driver-actuated kneeling device shall lower the coach during loading or unloading operations regardless of load to an equivalent floor height of no more than 18 inches measured on the step tread at the longitudinal centerline of the front door. . . .

A low floor alternative design for the RTS-II has been suggested by General Motors Corporation. General Motors has determined that, "lowering of the effective floor height to 24 inches may be possible in the relatively near future."[5]

Figure 3-1 shows the step heights for Transbus, RTS- II, RTS-II Low Floor, and Grumman Flxible 870 buses. The bus floor height on the Transbus prototypes was 23.5 inches (General Motors Corporation), 20 inches (AM General), and 17 inches (Rohr).

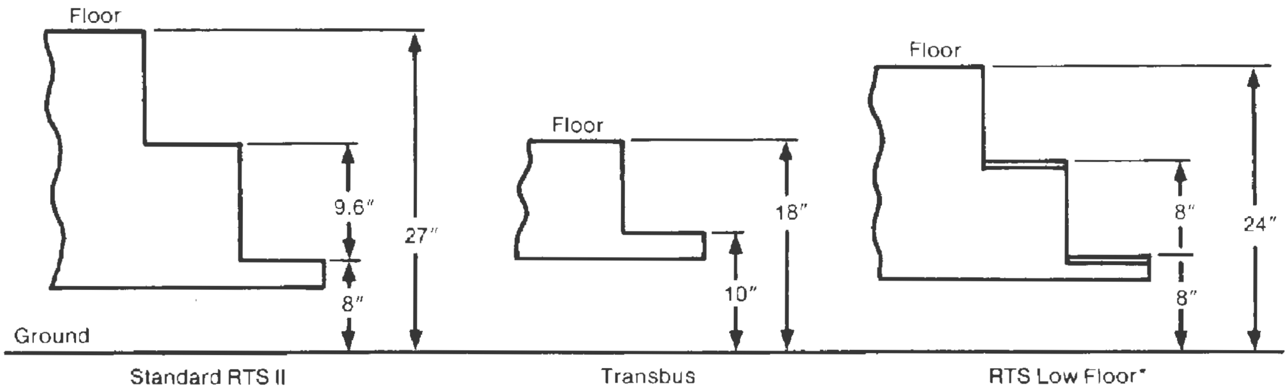
In a survey performed for General Motors by Metropolitan Detroit Market Research Incorporated, respondents who were transportation handicapped demonstrated a distinct preference for the two steps. There were a few who were able to climb two steps, although they could not climb three. Their preference tends to be confirmed by experience in the United Kingdom (Appendix B 3).

It can be concluded that the Transbus design is more accessible to the ambulatory handicapped than all other designs of buses, while the Grumman Flxible 870 and the proposed Low Floor RTS-II show significant improvement in accessibility over New Look buses.

Wheelchair Access

The relevant sections of the Transbus procurement documents state:

2.3.2 Passenger Seats
The coach shall accept seating arrangements that are basically transverse, perimeter or a combination of these with space and accommodations for a passenger (s) confined to a wheelchair.
. . .The wheelchair parking space shall be provided as far forward as practicable. . . .
Maneuvering room inside both the 102 and 96



Source: "Transbus, A Study by GMC," Truck and Coach Engineering," *May 1979.*
**These dimensions also apply to the Grumman Flxible 870 with low profile tires*

Not to scale

Figure 3-1
Entry Floor Height Comparisons

inch width coaches shall allow easy travel for a passenger in a wheelchair, with no width dimension in the doorway or aisle less than 34 inches. The vestibule and other areas requiring 90° turns of wheelchairs shall have a clearance arc radius dimension no less than 42 inches. In the parking area where 180° turns are required, space shall be clear in a full 60 inch diameter circle. These dimensions may be reduced to no less than 36 and 54 inches respectively on 96 inch wide coaches. Up to 12 inches of space on the outside of turning areas can be incorporated in the turning circle requirements, providing that a vertical clearance of 10 inches above the floor surface is unobstructed for foot rests.

Loading System

A system shall be incorporated at the front door to provide ingress and egress to handicapped passengers including those in wheelchairs from the street level or from curbs up to 20 inches in height. . . .
(2) Option: Lift-Loading System. Wheelchair passenger access shall be provided by an elevator or lift system.

The issue of wheelchair accessibility by wheelchair lift/elevator is basically one of evaluating the trade-offs between front- and rear-door access. For our analysis, we have assumed that the wheelchair parking spaces would be located adjacent to the rear door for rear door entry, and that the specification would be modified accordingly. Table 3-2 summarizes the differences.

Our analysis has shown that mobility within the bus is considerably easier with rear-door elevator/lift than for one mounted at the front door. However, access to the rear-door lift from the street may be more difficult, particularly where streets are congested.

Rear-door access presents operational problems because it requires the bus operator to leave the driver's seat. Rear-door access has less of an adverse impact on boarding and alighting, particularly if the bus is equipped with a wide front door. However, the driver is not available to monitor operations when operating the wheelchair lift.

The passengers seated on longitudinal seats over the front wheel housing will be subjected to some inconvenience in a 102 inch wide bus and considerable inconvenience in a 96 inch wide bus as a wheelchair is maneuvered from the front door to the parking area.

Ramp

The relevant section of the specification states:

2.6.6.1 Loading System
Option Ramp Loading System
The handicapped and wheelchair passenger access system shall be a [sic] extendable ramped surface no less than 6 foot in length.

The original Transbus specifications mandated the ramp. Subsequently, the transit systems were permitted to exercise the option of a ramp or a lift. In the

Table 3-2
Accessibility by Wheelchair Lift/Elevator

	Forward Loading	Rear Loading
Advantages	• Positioning the bus adjacent to curb becomes easier.	• Movement from lift to parking position is easier.
	• Controls are closer to the driver.	• Entry and exit from bus are possible when lift in use.
Disadvantages	• Maneuvering wheelchair is more difficult.	• Positioning the bus adjacent to curb is more difficult.
	• Entry is not possible while lift is in use.	• Driver must leave position and move to the back of the bus.
	• The lift is highly susceptible to damage.	

consortium procurement, sixty of the coaches for Miami were to be fitted with ramps; the balance called for wheelchair lifts.

Table 3-3 presents the ramp angles and ramp grades for a combination of ramp lengths, knelt floor height, and with or without a six-inch curb.

The ANSI specifications state, "A ramp shall not have a slope greater than 1 foot rise in 12 feet, or 8.33 percent, or 4 degrees 50 minutes."[6] To achieve the ANSI standard with Transbus would require an eighteen-foot ramp to the street, or a twelve-foot ramp to the curb. To achieve the ANSI standard with a six-foot ramp to street level would require a kneeled floor height of six inches.

UMTA tests have indicated that 96 percent of wheelchair users found a 14.5 degree slope satisfactory. This is the angle created when the ramp runs from the bus floor to the curb.[7] It is understood that these data were obtained from tests performed with a group of approximately eighty wheelchair occupants using the Transbus mockup of Booz-Allen. However, tests performed for General Motors indicated that 13 percent of the wheelchair users, 14 percent of the ambulatory handicapped, and 8 percent of the elderly were unable to get up the ramp.[8]

Whether a ramp on Transbus is a practical solution to providing access for the mobility disadvantage is still open to question. In the best case (bus kneeling, six-inch high curb) the ramp angle is twice that specified for making facilities accessible to the physically handicapped. The length of the ramp that would be required to meet the ANSI specifications is impractical for operating buses.

Further tests should be conducted to determine the extent to which wheelchair users and others with physical handicaps are able to board and alight from the bus using the ramp under varying conditions, including rain.

Productivity

Boarding and alighting at the narrow front door of New Look buses have long been recognized as a major source of transit delay since passengers must enter singly. Consequently, the goal of speeding up loading and unloading became a major consideration for future designs. By speeding up boarding and alighting, it was hoped that vehicle dwell times could be reduced so that average travel times would decrease significantly. Ultimately, this reduction would lead to greater service along with reduced pressures for fleet expansion.

One approach to speed up boarding and alighting is to reduce the number of steps on the bus. A second is to allow passengers to board while others are alighting. Several service time studies have shown that significant reductions in vehicle dwell time are possible with a front doorway wide enough to accommodate two streams of traffic.

Obviously, to take full advantage of such potential service improvements, the new bus could not provide less seating capacity than the current bus. Significant reductions of seating capacity would likely offset the improvements from streamlined boarding and alighting, since such reductions would necessitate a greater number of vehicles.

Door Widths and Step

The relevant sections in the Transbus Procurement Requirements state:

> 2.1.8.2 Dimension
> . . . Front door opening widths shall be no less than 44 inches with the doors fully opened. Rear door opening width shall be no less than 30 inches with the doors fully opened. . . . The clear door opening widths, including door mounted passenger assists or touch bars, shall be no less than 38 inches for the front door and 24 inches for the rear door.
> (1) Optional Wide Rear Door. The rear door shall have an opening width of no less than 44 inches with the door fully opened, and the clear door opening width shall be no less than 38 inches.

The relevant section on steps has previously appeared in the section dealing with Floor (Step) Height.

European transit operations using buses with 48-inch wide front doors have proven that two parallel or opposing streams of passengers can be readily accommodated. Forty-eight inches are an accepted design minimum for stairways intended to serve two-way traffic (e.g., MIL-STD-1472B).[9]

However, the steps of a transit bus more closely approximate the character of a doorway than a typical stairway. Only two or three steps are part of the bus entrance. Consequently, the potential area of

Table 3-3
Ramp Angles

Floor Height		6-Foot Length Ramp: Without Curb	6-Foot Length Ramp: With Six-Inch Curb	8-Foot Length Ramp: Without Curb	8-Foot Length Ramp: With Six-Inch Curb	10-Foot Length Ramp: Without Curb	10-Foot Length Ramp: With Six-Inch Curb
18″	Angle	14.5°	9.6°	10.8°	7.2°	8.6°	5.7°
	Grade	25.8%	16.9%	19.0%	12.6%	15.2%	10.0%
24″	Angle	19.4°	14.5°	14.5°	10.8°	11.5°	8.6°
	Grade	35.0%	25.8%	25.8%	19.0%	20.4%	15.29%

conflict is quite small and offers a traveler some opportunity for turning to avoid conflicts with other passengers. As a result, the width specification for a bus entrance need not be the same as that for a conventional stairway.

Passenger Service Time

Passenger service time depends on a number of factors. For the past two decades, at least, various studies have attempted to quantify the effects these factors have on passenger service time and thus on vehicle dwell time. A 1958 Rhode Island study found passenger service time accounts for 17 to 26 percent of total travel time and 50 to 76 percent of total delay time.[10] A 1959 St. Louis study recorded passenger service time as 18 percent of total trip time and 60 percent of total delay time.[10] A 1977 study report covering the results of surveys and photographic studies between 1967 and 1976 in eighteen cities in the U.S., Canada, and Puerto Rico concluded the time to board and alight transit vehicles accounted for 15 to 25 percent of total travel time and 50 to 80 percent of total delay time.[11]

Savings of up to 40 percent are possible because of double-wide doors as opposed to door widths which allow only a single stream of passengers. Tests on the prototype Transbus show that the times are similiar to those for the double-wide door and represent approximately equal improvements over New Look and ADB buses.

Double-wide doors offer substantial productivity improvements with all methods of fare collection. Potential savings of up to 40 percent of passenger service time can translate into average overall travel time savings of from 4 to 10 percent assuming passenger service time represents from 15 to 25 percent of total travel time.

Seating Capacity

The relevant section in the Transbus Procurement Requirements states:

> 2.3.2.1
> . . . . Seating capacity shall be no less than 46 when the wheelchair paths are not being utilized.

The nominal seating capacity of other designs of buses is given in Table 3-4. Although the manufacturers claim that it is not possible to achieve the specified capacity, MITRE has determined that it is probable that the requirement can be met.

The issue of Transbus productivity combines opposing factors. On the one hand, wider front doors may contribute to improved vehicle productivity by reducing vehicle dwell time and speeding up service. On the other hand, potential seating capacity reductions may tend to negate or even overwhelm any potential improvements in passenger service time.

Assume for the moment that an as-specified Transbus (forty-six seats) displaced the current fleet of buses (approximately 41,000). If the current fleet consisted entirely of GM's RTS-II with its standard forty-seven-seat configuration, then 2.1 percent more Transbuses would be required to maintain the same number of seats in the fleet. If the current fleet consisted entirely of GFC's 870 with its forty-eight seats, then 4.2 percent more Transbuses would be required.

Table 3-4
Nominal Seating Capacity of Forty-Foot Coaches

Coach	Capacity
Transbus (specified)	46
Flyer Industries	51
GMC - Canada	51
GMC RTS-II	47
GFC 870	48
Transbus Prototypes	
AM General	42
GM	41
Rohr	45

The 4 percent figure represents a maximum. Several factors tend to reduce the magnitude of the fleet expansion, including:

- the introduction of high capacity articulated vehicles to displace buses on which capacity limits have already been reached
- seated versus total (seated plus standing) capacity requirements

Nevertheless, the 2-to-4 percent range represents a value against which potential productivity improvements can be compared. Unless these improvements are of a similar magnitude to compensate for potential losses, Transbus would represent a net productivity degradation.

Performance

One of the six Transbus program criteria—speed of transit—was concerned with the reduction in overall transit time between boarding and destination points.[1] Factors affected by this program criterion included coach speed, acceleration, gradeability, and boarding time.[13] Requirements in these areas were specified in the Vehicle Performance subsection of the TPR issued in August 1978, as well as those for power, jerk, and fuel economy. Manufacturer concerns over TPR vehicle performance requirements are directly related to the expected weight of production Transbuses. Vehicle top speed, acceleration, gradeability, and fuel economy are all affected by vehicle weight.

The design operating profile is presented in Figure 3-2. It should be noted that except for the fuel economy requirement of 3.5 miles per gallon in the TPR, Transbus and ADB vehicle performance requirements governing gradeability, acceleration, and operating range are identical.

Because of shortcomings of performance-related information provided in the prototype test results and supporting data from the manufacturers, it was not possible to conduct an analysis of performance requirements based on operational data.

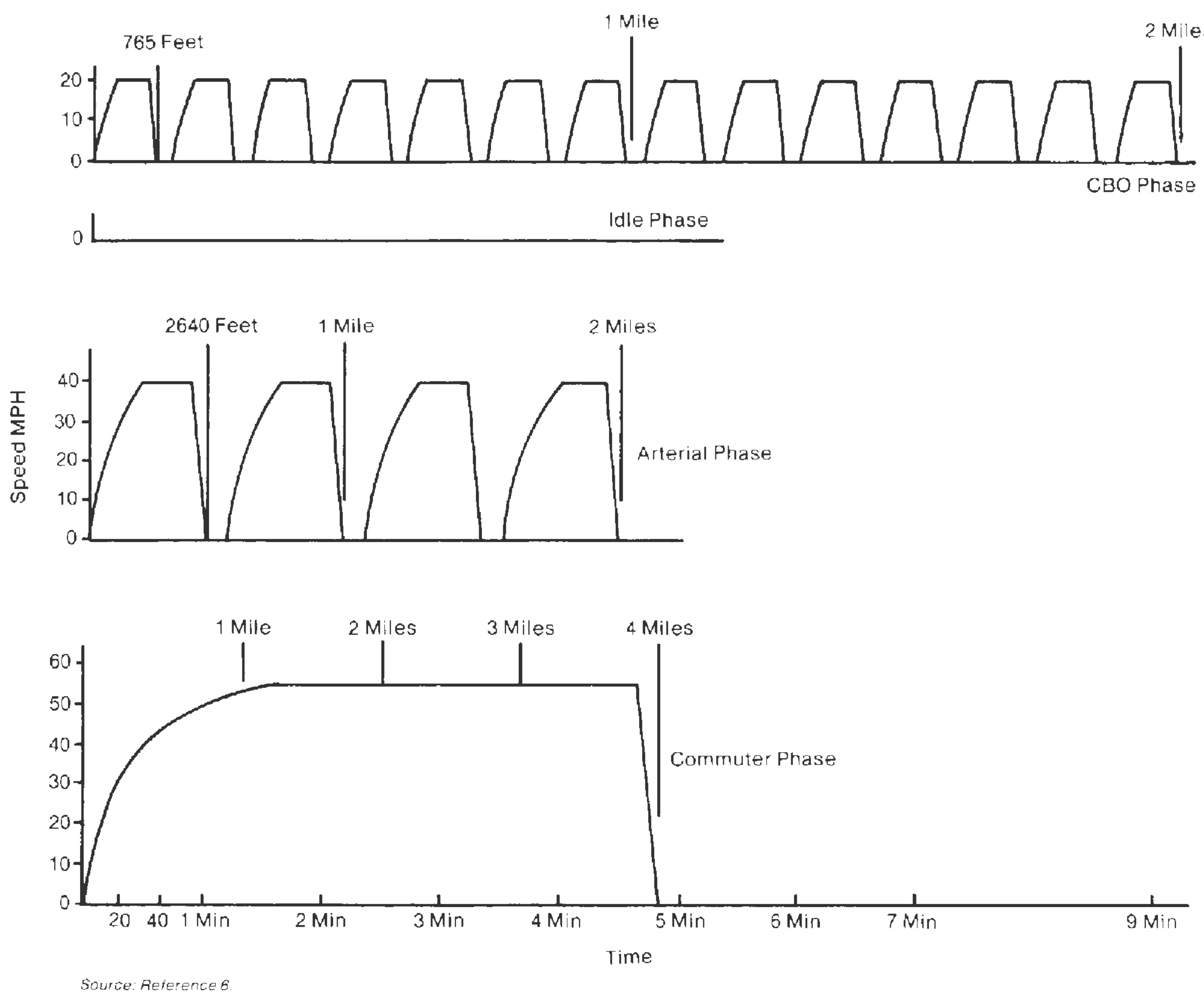
Instead, parametric studies were performed through the use of MITRE's Vehicle Performance Model. These studies addressed the effects of vehicle weight and driveline efficiency on Transbus acceleration, gradeability, and fuel economy potential. They also enabled us to assess the performance of a modified Transbus (Option 2 in Section 5.1).

Results from these runs of a "nominal" ADB and Transbus over the specification duty cycle profile described in Figure 3-2 formed the baseline comparison. Subsequent runs were made to evaluate the effects of weight and driveline efficiency on vehicle performance. Table 3-5 presents data for the ADB, Baseline, and modified Transbus.

Gradeability simulation results indicated that gradeability requirements could be met by a Transbus with a curb weight of 26,000 pounds and the 8V-71, V730 engine-transmission combination. However, the seven-mile-per-hour, 16-percent-grade requirement was barely met. Simulation gradeability results for the 27,000-pound curb weight Transbus indicated that the 16-percent grade requirement could not be achieved with the 8V-71, V730 motor transmission combination.

Acceleration potential was evaluated by simulating full-throttle acceleration to fifty miles per hour on a zero-percent grade. Acceleration runs were made for the nominal ADB, the nominal Transbus, and a 27,000-pound Transbus. Results indicate that a 26,000-pound Transbus should be able to partially meet specification acceleration requirements. Adding a thousand pounds to the nominal Transbus resulted in even longer acceleration times. A comparison of differences in the time to accelerate between the nominal Transbus and ADB and the nominal and heavy Transbuses indicates that it is driveline efficiency rather than weight that is the major influencing factor in not meeting the requirements.

Simulation fuel economy results support manufacturer beliefs that Transbus will exhibit fuel economy inferior to that obtainable by current ADBs and below that required in the Transbus specification. However, the fuel economy is heavily influenced by driveline efficiency. The modified Transbus would



Source: Reference 6.

Figure 3-2
Transit Coach Operating Profile Duty Cycle

Table 3-5
Nominal ADB and Transbus Characteristics

Characteristic	Nominal ADB	Nominal Transbus	Modified Transbus
Vehicle Curb Weight with Lift (lb.)	26,200[1]	26,000[2]	21,000
Seated Passsenger Weight (lb.)	7,050[3]	7,050	7,050
Seated Load Weight (lb.)	33,250	33,050	28,050
Vehicle Frontal Area (ft.^{2})[4]	84	81	81
Effective Frontal Area (ft.^{2})	76	73	73
Aerodynamic Drag Coefficient[5]	0.50	0.50	0.50
Driveline Efficiency (%)	90[6]	83.5[7]	90

[1] *Based on Atlanta ADB weight of 25,500 pounds and lift weight allowance of 700 pounds provided for in "Baseline Advanced Design Transit Coach Specifications."*

[2] *Maximum allowable Transbus curb weight, "Transbus Procurement Requirements."*

[3] *Calculated, based on forty-six passengers and a driver, and 150 pounds for each passenger and driver.*

[4] *"Transbus—Position of the Grumman Flxible Corporation with Respect to the Pending Initial Procurement of Transbuses," Grumman Flxible, March 12, 1979.*

[5] *T.J. McGean, Urban Transportation Technology, (Lexington, Massachusetts,Lexington Books, 1976), page 151.*

[6] *"Booz-Allen & Hamilton Performance Simulator—Input Samples," Booz-Allen & Hamilton.*

[7] *Estimate from "Transbus, A Study by GMC Truck and Coach Engineering," May 1979.*

have a fuel consumption of approximately 3.8 miles per gallon—an improvement of 8 percent over the baseline ADB.

Based on results of an evaluation of manufacturer conclusions and supporting data, discussions with manufacturers and relevant subcontractors, and simulation supported analysis, the following conclusions have been drawn.

It is reasonable to expect from a specification Transbus—operating with the Detroit Diesel 8V-71 engine and Allison V730 transmission—acceleration, gradeability, and fuel economy capabilities below those levels specified in the TPR. This may be attributable to the low Transbus driveline efficiency resulting from the tandem axle requirement. A thousand-pound increase in vehicle curb weight would result in reduced fuel economy, but not to the extent claimed by some manufacturers.

Transbus manufacturers may be able to overcome the predicted 0.6 percent loss in fuel economy, resulting from a thousand-pound increase in vehicle weight, through use of the new six-cylinder diesel engine recently introduced by Detroit Diesel for transit applications. Detroit Diesel claims it will provide more horsepower and higher torque than the 8V-71N, and will improve fuel economy.

Maintainability

Throughout the Transbus program, concern has been expressed regarding the adverse effect that the low floor design would have on the ease of servicing and maintaining the bus. The policy statement adopted by the American Public Transit Association on August 10, 1977 stated:

> DOT's Urban Mass Transportation Administration should include a technology and component development program which will concentrate on the following problems:
> (1) . . . .
> (2) Adequate street clearance with appropriate access to assure maintainability of subsystems located beneath the passenger compartment
> (3) . . . . (4) . . . .(5) . . . .
> (6) General maintainability considerations including access and durability.

This section addresses the issue of access to systems requiring maintenance.

The available underfloor area on Transbus is approximately half that of current coaches. Major items to be located in this area include:

- wheels, tires, and axles
- brakes and suspension
- steering linkages
- drive shaft and differential
- engine and transmission (partly)
- batteries
- fuel tank
- air tank and dryer

In 1972, industry and road call experience was surveyed by the American Transit Association (now the American Public Transit Association). The survey covered a total of 26,491 buses operating over a period of a year, accumulating approximately 800 million miles. Road calls averaged 0.7 per month per bus—or about one road call every six weeks per bus.

The four most common causes of road calls were:

- electrical - 17 percent
- braking - 10 percent
- engine cooling - 10 percent
- transmission - 9 percent

Electrical

The most critical subsystem is the battery. In addition to requiring regular inspection and servicing, the batteries must be easily replaced. They are normally located on a pull-out tray, so servicing on a Transbus should not differ significantly from that of other designs of buses.

Braking

Technical details of the braking systems have been covered in Section 2. In addition to the brakes and brake shoes, the following items are typical of those which must be mounted to facilitate routine maintenance:

- check values
- air strainer
- alcohol evaporation
- slack adjuster

Suspension Systems

Suspension systems present a major maintenance problem in the Transbus design. However, road calls due to suspension problems now occur about once every three years per bus. If this level was maintained on Transbus, suspension system failure would infrequently disrupt service severely.

Tires

Experience of tires on the Advanced Design Bus and Transbus prototypes suggests that road calls for tire failure will be more frequent than on the New Look bus that formed the basis for the survey. However, the low floor design of Transbus does not affect the maintainability of tires.

With care in design and location of components, accessibility for maintainability would not be inferior to existing bus designs.

Two exceptions are the suspension and the axles. When the design has matured, these units should only require unscheduled attention infrequently. However, as both represent new subsystems on Transbus, the design should be reviewed critically to ensure the maximum degree of accessibility for maintenance.

Reliability

Reliability is a measure of the extent that a bus is ready for revenue service assuming a given level of maintenance. Under normal transit operation, 90 percent of the system buses should be in revenue service during the peak operating hours. The remaining buses will usually be divided into two groups: on standby in case of revenue equipment breakdown, and in the maintenance shops for inspection or repair.

The reliability specifications for Transbus and its major components are listed in Table 3-6 along with the comparable figures for the New Look and RTS-II buses. Inherent in these specifications are scheduled maintenance tasks performed by a mechanic of skill level 3M or less, at mileage intervals of not greater than 6,000 miles. Although many of the Transbus components are similar to those found in the New Look and ADB (e.g., RTS-II) buses, this is only an indication that the life expectancy of the components in all three buses would be comparable. For instance, the Detroit Diesel Allison 8V-71 engine is almost a standard for all three buses. By adding an air conditioner to the bus—a standard on the Transbus and RTS-II—an extra load is placed on the engine, presumably causing a decrease in its life expectancy.

It is likely that Transbus will require a higher level of maintenance to equal the New Look bus in terms of reliability. Some Transbus design considerations have already been reflected in the ADB where they provide some improvement in the reliability of the electrical system and the coach in general. The low profile and relatively high weight of Transbus penalize the brake system, tires, differentials, and rear axle. As a result, the transit operator can be expected to provide more frequent maintenance for Transbus to assure a specified level of revenue service.

Table 3-6
Major Component Reliability, Thousands of Miles

	Transbus			
Item	Specification	Reference	New Look[1]	GMc[2] RTS-II
Coach	600	1.5.4.1		500
Engine	300	3.1.3.1	364 ± 47	300
Transmission	100	3.1.3.3	141 ± 29	100
Differential	Same as axle	3.2.1	442 ± 61	500
Generator	Not stated		148 ± 35	500
Starter	Not stated		125 ± 46	125
Brake Linings	15	3.5.1.2	44 ± 11[3]	20-25[3]
Suspension	Life of coach	3.3.1		Life of coach
Axles	200	3.2.1		200
Tires	Not stated			

[1] *V.S. Thurlow, "Maintenance Labor Requirements over the Service Life of Urban Transit Diesel Buses," WP-10525, (McLean, Virginia: The MITRE Corporation, February 1974).*

[2] *Estimates received from GM, Pontiac, Michigan, July 1979.*

[3] *The New Look estimates are based on brake materials prepared prior to enforcement of Standard FMVSS 121. The GM estimate is based on a recently developed brake material which is significantly better than one used on current RTS-II coaches.*

References

[1] U.S Department of Transportation, Urban Mass Transportation Administration, *Innovation in Public Transportation—A Directory of Research, Development and Demonstration Projects*, Fiscal Year 1977, Washington, D.C.: 1978.

[2] R. Dolson, and M.L. Tischer, "Comparative Analysis of Determinants of Modal Choices by Central Business District Workers," *Transportation Research Record* 649, 1977.

[3] "Nondiscrimination on the Basis of Handicapped in Federally-Assisted Programs and Activities Receiving or Benefiting from Federal Financial Assistance," 49 CFR Part 27, May 31, 1979.

[4] U.S. Department of Transportation, Urban Mass Transportation Administration, *Technical Report of the National Survey of Transportation Handicapped People*, Washington, D.C.: October 1978.

[5] General Motors Corporation, "Transbus: A Study by GMC Truck and Coach Engineering," May 1979.

[6] "Specifications for Making Buildings and Facilities Accessable to, and Usable by, the Physically Handicapped," American National Standards Institute, ANSI A117.1-1961 (R1971).

[7] Information provided at the August 7, 1978 Briefing on Transbus.

[8] Testimony to the Subcommittee on Oversight and Review Committee on Public Works and Transportation, May 16, 1979.

[9] "Military Standard, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities," MIL-STD-1472B, December 31, 1974.

[10] W.H. Kraft and T.J. Boardman, "Predicting Bus Passenger Service Time," *Traffic Engineering*, October 1969.

[11] Kraft and Eng-Wong, "Passenger Service Time Characteristics of Street Transit Systems," Forty-seventh Annual Meeting, Institute of Transportation Engineers, Mexico City, October 1977.

[12] M.A. Condill and P.F. Watts, "Bus Boarding and Alighting Times, Transport Road and Research Laboratory Report," LR 521, 1973.

[13] Booz-Allen and Hamilton, Inc., *Transbus Engineering Test Program*, Transbus Document TR77-003, Bethesda, Maryland: December 1977.

[14] J.A. Bachman, *Bus Repair and Overhaul Automatic Diagnostic Systems Definition*, MTR-6620, McLean, Virginia: The MITRE Corporation, February 1974.

Given that Transbus can be built within the specified time, how much will it cost to buy, operate, and maintain? At a meeting of the American Public Transit Association (APTA) Bus Technology Committee, and in testimony before Congress, Grumman Flxible Corporation (GFC) representatives estimated that the 1984 cost of a Transbus equipped with a lift will be about $230,000. This is equivalent to $175,000 in 1979 dollars—assuming an inflation rate of 7 percent over the 4.5-year development period. General Motors Corporation (GMC) representatives estimate that the cost will be $185,000 per bus in 1979 dollars. These estimates are substantially higher than current Advanced Design Bus (ADB) prices of $125,000, and have led some to question the rate at which the manufacturers would be amortizing their investment in Transbus.

Some have argued that operating and maintenance (O&M) costs will also be higher for several reasons:

- reduced maintenance accessibility to under-floor components caused by the low floor
- increased complexity of the tandem rear axle and vehicle suspension system
- shorter brake and tire life
- increased fuel consumption

Based upon the limited amount of data that could be assembled in the short time period of this study, MITRE estimates that the price of Transbus, with the lift rather than ramp option, will be in the range of $138,000 to $150,000 in 1979 dollars. Table 4-1 contrasts this estimate with other actual and estimated bus prices. With the same qualification, it is estimated that Transbus O&M costs will be 2 to 4 percent higher than a New Look bus and 2 to 3 percent higher than an ADB. It must be mentioned that these percentages apply only after an intial "break-in" period of one to two years, during which manufacturers discover and correct what is apt to be a host of minor deficiences. Table 4-2 shows the components comprising the percentages.

The preceding numbers become more meaningful when placed in the context of a typical urban fleet, or even the national bus fleet. The Southern California Rapid Transit District (SCRTD) operates some 2,500 New Look buses. This year, its total operating expense, less depreciation, will be in the vicininty of $200 million. If it were to replace its fleet over the next twelve years with ADBs equipped with wheelchair lifts at a price of $125,000 each, its equivalent annual ownership cost would be $46 million when the changeover was complete, and for the years thereafter. This assumes a twelve-year vehicle life, a 10 percent discount rate, and no accounting for inflation. Annual operating costs, less depreciation, would be approximately the same as at present. Thus total annual cost would be approximately $246 million.

If, on the other hand, SCRTD were to replace its fleet with Transbuses, which have a fifteen-year life and are priced at $150,000 each, its equivalent annual ownership costs would be slightly more than $49 million. Its operating expense, less depreciation,

Table 4-1
Summary of Bus Prices—Forty-Foot Coach
(Dollars in Thousands)

	Price					
	With Wheelchair Access (Lift)			Without Wheelchair Access		
	1975	1977	1979	1975	1977	1979
New Look Bus	68	80	112	64	75	102[4]
Advanced Design Bus						
GMC RTS-II	—	—	125	72[1]	—	116
GFC 870	—	—	121	72[1]	—	111
Transbus						
TPR	—	—	180[2]	77[1]	—	168[2]
TPR	—	—	138 - 150[3]	—	—	128 - 140[3]
Modified Transbus	—	—	130 - 142[3]	—	—	120 - 132[3]

[1]*Booz-Allen estimate.*
[2]*Derived from manufacturer's data.*
[3]*MITRE estimate.*
[4]*Bid to Alameda-Contra Costa Transit District, July 1979*

Table 4-2
Relative Operating and Maintenance Cost Increases for Transbus

Cost Category	Transbus % of Total Operating Expense[1]	% Increase Relative to New Look Bus[2]	Advanced Design Bus[2]
Maintenance	14.8	12.2-20.2	8.2-15.9
Tires	2.9	27.3-100.0	20.6-89.6
Fuel	8.9	7.1-13.9	2.0-8.5
Insurance & Safety	4.6	(19.7)-(19.7)[3]	(7.2)-(7.2)[3]
All Other (e.g., driver)	68.8	— —	— —
Total	100.0	2.2-3.6	1.9-3.3

[1]Excluding depreciations.
[2]Low end is Booz-Allen estimate (1975).
[3]Parentheses indicate a cost decrease.

would be $207 million, for a total of $256 million—an increase of $9 million or about 4 percent over the ADB.

On a national scale, the large bus fleet size is approximately 40,000 vehicles and operating expenses are near $4.0 billion. With an all ADB fleet, total annual costs (i.e., ownership, operations, and maintenance) would be $4.75 billion, whereas with a Transbus fleet, costs would be $4.95 billion—a difference of $200 million, or about 4 percent. We recognize, of course, that this would not be the cost of primary interest to transit properties. The federal government provides 80 percent of a property's capital expenditures and, nationally, only about 20 percent of operating costs. The maximum federal subsidy of operating costs is set by formula, and any increase in cost would have to be absorbed by the transit property.

Please note that the preceding figures take no account of the increase in Transbus trip speed which, ideally, might reduce fleet size slightly and, in turn, reduce ownership and operating cost. In the practical scheduling of buses, it is unlikely, however, that these considerations will significantly reduce the 4 percent cost increase.

The remainder of this section describes how the price and O&M cost estimates were developed.

Transbus Price

The discussion of the Transbus price estimation process will describe briefly the methodology, the principal data elements, and the results.

Methodology

One difficulty with the cost estimates used by the government is that they appear to be based on a "steady state" comparison which ignores the front-end investments involved. MITRE's estimates assume Transbus production to be a new undertaking. Our method for estimating a reasonable price for Transbus involves three steps. First, the total investment needed by a hypothetical Transbus manufacturer is estimated. Second, a brief income statement for the manufacturer is developed for a series of years. Third, after production stabilizes, the after-tax profit as a percent of sales and as a return on equity are compared to desired, or target, values.

The target values adopted in this study are those recently being achieved by GM for their overall operation. According to Standard & Poor's, GM's recent after-tax profit as a percent of sales has been 5.5, 6.1, and 6.2 in the years 1978, 1977, and 1976. Over those same years its return on equity has been 21.3, 22.5, and 21.5 percent.

Based on this information, and assuming uniform profit margins across the corporation, a reasonable Transbus price would be one yielding a profit of approximately 6 percent on sales and 22.0 percent of equity.

It is worth noting that this method of estimating Transbus price is different from that used by Booz-Allen in their evaluation of Transbus.[1] They obtained a distribution of New Look bus manufacturing costs by component or subsystem and scaled those costs upward or downward as dictated by the professional judgment of their staff.

Data

The data needed to estimate a reasonable Transbus price were obtained from a number of sources. Discussions were held with representatives of GFC and GM; with consultants to the bus, truck and automobile manufacturing industries; and with members of the Booz-Allen Transbus project team. The literature provided some data for estimating manufacturing costs, and the tour of the GFC and GM bus manufacturing facilities provided a feel for the complexity of converting an ADB into a Transbus.

In order for GM or GFC to produce Transbus in accordance with the TPR, it is highly likely that a completely new bus must be designed with weight reduction in mind. This implies extensive new tooling and, in turn, either a plant shutdown or construction of a new plant. We have assumed here as a base case that a new plant will be built.

Substantial investments are required for designing, developing, and testing a new bus, and for constructing, equipping, and tooling a new plant. Estimates of the cost of these activities are provided in Appendix C. *All costs are in 1979 dollars.*

Product development is estimated to require $41 million. This includes fourteen prototype and six preproduction vehicles for various levels of component and subsystem testing at test facilities and in simulated service. A modest amount is also allocated for interface work with principal vendors. The complete development of principal components, such as the tandem rear axle and tires, is expected to be borne by vendors and will be reflected ultimately in the price paid to the vendor.

Additionally, an initial working capital allocation must be made to the project, and start-up costs will be incurred. Estimates of these amounts are shown in Tables C-5 and C-6. It is worth noting that much of these data are derived from the production cost data described below utilizing standard ratios and rates. The total investment before taxes, phased over the first four years of the project is shown in Table 4-3. We have assumed that product development and start-up costs would be covered by equity financing and that the plant, equipment, tooling, and working capital would be financed through loans at 12 percent interest.

In addition to investment, estimates must be developed for production or manufacturing costs; operating expenses such as selling and general and administrative expenses; and debt servicing. Production cost is by far the largest determinant of price, and the most difficult to estimate because of the large number of influencing factors. This study's time constraints mandated a simplified approach to develop the estimates. The selected approach relies on estimates of five key factors:

1. material costs per bus
2. hourly labor wage and fringe benefit rate
3. direct labor hours required to build the first production bus
4. direct labor hours per bus once the labor force "learns" to produce the bus
5. the number of buses that must be produced before this maximum productivity point is reached

Table C-10 (Appendix C) lists a range of values for these factors. They stem from discussions with the manufacturers and with consultants to the industry. Of the five factors, material cost is the most significant. In the case of the $78,000-per-bus amount, it includes a basic amount of $60,000, $6,000 for a lift assembly and $12,000 for a tandem rear axle assembly. Table C-7 lists the material costs in more detail.

The labor rate includes wages and fringe benefits. The $15.00-per-hour amount is in accord with the United Automobile Workers' Union scale. One manufacturer is, however, several dollars below that scale. The direct labor hours per bus includes unproductive as well as productive time. One manufacturer's target for direct labor per bus is 1,000 hours; this desired value has yet to be achieved, however.

In order to translate the values in Table C-10 into more meaningful terms, some assumptions must be made about market size, and the rate at which direct labor personnel move into the new production process. Market size is assumed to be 4,000 buses per year with two manufacturers sharing this total equally—2,000 buses per year for each. The labor build-up rate is assumed to be forty persons per week, whether by transfer from other work or from new hires. Under these conditions and standard labor learning rates, the plant can be expected to produce 101 buses in the first quarter of actual production (in the fifth year), 289 in the second quarter, 443 in the third, 496 in the fourth, and a steady state rate of 500 in the fifth quarter. The estimated cost of producing buses according to such a schedule is shown in Table C-11. Manufacturing overhead includes items such as liability insurance, property tax, warranty set-asides, utilities, services. Standard straight-line depreciation schedules are assumed: thirty years for the building,

Table 4-3
Project Budget
(Dollars in Millions)

Category	Year 1	2	3	4	5	Total
Product Development	$6.0	$11.0	$15.0	$ 9.0	—	$ 41.0
Plant Construction & Land		0.5	14.1	18.9	—	33.5
Plant Equipment		—	—	18.1	$ 1.2	19.3
Special Tooling		—	3.6	28.8	3.6	36.0
Initial Working Capital		—	—	2.2	55.4	57.6
Start-Up Costs	0.6	0.8	3.8	12.0	15.4	32.6
Total	$6.6	$12.3	$36.5	$89.0	$75.6	$220.0

fifteen for equipment, and five for special tooling.* The ratio of direct to indirect labor is assumed to be three to one.

Operating and debt service expenses are shown in Tables C-8 and C-9.

Results

Table 4-4 is a pro forma income statement. It shows that a 6 percent profit on sales can be achieved in the eighth year using a bus price of $150,000 and a build-up from 385 buses produced in the fifth year to just under 2000 buses per year in the sixth year and to 2000 buses in the seventh year.

Cost details supporting Table 4-4 are in Appendix C. However, some additional explanation is in order. For convenience, product development costs in the first four years have been placed under "Cost of Goods Sold." Also for convenience, payment of debt principal is assumed to take place in equal annual installments for each item financed through debt. In the case of depreciable items, this makes the annual depreciation expense and the annual principal payment equal, so that all cash flow generated by depreciation is used to pay the principal. Finally, since the manufacturer is assumed to be a part or a subsidiary of a larger, profitable corporation, the before-tax losses in the first five years can be applied to reduce the corporate tax burden. These tax savings are shown as negative income tax in those years.

*We recognize that it is possible to use accelerated depreciation schedules and to take advantage of tax credits on equipment investment. These would make the investment slightly more attractive than depicted here, or lower the bus price very slightly.

It remains now to determine the series of returns on equity and to compare that result with the desired value of 22 percent. The measure is defined as the ratio of after-tax profit to stockholders' equity in this portion of the corporation. Over time, some earnings would be paid as dividends to the stockholders, while the remainder would be retained such that stockholders' equity will climb from an initial investment of about $50 million to an amount sufficient to cover the steady state working capital requirement of $80 million (see Table C-5) plus an amount to cover contingencies, product development, and future expansion. A reasonable estimate of this additional amount would be 5 percent, or $4 million, bringing total equity to $84 million. This amount is used in computing the return on equity.

Both profit on sales and return on equity are shown in Table 4-4. As production stabilizes, both measures approach the desired values. The implication is that $150,000 (in 1979 dollars) is a reasonable estimate for the price of Transbus given a market share of 2,000 buses per year and the conservative assumptions of Table C-10. Furthermore, since annual depreciation expense is assumed to equal annual debt principal payment, the after-tax profit in Table 4-4 is a good estimate of net cash flow. A discounted cash flow analysis reveals that if the bus would remain in production for at least seven years the return on investment would be about 20 percent. A longer production period would increase the return. Without discounting, Table 4-4 shows that the investment is recovered in eight years.

As a check on the sensitivity of final price to the conservative material and labor costs, we repeated

Table 4-4
Pro Forma Income Statement—Price at $150,000/Bus—Conservative Assumptions (Dollars in Millions)

Item[1]	Year 1	2	3	4	5	6	7	8	9	10
Sales	—	—	—	—	59	291	300	300	300	300
Less: Cost of Goods Sold[2]	6	11	16	12	65	230	235	235	235	235
Income from Sales	(6)	(11)	(16)	(12)	(6)	61	65	65	65	65
Less: Operating Expenses[3]	1	1	3	9	15	18	18	18	18	18
Operating Income	(7)	(12)	(19)	(21)	(21)	43	47	47	47	47
Less: Interest Expense	—	—	—	2	10	17	16	14	12	10
Profit before Tax	(7)	(12)	(19)	(23)	(31)	26	31	33	35	37
Less: Income Tax[4]	(3)	(6)	(9)	(11)	(15)	12	15	16	17	18
Profit after Tax	(4)	(6)	(10)	(12)	(16)	14	16	17	18	19
Cumulative Profit after Tax	(4)	(10)	(20)	(32)	(48)	(34)	(18)	(1)	17	36
% Profit on Sales	—	—	—	—	—	5	5	6	6	6
% Return on Equity	—	—	—	—	—	17	19	20	21	23

[1]*See Appendix C for supporting data.*
[2]*Includes product development and some start-up costs in first four years.*
[3]*Includes some start-up costs in first four years.*
[4]*Assumes 48 percent tax rate, and accounts for taxes on other corporate profits due to loses in first five years here.*

the analysis with the less conservative assumptions of Table C-10. The price of Transbus would then be about $138,000. Table 4-5 shows the abbreviated income statement. Again, the desired returns are achieved. However, the payback period is extended slightly to just over eight years—still an acceptable time.

If a manufacturer's anticipated share of the market is less than 2,000 buses, then the price of Transbus will, of course, be higher, assuming that the manufacturer decides to recover the investment over the same period of time.

A modified Transbus with single rear axle is assumed to cost $8,000 less than Transbus, due to deletion of the tandem rear axles. Thus, estimates for modified Transbus range from $142,000 (conservative assumptions) to $130,000 (optimistic assumptions).

Transbus Operation and Maintenance Cost

As above, the discussion of the Transbus O&M cost estimation process is divided into three parts: methodology, data, and results.

Methodology

In 1975, Booz-Allen Applied Research performed an in-depth evaluation of Transbus which, among other things, resulted in a set of O&M cost estimates relative to the New Look bus and the then-pending Advanced Design Bus (GMC's RTS-II).[1] Since that work was well done and well documented, and since there is very little new data available about either ADB or Transbus O&M costs, the Booz-Allen results form the cornerstone of the estimating process used here.

The process consisted of four steps. First, telephone calls to five transit properties obtained ADB O&M cost data or a qualitative assessment of O&M problems. Second, the technical specification portion of the Transbus Procurement Requirement was reviewed by staff members knowledgeable about bus operation and maintenance practices.[2] This identified the areas likely to be affected and provided a qualitative assessment of the direction and magnitude of the impact. Third, the Booz-Allen work was thoroughly reviewed. Based on the qualitative assessment of ADB problems and the review of the Transbus specification, the O&M subcategory cost estimates which needed revision were identified.

Fourth, new estimates of the percent increase or decrease in cost by subcategory were made. In the case of fuel, the new percentage estimate was based on results of the performance simulation model used to answer other operational questions in Section 3 of this report. In the case of tires, the new estimate was based on discussions with bus and tire manufacturers. The revised estimates for maintenance are solely the professional judgment of the MITRE staff. Finally, estimates of various subcategories of O&M costs were developed for the New Look bus and translated into 1979 dollars using the wage-rate index of local transit operating employees published by the U.S. Department of Labor.[3] These estimates were then multiplied by the corresponding Booz-Allen, or MITRE revised, percentages to yield the absolute values of expected O&M costs reported here.

Table 4-5
Pro Forma Income Statement—Price at $138,000/Bus—Optimistic Assumptions (Dollars in Millions)

	Year									
Item[1]	1	2	3	4	5	6	7	8	9	10
Sales	—	—	—	—	53	266	276	276	276	276
Less: Cost of Goods Sold[2]	6	11	16	12	58	207	213	213	213	213
Income from Sales	(6)	(11)	(16)	(12)	(5)	59	63	63	63	63
Less: Operating Expenses[3]	1	1	3	9	14	18	18	18	18	18
Operating Income	(7)	(12)	(19)	(21)	(19)	41	45	45	45	45
Less: Interest Expense	—	—	—	2	10	17	16	14	12	10
Profit before Tax	(7)	(12)	(19)	(23)	(29)	24	29	31	33	35
Less: Income Tax[4]	(3)	(6)	(9)	(11)	(14)	12	14	15	16	17
Profit after Tax	(4)	(6)	(10)	(12)	(15)	12	15	16	17	18
Cumulative Profit after Tax	(4)	(10)	(20)	(32)	(47)	(35)	(20)	(4)	13	31
% Return on Sales	—	—	—	—	—	5	5	6	6	7
% Return on Equity	—	—	—	—	—	15	19	20	21	23

[1]*See Appendix C for supporting data.*
[2]*Includes product development and some start-up costs in first four years.*
[3]*Includes some start-up costs in first four years.*
[4]*Assumes 48 percent tax rate, and accounts for taxes on other corporate profits due to loses in five years here.*

Data

Telephone calls to the transit properties which now operate ADBs yielded no quantitative data about O&M costs. None of the properties keep O&M records by bus type, and virtually all maintenance is still being performed under warranty. Attempts to secure O&M cost data from the manufacturers were also unsuccessful. The calls did, however, point to ADB problem areas. Several were consistently reported: sharply increased brake wear; increased tire wear; increased fuel consumption; and increased maintenance costs, especially for air conditioning problems.

All ADB problem areas cited above were recognized in the Booz-Allen study as areas in which Transbus costs would be even higher than the ADB.

These same areas were also identified by this study's staff as needing revised estimates. Within the maintenance area, an *additional* 10 percent increase was placed on maintaining mechanical components in the confined space of the low floor and engine compartment. This included the starter, generator, suspension, rear axle and drive-train, and the front axle and steering assembly. In the case of the tandem rear axle, the increase also accounts for the added mechanical complexity. Regarding brakes, the tandem rear axle arrangement also introduces two additional braking surfaces over the single axle configuration. Thus, it is reasonable to expect that brake maintenance cost will be higher due to additional surfaces and reduced accessibility. Fifty percent was *added* to account for the additional axle and reduced accessibility.

The smaller diameter, wider tires are also expected to increase costs. Additional heat will be generated by rolling friction, there will be more road surface contact per mile, and brake-generated heat will not be as easily dissipated in the confined space. All these factors shorten tire life. Based on discussions with tire manufacturers, the tires on Transbus are expected to cost about twice as much as those on a New Look bus. This turns out to be about 73 percent more than the Booz-Allen estimate. Finally, computer simulations of Transbus and ADB performance over the prescribed route profile indicated that Transbus is likely to use 2 percent more fuel than an ADB. The Booz-Allen estimate was revised accordingly.

The Transbus operating and maintenance costs discussed above can be classified as costs that are directly affected by bus design. There is, however, another subset of Transbus operating costs that will be indirectly affected by bus design—safety and insurance costs. Since new data or information about safety and insurance costs could not be uncovered in the short time frame of this study, and since the Booz-Allen work was extensive and well done, their percentage estimates of cost *decreases* were adopted.

Results

Table 4-2 summarized the estimates of percent changes in Transbus O&M costs relative to an ADB and a New Look bus. To place those numbers into better perspective, estimates of typical New Look bus O&M costs in absolute, as opposed to percentage, terms were developed from reported data, and used as a basis for extrapolating absolute Transbus and ADB O&M costs. Thirteen all-bus transit properties, all reporting in the same accounting system format

Table 4-6
Maintenance Cost Comparisons
(1979 Dollars)

		Booz-Allen Estimate (1975)					
		Advanced Design Bus		Transbus		MITRE Transbus Estimate	
Component or Subsystem	New Look Bus (¢/Mile)	¢/Mile	% Change from New Look	¢/Mile	% Change from New Look	¢/Mile	% Change from New Look
Power Plant	5.84	5.84	—	5.84	—	5.84	—
Transmission	2.61	3.26	24.4	3.26	24.4	3.26	24.4
Electrical, Starter	3.55	3.55	—	3.55	—	3.90	10.0
Suspension, Chassis, Rear Axle, Drive Train	4.69	4.69	—	7.03	49.7	7.50	59.7
Front Axle, Steering	1.56	2.26	44.9	2.26	44.9	2.42	54.9
Brakes	3.60	5.59	54.9	5.59	54.9	7.39	104.9
Air System	1.19	1.31	10.8	1.31	10.8	1.31	10.8
Body & Doors	5.36	5.11	-4.8	5.74	7.1	5.74	7.1
Accidents	4.44	2.56	-42.4	2.56	-42.4	2.56	-42.4
Air Conditioning	2.04	2.04	—	2.04	—	2.04	—
Subtotal	34.88	36.21	3.7	39.18	12.2	41.96	20.2
Daily Servicing & Inspection	8.97	8.97	—	8.97	—	8.97	—
Tires	4.09	4.32	5.5	5.21	27.3	8.19	100.0
Total	47.94	49.50	3.2	53.36	11.2	59.12	23.2

Table 4-7
Consumable and Indirectly Affected Costs Comparison (1979 Dollars)

Component or Subsystem	New Look Bus (¢/Mile)	Booz-Allen, Estimate (1975): Advanced Design Bus ¢/Mile	Advanced Design Bus % Change from New Look	Transbus ¢/Mile	Transbus % Change from New Look	MITRE Transbus Estimate ¢/Mile	MITRE Transbus Estimate % Change from New Look
Consumables							
Fuel	23.32	24.49	5.0	26.56	13.9	24.98	7.1
Oil	0.48	0.48	—	0.48	—	0.48	—
Subtotal	23.80	24.97	4.9	27.04	13.6	25.46	7.0
Safety & Insurance							
Traffic Claims	7.85	5.92	-24.6	5.92	-24.6	5.92	-24.6
Passenger Claims	3.73	3.53	-5.4	2.65	-28.8	2.65	-28.8
Pedestrian Claims	1.36	1.28	-5.6	1.15	-14.8	1.15	-14.8
Insurance & Other	3.31	3.31	—	3.31	—	3.31	—
Subtotal	6.25	14.04	-13.5	13.03	-19.7	13.03	-19.7
Total	40.05	39.01	-2.6	40.07	0.1	38.49	-3.9

Table 4-8
Operating and Maintenance Cost Summary[1] (1979 Dollars)

	New Look Bus	Booz-Allen Estimate (1975): Advanced Design Bus	Booz-Allen Estimate (1975): Transbus	MITRE Transbus Estimate
Directly Affected by Bus Design: Fuel, Oil, Tires, Repairs, Service, Maintenance & Cleaning	71.7	74.7	81.0	84.9
Indirectly Affected by Bus Design: Safety & Insurance	16.2	14.1	13.1	13.1
Unaffected by Bus Design: Taxes & Licenses, Station, Traffic, Advertising, Operating Rents, General & Administrative, Maintenance Overhead	76.3	76.3	76.3	76.3
Drivers' Wages[2]	109.8	109.8	109.8	109.8
Total	274.0	274.9	280.2	284.1
Percent Increase from "New Look"	—	0.3	2.2	3.6

[1]*Costs do not include depreciation of capital equipment.*
[2]*No driver productivity increase assumed as a result of increased trip speed.*

(ICC) were selected from APTA's Transit Operating Report for 1976.[4] Weighed averages of the various subcategories of O&M costs were determined. The results were then scaled upward by 20 percent, an amount determined by the U.S. Department of Labor to account for cost increases since 1976.[3] Tables 4-6 through 4-8 show the results of this process.

For the modified Transbus, it is assumed that O&M costs will be the same as for an ADB. This assumption is based upon the argument that greater service and maintenance costs will be offset by reduced costs for fuel, safety, and insurance.

References

1 Booz-Allen Applied Research, and Simpson and Curtain, *Transbus Operational, Passenger, and Cost Impacts*, Transbus Document TR 75-002, Bethesda, Maryland, July 7, 1976: Appendix B.

2 U.S. Department of Transportation, Urban Mass Transportation Administration, *Transbus Procurement Requirements*, Washington, D.C.: August 1978.

3 U.S. Department of Labor, Bureau of Labor Statistics, *Union Wages and Hours: Local Transit Operating Employees, July 1, 1978*, Bulletin 1995 (Washington, D.C.: GPO 1978), page 4.

4 American Public Transit Association, *Transit Operating Report for Calendar/Fiscal Year 1976*, Washington, D.C.: November 1978.

Evaluation of Options

After review of the many technical and procurement options available, a limited set of alternatives were selected for more detailed consideration. In the first section, we will describe three different technical approaches. The following section discusses how a program can be established to bring the selected options into operation. The final section summarizes the cost for each of the options, based on a ten-year production run of 4,000 vehicles per year.

The three technical alternatives are:

- Transbus
- modified Transbus
- improved ADB

One option that was considered, but rejected, was to eliminate *all* mandates, i.e., allow transit companies complete freedom of choice. This was eliminated for two reasons.

1. Section 16 of the UMTA Act specifically requires that "efforts shall be made in the planning and design of mass transit facilities and services so that the availability to elderly and handicapped of mass transportation which they can effectively utilize will be assured."
2. A mandate that requires all buses to be at least as accessible as the most accessible bus currently in production is justified.

Several other options were considered and rejected, either on technical grounds, or because they offered little or no advantage over the three selected. These were identified in Section 1.

Alternative Designs

Transbus

Our analysis has shown that a bus can be built to meet the Transbus specification, but at a higher price than the ADB. Some minor adjustments of detail would be needed, but these would certainly not violate the Transbus concept. (Additional information is contained in Section 2, "Manufacturing Considerations.") However, a change in the procurement procedures would be necessary to encourage manufacturers to participate by reducing the risk they would incur. (This is discussed further in the following section.)

Modified Transbus

In this option the main features of the Transbus design would be retained, but some modifications to the specification would be introduced. Three major changes would be:

- the method of specifying weight requirements
- fuel economy requirements
- future price offsets

Weight Requirements

The maximum weight allowed in the Transbus specification was based on the weight of the Advanced Design Buses. It was felt that this weight required the specification of a tandem rear axle to meet federal axle load limits. Delivered ADBs have exceeded these limits when carrying a full seated load. The tandem axle should not have been interpreted as a goal in itself for Transbus. It reflects the experience of those involved in the Transbus development program. The real objective is to ensure that a bus supplied to the Transbus specification complies with legal axle load limits.

This option uses a performance rather than a design specification to meet the objective. It would allow the designer the choice of a single or tandem axle, provided the bus met legal weight limits. Removing the overall weight limit would also allow the total weight to increase (with a tandem axle), but the extent to which this could occur would be limited by the requirement to meet the specified fuel consumption.

Fuel Economy

When the goals for Transbus were established, fuel economy was less important than it is today. Fuel costs have soared and are approaching 10 percent of operating costs. With the nation facing the potential of reduced oil supplies, effective utilization of oil resources is essential.

Analyses using the MITRE Performance Simulator have shown that reducing the weight of an ADB (equivalent to a single axle Transbus) to 21,000 pounds would reduce fuel consumption by 8 percent—giving approximately 3.8 miles per gallon. The DeLorean Motor Company has claimed that fuel consumption of the order of 4.1 miles per gallon can be achieved. A newly announced six-cylinder Detroit Diesel engine that meets bus requirements is available with a lower fuel consumption than existing engines but with higher performance.

Future Price Offsets

The specification would indicate those service and maintenance functions to which price offsets could be applied at a later date, based on actual operating experience. These would include such criteria as "hours to perform" routine servicing, relative to a standard; and mean time between overhaul. In production procurements, price offsets would be applied based upon operating experience.

This would provide an incentive for designers to consider accessibility, maintainability, and reliability in their approach, and would be a first step toward bidding on the basis of life-cycle costs.

Improved ADB

The analyses in Section 3 have shown that ADB accessibility can be enhanced and its productivity improved by some modifications to its design. Two specific items are:

1. reduction of the bus floor height to twenty-four inches kneeled.
2. provision of a wide front door with at least thirty-eight inch clear opening

A decision concerning the specification of a wheelchair lift position (front or rear door) should be deferred until further operational experience has been accumulated, specifically in connection with:

- user reactions
- operation implications
- susceptibility to front-end damage
- costs

Program Options

The procedure adopted by the consortium was basically the same as has been used successfully for years to purchase buses. However, at least four companies—Rohr Industries (BART and WMATA heavy rail cars), St. Louis Car (R44 cars), Pullman (R46 cars), and Boeing Vertol (Urban Light Rail Vehicle)—have withdrawn from transit vehicle manufacturing. This comes to some degree, as a result of their financial experiences following acceptance of a fixed- price contract for a vehicle that involved some technical development. It is hardly surprising that companies which continue to manufacture vehicles have adopted a conservative business approach regarding their potential warranty cost and possibility of litigation with their customers and the government. The program options that follow have been selected on the basis that there must be some degree of risk-sharing if the Transbus program is to overcome the current stalemate.

It is MITRE's view that a procurement approach that attempts to eliminate the need to make hard technical decisions by limiting choice purely to selecting the lowest bidder in a fixed-price procurement is inappropriate in the introductory order for new transit vehicles. Before full-scale production is initiated, a comprehensive testing program must be conducted to ensure that the vehicle qualifies for operational use. Attempts to place the responsibility on the manufacturer who is required to work under a fixed price contract awarded on the basis of a low bid have proved unsuccessful.

Whichever option is selected, there are major advantages in separating the technical from the cost procurement procedure. This is a standard procurement technique when purchasing complex systems or constructing facilities. Each bidder provides an unpriced technical proposal in response to a performance specification. Negotiations are held individually with each bidder to resolve ambiguities and to ensure that the product supplied is consistent with the intent of the specification. Each bidder's proposal is considered proprietary, but changes in the specification are issued to all bidders. Subsequently, each bidder submits a revised technical and cost proposal.

Finally, variations in policy at DOT have been a problem to the industry. One way of encouraging industry participation would be to make Transbus a legislative rather than an administrative mandate, thus guaranteeing a stable environment and reducing the possibility of change. However, in view of the transit industry's opposition to a mandated bus design, the necessary legislation might be difficult to obtain.

Option 1 - Transbus

The primary advantage of this option is that it would ensure that any supplied bus meeting the specification would also meet the legal requirements for axle-weight limits.

However, the bus would carry fewer passengers than existing ADBs and would consume more fuel. (See Section 3.) This option also requires the largest amount of component development, with associated risks, and the bus would require more maintenance because of the tandem rear axle.

The two-stage procurement process originally planned for Transbus should be followed. Initially, multiple contracts would be awarded for the design, development, engineering, and initial production of more than one design of Transbus. In the second stage, production orders would be awarded on a fixed-price basis to the designs that met the requirements of the specification. The first stage of this option could be implemented in two ways.

Option 1a: Fixed-Price Plus Fixed-Price

In this option, the initial order would be for a relatively large number of buses (approximately 100) on a fixed- price basis. These would essentially be the first of a production run.

Option 1b: CPFF Plus Fixed-Price

This option would call for an initial procurement of a much smaller number of buses (approximately ten) on a Cost-Plus-Fixed-Fee basis. Rather than preproduction samples, these would be hand-built prototypes.

To increase the probability of participation by qualified manufacturers, a procedure should be adopted that would provide some assurance of government support through both stages. A procedure similar to the capital grant program for projects which require long-term commitments would be appropriate.

Option 2 - Improved Transbus

Among the advantages of this option are that it encourages innovation. The bus should be lower in price than Option 1, and will cost less to operate. Fewer new developments in subsystem technology may be required. It will comply with the intent of the Transbus procurement.

The main disadvantage is that there is no guarantee that a delivered single axle Transbus will meet the legal weight limits.

The procurement process should be the same as described in the previous section for Transbus. The same two options would be applicable.

- Option 2a: Fixed-Price Plus Fixed-Price
- Option 2b: CPFF Plus Fixed-Price

Option 3 - Improved ADB

This option is the low-risk alternative. It can be made effective in the shortest period of time, and maintains the highest degree of commonality with existing bus design, thereby minimizing problems in the operating properties where any change is expensive. It is also the lowest cost option. Essentially it represents a return to the mandate of July 27, 1976.

At present, Advanced Design Buses have a number of technical problems. However, by the time this option is implemented, ADB operational performance should be acceptable, and the changes recommended should not affect this significantly.

With this option the possibility of installing a ramp has been lost. The opportunity to improve fuel efficiency is less and the bus already exceeds the legal weight limit when carrying a full seated load. Also, since the bus does not comply with the Transbus mandate, there is the possibility of a lawsuit over non-compliance.

Note that this option does *not* preclude introduction of Transbus at a later date. UMTA's policy could revert to that of July 27, 1976, at which time an effective floor height of twenty-four inches was mandated. As the policy stated:

> Nevertheless, the lower bus floor height will continue to be a policy objective for the UMTA program. Any manufacturer who wishes to offer such a bus for purchase will be assisted through sole source procurement arrangements and progress payments. Further, in order to maintain progress toward achieving the low floor objective, the UMTA Research and Development program will assist manufacturers to develop the reliability componentry which is still needed before the low floor can become a reality.

Schedules and Costs

In our view, assuming a start in 1980, first deliveries of Improved ADBs (Option 3) might begin in 1982, with competitive procurement a year later. In the case of both Transbus and Modified Transbus, initial models under a CPFF arrangement might be delivered in 1984, and under a FP arrangement in 1985. Initial production might start in 1987 with a competitive procurement the next year.

Table 5-1 gives a rough idea of the costs for each of the three technical approaches. For simplicity, we have not attempted to discount the expenditures in future years, which vary with each option depending on the additional development required.

The prices shown in Table 5-1 assume that the manufacturer is permitted to recover *all* expenses incurred in each stage, including annual amortization of plant, equipment, tooling, and debt. Therefore, the higher price per bus in the early stages stems from the recovery of all product development and start-up costs in Stage I, and the need to adjust to the new production process in Stage II. Since these costs are fully recovered in the early stages, the price per bus in the competitive production stage is lower than that shown in Section 4. There, it is assumed the price is constant and the cost of product development and early inefficiencies are not recovered when they are incurred. Thus, in the case of Transbus, the

Table 5-1
Capital Cost of Options
(Dollars in Millions)

					Option 1 Transbus		Option 2 Modified Transbus		Option 3 Improved ADB	
		Stage	Number of Buses	Terms	Price per Bus	Total Stage Price	Price per Bus	Total Stage Price	Price per Bus	Total Stage Price
	I	Product Development	200	FP	$3.600	$ 72	$3.600	$ 72		
(a)	II	Initial Production	1,000[1]	FP	0.186[2]	186	0.178[2]	178		
	III	Competitive Production	4,000/yr.[3]	FP	0.143	5,720	0.135	5,400		
						$5,978		$5,650		
	I	Product Development	20	CPFF	$0.467	$ 93	$0.457	$ 91		
(b)	II	Initial Production	1,000[1]	FP	0.183[2]	183	0.175[2]	175		
	III	Competitive Production	4,000/yr.[3]	FP	0.143	5,720	0.135	5,400		
						$5,996		$5,666		
	I	Product Development							$0.1255	$ 125
—	II	Initial Production	1,000[1]	FP					0.1255	5,020
	III	Competitive Production	4,000/yr.[3]	FP						$5,145

[1] *Two orders of 500 with two manufacturers.*
[2] *All labor recovered plus one year of amortized expenses.*
[3] *Ten-year production.*

estimated price per bus varies from $183,000 to $186,000 in the initial production run of 1,000 buses, and approximately $143,000 thereafter—regardless of the program option. After ten years of production, total program cost will be near $6.0 billion.

In the case of a modified Transbus the estimated price per bus varies from $175,000 to $178,000 in the initial production run and $135,000 thereafter. Total program costs would approach $5.7 billion—about $300 million less than Transbus.

As shown in Table 5-1, cost of the improved ADB option is $5.1 billion, or about $600 to $900 million less than the other two options.

With simplifying assumptions concerning the mix of buses over the initial ten-year period, the additional O&M cost for Transbus over an improved ADB, assuming an average mileage of 30,000 per bus, would be $600 million (based on an increase in O&M costs of 9.2 cents per mile as established in Section 4, "Results"). When capital and product development costs are included, the additional cost is approximately $1.5 billion. Since O&M costs for a modified Transbus are assumed to be the same as for the ADB, the additional cost of a modified Transbus over an improved ADB would be approximately $600 million over the ten-year period.

Appendix A-1
Sections that Need Correction in the Transbus Procurement Requirements

Correct an Error

TPR Item 2.1.8.3 Door Glazing

> . . . The edge of a 6-inch high curb shall be visible to the seated driver through the closed front door when the coach is more than 6 inches from the curb.

An error was made in the layout drawing for this specification. Because structural framing was omitted from the bottom of the door in the layout drawing, the seated driver will be unable to see a curb as low as six inches when the door is closed and the bus is only six inches from the curb. The transit operators should be consulted to determine the best compromise for this requirement.

Remove Restrictive Terminology

TPR Item 1.2 Definitions

(17) Design Operating Profile

> . . . The track surface used for testing coaches on the design operating profile shall have potholes and perturbations typical of urban streets and roads.

Although previous bus procurements have been made with similar wording, this requirement should now be changed to include a definition of roughness, in a deterministic form, for a typical urban street and road.

TPR Item 1.5.4.2 Maintenance and Inspection (as amended)

The sentence, "Scheduled maintenance tasks shall be generally no more burdensome or complex than that required for 40-foot transit buses manufacturered prior to 1978," should be modified to recognize the additional complexity of Transbus. While such a requirement may be desired by the Consortium (50 percent of maintenance costs are funded locally; only 20 percent of initial costs come from local funds), it is undeniable that the bus specified is a more complex vehicle than the New Look buses and the maintenance tasks will be more burdensome and complex.

TPR Item 2.6.6.1 Handicapped Passengers Loading System

> "A system shall be incorporated at the front door to provide ingress and egress to handicapped passengers including those in wheelchairs from the street level or from curbs up to 22 inches in height."

This requirement may necessitate a change to state a maximum curb height less than twenty-two inches. This would allow a ramp of finite thickness to be deployed to the curb, but not require the manufacturer to provide both positive and negative ramp slope for loading.

Discussion between the bus manufacturer and the Bus Technology Committee is needed to establish an acceptable curb height.

TPR Item 3.6.4.1 Electrical System General Requirements

> . . . The electrical power generating system shall be rated on no less than total possible electrical load under all possible operating conditions including the engine at idle.

This requirement should be changed to state the *specific* operating conditions that the manufacturer is required to meet.

Clarify Intent

The following items are examples of recommendations for minor modifications or additions to the present wording of the Specification for simple clarification where misunderstandings are known to have arisen or where legitimate protection of the manufacturers' interest may be involved. If Transbus were to be built according to the Specification, MITRE would recommend a thorough review of the entire Specification to ensure that all items of this nature are recognized and revised.

TPR Item 2.1.2.1 Strengths and Fatigue Life

MITRE recommends that a proviso to the effect that the bus structure must be continually maintained according to manufacturers' recommended maintenance procedures be added to the existing requirement that the bus structure be able to withstand the impacts of normal operation.

TPR Item 2.1.2.4 Material

So that the prohibition against fiberglass and plastics be interpreted reasonably, it is recommended that the term "basic body construction" be defined, or that the paragraph be deleted entirely. The present phrasing could easily be interpreted to preclude certain manufacturing techniques inherent in many buses now on the streets, or to prevent certain bus manufacturers from bidding.

TPR Item 2.1.4.1 Headroom

The apparent conflict in intent between the stipulated headroom over the centerline of the aisle seats (seventy-eight inches) and the minimum height of the overhead passenger assists (seventy inches) at the same position should be resolved and the intent clarified.

TPR Item 2.2.1.4 Emergency Operation of Doors

> . . . Locked standard configuration doors shall require a force of more than 100 pounds to open manually and push out rear doors, Option 2.1.8.4 (1) shall require more than 500 pounds to manually open.

This requirement should be clarified by the inclusion of the words "a locked door," as follows:

> . . . Locked standard configuration doors shall require a force of more than 100 pounds to open manually and push out rear doors, Option 2.1.8.4(1) shall require more than 500 pounds to manually open a locked door.

TPR Item 2.6.6.1(2) Lift Loading System

The storage and deployment time specification of five seconds should be clarified to preclude the interpretation of 2.5 seconds for each. The phrase "other phases of the loading or unloading operation" should be defined, especially to exclude the actual loading of the passengers onto the lift, an operation over which the bus manufacturer has no control.

TPR Item 3.3.1 General Requirements (Suspension)

MITRE recommends that the requirement that adjustment points be minimized and not subject to a loss of adjustment in service be modified and clarified. We believe that the intent was not to preclude loss of adjustment through wear, but rather to ensure that adjustment is not shaken loose from day to day. A wording change would correct apparent misunderstanding by potential manufacturers.

Appendix A-2 Development Considerations Associated with a Tandem Rear Axle

If a tandem axle is required to meet federal axle load limits, there are three major components requiring substantial development: the tandem axle itself, low profile tires, and new brakes for small wheels. These components are not available commercially and would have to be specially developed.

Discussions with the major bus component manufacturers support a general conclusion that, given sufficient time and money, the necessary components could be designed, developed, and placed in commercial production. However, at present, the companies' position on warranties and the requirements of the TPR are not compatible: the TPR presently requires the products to be warranted at the initiation of the procurement for a particular period of time or vehicle mileage, whereas the basic position of the manufacturers is that warranties can be established only after the new product has undergone testing in actual field service, and that terms of the warranty must be established after testing. Furthermore, the manufacturers maintained that they had consistently pointed out the need for development of the necessary items for the Transbus program. They were disturbed by the cancellation of what they regarded as the development phase of Transbus, namely procurement and placing in service 150 or 200 buses, while the design of the prototype components could be perfected.

Particular information concerning each component is given below.

Tandem Axles

The Rockwell staff emphasized that the nine Transbus vehicles which were manufacturered were "idea" or "concept" vehicles and not production prototypes. However, they anticipate no undue problems in designing the tandem axle. They stated that their position was, and still is, that they could be in production with a tandem axle drive in four years. This is predicated upon determining, during an evaluation phase, what the warranty should be.

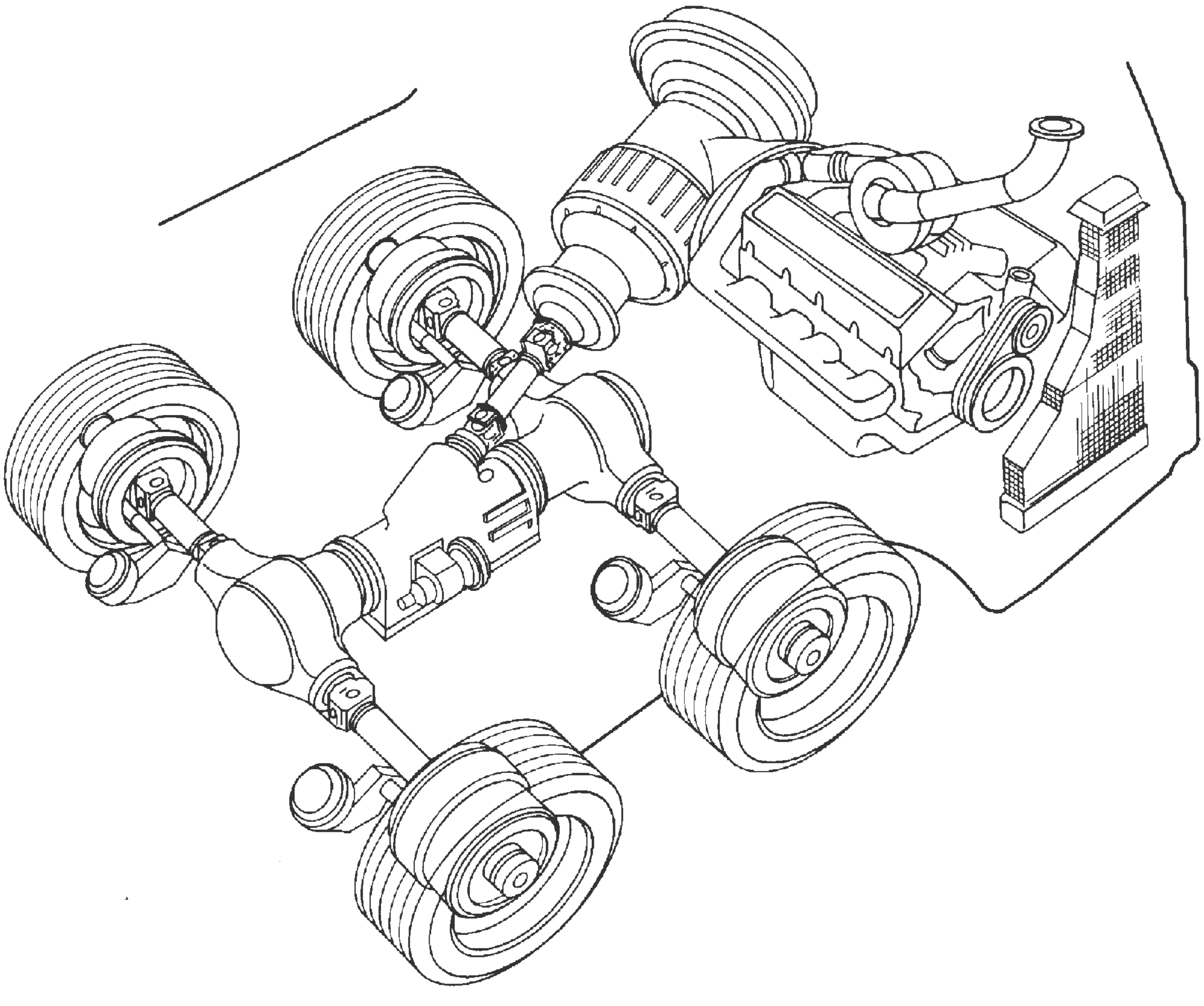
They noted that, normally, new product development of this nature takes seven years from inception. However, they can reduce the estimated time because of experience on the equipment supplied for the nine Transbus vehicles. Figure A2-1 shows the proposed axle configuration.

The development of an axle for the low floor Transbus (where space requirements dictate that the differential be mounted to the bus frame) as a new piece of equipment normally entails the following sequence of events:

(a) layout (for housing)
(b) detailed design
(c) procurement of four or five prototypes (eight to ten weeks for castings)
(d) deflection studies (stresscoat, strain gaging)
(e) another (shorter) procurement
(f) restudy
(g) gear contact study (after assembly)
(h) dynamometer testing

At this point, a vehicle is required for testing in place.

(i) resolution of interface problems
(j) field testing with buses (until customer is satisfied)
(k) pre-production run (100 to 150 items)



Source: Rockwell International

Figure A2-1
Tandem Drive—Transbus

(l) in-service testing (over several years and many miles)
(m) production of item with warranty

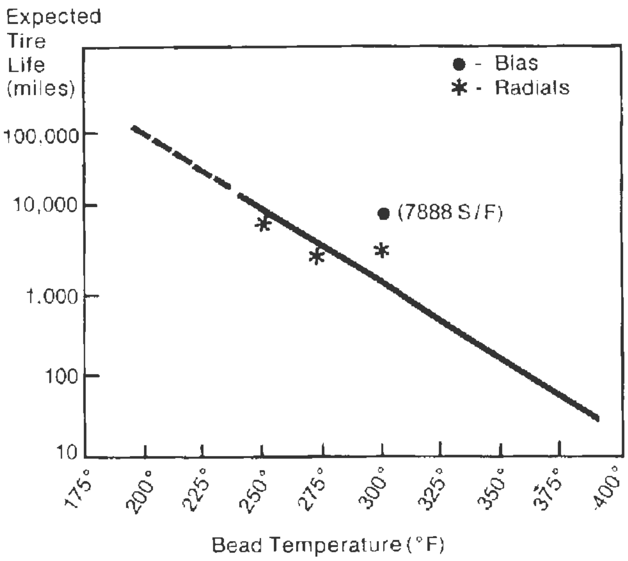
There are serious interface problems between the axle and brake manufacturers and the tire manufacturers. Although the axle manufacturers recognize the thermal problem created by braking, they could not at this time guarantee that the rim would be maintained at the temperature required by the tire manufacturers. The problem is partially attributable to the difficulty of analyzing heat transfer in a configuration which has not been designed. The problem cannot readily be solved without hardware production.

Tires

As mentioned above under Tandem Axles, one of the most serious areas of concern in the development of a tire suitable for Transbus is the thermal environment in which the tire will be required to operate. In general, the life of the tire is related to the operating temperature: the higher the temperature, the shorter the tire life. The tire itself can withstand the temperature induced internally by the energy dissipation during flexing, but a major problem will remain at the tire bead-wheel rim interface, which is most susceptible to temperature.

Figure A2-2 shows the degradation in tire life caused by excessive bead temperatures.

As mentioned before, the adverse thermal environment is created by the confined space around the tires and wheels and the difficulty of dissipating the heat generated by braking. The new Federal Motor Vehicle Safety Standard 121 has made the thermal design problem more difficult by imposing sharper deceleration rates upon the vehicle. A low profile tire (such as



Source: Goodyear Tire & Rubber Co.

Figure A2-2
Radial Bus Tire Durability at Various Bead Temperatures

that needed by Transbus) will be more likely to fail catastrophically in the bead areas than would that same tire in a less hostile thermal environment. The manufacturers recommend strongly, therefore, that temperatures in the area of the tire bead-wheel rim interface be maintained at levels no greater than 200°F for the radial tire and 250°F for the bias ply tire. They do not currently honor warranty claims if they feel that bus operations create higher temperatures.

The design continually evolves as a tire is developed, reflecting information from field testing. Evaluation of the tire's performance in service is the most important aspect of development. A tire suitable for commercial service must have been thoroughly tested in actual operation.

Other areas of major concern with regard to the development of the low profile tire are high operating pressures required to satisfy load requirements, the lack of the usual regroove capability (thick rubber must be eliminated), and the high operating cost due to the estimated tread wear (tread mileage is almost linearly related to circumference).

In summary, although both tire manufacturers stated that they could produce a warranted tire within a four-year development period, during the final portion of which the tire design would be perfected by operational testing and service in the actual thermal environment of the production vehicle, we face more than the straightforward scaling approach that can be used for axles, brakes, etc. Tires are already a major problem in transit operations: they must be improved whether or not there is a Transbus.

Table A2-1 shows a comparison between one tire proposed for Transbus and a current transit tire.

Table A2-1
Proposed Tire for Transbus

Parameter	Current Coach	Transbus
Size	12.5-22.5	K50C-19.5
Outside Diameter	42.8"	35.4"
Section Width	12.0"	15.55"
Rim Width	9.0"	9.25"
Statistically Loaded Radius	20.3"	15.9"
Rated load	6270@90 PSI	6560@90 PSI
Tires/bus	6	6

Source: Firestone Tire and Rubber Co.

Brakes

Because of the low bus floor, wheels and tires will be smaller, with smaller diameter brake drums. With the reduction in diameter and the need for higher deceleration rates imposed by FMVSS 121, the brakes must be wider to provide the necessary braking torque. The smaller diameter and wider width require the development of new brakes.

Rockwell International conducted a study of brake options for Transbus. Table A2-2 summarizes the results of the study using the preliminary design specifications shown in Table A2-3. The table compares the anticipated characteristics of the Transbus brakes to buses now in production and operation. Note that the total brake lining area for Transbus is almost 50 percent greater than present buses. This increase comes from the additional set of wheels one gets with tandem axles.

The design of the brakes must interact with the wheel design and the tire design to alleviate the thermal problem at the tire bead-wheel rim interface referred to in the previous section. While it is recognized that the heat from the brakes will impose a burden on the tire manufacturer, the heat load will be spread over six wheels rather than four. It is not certain, however, that the temperature reduction due to spreading heat among six wheels will be sufficient to meet the tire requirements.

A retarder will probably be required to dissipate the heat generated while braking at higher speeds. This approach offers an additional advantage beyond alleviating the temperature problem at the tire bead-wheel rim interface.

Retarders are common in Europe and some experience has been obtained in the United States and Canada. Portland, Oregon, has doubled brake lining life since installing a Telma Electric Retarder on several buses. Current retarders are most effective at high speeds and inherently lose their capability at low speeds. To counteract this tendency, a hydraulic retarder proposed by Detroit Diesel Allison provides a multi-disk oil-cooled friction brake as part of the retarder itself. This enables the retarder to provide meaningful retarding torque even in the low speed ranges. Such a retarder is expected to be developed as a commercial product in the next four years.

Table A2-2
Primary Transbus Foundation Brake Options (19.5-Inch Rim)

Brake	Reliability	Lining Life	Customer Acceptance	Cost in Production
13½-In. Cam	Excellent	Good	Excellent	Moderate
Dual Wedge	Good	Good Limited Exp.	Good Limited Exp.	Moderate
Liquid Cooled Disc	Unknown[1]	Excellent (Expected)	Unknown[1]	High
Hydraulically Operated Disc	Good	Unknown[1]	Poor	High

[1] *Relative to Transit Coach Service.*
Source: Rockwell International

Table A2-3
Transbus Cam Brake (13") vs. Present Bus Brakes

Parameter	ADB	Transbus
Brake Size		
Front	14½ x 5—2Req'd.	13½ x 8—2 Req'd.
Rear	14½ x 10—2 Req'd.	13½ x 8—4 Req'd.
Total Lining Area	765 Sq.In.	1140 Sq.In. (+49%)
Total Drum Weight	500 Lb.	720 Lb. (+44%)
Heat Rejection Area	2695 Sq.In.	3944 Sq.In. (+46%)
Brake Drum to Tire Bead	2.5 In.	2 In.
Max. Operating Temperature	700°F	Less Than 700°F

Source: Rockwell International

Appendix A-3 Development Considerations Associated with the Wide Front Door and the Front End

Bus Front End Design

The Specification requires a minimum approach angle of ten degrees, a minimum front door width of forty-four inches and a maximum floor height of twenty-two inches as measured at the front door. In addition, the windshield should be arranged so that reflections from the bus interior are minimized. The design problem is to fit a wide door ahead of the front bus wheels, low to the ground but allowing a ten degree clearance from the bottom of the front wheels to the lowest point of the front overhang, while slanting the windshield back to minimize interior reflections. (See Figure A3-1.) Door actuator controls, hand-rail mounting provisions, etc. make the front of the bus particularly congested.

Preliminary studies by U.S. bus manufacturers indicate that it is very difficult to meet all of the above requirements. A compromise on the approach angle requirement may expose the vehicle front end to damage caused by driveway ramps or street slopes. Damage in this area is particularly serious because of the proximity to driver controls and lift/ramp equipment. Reflections from the vehicle interior are minimized when the windshield is sloped in slightly at the top. Compromises in this slope, producing an almost vertical windshield at the right hand side, are required to accommodate the forty-four inch front door. The more vertical the windshield, the more prone it is to generate reflections into the driver's eyes. The blunt bus front also slightly increases aerodynamic drag. The overall bus length limitation and even the number of seats required, enter into the design problem.

Ideally, the front-end design should be addressed as a subsystem development problem. If the Transbus mandate is delayed, further design studies should be encouraged or even supported by the government. (The Transbus prototypes did not "solve the problem." Rohr had a nine degree slope and forty inch door. GM had a thirty-three inch door. AMG met the specification but had only forty-two seats).

Steering Force

The specified sixty-five pounds maximum steering force at the steering wheel rim should be a design goal rather than a requirement. The relationship of steering force to the (undeveloped) tire design must be determined. Furthermore, because a restriction has been imposed upon the design of the steering system in the form of the maximum number of lock-to-lock turns, a trade-off may be required.

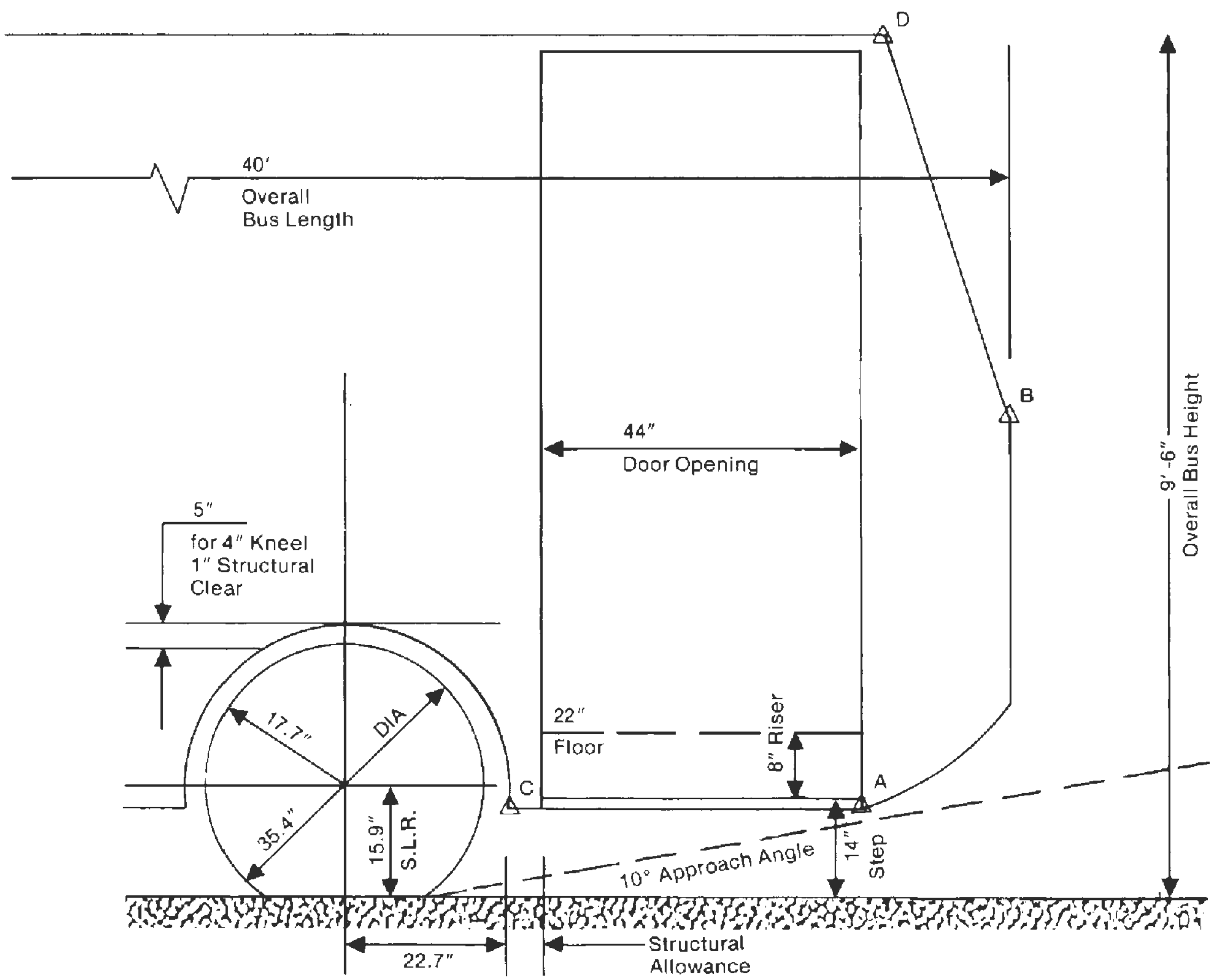


Figure A3-1
Front End Considerations

Appendix B
Operational Performance

UMTA's Transbus program was designed to achieve the most advanced bus design practicable within the state-of-the-art. The particular areas of improvement identified were: comfort and ride quality; improved safety for passengers, pedestrians, and occupants of other vehicles; reduced maintenance; and lower floor and better access and interior arrangements which accommodate elderly and handicapped riders.[1]

This appendix compares Transbus with the operational performance of other buses readily available on the U.S. market: the Advanced Design Buses (RTS-II manufacturered by General Motors Corporation, and 870 by Grumman Flxible Corporation); and the New Look buses manufacturered by Flyer Industries Limited and General Motors of Canada. Table B-1 provides comparative data for each of the buses.

Specific aspects covered are:
- accessibility
- productivity
- performance
- maintainability
- reliability

Table B-1
Bus Specifications

Specified Item	Transbus[1]	Flyer	GMCL	GMC RTS-II	GFC 870
A. Technical					
1. Dimensional					
Ground to 1st Step					
- Entrance	14" max	13.5"	13.5"	13.0"	14.0"
- Exit	15" max	14.0"	15.7"	15.7"	15.0"
First to 2nd Step & 2nd to Floor					
- Entrance	8" (1st to floor)	10.7"	10.0"	9.6"	8.0"
- Exit	9½" (1st to floor)	10.7"	9.6"	10.0" est.	10.2"
Floor Height at Front	22" max	34.9"	33.2"	32.0"	30.0"
- Kneeled	18"	30.9"	29.2"	28.0"	24.0"[10]
Door Clearance					
- Entrance	38" min	38.0"	44-48"[2]	30.0"	36.0"
- Exit	24" min	26.5" (push)	26.5" (push)	44.0"	30.0" (push)
Aisle Width	20" min	25.0"	26.0"	22.5"	26.0"
2. Suspension	Automatic Height Control	Air Suspension & Height Control	Air Suspension & Height Control	Air Suspension & Height Control	Air Suspension & Height Control
3. Axle					
- Front	Single	Single, Rockwell Reverse Elliot Type	Single, Rockwell Reverse Elliot Type	Single Rockwell	Single, Rockwell
- Rear	Tandem	Single, Rockwell 63° Drive Angle	Single, Rockwell 63° Drive Angle	Single, 63° Drive Angle	Single, Rockwell
4. Brakes	Air Actuated	Air Actuated: 14.5"x5" Front; 14.5"x10" Rear	Air Actuated: 14.5"x5" Front; 14.5"x10" Rear	Air Actuated: 15"x6" Front; 15"x10" Rear	Air Actuated: 14.5"x6" Front; 14.5"x10" Rear
5. Wheels	Compatible with Tires	22.5"x8.25"-10 Stud		22.5"x8.25"	22.5"x8.25"
Dual Wheel Spacing	Not Applicable	13¼"	13¼"		
6. Tires	Suitable for Conditions	6-11:00x22.5" 43.5" OD&11" Width	6-11.5x20"	6-12.5x22.5	6-11:00x22.5"

Continued on next page.

Table B-1 (Concluded)
Bus Specifications

Specified Item	Transbus[1]	Flyer	GMCL	GMC RTS-II	GFC 870
7. Engine	DD8V71, 6V71 or Equivalent	DD6V71 Cum. VTB-903	DD8V71 / 6V71	DD8V71 / 6V71	DD8V71 / 6V71
8. Transmission	Allison 730 (Automatic)	Allison 730 (Automatic)	Allison 730 (Automatic)	Allison 730 (Automatic)	Allison 730 (Automatic)
9. Electrical System	12 or 24V / Generator	12V / Alternator	12V / Generator	24-12V / Generator	12V / Alternator
10. Odometer		Yes	Yes		
11. Body Construction	Durable, Exterior Surface Free of Fasteners	Steel Structure & Aluminum Panels	Monocque	Unitized Construction	Semi-Monocque
12. Windows	Fixed	Slides at Side Fixed at Rear	Slides at Side Fixed at Rear	Fixed Acrylic	Fixed Acrylic
14. W/C Lift Available	Yes (or Ramp)	Yes	Yes[2]	Yes (Rear Door)	Yes
B. Operations					
Capacity, Seats	46 min	51 nom.	51 nom.	47	48
Curb Weight, lbs.[3]	25,300 max	22,900[5]	22,000[2]	26,000[4]	24,800[9]
Seated Load Weight, lbs.[3]		30,500	30,000	33,100	32,100
- SLW Front Axle	20,000 max[8]	8,800	8,500	11,900	10,500
- SLW Rear Axle	34,000 max[8]	21,700	21,500	21,200[4]	21,600
Gross Vehicle Weight, lbs.[3] (Number of Passengers)		35,300(80)	34,200 (80)	38,000 (80)	36,800 (80)
Rear Axle (estimated)		23,500	23,700	23,600	24,000

[1]*Design Specifications*
[2]*Information from GMCL.*
[3]*Without wheelchair lift.*
[4]*Information from GMC. Weights can vary depending upon equipment. Bus has A/C.*
[5]*Information from Flyer: Axle load = 6,350 (front) & 16,050 (rear) for curb weight.*
[6]*Front axle load = 42% of total passengers.*
[7]*WMATA bid from GFC.*
[8]*Federal Interstate Specifications.*
[9]*Information from GFC. Bus has A/C.*
[10]*With low profile tires. 26.0" with standard tires.*

Two issues must be raised at this point. First, we will be comparing the performance of buses that have been in production, in their basic form, for twenty years, with two bus designs that have been in operation for less than two years, and with a yet-to-be-built bus with specifications based on nine experimental vehicles. Naturally, much of the data have had to be adjusted to compensate for the inevitable problems that arise in the introduction of new vehicles, or have had to be estimated (guessed) because firm numbers were not available. Wherever possible, the source of the original data has been identified, and any adjustments or modifications which MITRE made have been explained.

Second, much of the analysis herein is based on service *offered* by the transit system rather than service used by the public. This is particularly important when dealing with productivity and fuel efficiency. For example, while it is straightforward to compute fuel consumption in terms of seat-miles, an attempt to provide a comparison in terms of passenger-miles introduces a variable (load factor) which depends upon a number of factors, including the extent to which a particular design of bus can attract additional riders.

Any bus that meets the objectives of decreased trip time; increased passenger convenience, comfort, and safety; and greater aesthetic appeal will tend to attract more riders from cars and (at other than crush load times) operate at a higher load factor. As one paper states "there is unquestionably a strong association between perceived system attributes and modal choice."[2] Perceived system attributes include comfort, convenience, ease of use, and vehicular and personal safety. Unfortunately, no data exist that would allow one to determine the modal split resulting from the introduction of Transbus.

Accessibility

Probably no elements of the Transbus design are more critical or controversial than those associated with accessibility, specifically:

- floor (step) height
- wheelchair access
- ramp

The requirement for accessibility is defined in the regulations published in the May 31, 1979 *Federal Register.*[3] Paragraph 27.85, subsection (b) states:

> New vehicles. New fixed-route buses of any size for which solicitations are issued after the effective date of this part shall be accessible to handicapped persons, including wheelchair users. With respect to new, standard, full size urban transit buses, this requirement remains in effect until such time as solicitations for these buses must use UMTA's bid package entitled 'Transbus Procurement Requirements.'

This regulation was introduced to ensure compliance with the requirements of Section 16 of the Urban Mass Transportation Act (as amended) and Section 504 of the Rehabilitation Act.

The Transbus concept has always assumed easier access for the general public and for transportation handicapped people. UMTA defines transportation handicapped people as those who:

1. experienced general problems in past twelve months such as visual, hearing, mechanical aids, wheelchair or other problems (i.e., walking/going more than one block, waiting/standing, going up and down stairs, etc.)
2. perceive they have more difficulty in using public transportation than persons without their general problems
3. are *not* homebound (go/can go outside home at least once a week with or without the help of another person[4]

A survey showed that approximately 5 percent of urban residents classed themselves as transportation-handicapped.

The original Transbus specification called for an extending ramp. Subsequently, a wheelchair lift was permitted as an alternative.

As a result of the recently published regulation, all Advanced Design Buses and New Look buses purchased after May 31, 1979 must be fitted with wheelchair lifts. On June 29, 1979 the American Public Transit Association filed suit to stop the new regulation from going into effect. However, all the comparisons in the report assume that wheelchair lifts are installed.

Floor (step) Height

The relevant sections in the Transbus procurement specification states:

> 2.1.5.1 Height
>
> Height of the floor above the street shall be no more than 22 inches measured at the centerline of the front door with the coach at curb weight. At this weight, the height of the floor above the street shall be no more than 24 inches, measured at the centerline of the rear door. The floor may be inclined only along the longitudinal areas of the coach. The floor incline shall be less than 1 degree of the horizontal.
>
> 2.1.6.1 Steps
>
> A maximum of two steps shall be required for passenger ingress and egress. . . . At the front door, the first step up from the street level shall not exceed 14 inches with the coach at curb weight, and the second step riser height to coach floor level shall be no more than 8 inches. At the rear door, the interior step down shall not exceed 9 and ½ inches, and the second step to street level shall not exceed 15 inches with the coach at curb weight.

A related section states:

> 3.3.2.2 Kneeling
>
> A driver-actuated kneeling device shall lower the coach during loading or unloading operations regardless of load to an equivalent floor height of no more than 18 inches measured on the step tread at the longitudinal centerline of the front door.

Manufacturers' Comments

General Motors Corporation: "The RTS low floor alternative with its rear elevator and the optimization of the front steps to the (8″ + 8″ + 8″ = 24″ effective floor height) will provide essentially the same level of accessibility for the elderly and handicapped that the Transbus would provide."[5]

Figure B-1 illustrates the conditions for the standard RTS II, the Transbus and the RTS Low Floor.

Grumman Flxible Corporation: The nominal floor height in the Transbus specification is reduced to twenty-two inches from the current ADB height of thirty inches, with kneeling to eighteen inches on Transbus, versus the current ADB twenty-four inches. The net result of this lower floor is to eliminate one step *inside* the bus and to permit use of the ramp which is now optional. However, the first step into the Transbus would now be 10 inches versus today's eight inches on the Grumman Flxible Advanced Design Bus,* resulting in greater difficulty for the elderly and handicapped to board.[6]

Comparative Dimensions

Table B-2 illustrates the step heights for the buses under review.

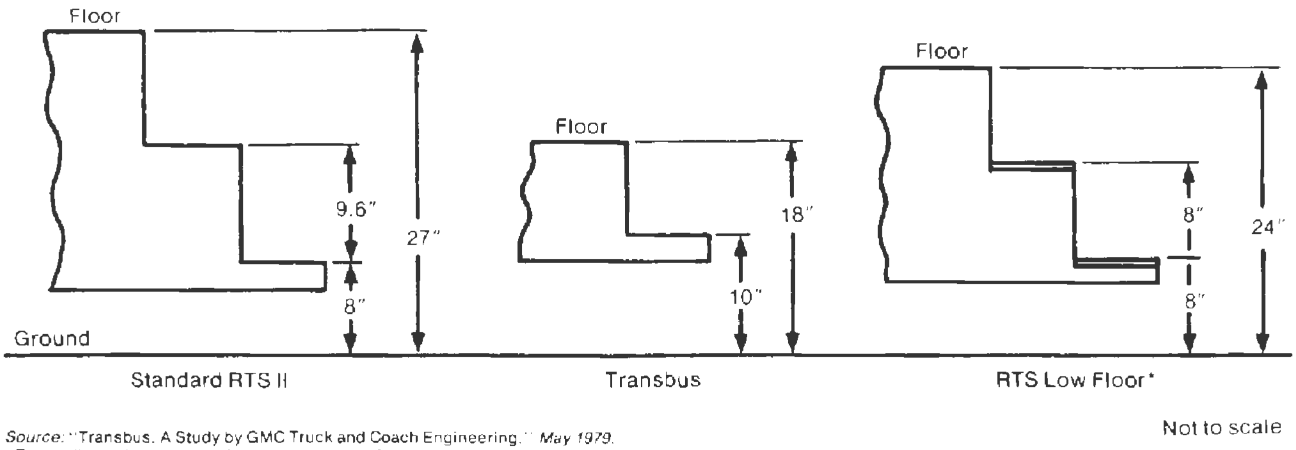
The low floor alternative design for the RTS-II has been suggested by General Motors Corporation. General Motors has determined that "lowering of the effective floor height to 24 inches may be possible in the relatively near future."[5]

The bus floor height on the Transbus prototypes were 23.5 inches (General Motors Corporation), twenty inches (AM General), and seventeen inches (Rohr).

Analysis

An analysis performed by Dr. G. Lehman[7] indicated that a 200 mm (approximately eight inches) step height is optimum in terms of minimum energy expended. The ANSI standards states that "steps

*Note: This dimension only applies to buses fitted with low profile tires.



Source: "Transbus, A Study by GMC Truck and Coach Engineering," May 1979.
*These dimensions also apply to the Grumman Flxible 870 with low profile tires.

Figure B-1
Entry Floor Height Comparisons

Table B-2
Bus Step Heights

Parameter	Transbus	GMC RTS-II Standard	GMC RTS-II Low Floor	Grumman Flxible 870	New Look Flyer Industries	New Look GMC Canada
Front Floor Height	22"	32"	29"	30"	34.9"	33.2"
Front Floor Height-Kneeled	18"	27"	24"	24"[1]	30.9"	29.2"
Front Steps Number	1	2	2	2	2	2
Step Height Nominal	14"	13"	13"	14"	13.5"	13.5"
Step Height Kneeled	10"	9.5"	8"	8"[1]	9.5"	9.5"
Front Steps Riser Height	8"	9.5"	8"	8"	10.7"	10"
Rear Door Floor Height	24"	35"	—	35"	34.9"	—
Rear Steps Number	1	2	2	2	2	2
Rear Steps Riser	9.5"	—	—	10.2"	10.7"	9.6"

[1]With low profile tires. 10 inch with standard 26-inch tires.

should, wherever possible, and in conformation with existing step formulas, have risers that do not exceed seven inches."[8] The technology groups studying Transbus concluded that step risers no greater than eight inches nor less than seven inches were required.[9] It is generally accepted that, for safety reasons, all risers should be the same height.

A survey has indicated that a 5.5 inch curb height is average in the United States.[9] This is consistent with measurements in Europe, which show curb heights in the range of 4.7 inches to 5.5 inches.[7]

Table B-3 illustrates the front door step heights for each of the buses (a) at curb, without kneeling, and (b) at street, kneeled.

When the front door of the bus is adjacent to a 5.5 inch curb, the Transbus 870 and Low Floor RTS-II both have steps that are in the range of eight inches ± one half inch. Transbus would require two steps up; the others would require three. All the other designs have step height differences of two inches or greater, and involve steps of 9.5 inches or greater.

When there is no curb and the front of the bus is kneeled, Transbus presents two steps of different heights. RTS-II Low Floor and 870 present three equal eight inch steps. RTS-II has three equal nine inch steps. The remaining two buses have three unequal steps.

It is apparent that two steps will be easier to climb than three of the same height. Figure B-2 illustrates the results of a survey performed for General Motors by Metropolitan Detroit Market Research Incorporated. Those who responded distinctly prefered the two steps, and there were a few who were able to climb two steps, although they could not climb three.

Table B-3
Front Door Step Heights

Parameter	Transbus	RTS-II Standard	RTS-II Low Floor	870	Flyer	GMC Canada
Curb to 1st Step	8.5"	7.5"	7.5"	8.5"	8"	8"
Street to 1st Step (Kneeled)	10"	9.5"	8"	8" (10" with standard tire)	9.5" +	9.5" +
Interior Steps	8"	2 x 9.5"	2 x 8"	2 x 8"	2 x 10.7"	2 x 10"

QUESTION: Now that you have evaluated both of these Transit Bus systems at the *curb level*, I would like you to tell me which system you prefer.

Step Design	Ambulatory	Elderly
Low Floor RTS	41%	31%
Transbus	59	69
Total	100%	100%
(Sample Size)	(108)	(138)

Note: % Unable to Walk Up Steps

	Curb Level	
Step Design	Ambulatory	Elderly
Low Floor RTS	14%	14%
Transbus	11	14

Source: Reference 16 (modified by MITRE)

Figure B-2
Public Transit Bus Entry/Exit Step Preference (Boarding Position at Curb Level)

QUESTION: Now that you have evaluated both of these Transit Bus step systems at the *street level*, I would like you to tell me which system you prefer.

Step Design	Ambulatory	Elderly
Low Floor RTS	40%	39%
Transbus	60	61
Total	100%	100%
(Sample Size)	(105)	(130)

Note: % Unable to Walk Up Steps

	Curb Level	
Step Design	Ambulatory	Elderly
Low Floor RTS	18%	20%
Transbus	17	19

Source: Reference 16 (Modified by MITRE)

Figure B-3
Public Transit Bus Entry/Exit Step Preference (Boarding Position at Street Level)

Mounting from the street is rather different than mounting from the curb. In addition to two versus three steps, the initial step height for the two-step Transbus is higher than the desirable eight inches. Figure B-3 illustrates the survey results for this case. There is an increased preference for Transbus, although with this small sample size the change is not significant. The number of people unable to walk up three steps was also higher than those able to walk up two steps.

When the questions about alternative step heights were rephrased to elicit acceptability rather than preference, the expressed differences between the two approaches narrowed considerably. However, the two-step approach was consistently more acceptable than the three-step approach (Figure B-4). Although the methodology and the wording of the survey are subject to criticism, the results tend to be confirmed by experience in the United Kingdom. (See the performance section of this appendix.)

Findings

The Transbus design is more accessible to the ambulatory handicapped and the elderly than other bus designs. The Grumman Flxible 870 and the Low Floor RTS-II would be equally accessible, but less accessible than Transbus. The existing RTS-II is less accessible than Transbus, the Grumman Flxible 870, or the Low Floor RTS-II. There is some evidence that (within limits) the number, rather than the height, of steps are problems.

New Look buses are inferior to all the other designs in terms of accessibility.

Wheelchair Access

The relevant sections of the Transbus procurement documents state:

> 2.3.2 Passenger Seats
> The coach shall accept seating arrangements that are basically transverse, perimeter or a combination of these with space and accommodations for a passenger(s) confined to a wheelchair.
>
> The wheelchair parking space shall be provided as far forward as practicable.

QUESTION: Would you consider either one or both of these boarding steps to provide an acceptable means for entering and exiting public buses at curb level/street level?

	Curb Level		Street Level	
Step Design	Ambulatory	Elderly	Ambulatory	Elderly
RTS				
Yes	78%	72%	74%	68%
No	22	28	26	32
Transbus				
Yes	84	88	80	78
No	16	12	20	22

Source: Reference 16 (modified by MITRE)

Figure B-4
Acceptability of Step Designs

Maneuvering room inside both 102 and 96 inch width coaches shall allow easy travel for a passenger in a wheelchair, with no width dimension in the doorway or aisle less than 34 inches. The vestibule and other areas requiring 90° turns of wheelchairs shall have a clearance arc radius dimension no less than 42 inches. In the parking area where 180° turns are required, space shall be clear in a full 60-inch diameter circle. These dimensions may be reduced to no less than 36 and 54 inches respectively on 96 inch wide coaches. Up to 12 inches of space on the outside of turning areas can be incorporated in the turning circle requirements, providing that a vertical clearance of 10 inches above the floor surface is unobstructed for foot rests.

2.6.6.1 Loading System
A system shall be incorporated at the front door to provide ingress and egress to handicapped passengers including those in wheelchairs from the street level or from curbs up to 20 inches in height. . . .

(2) Option: Lift Loading System. Wheelchair passenger access shall be provided by an elevator or lift system.

Manufacturers' Comments

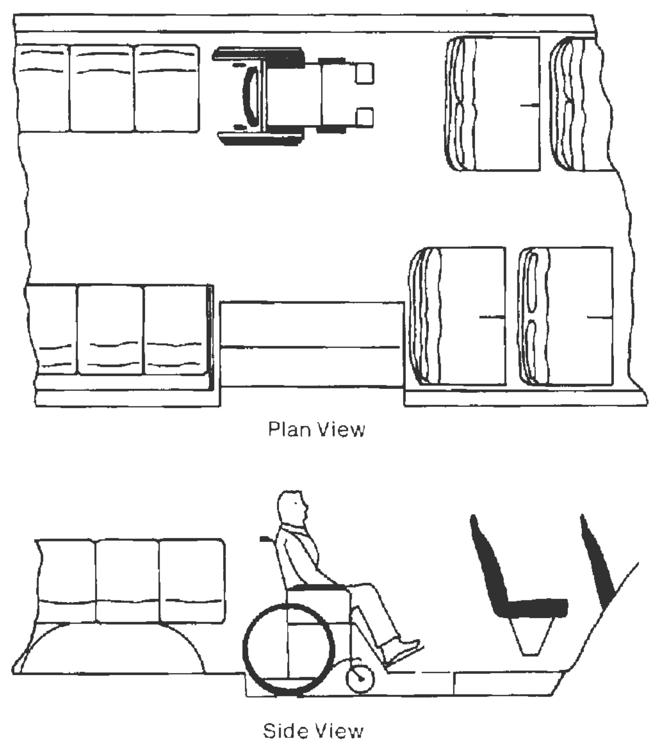
General Motors Corporation: "The RTS low floor alternative with rear elevator will provide essentially the same level of accessibility for the elderly and handicapped that the Transbus would provide.[5] The access needs of the handicapped, particularly wheelchair bound and semi-ambulatory (walkers, crutches, etc.) are better served through entrance and exit through the rear door. The GMC designed wheelchair lift system affords several positive features to . . . the vehicle operator. . . . rear entry/exit via a lift provides access to fixed route public transport for a broader spectrum of elderly and handicapped than does front ramp entry. . . . Overall the rear entry approach contains fewer negative factors, psychological, safety and other."[11]

Figure B-5 is an illustration of the proposed GMC layout.

Grumman Flxible Corporation: "Due to specified length, width, and height restrictions, wheelchair maneuvering dimensions within the bus appear to be unobtainable, but this cannot be confirmed pending final design."[6]

Wheelchair Access Configuration

The Transbus specification calls for the lift/elevator to be located at the front door. The wheelchair parking area is "as far forward as possible."



Wheelchair Passenger Shown in Travel Position

Figure B-5
GMC Truck and Coach Division Proposed Rear Door Entry/Exit for Wheelchair Passengers

The GM RTS-II power lift is located at the rear door with wheelchair parking immediately across the aisle.

The Flxible 870 and New Look buses have wheelchair lifts mounted at the front of the bus with wheelchair parking immediately behind the front wheel housing.

Analysis

The issue of wheelchair accessibility by lift/elevator is basically one of evaluating the trade-offs between front and rear door access. For this analysis, it is assumed that the wheelchair parking spaces would be near the rear door for rear door entry, and that the specification would be modified accordingly. Table B-4 summarizesc the differences. These can be grouped under the following headings:

- wheelchair maneuverability
- operating convenience
- bus positioning
- impact on loading/unloading
- possibility of damage

Wheelchair Maneuverability A wheelchair entering via the front door is required to rotate 90 degrees by the farebox, move down the aisle between the front wheel housings that may have passengers sitting on longitudinal seats, rotate 90 degrees to move into the wheelchair parking position, and a further 90 degrees to move into the final rest position.

A wheelchair entering by the rear door is required to rotate 90 degrees after entering the wheelchair parking position.

The Urban Mass Transportation Administration has stated that:

> All the wheelchair maneuvering dimensions except for door width have been attained in the 102 inch wide New Look buses. Also, all the dimensions specified have been attained in the full size typical Transbus (102 inch wide) mockup at Booz-Allen (used for testing wheelchair ramps and internal wheelchair maneuvering).[12]

Figure B-6[13] illustrates the wheelchair clearance at the front wheel housing of a 102 inch wide bus for a wheelchair with an overall width of twenty-six inches—accommodating 85 percent of the wheelchair user population. This illustrates the clearance in the New Look bus. It is apparent that care must be exercised in the design of the Transbus wheel housings and seating to ensure adequate clearances.

Figure B-7 illustrates the equivalent clearances for a ninety-six inch aisle bus.[13] The reference report stated "with the input from those studies it was determined that the interior conditions of a ninety-six inch bus makes the wheelchair lift installation impractical." It should be noted that this refers to the New Look bus design, with a narrow front door and

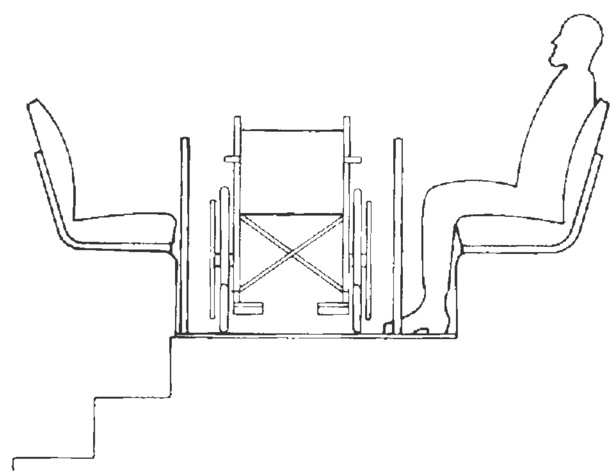


Figure B-6
102-Inch Bus Wheelchair Clearance

Table B-4
Accessibility by Wheelchair Lift/Elevator

	Forward Loading	Rear Loading
Advantages	• Positioning the bus adjacent to curb becomes easier.	• Movement from lift to parking position is easier.
	• Controls are closer to the driver.	• Entry and exit from bus are possible when lift in use.
Disadvantages	• Manuevering a wheelchair is more difficult.	• Positioning the bus near to curb is more difficult.
	• Entry is not possible while lift is in use.	• Driver must leave position and move to the back of the bus.
	• The lift is highly susceptible to damage.	

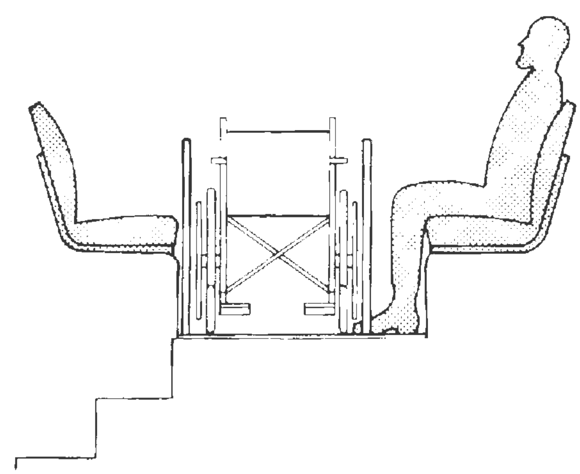


Figure B-7
96-Inch Bus Wheelchair Clearance

less room for maneuvering from the lift into the aisle. Therefore, it does not necessarily apply to Transbus, which has a wide front door.

Table B-5 shows the distribution between front door and rear door lifts for the Advanced Design Buses for which bids were submitted during the first five months of 1978. No bids were submitted by Grumman Flxible for ninety-six inch wide Model 870 buses equipped with front door lifts. However, this was for production scheduling reasons rather than because of the impracticability of maneuvering the wheelchair on a ninety-six inch wide bus. MITRE staff have determined in experiments using the bus manufacturers' mockups that it is possible to maneuver a wheelchair in a ninety-six inch wide bus. However, this inconveniences passengers sitting in longitudinal seats.

Table B-5
Wheelchair Lift Locations
Contracts Awarded January-May 1979

Bus Width	Front Door	Rear Door
102"	230	381
96"	0	60

Only limited information is available on the preferences of handicapped users. The survey performed for General Motors addressed the issue indirectly, and the results indicated a strong preference for the rear-mounted elevator (Figure B-8). Combining the elevator and ramp figures, it would appear that 80 percent of wheelchair users preferred entering the bus from the rear rather than the front. However, in the tests performed for General Motors, the wheelchair parking position was opposite the rear door and not immediately behind the front wheel housing. The configuration tested required the wheelchair passenger to move down the aisle to reach the wheelchair parking position, a maneuver that would not be required on Transbus.

At the Annual Conference on Transportation for the Elderly and Handicapped at Michigan State University in July 1976, strong objections were raised to the rear door location. (See AMC's "A Study of Wheelchair Access to the Current Bus Design"[13] pages 12 and 13 for additional details.)

Operating Convenience The bus operator plays a key role in the use of the wheelchair lift. The sequence of operations for one lift is as follows.[14]

1. The driver activates the power for the lift with a key operated switch on the driver's control panel. With the door "open" both the acceleration and brakes are interlocked; the door cannot be closed.
2. Using the master key, the driver activates the power switch. This immobilizes the coach.
3. With the power on, the driver activates the deploy/park switch into the deploy position. This releases the slip lock under the coach and allows the slip mechanism to unfold into a loading platform.

QUESTION: Now, I would like you to rank these two systems, assuming that they could be placed at either the front or rear door.

Please note when choosing the elevator system in the front of the bus, you would still have to maneuver down the aisleway, to the ride position. On the other hand, if you choose the ramp at the rear, you would move directly across the aisleway to the ride position.

What would be your first choice, second, third, (last—DON'T READ) at curb level?

System Location	Wheelchair Users	Ambulatory	Elderly
Elevator (at rear of bus)	78%	46%	46%
Elevator (at front of bus)	15	33	35
Ramp (at front of bus)	5	16	12
Ramp (at rear of bus)	2	5	7
Total	100%	100%	100%

[1] *Ratings by people who would not use steps, when boarding a bus.*

Source: Reference 16 (modified by MITRE)

Figure B-8
Public Transit Bus Entry/Exit System Preference[1]
(Boarding Position at Curb Level)

4. The driver activates the up/down switch in the down position. The platform lowers to the ground.
5. After the wheelchair passenger has boarded the platform, the driver activates the up/down switch in the up position to raise the platform to coach floor. The passenger leaves the lift.
6. The driver than "parks" the power lift by activating both the deploy/park position and the platform unlock switch. The power switch is then turned off, deactivating the lift.
7. Using the master switch key, the driver locks the rear control panel and replaces the master control key in the master switch to return the coach to normal run condition.

A similar sequence would be required for each front or rear door operation. However, for rear door operation it will be necessary for the bus operator to leave the driving position and move through the center aisle of the bus to the rear door. For front door operation, it should be possible for the operator to control the wheelchair lift near the normal driving position. At least one transit system is paying fifty-cent bonuses each time the lift is operated.

Bus Positioning Frequently buses are required to pick up passengers where the bus stop is blocked by parked cars. Normally, the bus's door is adjacent to the curb. The geometry of the lift design usually extends the lift twelve to eighteen inches from the side of the bus when it is in its lowered position. This acts as a bridge between a diagonally stopped bus and the curb (Figure B-9).

Locating the rear door of a bus adjacent to the curb requires considerably more clearing near the bus

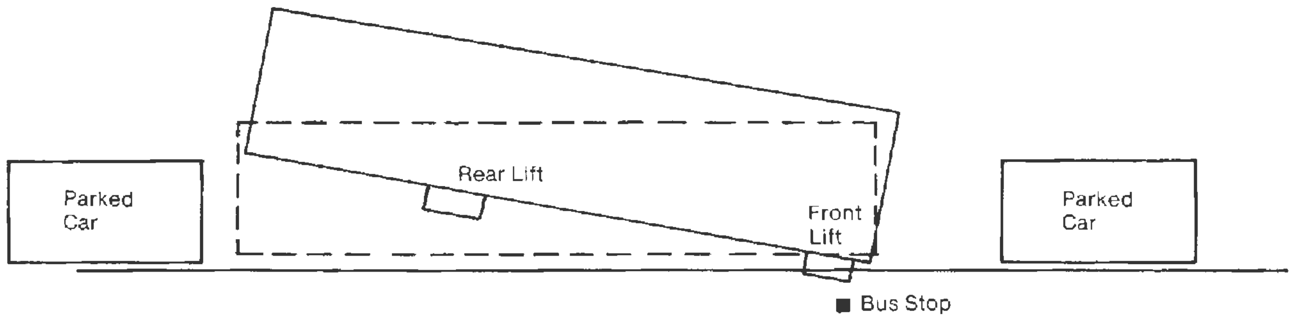


Figure B-9
Lift Positions Restricted Bus Stop Access

stop. Without this space, the wheelchair user must move from the sidewalk, over the curb, and into the street to get to the bus.

Impact on Loading/Unloading Ambulatory boarding passengers cannot get on the bus while a wheelchair lift is in operation at the front door. Passengers can exit normally from the rear door.

Exiting from the rear door is banned while the rear door lift is in operation. Entry and exit can take place through the front door. These will be facilitated by the wide front door on Transbus, since entry and exit take place simultaneously. However, since drivers must leave their seats to operate the lifts, they cannot monitor fare collection.

Possibility of Damage The right front (curb side) corner of the bus is the area most susceptible to damage from impact with other objects. Such damage could result in a lift becoming inoperable, although not necessarily removing the bus from service. The probability of such damage at the rear doors is remote.

Any design of lift at the front door should take this factor into consideration—for example, by locating working mechanisms where they would be less susceptible to damage, and by arranging adequate clearances so that the lift could continue to operate when minor damage had occurred to the skin or door, including distortion of the door frame.

Findings

Mobility within the bus is considerably easier with elevator/lifts at the rear door than at the front door.

Access to the rear door lift from the street may be more difficult, particularly where street conditions are congested.

Rear door access presents operational problems, as it requires the bus operator to leave the driver's seat.

Rear door access impedes boarding and alighting less, particularly when the bus is equipped with a wide front door. However, the driver cannot monitor operations while operating the wheelchair lift.

Passengers seated on longitudinal seats over the front wheel housing will be subjected to some inconvenience in a 102 inch wide bus, and considerable inconvenience in a ninety-six inch wide bus, as a wheelchair is maneuvered from the front door to the parking area.

Ramp

The relevant section of the specification states:

> 2.6.6.1 Loading System
> Option Ramp Loading System
> The handicapped and wheelchair passenger access system shall be a [sic] extendable ramped surface no less than 6 foot in length.

Also relevant in view of one manufacturers comments is an earlier part of Section 2.6.6.1, which states:

> The height of the transition from the sidewalk or street to the loading area shall be minimized and shall not exceed ¼ inch.

The original Transbus specifications mandated the ramp. Subsequently, transit systems were permitted to chose a ramp or a lift. In the consortium procurement, sixty of the coaches for Miami were to be fitted with ramps; the balance called for wheelchair lifts.

Manufacturers' Comments

General Motors Corporation: "The ramp is required (2.6.6.1) to have a minimum length of six feet, which in our judgment becomes the maximum practical length. A separate study for UMTA by Booz-Allen entitled 'Boarding Ramps for Transit Buses' determined that a longer ramp is undesirable because of potentially hazardous effect on roadway or sidewalk traffic. If the bus stops at the normal distance from the curb, a ramp longer than six feet will interfere with pedestrian traffic. If the bus stops farther out in the street to keep the ramp from being a disturbance to pedestrian traffic, the bus becomes an obstruction to vehicular traffic, and exiting passengers at the rear door would step on to the street—creating a potential safety problem. A six foot ramp system built to satisfy the Transbus specification will, therefore, have ramp angles as charted below:

	Floor Knelt to 18″ with 6″ Curb	No Curb
Net Climb, inches	12″	18″
Ramp Angle° (A)	9.6°	14.5°
Ramp Slope (Tan a)	1:5.9	1:3.9
Ramp Grade, %, (100 x Tan a)	16.9%	25.8%

"Contrast the above angles with the universally accepted architectural standards for people in wheelchairs establishing the maximum slope of one inch for every twelve inches or a maximum ramp grade of 8.5 percent.

"To prevent rolling off the sides of the ramp, a retractable guard rail is required by the Transbus specifications. In addition, sophisticated safety controls will also be required. Therefore, the ramp will not be a simple device as first conceived. In fact, the complexity of the ramp and its essential safety systems, plus its function as a natural barrier when slope is steeper than about 1:8, renders it inferior to a lift for a larger percentage of the community which Transbus is intended to serve. We have serious reservations as to the practicality and workability of a ramp system."

General Motors' investigation into the use of ramps disclosed a further safety problem. "The coefficient of friction is limited to a maximum of one, by physical law. A six-foot ramp with an eighteen inch rise would require a coefficient of friction in excess of 1.5 when going down the ramp. The problem, therefore, is that the exiting wheelchair passenger slides down the ramp because there is not enough weight on his driver-braking wheels to allow for adequate traction. As the ramp becomes dirty or wet, the actual coefficient of friction is reduced from the value when it was clean and dry. This, in turn, reduces the upper limit of a safe ramp angle."

Grumman Flxible Corporation: "Lifts or ramps must be deployable to a twenty-two inch high curb with a maximum ½ inch upward movement. Due to bus floor height restraints, this can be achieved only with a ramp thickness of zero inches. Impossible."

UMTA Comments

The phrase "with a maximum of ½ inch upward movement" does not appear in the ramp specification, nor does the specification impose any restriction on ramp thickness.

Analysis

Table B-6 presents the ramp angles and ramp grades for a combination of ramp lengths, kneeled floor height, and with or without a six inch curb.

The ANSI specifications state "A ramp shall not have a slope greater than one foot rise in twelve feet, or 8.33 percent, or 4 degrees 50 minutes."

To achieve the ANSI standard, the Transbus would require an eighteen foot ramp to the street, or a twelve foot ramp to the curb.

To achieve the ANSI standard with a six foot ramp to street level would require a kneeled floor height of six inches.

UMTA tests have indicated that 96 percent of wheelchair users found a 14.5 degree slope satisfactory. At this angle, the ramp runs from the bus floor to the curb.[15] This data was obtained from tests with approximately eighty wheelchair occupants using the Transbus mockup of Booz-Allen. However, tests performed for General Motors indicated that 13 percent of the wheelchair users, 14 percent of the ambulatory handicapped, and 8 percent of the elderly were unable to get up the ramp.[16]

Findings

Whether a ramp on Transbus is a practical solution to providing access for the mobility-disadvantaged is still an open question. In the best case (bus kneeling, six inch high curb) the ramp angle is twice that specified for making facilities accessible to the physically handicapped. The length of the ramp that would be required to meet the ANSI specifications is impractical.

Further test should be conducted to determine the extent to which wheelchair users and others with physical difficulties are able to board and alight from the bus using the ramp under varying conditions, including rain.

Productivity

Passenger boarding and alighting activities at the narrow front door of New Look buses has long been recognized as a major delay, since passengers must enter in a single stream. Studies performed in Providence, Rhode Island, in 1958 revealed that passengers service time required to load and unload passengers accounted for 17 to 26 percent of total travel time, and 50 to 76 percent of total delay time.[17] Although most buses provide a second doorway for alighting passengers, nearly half of all riders continue to use the front door as an exit.[18] Because of the single stream channel in New Look buses, new passengers cannot enter until all those who wish to exit at the front door do so.

Consequently, speeding up loading and unloading became a major consideration for future designs. By

Table B-6
Ramp Angles

Floor Height		6-Foot Long Ramp Without Curb	6-Foot Long Ramp With Six-Inch Curb	8-Foot Long Ramp Without Curb	8-Foot Long Ramp With Six-Inch Curb	10-Foot Long Ramp Without Curb	10-Foot Long Ramp With Six-Inch Curb
18″	Angle	14.5°	9.6°	10.8°	7.2°	8.6°	5.7°
	Grade	25.8%	16.9%	19.0%	12.6%	15.2%	10.0%
24″	Angle	19.4°	14.5°	14.5°	10.8°	11.5°	8.6°
	Grade	35.0%	25.8%	25.8%	19.0%	20.4%	15.29%

speeding up boarding and alighting, it was hoped that vehicle dwell times could be reduced enough to decrease average travel times significantly. Ultimately, this would lead to greater service capacity or reduced pressures for fleet expansion.

One approach to speeding up boarding and alighting is to reduce the number of steps required to enter and leave the bus. A second is to allow boarding and alighting simultaneously.

Several service time studies have shown that significant reductions in vehicle dwell time are possible using a vehicle with a front doorway wide enough to accommodate two steams of traffic. The narrow front door of conventional buses makes it virtually impossible for two passenger streams to pass at the front door simultaneously, although boarding passengers in the stepwell will often clear enough space for an exit. A wide front door would permit boarding to occur independently of alighting and would reduce dwell time by the amount consumed by exits.

Door Widths and Step

The relevant sections in the Transbus procurement specifications state:

> 2.1.8.2 Dimension
>
> . . . Front door opening widths shall be no less than forty-four inches with the doors fully opened. Rear door opening width shall be no less than thirty inches with the door fully opened. . . . The clear door opening widths, including door mounted passenger assists or touch bars, shall be no less than thirty-eight inches for the front door and twenty-four inches for the rear door.
>
> (1) Optional Wide Rear Door. The rear door shall have an opening width of no less than forty-four inches with the door fully opened, and the clear door opening width shall be no less than thirty-eight inches.

The relevant section on steps has appeared previously.

Manufacturers' Comments

General Motor Corporation: "The approximate fifty inch body opening required to satisfy the door opening specification of forty-four inches, coupled with the additional eight inch space for mechanism, reduces the space availability for seating on the right hand side of the coach."

Grumman Flxible Corporation: "The original Transbus program and a Booz-Allen Hamilton study indicated that a forty-eight inch door would be required to provide double stream entry and exit. This was originally supposed to speed up service, making the bus more efficient. . . . The forty-four inch door called [for] by the current Transbus specification fails to achieve the double stream entry."

Manufacturers comments on steps have appeared earlier.

Comparative Dimensions

Table B-7 shows the front and rear door widths for Transbus and four other types of buses. The dimension shown is the clear opening.

The clear front and rear door openings for the three Transbus prototypes are shown in Table B-8.

Comparative dimensions of steps appear in Table B-2.

Analysis

Door Width Early versions of the Transbus specifications called for a forty-eight-inch wide front door. The forty-eight inch dimension is an accepted design minimum for stairways intended to serve two-way traffic (e.g., Mil. Spec. 1472B).[19] European transit operations using buses with forty-eight inch wide front doors have proven that two parallel and/or opposing streams of passengers can be readily accommodated.

The forty-eight inch dimension is an accepted architectural minimum for stairways. However, the steps of a transit bus more closely approximate the character of a doorway than a typical stairway. Only two or three steps are part of the bus entrance. Consequently, the potential area of conflict is quite small and passengers may turn to avoid conflicts. A stairway must be designed to permit full-body passing, but since one can angle one's body to a limited degree on bus "stairs" one can reduce the conflict area because of the short distances. As a result, the width specification for a bus entrance need not be the same as a conventional stairway.

Consider for example, the shoulder breadth and chest depth dimensions for the 97.5 percentile male. Two such men would require at least a total clearance of 39.6 inches standing side-by- side and shoulder-to-shoulder. Adding winter-weight clothing, the forty-four inch specified dimension becomes very tight. Assuming just one of these individuals turns his body to present a compromise between the space required for his shoulders (19.8 inches) and the space of his

Table B-7
Front and Rear Door Widths (Clear Widths)

Door	Transbus	Flyer Industries	RTS	GMCL	870
Front	38″	38″	30″	30″	36″
Rear	24″	26.5″	44″	44″	30″

Table B-8
Transbus Prototype Door Widths (Clear Opening)

Door	AMG	GM	Rohr
Front	40"	33"	40"
Rear	30"	49"	30"

chest (10.7 inches), the forty-four inch opening should be more than adequate for passing. Very often boarding passengers will not occupy every step; consequently, the two streams will probably space themselves on different steps and avoid shoulder-to-shoulder conflicts altogether.

As part of the Transbus prototype testing, Booz-Allen conducted boarding and alighting experiments to measure the speed with which passengers could enter and exit the various Transbus prototypes. The wider front doors of the Rohr and AM General Transbuses "clearly demonstrated two stream counterflow was possible and probably would occur in service."[20] Both of these vehicles had a front door width of approximately forty inches.

Passenger Service Time Passenger service time is dependent on a number of factors including:

- method of fare collection
- number of doors
- width of doors
- direction of passenger flow
- standees
- orientation of the passenger with the system
- physical characteristics of the passenger
- amount of baggage
- seating configuration
- aisle width
- placement of handrails
- step height
- orientation of the bus with the curb
- type of service

For at least twenty years, various studies have attempted to quantify the effects these factors have on passenger service time and vehicle dwell time. As noted previously, a 1958 Rhode Island study found passenger service time to account for 17 to 26 percent of total travel time and 50 to 76 percent of total delay time.[17] A 1959 St. Louis study recorded passenger service time as 18 percent of total trip time and 60 percent of total delay time.[17] A 1977 study of surveys and photographic studies between 1967 and 1976 in eighteen cities in the U.S., Canada, and Puerto Rico concluded that boarding and exiting accounted for 15 to 25 percent of total travel time and 50 to 80 percent of total delay time.[21] Table B-9 summarizes the observations in the most recently study.

The majority of the studies to date have examined the effects of change in fare collection procedures or the effects of different vehicle configurations on passenger boarding times. British studies, for example, have investigated the switch from conductor operations to one-man operations almost exclusively. Because of significant differences in fare collection practices between British and U.S. systems, many of the British observations and conclusions are not directly relevant to the issue of Transbus productivity

Table B-9
Summary of Service Time Effects

	Factor	Effect
Human Factors	Passenger Orientation	Degree of passenger orientation is inversely proportional to the amount and variability of service time—variability of 52 to 168 percent reported
	Passenger Sex	Average time per passenger reduced by 0.0103 times the percentage of women
	Age and Handicaps	Not quantified because of difficulty in categorizing attributes: observed to increase service time
	Baggage	Passengers with more than one item increase service time by 0.0112 times the percent of such passengers
Vehicle Characteristics	Two-Door Alighting	No difference between front door and rear door alighting times
	Simultaneous Alighting	Using both doors to alight produces time reductions of from 27 to 80 percent
	Double-Stream Alighting	Double stream alighting requires from 27 to 46 percent less time than single-stream alighting
Fare Collection	Two-Door Boarding	Two-door boarding requires more than half the time required for one-door boarding
	Aisle Width	Decreased aisle width increases service time
	Pay Leave Collection	Up to a 200 percent increase with pay enter collection over pay leave methods
	Fare Register	Up to 100 percent increase with fare register operation over farebox method
	Exact Change	Exact change results in a savings of from 9 to 23 percent

Source: Reference 21.

versus the productivity of New Look and Advanced Design Buses, except for:

- the comparison of the relative ability of the elderly and the handicapped to more physically agile passengers
- the estimated boarding and alighting times recorded for particular British buses which, for all practical purposes, approximates the low floor equivalent of Transbus.

The Transport Road and Research Laboratory (TRRL) study confirms the slower boarding and alighting characteristics of the elderly and the handicapped.[22] Table B-10 compares the mean delay for such individuals with the range of boarding and alighting averages for samples excluding these individuals.

Several of the buses investigated by TRRL provide a low-floor entry/exit. The Peckham Bus* had a single step (from the curb) to a large vestibule followed by a second step to coach interior; its single double-wide doorway is used for both boarding and alighting. The "Autofare" Bus in Hull* was basically identical to the Peckham Bus, except that it had two double-wide doors—one for boarding and one for alighting. Both buses have a third step near the middle of the bus (behind the rear door in Hull). Table B-11 compares the boarding and alighting times for these two buses to the more typical U.S. style of bus used in Reading.* The data shows that substantial improvements on the order of 37 percent are possible with double-stream entry and lower floors.

To what extent the lower floor contributes to this improvement cannot be readily determined. TRRL cites step heights as having an effect on passenger service times but concludes:

> Whilst attention to such details can facilitate bus usage by invalids and people with luggage. . . the effect of such factors on average stop-times is thought to be small in comparison with other factors.[22]

Data in Table B-12 and Table B-13 indicate that savings of up to 40 percent are a direct result of the double-wide doors as opposed to door widths which allow only a single stream of passengers to board and alight. Consequently, very little improvement appears to be directly attributable—at least not to the point of being quantifiable—to the low floors.

Booz-Allen studies of passenger boarding and alighting times during the Transbus prototype tests provide partial evidence that the low floor contributes to reduced passenger service times, particularly for the elderly and handicapped. Table B-13 presents the results of the Transbus tests comparing typical single stream and double-wide door bus times. The data show that the Transbus times are similar to those for the double-wide door configuration and represent approximately equal improvements over New Look and ADB buses. Booz-Allen's

*The bus is referred to by the city or town in which the measurements were performed.

Table B-10
Elderly and Handicapped Boarding and Alighting (Seconds)

Parameter	Boarding		Alighting	
	Peak	Off-Peak	Peak	Off-Peak
Average Time/Passenger Two Door Vehicles One-Man Operations	2.5-4.8	2.6-6.6	1.1-1.4	1.1-1.5
Average Delay (E&H)	4.0	3.0	1.5	3.0
Average Time/Passenger Elderly and Handicapped (Infirm)	6.5-8.8	5.6-9.6	2.6-2.9	4.1-4.5

Source: Reference 22.

Table B-11
Boarding and Alighting on British Buses (Seconds)

Location	Boarding		Alighting	
	Peak	Off-Peak	Peak	Off-Peak
Peckham	3.0	3.3	1.25	1.45
Hull	2.45	2.6	1.05	1.25
Reading	3.9	3.5	1.2	1.35

Source: Reference 22.

Table B-12
Comparison of Average Boarding and Alighting Times by Fare Method and Door Width (Seconds)

	Single Door	Double Door
Boarding—Fare Prepayment	2.0	1.2
Boarding—Single Coin Payment	3.0	1.8
Alighting	1.7	1.0-1.2

Source: References 14 and 23.

summary of its test results does not specifically identify the improvement as a direct result of the lower floor. For the able-bodied, the elderly, and the handicapped, the width of the doorway appears to be at least equally significant for reduced passenger service time.

The conclusion, therefore, is that lower floors can be more easily managed by the elderly and handicapped. They may contribute to speedier boarding and alighting for such individuals. However, the overall effect from a productivity standpoint is thought to be small compared to the productivity improvements from wider entry and exit doorways. TRRL attempted to estimate the overall impact of such slow entries and exits (Table B-14); their analysis indicates an impact approximately equal to that created by individuals with luggage—a very small overall effect. Unusual occurrences, such as boarders requiring directions, or the bus waiting for late passengers had a more significant—albeit still small—impact.

Double-wide doors, on the other hand, do appear to offer substantial productivity improvements with all methods of fare collection. Potential savings of up to 40 percent of passenger service time can translate into average overall travel time savings of from 4 to 10 percent, assuming passenger service time represents from 15 to 25 percent of total travel time.

Seating Capacity

The relevant section in the Transbus Procurement Specifications states:

> 2.3.2.1
> Seating capacity shall be no less than 46 when the wheelchair paths are not being utilized.

Manufacturers' Comments

General Motors Corporation: "The number of seats we can provide is one less than the specified requirement on a 40 foot coach."

Grumman Flxible Corporation: "The specification mandates a minimum of 46 seats and proceeds to specify bus length, width, and height for the interior as well as the exterior. The two requirements are contradictory. A more likely capacity is 42-44 seats. . . ."

Comparative Data

The nominal seating capacity of other bus designs is given in Table B-15.

Analysis

The tandem axles and the low floor of Transbus have major effects on seating capacity. Both GM and Grumman claim that, as a result of floor height and slope restrictions, Transbus cannot provide the specified capacity of forty-six seats. GM quotes an expected capacity for Transbus of forty-five seats. Grumman suggests that forty-two to forty-four seats are more likely.

Figure B-10 depicts a reconfigured Rohr prototype which includes contoured wheel housings and a conventional bench seat in the rear. The drawing suggests that a forty-six-seat configuration is possible using a seat pitch of twenty-eight inches.

Figure B-10 demonstrates that there is very little margin for expanded seat pitch, i.e., increasing seat pitch to accommodate such factors as the thickness of the seat back by even a half inch would probably make the configuration unworkable. In light of the seat pitch of 28.5 to 29 inches used in Advanced Design Buses, this would appear to be true. However, the Transbus specification, unlike the ADB specification, does not explicitly identify seat

Table B-13
Comparison of Estimated Transbus Service Times (Seconds)

	Normal		Elderly & Handicapped	
Type of Bus	Boarding	Alighting	Boarding	Alighting
Single Stream Door	3.0	1.7	NA	NA
Double-Wide Door Bus[1]	2.0	1.2	6.5	3.5
Transbus Estimates[2]	2.0	0.9	2.0	1.7

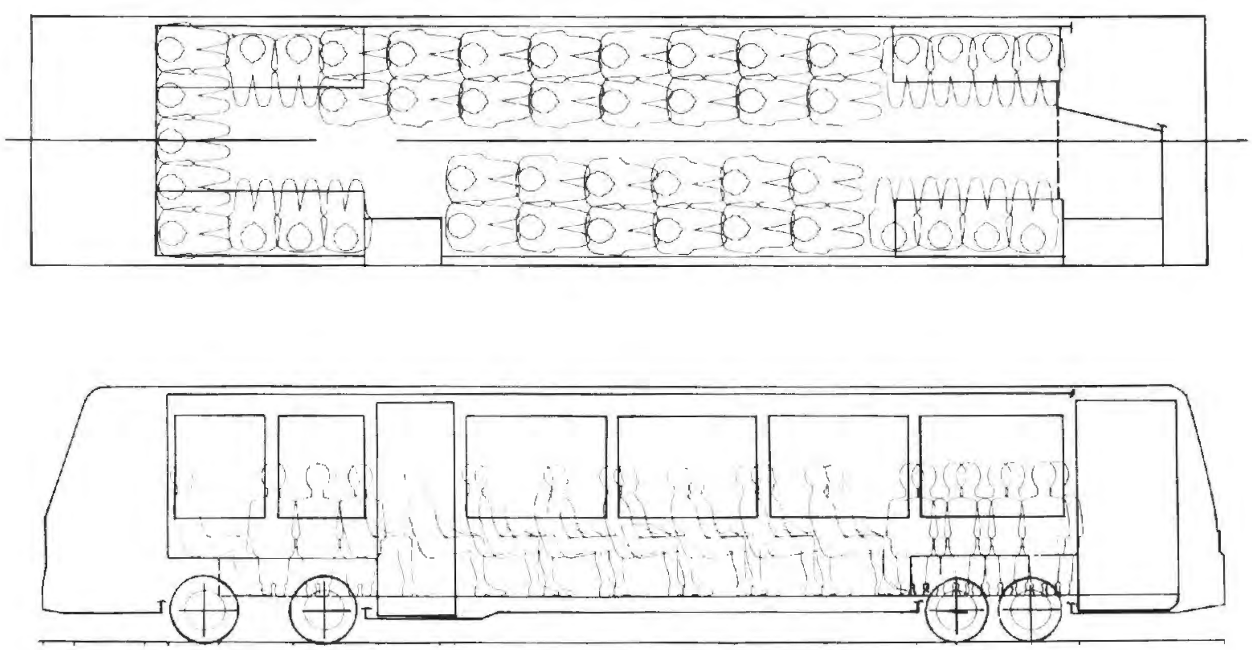
[1]E&H figures for double-wide door based on mean delay reported by TRRL (Table B-10).
[2]Values calculated using Booz-Allen estimates of Trasbus service times compared to New Look buses (Reference 20).

Table B-14
The Effect of Other Miscellaneous Factors

Factor	Mean delay per unit of factor seconds		Typical extent of occurrence of factor %		Typical increase in Average Stop-Time resulting for both one- and two-doorway vehicles (with a mean of 3 boarders and 3 alighters per stop)	
	Peak	Off-Peak	Peak	Off-Peak	Peak	Off-Peak
Slow boarders (infirm)	4	3	Up to 1[1]	1 → 4[1]	0.1	0.2
Slow boarders (luggage)	6	4	Up to 1[1]	Up to 2[1]	0.1	0.2
Passes	-1.5	-2	Up to 7[1]	1 → 4[1]	-0.2	-0.1
Slow alighters (infirm)	1.5	3	Up to 2[2]	1 → 9[2]	0.0	0.3
Slow alighters (luggage)	4	2.5	Up to 1[2]	Up to 3[2]	0.1	0.1
Baulking	6	5	Up to 17[3]	Up to 13[3]	0.3	0.3
Other unusual occurrences	5	7	1 → 5[3]	Up to 7[3]	0.2	0.3
				Totals	0.6	1.3

[1] *Percent of all boarders*
[2] *Percent of all alighters*
[3] *Percent of all stopping events*

Source: Reference 22



Source: Reference 24

Figure B-10
Rohr Transbus Prototype with 46-Seat Configuration

Table B-15
Nominal Seating Capacity of Forty-Foot Coaches

Bus	Seating Capacity
Transbus (specified)	46
Flyer Industries	51
GMC—Canada	51
RTS	47
870	48
Transbus Prototypes	
AM General	42
GM	41
Rohr	45

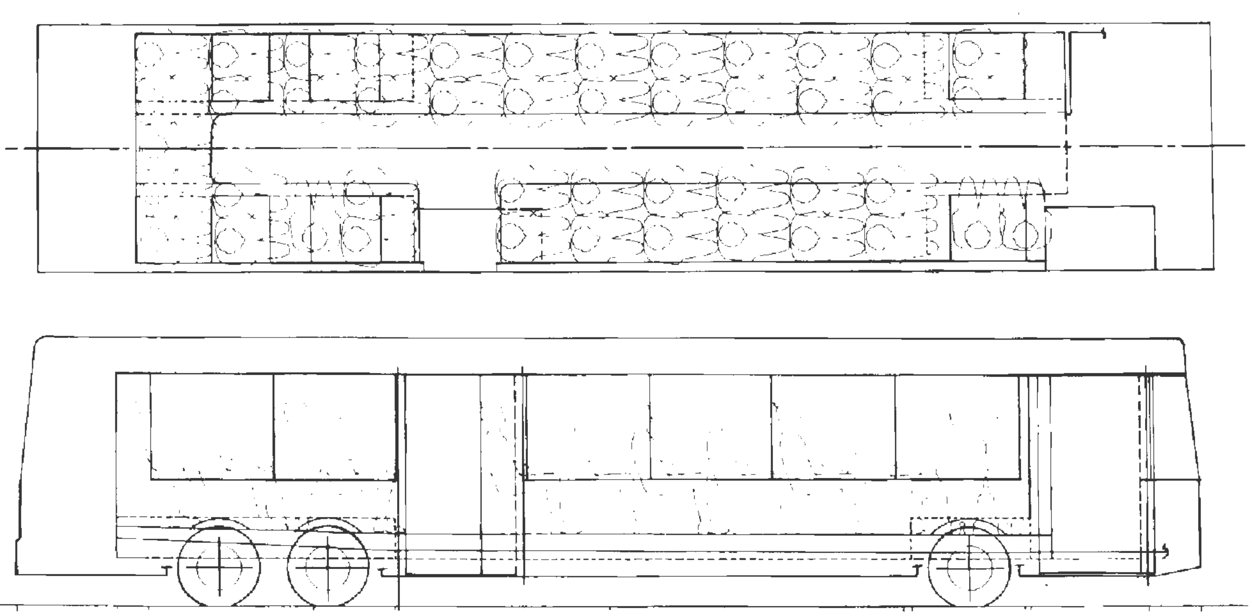
pitch. The Transbus specification calls for a minimum hip-to-knee room of twenty-seven inches and specifies that "the seat back thickness shall be minimized to reduce seat pitch and shall not exceed 1/2 inch in the knee room area."[6] Based on these requirements, a Transbus with a seat pitch as low as 27.5 inches would comply. Therefore, drawings like Booz-Allen's, which use a nominal seat pitch greater than the 27.5 inch absolute minimum, are valid representations of potential Transbus seating configurations.

Other drawings prepared by Booz-Allen indicate similar reconfigurations of Transbus prototypes using contoured wheel housing, rear bench seats, and other design features to increase capacity. Figures B-11 and B-12 depict a modified AM General prototype yielding forty-six seats and Figure B-13 depicts a modified GM prototype containing forty-seven seats.

The configuration in Figure B-11, although it has a very comfortable seat pitch of thirty inches, is unacceptable for two reasons. The configuration shows all seats elevated on a platform, which effectively relocates the third step of the traditional bus from the front door to the bus interior. This arrangement is helpful to many elderly and disabled people, since it reduces the amount that they are required to lower themselves from a standing position to initially seat themselves.[25] However, such an arrangement has not been accepted in the U.S. except for intercity coaches, and was rejected by the consortium. More significant, the arrangement would not provide enough aisle space at the front of the bus so that a wheelchair might be maneuvered to its parked position.

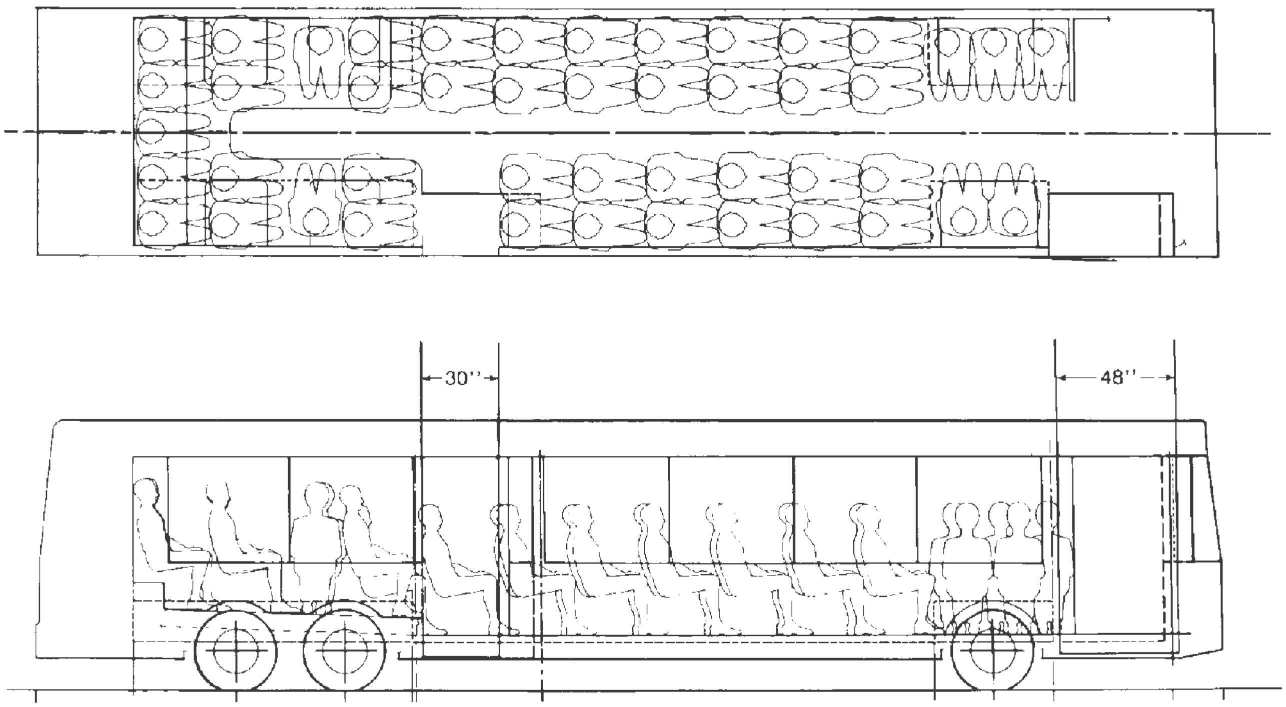
Figure B-13, on the other hand, uses longitudinal seats behind the vestibule and contains a platform behind the rear door only. Although rejected by the consortium cities, the approach has merit; the majority of the bus would have a low floor configuration. (Such rear platforms are common on British buses.) However, the configuration does not technically comply with the specification, and additional study regarding acceptability in light of issues such as safety and equality would be necessary before its introduction.

Figure B-14, however, demonstrates that a Transbus of the same basic design as the AM General



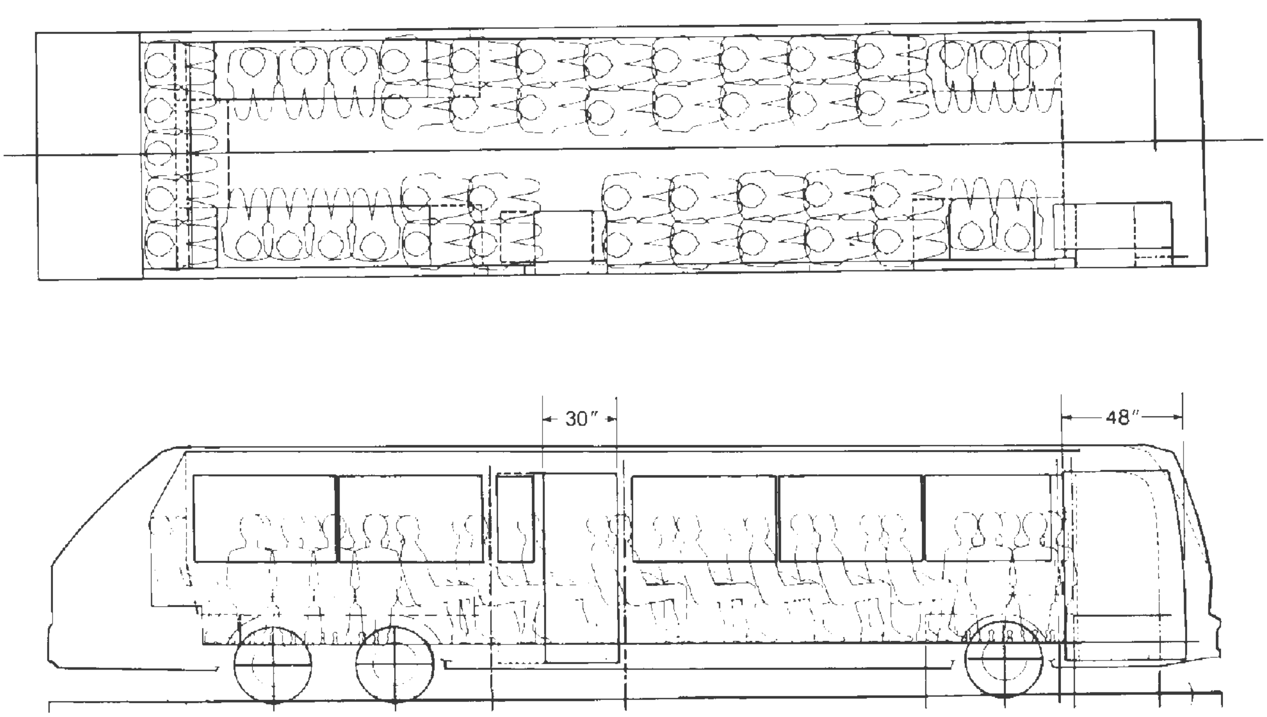
Source: Reference 24.

Figure B-11
Reconfigured AM General Transbus Prototype



Source: Reference 24.

Figure B-12
Reconfigured AM General Prototype



Source: Reference 24.

Figure B-13
GM Transbus Prototype with 47 Seats

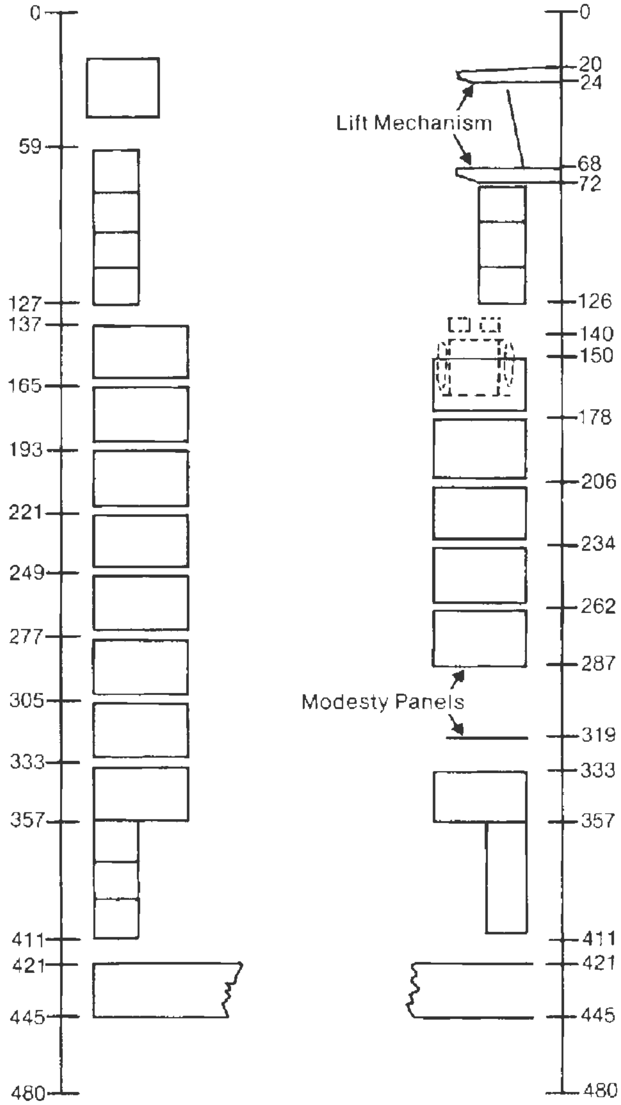


Figure B-14
Reconfigured AM General Prototype with 46 Seats

prototype could—with longitudinal seats over the rear wheel housings and the rear doorway relocated slightly forward—meet the forty-six seat requirements.

The likely objection to a reconfigured GM Transbus prototype with a capacity of forty-seven seats (Figure B-13) is that the rear bulkhead has been moved backward fifteen inches to provide the additional capacity. Although this seems possible considering the greater space consumed by the GM prototype for the engine compartment compared to the prototypes of the other manufacturers, the validity of such an adjustment is not readily defensible. Figure B-15, however, supports a similar conclusion based on the modification of the current RTS-II design. By closing the seats to the minimum allowed by the Transbus specification and eliminating one transverse seat on the driver's side, enough space is provided to accommodate two longitudinal seats. These seats replace those lost by the displacement of the transverse seat.

Other alternatives to increase the capacity of Transbus, such as rearward-facing transverse seats, have been suggested. Rearward-facing transverse seating is common on European buses, particularly over the front wheel wells. However, space requirements to permit wheelchair access at the front door prohibit such an option over the front wheels. Figure B-16 illustrates that no advantage would be gained from such an option over the rear wheels, since it consumes as much space as longitudinal seating.

Dwell Time and Capacity Effects on Productivity

The issue of Transbus productivity is a combination of opposing factors. On one hand, wider front doors may contribute to improved vehicle productivity by speeding up service through the reduction of vehicle dwell times. On the other hand, potential capacity reductions may offset or even more than offset any potential improvements in passenger service time. Assume for the moment that the nation's 41,000 buses were all GM's RTS-II—each with forty-seven seats. If Transbus, with its forty-six seats, were to replace this fleet, then approximately 2.1 percent more buses would be needed to maintain the same seating capacity. If the nation's fleet were entirely composed of Flxible's 870 with forty-eight seats; then at least 4.2 percent more Transbuses would required. Previous comparisons of the impact of Transbus with New Look capacities are no longer valid because, except for the fraction of the market represented by Flyer and GM-Canada, the basic alternatives for future procurements are ADBs. In effect, the developments of the past few years mitigate the capacity effects of Transbus. A significant portion of the capacity losses have already been accepted with the deployment of the ADB.

The 2 to 4 percent figure represents a maximum. Several of the following factors reduce the magnitude of the fleet expansion:

1. high capacity articulated vehicles have been introduced to displace buses which have already reached capacity limits
2. seated versus total (seated plus standing) capacity requirements
3. passenger loadings

Nevertheless, 2 to 4 percent represents a figure against which potential productivity improvements can be compared. Unless these improvements are of a similar magnitude to compensate for potential losses, Transbus would represent a net productivity degradation.

Table B-16 summarizes Booz-Allen estimates of the impact the ADB and Transbus would have on fleet size. The increases noted are compared to New Look buses. In these figures, Transbus would represent an approximately 2 percent increase, compared to the New Look fleet. Comparisons with a New Look bus fleet, however, can be misleading since the presently available bus is the ADB. Without Transbus, the fleet would, over time, be dominated

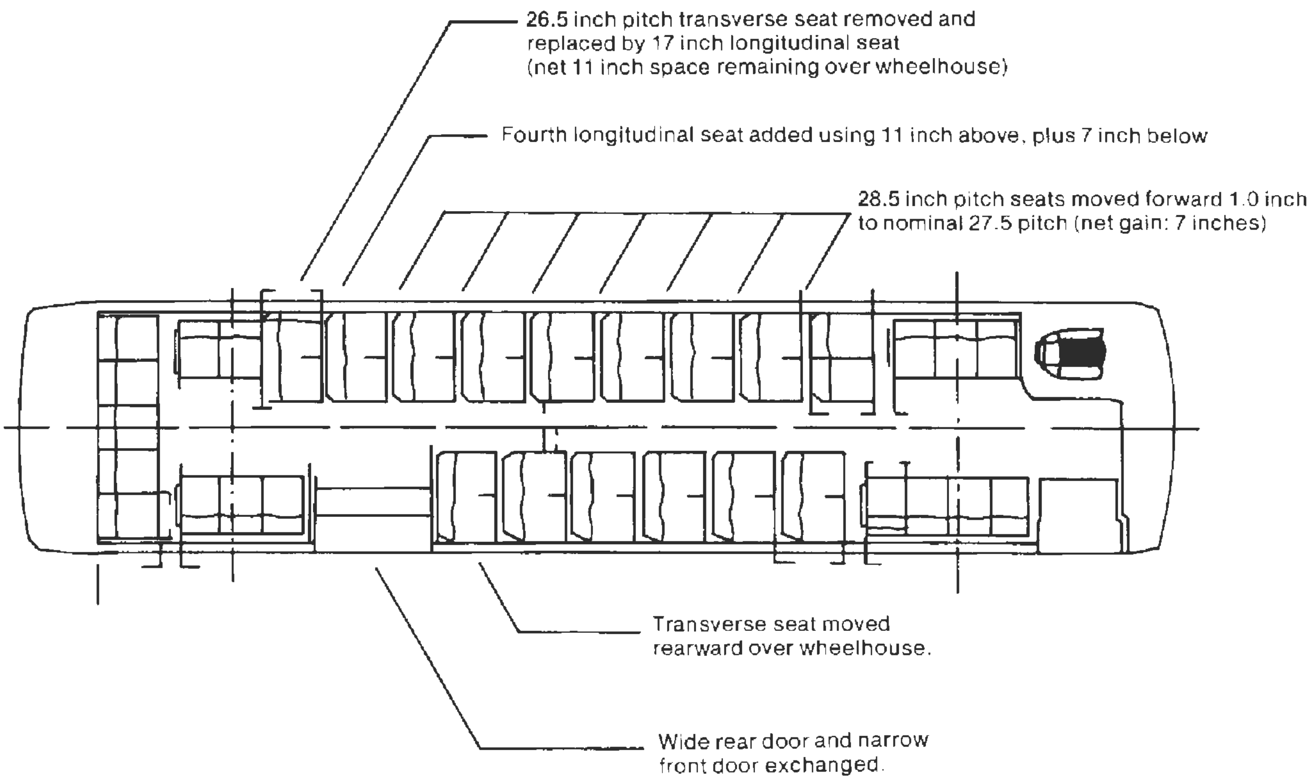


Figure B-15
Potential Reconfiguration of RTS-II to Produce 47 Seat Transbus

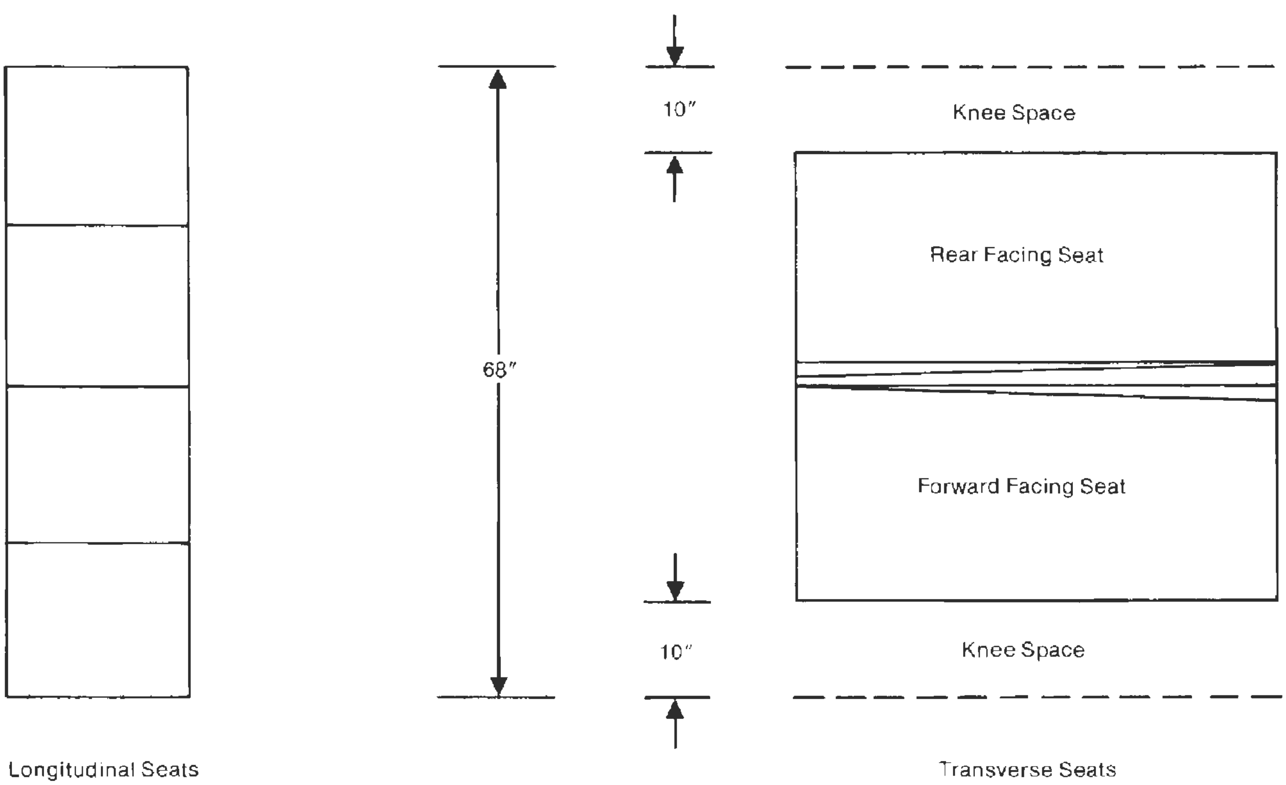


Figure B-16
Comparison of Transverse versus Longitudinal Seating over Wheel Housings

Table B-16
Impact of Bus Capacity on Fleet Size

System Type / Bus Type	Arterial[1]	Express / Suburban[2]	Circulator	Feeder / Crosstown	Tripper / Spare	Total[3]
Large Systems: Total	13,750	3,750	500	2,500	4,500	
— Interim Bus Increase	225-550	—	—	13-25	—	25,000
— Transbus Increase	385-770	23-45	—	18-35	—	
Medium Systems: Total	7,600	1,600	200	600	2,000	
— Interim Bus Increase	76-152	—	—	—	—	12,000
— Transbus Increase	107-213	3-6	—	—	—	
Small Systems: Total	8,400	1,200	—	—	2,400	
— Interim Bus Increase	—	—	—	—	—	12,000
— Transbus Increase	—	—	—	—	—	
Total	29,750	6,550	700	3,100	8,900	49,000
Increase for Interim Bus	301-602	—	—	13-25	—	314-627
Increase for Transbus	492-983	26-51	—	18-35	—	536-1,069

[1]*Total crush load capacities of Transbus (78) and interim bus (79-81) are less than current bus (83-85)*
[2]*Total seated load capacity of Transbus (46) is one less than interim bus and current bus (47), at moderate comfort configuration and narrow front door.*
[3]*Contains approximately 65 percent 40-foot coaches, 25 percent 35-foot coaches, and 10 percent coaches under 35 feet in length (5).*

by the ADB, Consequently, Transbus should be compared with ADB when charting alternative futures. On this basis, Transbus would represent less than a 1 percent increase—using the worst case assumptions in the Booz-Allen study.

Findings

The preceding analysis indicates the following.

1. The forty-four inch front door, as specified, is capable of handling two parallel streams of passengers.
2. A Transbus with a forty-six seat configuration is possible.
3. Double-wide entry doors do net substantial improvements.
4. Low floors and fewer steps do not appreciably improve service productivity with non- handicapped passengers.
5. Accessibility for the elderly and handicapped is improved with a low floor and fewer steps.
6. Service productivity increases through reduced passenger service times would more than compensate for capacity losses.

Performance

One of the six Transbus program criteria—speed of transit—was concerned with the reduction in overall transit time between boarding and destination. Factors affected by this program criterion included coach speed, acceleration, gradeability and boarding time.[28] Requirements in these areas were specified in the Vehicle Performance subsection of the Transbus Procurement Requirements (TPR) issued in August 1978, as well as those for power, jerk, and fuel economy. Manufacturer concerns over TPR vehicle performance requirements are directly related to the expected weight of production Transbuses. Vehicle top speed, acceleration, gradeability, and fuel economy are all affected by vehicle weight.

Performance requirements which are of concern to potential Transbus manufacturers are presented in the following sections, along with manufacturer comments, and our analysis and findings.

Performance Requirements

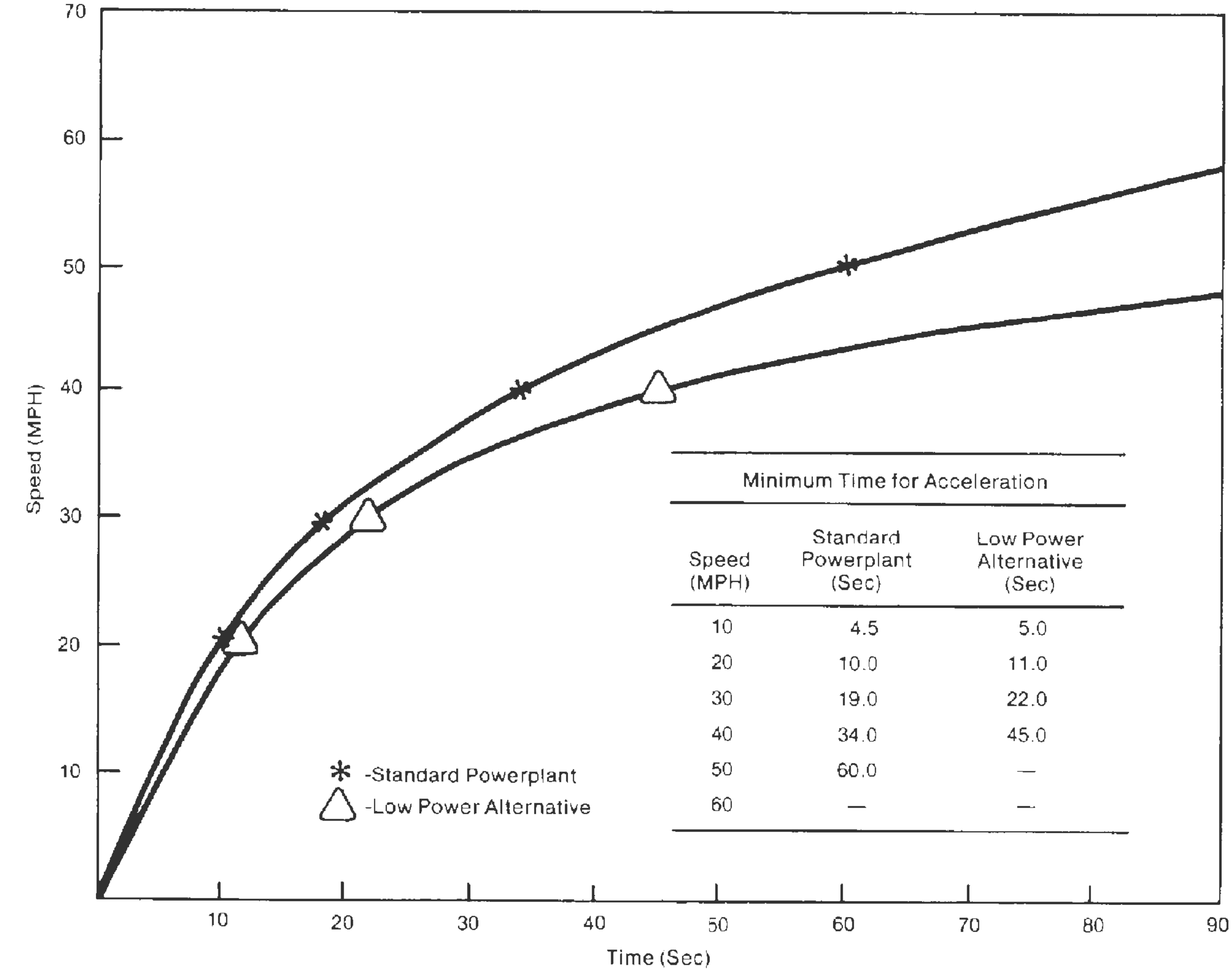
Performance requirements which are of concern to General Motors and Grumman Flxible address gradeability, acceleration, and operating range. These requirements are present below.

> Gradability [sic]
>
> Gradability [sic] requirements shall be met on grades with a surface friction coefficient of 0.3 and above at Seated Load Weight (SLW) with all accessories operating. The standard configuration powerplant shall enable the coach to maintain a speed of 45 mph on a 2 and 1/2 percent grade and 7 miles per hour on a 16 percent grade. The alternate powerplant shall enable the coach to maintain a speed of 35 miles per hour on a 2 and 1/2 percent grade and 7 miles per hour on a 12 percent grade.
>
> Acceleration
>
> An average acceleration rate of at least 0.06g shall be achieved at SLW between 0 and 15 miles per hour. Acceleration measurement shall commence when the accelerator is depressed. The minimum acceleration rate for both power alternatives are given in . . . (Figure B-17).

Operating Range

The operating range of the coach run on the design operating profile shall be at least 350 miles on a fill-up of fuel, and shall average no less than 3.5 miles per gallon.[6]

The design operating profile is presented in Figure B-18. It should be noted that except for the fuel



Minimum Time for Acceleration

Speed (MPH)	Standard Powerplant (Sec)	Low Power Alternative (Sec)
10	4.5	5.0
20	10.0	11.0
30	19.0	22.0
40	34.0	45.0
50	60.0	—
60	—	—

Source: Reference 6.

Figure B-17
Minimum Acceleration Rates/Power Options

economy requirement of 3.5 miles per gallon in the TPR, Transbus and ADB vehicle performance requirements governing gradeability, acceleration, and operating range are identical.

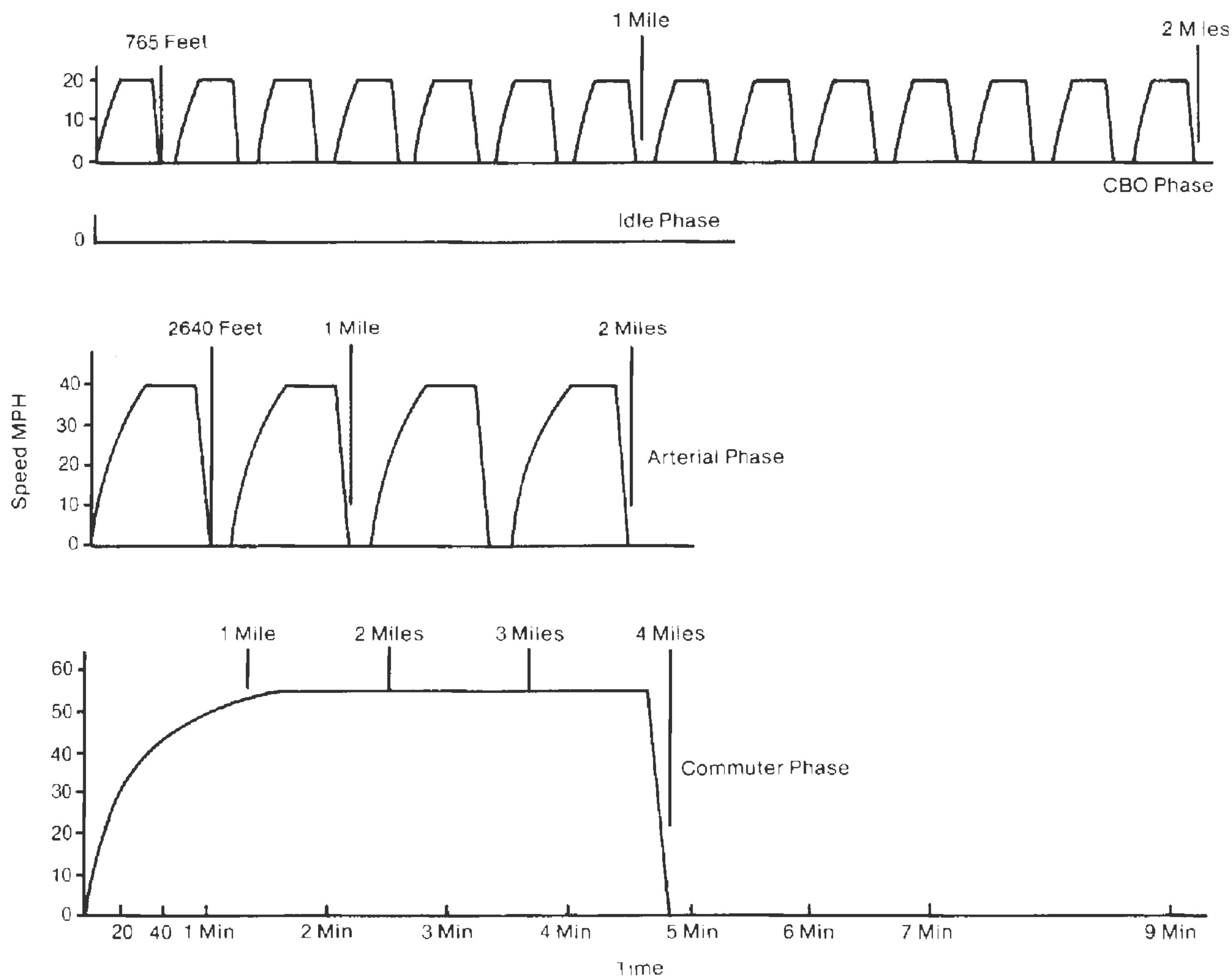
Manufacturers' Comments

The major manufacturer concern in regard to the above performance requirement is that weight penalties imposed by other requirements will make performance requirements difficult if not impossible to achieve. GM and Grumman Flxible feel that the expected greater weight of Transbus, relative to the weight of their ADBs, will result in performance below that required. The DeLorean Motor Company (DMC) does not anticipate problems in meeting Transbus peformance requirements. Specific manufacturer concerns are summarized below.

GM concluded that Transbus will consume 7.5 percent more fuel than the RTS when the two buses are operated on the ADB duty cycle. The ADB duty cycle is identical to the Transbus duty cycle. GM used computer simulation to study vehicle performance and fuel economy. Study results indicated a 7.5 percent decline in fuel economy for the Transbus, when it was operated on the same schedule as the RTS. GM's predicted Transbus fuel economy losses, relative to the RTS, are presented in Table B-17.[29]

It is the position of Grumman Flxible that Transbus will weigh more than the ADBs because of the extra weigh of the second rear axle. Grumman Flxible feels that because current ADBs, which are lighter, do not meet these requirements, they cannot guarantee meeting Transbus performance requirements with a heavier Transbus. No specific performance requirement was identified as a major concern. Grumman Flxible did find the fuel economy requirement of 3.5 miles per gallon unacceptable. Their concern was based on the fact that the economy of the engine was beyond their control, not solely because of weight or other design features, as was the case with GM.[30]

DMC does not see vehicle performance requirements as unattainable. They believe that the weight goal can be achieved or bettered, and performance and fuel economy goals achieved as a result. DMC believes that through weight reduction



Source: Reference 6.

Figure B-18
Transit Coach Operating Profile Duty Cycle

Table B-17
GMC Predicted Transbus Fuel Economy Losses

Influencing Factor	Fuel Loss (%)	Comments
Vehicle Weight	2.0	Weight increase estimated at 1,000 pounds because of additional axle, additional brakes, larger cooling system, and heavier understructure.
Driveline Efficiency	4.5	Interaxle differential "creep" plus 32 additional bearings in drive axles.
Rolling Resistance	1.5	Tire development is premature, breakthrough is needed to lower rolling resistance to level of existing tires.
Frontal Area	(0.2)[1]	Controlled by specification. Transbus will be approximately 6 inches lower than an ADB, therefore smaller frontal area.
Air Drag Coefficient	0	It was assumed that Transbus can be designed as aerodynamically clean as the RTS.

[1] *Parentheses denote a fuel gain.*

and other design improvements, a Transbus fuel economy of 4.1 miles per gallon can be achieved.[31]

Comparative Data

Results from the Transbus prototype program and data submitted by GM and Grumman Flxible in support of their decision not to bid provided little comparable data for a meaningful evaluation of the manufacturers' position on performance requirements of the TPR.

The prototype durability test program did result in data on prototype acceleration and fuel economy characteristics. These data, however, are not comparable with the specification requirements for the following reasons:

1. Acceleration requirements were to be met under SLW conditions. Prototype coaches' acceleration results were based on vehicle curb weight, a difference of approximately 6,900 pounds (46 passengers, at 150 pounds per passenger).[28]
2. Manufacturer prototypes differed appreciably in engine and transmission characteristics and capabilities. Each manufacturer used a different transmission, engine, drive-train arrangement, and accessory drive system (Table B-18). None of these engine choices were considered as the powerplant for the production Transbus.
3. There were considerable weight differences between the prototypes for which fuel economy data were recorded.
4. Discrepancies exist between durability test fuel economy results reported in the Transbus program final report and the durability test report (Table B-19).

Grumman Flxible did not provide any data supporting their performance-related concerns. GMC's only expressed performance concern was on the subject of fuel economy. Data supporting their conclusion was the result of simulation studies, as opposed to empirical data, and was presented in table B-17. These studies addressed expected Transbus fuel economy relative to their ADB, as opposed to a New Look coach, as was the case with Transbus prototype test results.

Even if the manufacturers' data and reported durability test data were acceptable, they are not comparable because the manufacturers' data are theoretical and the durability test data are empirical.

Analysis

Because of shortcomings of performance-related information provided in the prototype test results and supporting data from the manufacturers, it was not possible to conduct an analysis of performance re-

Table B-18
Transbus Prototype Engine and Transmission Characteristics

Manufacturer	Propulsion	Transmission
AM General	Caterpillar 3406 TAPC, 6-cylinder in-line turbocharged, after-cooled diesel; 375 bhp at 2100 rpm.	Dana Turbo-matic 186, two speeds forward plus torque converter, 90° drive, shaft driven.
GMC Truck and Coach	Detroit Diesel Allison GT404, regenerative, split-shaft, gas turbine, 280 bhp at 2900 rpm.	Allison HT-740T, 4 speeds forward plus fluid-coupling, in-line drive, silent chain-driven transfer case.
Rohr Industries	Cummins VT903, V8, turbocharged diesel, 350 bhp at 2600 rpm.	Allison V-730, 3 speeds forward plus torque converter, 63° angle drive, shaft driven.

Source: Reference 28.

Table B-19
Transbus Prototype Fuel Economy

	Average Fuel Economy	
Bus Type	Booz-Allen & Hamilton	Dynamic Science
Baseline Bus	3.50	3.51
AM General Transbus #2	2.80	2.68
GMC Transbus #2	1.70	1.54
GMC Transbus #3	2.10	2.10
Rohr Transbus #2	3.30	3.13

Source: References 28 and 32.

quirements based on operational data. Instead, parametric studies were performed using MITRE's vehicle performance model. These studies addressed the effects of vehicle weight and driveline efficiency on Transbus acceleration, gradeability, and fuel economy potential.

MITRE's vehicle performance model predicts vehicle performance over any given driving cycle and uses characteristics of specific powerplants and drive trains. Actual vehicle performance is determined by solving Newton's equation of motion at regular time intervals, subject to constraints of engine and vehicle characteristics.[33]

Because of time and data constraints, only nominal ADB and Transbus coaches and the modified Transbus were simulated. Nominal ADB and Transbus characteristics are presented in Table B-20. Both coaches used the Detroit Diesel 8V-71 engine with N-60 injectors, and the Allison V730 automatic transmission. This combination is the standard engine and transmission used by both GM and Grumman Flxible for their ADBs, and mentioned by both as the most likely powerplant and transmission combination for a production Transbus. The low power option was not addressed because of limited time and because none of the consortium cities selected the low power option.[34]

The nominal ADB and Transbus coaches were operated over the specification duty cycle profile described in Figure B-18. Results from these runs formed the baseline for comparison. Subsequent runs were made to evaluate the effects of weight and driveline efficiency on vehicle performance.

Gradeability simulation results indicated that gradeability requirements could be met by a Transbus with a curb weight of 26,000 pounds and the 8V-71, V730 motor and transmission combination. However the requirement of seven miles per hour on a 16 percent grade was barely met. Simulation gradeability results for the 27,000-pound curb weight Transbus indicated that the requirement of a 16-percent grade could not be achieved with the 8V-71, V730 motor and transmission combination.

Acceleration potential was evaluated by simulating full throttle acceleration to fifty miles per hour on a zero percent grade. Acceleration runs were made for the nominal ADB, the nominal Transbus, and a 27,000 pound Transbus. Simulation results are presented in Table B-21. Results indicate that a 26,000 pound Transbus should be able to partially meet specification acceleration requirements. Adding a thousand pounds to the nominal Transbus resulted in even longer acceleration times. A comparison of differences in the time to accelerate between the nominal Transbus and ADB and the nominal and heavy Transbuses indicates that weight is not the major influencing factor in not meeting the requirements. The ADB with its higher driveline efficiency achieved better acceleration times than the nominal Transbus which weighed 200 pounds less.

Simulation fuel economy results support the manufacturers' belief that Transbus will exhibit fuel economy inferior to that obtainable by current ADBs, and below that required in the Transbus specification. The effects of weight and driveline efficiency on fuel economy are shown in Tables B-22 and B-23, respectively. As expected, results show that weight increases will lower fuel economy potential.

Table B-20
Nominal ADB and Transbus Characteristics

Characteristic	Nominal ADB	Nominal Transbus	Modified Transbus
Vehicle Curb Weight with Lift (lb.)	26,200[1]	26,000[2]	21,000
Seated Passenger Weight (lb.)	7,050[3]	7,050	7,050
Seated Load Weight (lb.)	33,250	33,050	28,050
Vehicle Frontal Area ($ft.^2$)[4]	84	81	81
Effective Frontal Area ($ft.^2$)	76	73	73
Aerodynamic Drag Coefficient[5]	0.50	0.50	0.50
Driveline Efficiency (%)	90[6]	83.5[7]	90

[1]*Based on Atlanta ADB weight of 25,500 pounds and lift-weight allowance of 700 pounds provided for in "Baseline Advanced Design Transit Coach Specifications."*
[2]*Maximum allowable Transbus curb weight. "Transbus Procurement Requirements."*
[3]*Calculated, based on 46 passengers and a driver, and 150 pounds for each passenger and driver.*
[4]*"Transbus—Position of the Grumman Flxible Corporation with Respect to the Pending Initial Procurement of Transbuses." Grumman Flxible, March 12, 1979*
[5]*Thomas J. McGean, Urban Transportation Technology, (Lexington, Massachusetts: Lexington Books, 1976), page 151.*
[6]*"Booz-Allen & Hamilton Performance Simulator—Input Samples" Booz Allen & Hamilton*
[7]*Estimate from "Transbus. A Study by GMC Truck and Coach Engineering." May 1979*

Table B-21
Simulation Acceleration Results

Speed (mph)	Time to Accelerate (seconds)			
	Specification	26,000-lb. ADB with Lift	26,000-lb. Transbus	27,000-lb. Transbus
10	4.5	3.1	4.5	4.6
20	10.0	9.0	9.5	9.8
30	19.0	18.2	19.4	19.9
40	34.0	30.1	32.5	33.3
50	60.0	62.5	69.5	73.0

Table B-22
Effects of Weight on Fuel Economy

Vehicle[1]	Weight (lb)[2]		Fuel Economy (% of Baseline)	Fuel Economy Loss (%)
	Curb	SLW		
ADB	25,950	33,000	100.3	(0.3)[4]
ADB[3]	26,200	33,250	100.0	0.0
ADB	26,450	33,500	100.0	0.0
ADB	26,950	34,000	99.4	0.6
ADB	27,450	34,500	97.2	2.8
Transbus	26,000	33,050	97.5	2.5
Transbus	27,000	34,050	96.9	3.1

[1] *Driveline efficiency: ADB = 90 percent, Transbus = 83.5 percent*
[2] *Weight with lift device*
[3] *Baseline bus*
[4] *Parentheses denote fuel economy gain.*

Table B-23
Effects of Driveline Efficiency on Fuel Economy

Vehicle	Seated Load[1] Weight (lb.)	Driveline Efficiency (%)	Fuel Economy (% of Baseline)	Fuel Economy Loss (%)
ADB[2]	33,250	90.0	100.0	0.0
Transbus	33,050	80.0	95.6	4.4
Transbus	33,050	83.5	97.5	2.5
Transbus	34,050	83.5	96.9	3.1
Transbus	33,050	90.0	100.3	(0.3)[3]
Transbus	33,050	95.0	103.1	(3.1)[3]

[1] *Weight with seated passengers and lift*
[2] *Baseline bus*
[3] *Parentheses denote fuel economy gain.*

Driveline efficiency simulation results indicated that fuel economy would suffer, relative to an ADB, even if the specification curb weight requirement were met.

Findings

Based on results of an evaluation of manufacturers' conclusions and supporting data, discussions with manufacturers and relevant subcontractors, and simulation supported analysis, the following conclusions have been drawn:

1. It is reasonable to expect from a specification Transbus operating with the Detroit Diesel 8V-71 engine and Allison V730 transmission, acceleration, gradeability, and fuel economy capabilities below those levels specified in the TPR. This may be attributable to the low Transbus driveline efficiency resulting from the dual axle requirement.

2. A 1,000-pound increase in vehicle curb weight should result in reduced fuel economy, but not to the extent claimed by GM. The GM fuel economy study did not reflect the effect of driveline efficiency on the sensitivity of fuel economy to weight increases.
3. With regard to improving fuel economy, attention should be given to improving driveline efficiency. Fuel economy comparisons indicate that the lower Transbus driveline efficiency would result in a Transbus fuel economy lower than that of an ADB, even if the specification weight was met.
4. Transbus manufacturers may be able to overcome the predicted 0.6 percent loss in fuel economy, resulting from a 1,000-pound increase in vehicle weight, through use of the new six-cylinder diesel engine recently introduced by Detroit Diesel for transit applications. Detroit Diesel claims it will provide more horsepower and higher torque than the 8V-71N, with improved fuel economy (Figure B-19).

Comparison with the Automobile

Automobiles delivered in late 1984 (approximately the same time as was set for the first deliveries of Transbus) will be required to have an average fuel consumption of 27.5 miles per gallon, which results (for a four-seat automobile) in 110 seat-miles per gallon of fuel used.

The Transbus specification of 3.5 miles per gallon and forty-six seats, results in 161 seat-miles per gallon of fuel used. With a fully loaded bus, this is also the passenger-miles per gallon.

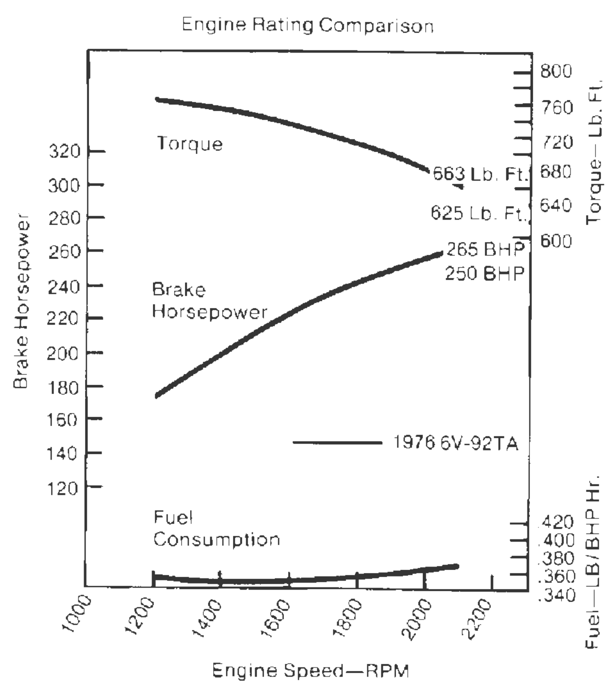
At an average automobile load of 1.4 passengers, the corresponding number is 38.5 passenger-miles per gallon.

Using figures prepared by the American Public Transit Association the total seat-miles operated by motor buses in 1977 was 78 billion (assuming an average of forty-eight seats per bus). The total passenger-miles was 24.9 billion, i.e., the average load was fifteen passengers.

On this basis, the average performance for Transbus would be 52.5 passenger-miles per gallon compared to the automobile average of 38.5 passenger-miles per gallon.

The former Secretary of Transportation set a goal of fifty miles per gallon for the automobiles, and this is already being approached by some vehicles. With the same average passenger load, the fuel performance improves to seventy passenger-miles per gallon.

While the differences between operating profiles of buses and automobiles make a direct comparison impossible, obviously, improved fuel economy should be an important criterion in future bus procurements if buses are to remain competitive with the automobile in terms of energy efficiency.



Source: Detroit Diesel Allison Brochure, 75A 654, March 1979

Figure B-19
Detroit Diesel Allison 6V-92TA Engine Performance Characteristics

Maintainability

Throughout the Transbus program, concern has been expressed regarding the adverse effect that the low floor design would have on the ease of servicing and maintaining the bus. The policy statement adopted by the American Public Transit Association on August 10, 1977 stated:

> DOT's Urban Mass Transportation Administration should include a technology and component development program which will concentrate on the following problems:
> (1) . . . .
> (2) Adequate street clearance with appropriate access to assure maintainability of subsystems located beneath the passenger compartment
> (3) . . . (4) . . . (5). . .
> (6) General maintainability considerations including access and durability.

This section addresses the issue of access to systems requiring maintenance. The following section discusses reliability.

The relevant section of the specification states:

> 1.5.4.5 Accessibility
> All systems or components serviced as part of periodic maintenance or whose failure may result in Class 1 or Class 2 failures shall be readily accessible for service and inspection. To the extent practicable, removal or physical movement of components unrelated to the specific maintenance and/or repair tasks involved shall be unnecessary.

Relative accessibility of components, measured in time required to gain access, shall be inversely proportioned to frequency of maintenance and repair of the components.

A Class 1 failure affects physical safety. A Class 2 failure is a road call.

Manufacturers' Comments

General Motors Corporation: "The necessity of packaging major components under the floor of the coach presents several limitations in complying with the Transbus specification. Certain conclusions can be drawn as follows:

(1)Net usable underfloor volume for packaging of accessory components will be reduced by 54 percent from 352 cubic feet on the 40 foot ADB to 163 cubic feet on the Transbus 40 foot coach, resulting in crowding of components requiring increased servicing, labor, and facility time.

(2)Net usable underfloor volume for packaging of accessory components will be reduced by 56 percent from 282 cubic feet on the 35 foot ADB to 123 cubic feet on the Transbus 35 foot coach, resulting in crowding of components requiring increased servicing, labor, and facility time.

(3)Two (2) separate fuel tanks with potential mounting, leakage, and fuel delivery [sic] are required for the 35 foot Transbus. Two fuel tanks may be required for the 40 foot coach.

"Of the major components, suspension, axles, fuel tanks, handicapped loading systems, and air dryness must be of a new design. Although through extensive redesign and development programs, the above items can be physically positioned under the floor. . . the proximity to each other of the fittings and plumbing required will increase the difficulty of servicing or replacement of any individual component.

". . . Placement of air tanks in close proximity to one another increases assembly labor time, and most importantly, causes higher maintenance times for servicing."

Grumman Flxible made no comments on this subject. However, exception was taken to clause 3.3.1 which required all bushings and air suspensions to be "easily" [sic] and quickly replaceable by a 3M mechanic in thirty minutes or less, on the basis that the front and rear suspension systems would be the major design tasks for Transbus. Due to the limited space under the bus, this could not be guaranteed.

Comparative Data

The *total* underfloor volume of the four basic designs of buses is shown in Table B-24. The cut-offs to achieve the necessary approach and departure angles, the skin and frame thickness, and step recesses must be deducted to obtain the working area. After deducting the aisle and wheel-zone clearances, the balance is available for housing engine, transmission, and other accessories.

Table B-24
Total Underfloor Volume Available (Cubic Feet)

	Size	
Bus Type	40′ x 102″	35′ x 96″
New Look	680	560
870	570	470
RTS	650	535
Transbus	340	280

Note: Assumes ten-inch ground clearance. No allowance made for approach or departure angle.

Analysis

The available underfloor area on Transbus is approximately half that of current coaches. Major items to be located in this area include:

- wheels, tires, and axles
- brakes and suspension
- steering linkages
- drive shaft and differential
- engine and transmission (partly)
- batteries
- fuel tank
- air tank and dryer

Road-Call Experience

In 1972, industry road-call experience was surveyed by the American Transit Association (now the American Public Transit Association). The survey covered a total of 26,491 buses operating under a period of a year, accumulating approximately 800 million miles. Road calls averaged 0.7 per month per bus—or about one road call every six weeks per bus.[35]

The relative occurrences of road calls is shown in Figure B-20. The four most common causes of road calls were:

- electrical - 17 percent
- braking - 10 percent
- engine cooling - 10 percent
- transmission - 9 percent

Two of these areas, electric (in part) and braking, are located in the underfloor area. The other two are partially in the underfloor area but are located towards the rear of the bus where access to the subsystems is somewhat easier.

Accessibility Problems

Electrical The most critical area in terms of subsystems is the battery. In addition to requiring regular inspection and servicing, the batteries must be easily replaceable. These are normally located on a pull-out tray so servicing on a Transbus should not differ significantly from that of other designs of buses.

The generator is normally flange-mounted on the engine and gear-driven. Access to the generator is through the rear compartment.

Braking Technical details of the braking systems have been covered in Section 2. In addition to the

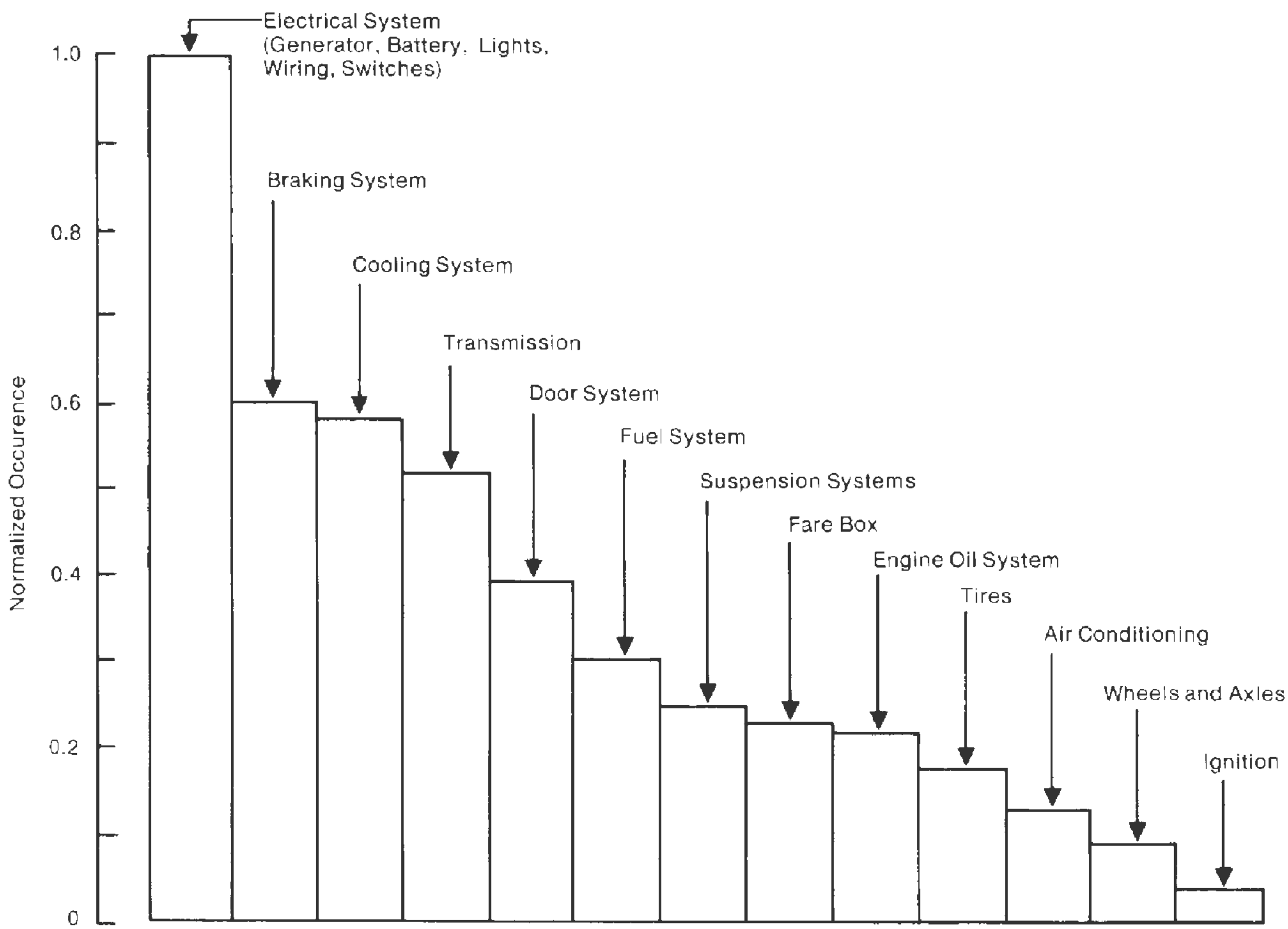


Figure B-20
Relative Occurrence of Road Calls by Contributing System

brakes and brake shoes, the following items are typical of those which must be mounted to facilitate routine maintenance:

- check valves
- air strainer
- alcohol evaporator
- slack adjuster

The various other elements associated with the brakes (and suspension system) need to be inspected regularly but not frequently, e.g., annually, or every 50,000 miles. These items include wet and dry air reservoirs for brake operation and a suspension air reservoir. These would normally be inspected at the time the bus was over a pit or mounted on a lift. The need for regular servicing is reduced when a retarder is installed. Some reports indicate a reduction as high as 4:1 is achievable.

Other Subsystems

1. Fuel System—most fuel system items are associated with the engine. The fuel tanks must be inspected frequently (typically every 5,000 miles).
2. Suspension Systems—suspension systems present a major maintainability problem in the Transbus design. However, if the current level of road calls and proportion of road calls due to suspension problems remains constant, it would appear that road calls would occur infrequently—approximately once every three years of service on a bus.
3. Tires—experience of tires on the Advanced Design Bus and Transbus prototypes suggest that road calls due to tire failures will be more frequent than on the New Look bus that formed the basis for the survey. However, the low floor design of Transbus does not affect the maintainability of these.
4. Wheels and Axles—while wheels will be as accessible as on existing buses, axles and the related units will be less accessible. With the same caveats as for suspensions systems, it would appear that wheels and axles would result in a road call approximately once every seven years.

Findings

Approximately half the volume is available on Transbus to absorb underfloor units as is available on other designs of buses. This will adversely affect maintenance access to underfloor components and subsystems, and tend to increase maintenance costs. Over time, but probably not within the four-year development time allowed in the TPR, improved components will be developed which require less maintenance, and design modification will be discovered which increase access.

Reliability

Reliability is a measure of the extent that a bus is ready for revenue service assuming a given level of maintenance. Under normal transit operation, 90 percent of the system buses should be in revenue service during the peak operating hours. The remaining buses will usually be divided into two groups: on standby in case of revenue equipment breakdown, or in the maintenance shops for inspection or repair.

The New Look bus, which has been in operation for nearly twenty years, forms the basis for measured comparison of both the Transbus and ADB. During the years of manufacture, the bus manufacturers have fine-tuned the components of the New Look bus to a considerable degree. The maintenance departments in the transit operations have benefited by the manufacturing program to such an extent that they are satisfied with the New Look reliability or have simply accepted the premise that they must learn to "live" with the components.

The reliability specifications for both the Transbus and its major components are listed in Table B-25 along with comparable figures for the New Look and RTS-II buses. Inherent in these specifications are scheduled maintenance tasks to be performed by a mechanic of skill level 3M or less at mileage intervals of not greater than 6,000 miles. Although many of the components of the Transbus are similar to those found in the New Look and ADB (e.g., RTS-II) buses, this is only an indication that the life expectancy of the components in all three buses would be comparable. For instance, the Detroit Diesel Allison 8V-71 engine is almost a standard for all three buses. By adding an air conditioner to the bus—a standard on the Transbus and RTS-II—an extra load is placed on the engine presumably causing a decrease in its life expectancy.

A summary showing a comparison of expected Transbus and New Look reliability is shown in Table B-26 and described in detail below.

Coach Reliability

Data on the life expectancy of a New Look coach would be difficult to obtain and analyze. The life of the coach is determined almost as a policy decision of the transit system management. The transit system puts the newest and best coaches out on the street for a twenty-hour day. Older coaches are used as "trippers" and in standby operation, and retired from active service only when replacements are found. The Transbus Specification reads:

> 1.5.4.1 Service Life
> The coach shall be designed to operate in transit service for at least 15 years or 600,000 miles. It shall be capable of operating at least 40,000 miles per year including the fifteenth year, providing the Procuring Agency conducts normal inspections and schedules preventive maintenance procedures as recommended in the Contractor's maintenance manuals.

If this term is interpreted as a design goal, rather than a rigid specification, then the goals are possible. Some New Look coaches have been driven past the 600,000-mile goal but very few are capable of going 40,000 miles per year in the fifteenth year of operation.

Table B-25
Major Component Reliability
(Thousands of Miles)

Item	Transbus Specification	Transbus Reference	New Look[1]	GM[2] RTS-II
Coach	600	1.5.4.1		500
Engine	300	3.1.3.1	364 ± 47	300
Transmission	100	3.1.3.3	141 ± 29	100
Differential	Same as axle	3.2.1	442 ± 61	500
Generator	Not stated		148 ± 35	500
Starter	Not stated		125 ± 46	125
Brake Linings	15	3.5.1.2	44 ± 11[3]	20-25[3]
Suspension	Life of coach	3.3.1		Life of coach
Axles	200	3.2.1		200
Tires	Not stated			

[1]V.S. Thurlow, "Maintenance Labor Requirements over the Service Life of Urban Transit Diesel Buses," WP-10525, McLean, Virginia, The MITRE Corporation, February 1974.
[2]Estimates received from GM, Pontiac, Michigan, July 1979.
[3]The New Look estimates are based on brake materials prepared prior to enforcement of Standard FMVSS 121. The GM estimate is based on a recently developed brake material which is significantly better than one used on current RTS-II coaches.

Table B-26
Reliability Comparison of Transbus and New Look Bus

Component	Transbus Relative to New Look Bus				
	Much Worse	Worse	Equal	Better	Much Better
Coach				X	
Engine			X		
Transmission			X		
Differential		X			
Generator				X	
Starter				X	
Brake Linings	X				
Suspension			X		
Axles	X				
Tires	X				

Engine Reliability

The modern day bus engines are basically two-cycle powerplants manufactured by Detroit Diesel Allison. Transit personnel have a wealth of experience in maintaining both the 8V-71 and 6V-71 engine models. The Cummins VTB-903, a four-cycle, eight-cylinder engine, has also been successfully used by both GFC and Flyer Industries.

Problems with engine design will rise as the federal specifications for automotive pollution grow more stringent. Detroit Diesel is currently marketing a new engine, their 6V-92, to accommodate these new requirements. Although the new engine is undoubtedly based on considerable experience with the "71" series, a new engine means a new learning curve and a new set of spare parts. This new engine will undoubtedly have an impact on buses manufactured in the 1980s.

Transmission Reliability

The Detroit Diesel Allison V730 transmission is another unofficial standard for the bus industry. The transmission has come through the problems in its early stages and is considered a reliable component.

Future use of the V730 transmission may be integrated with a retarder unit to be used to supply additional braking power for the coaches. As the brake systems are designed to accommodate smaller wheels and the brake compounds limited by federal regulation, the retarder/transmission combination may take up some of the required braking load.

The system, when in use, will transmit braking energy to the transmission fluid. In turn, this energy will be transferred to the radiator. The net result of the new transmission/retarder may be a redesign of the engine coolant system.

Generator/Starter Reliability

The reliability of the generator/starter motor and electrical system in general should be enhanced for the Transbus as compared to its predecessors. This is primarily due to the redundant circuits, higher capacity conductors and improved failure isolation features in the Transbus electrical system.

Brake Lining Life Expectancy

The brake lining life expectancy varies with brake drum size, lining material composition, and bus weight.

The brake drum size on the Transbus is smaller than on the New Look or ADB. A smaller drum size to stop a given load will increase the wear rate. It has been reported that the wheels and drums on the GFC 870 buses sent to Atlanta were recently changed by the tire vendor. It was thought that the small drum size combined with the use of a softer brake lining caused excessive heat buildup in the tires.

The softer brake lining resulted from more stringent regulations in FMVSS 121. The softer lining also produces a more extensive wear rate. GM claims that new, longer life compounds which adhere to the FMVSS 121 regulations are under development.

The Transbus, because of more weight, will also impose greater wear on the brakes. Although some weight reduction programs can reduce the extent of this problem, it is doubtful if the Transbus weight can approach that of the New Look bus.

Suspension System Reliability

The Transbus specification for suspension system reads as follows:

> 3.3.1 General Requirements
> The front axle shall be nondriving and it shall have a load rating sufficient for the coach loaded to GVWR. Both the front and rear axle suspensions shall be pneumatic type. The basic suspension system shall last the life of the coach without major overhaul or replacement. Items such as bushings and air springs shall be easily and quickly replaceable by a 3M mechanic in 30

minutes or less. Adjustment points shall be minimized and shall not be subject to a loss of adjustment in service. Necessary adjustments shall be easily accomplished without removing or disconnecting the components.

Since the introduction of the air springs in the late 1950s, the suspension system has proven to be a very reliable feature in buses. The introduction of Transbus should not change this.

Axle and Differential Reliability

Inherently, the need for twin (tandem) axles and two differentials will decrease the reliability of the Transbus. In addition, the axle manufacturers claim that the tandem system requires large development efforts to allow them to extend the warranty required by the Transbus specification. Since the tandem axle is unique to the Transbus within the transit industry, higher initial maintenance costs may likely be incurred.

Tire Reliability

The present market for tires of a size used by Transbus is very limited. Accordingly, the tire manufacturers have placed very little emphasis on their development. Present tires have a marginal utility for the Transbus.

Tire manufacturers also claim that the characteristic weight of the Transbus and the need for low profile tires will increase the mileage charge per bus.

Findings

It is expected that Transbus will require a higher level of maintenance to equal the service reliability of the New Look bus's. Some of the design considerations of Transbus are already reflected in the ADB and do improve reliability in the electrical system and coach, in general. The low profile and relatively high weight of the Transbus penalize the brake system, tires, differentials, and rear axle. As a result, the transit operator must provide maintenance for the Transbus more frequently to assure a specified level of revenue service.

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Appendix C
Supporting Data for Transbus Price Estimation

Table C-1
Product Development Budget
(Dollars in Millions)

Category	Amount
Design & Engineering	
Tandem Rear Axle, Brakes & Suspension	$ 0.5
Front Axle, Brakes & Suspension	2.0
Body & Other	9.5
Subtotal	$12.0
Prototype Tooling	
Tandem Rear Axle, Brakes & Suspension	$ 0.5
Front Axle, Brakes & Suspension	1.0
Body & Other	5.5
Subtotal	$ 7.0
Prototype Construction	
Tandem Rear Axle, Brakes & Suspension	$ 0.5
Front Axle, Brakes & Suspension	1.0
Body & Other	12.0
Subtotal	$13.0
Prototype Testing	
Tandem Rear Axle, Brakes & Suspension	$ 0.3
Front Axle, Brakes & Suspension	0.3
Tires	0.3
Body & Other	2.1
Subtotal	$ 0.3
Subtotal	$35.0
Contingency (20 percent)	7.0
Total	$41.0

Table C-2
Plant Construction Budget
(Dollars in Millions)

Category	Unit Cost	Total
Building (500,000 sq. ft.)	$40/sq. ft.	$20.0
Electrical Services	$ 5/sq. ft.	2.5
Mechanical Services	$12/sq. ft.	6.0
Subtotal		$28.5
Fees (5 percent)		1.5
Subtotal		$30.0
Contingency (10 percent)		3.0
Subtotal		$33.0
Land (25 acres)	$20,000/ acre	0.5
Total		$33.5

Table C-3
Plant Equipment Budget
(Dollars in Thousands)

Work Area	Cost
Receiving & Inspection	$ 250
Parts Fabrication	3,100
Understructure Subassembly	200
Understructure Assembly	600
Body Subassembly	250
Body Assembly	300
Body & Understructure Integration	300
Paint	2,750
Final Assembly	1,500
General	6,850
Subtotal	$16,100
Contingency (20 percent)	3,200
Total	$19,300

Table C-4
Special Tooling Budget
(Dollars in Millions)

Category	Cost
Dies	$10.8
Fixtures	8.4
Templates	2.4
Gauges	1.2
Jigs	1.2
Vendor Tooling	3.6
Miscellaneous	2.4
Subtotal	$30.0
Contingency (20 percent)	6.0
Total	$36.0

Table C-5
Initial Working Capital Budget
(Dollars in Millions)

Category	Year 4	Year 5	Year 6
Annual Budget			
Inventory			
Work-in-progress		$ 3.8	$ 2.7
Raw Materials	$0.9	22.4	35.0
Subtotal	$0.9	$26.2	$37.7
Accounts Receivable		28.8	40.1
Operating Cash	1.3	2.6	2.6
Total	$2.2	$57.6	$80.4
Increase in Working Capital	$2.2	$55.4	$22.8

Table C-7
Material Cost Estimates
(Dollars in Thousands)

Component or Subsystem	Material Cost
Body Structure, Doors & Glazing	$13,000
Engine & Accessories	7,600
Transmission	6,000
Rear Axle, Brakes & Suspension	13,000
Front Axle(s), Brakes & Suspension	3,000
Steering	1,000
Heating, Ventilating & Air Conditioning	6,700
Electrical	3,700
Interior Trim, Fittings & Seats	14,000
Lift	6,000
Other	4,000
Total	$78,000

Table C-6
Start-Up Costs
(Dollars in Thousands)

Category	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Salaries	$300	$385	$2,065	$ 5,830	$ 8,500	$17,080
General Expenses	150	190	1,035	2,915	4,250	8,540
Labor	—	—	—	1,000	19,700	20,700
Material	—	—	—	—	30,400	30,400
Plant Overhead	—	—	300	1,500	6,100	7,900
Professional Services	150	200	400	300	200	1,250
Marketing	—	—	—	500	1,000	1,500
Property Taxes	—	—	—	—	3,800	3,800
Total	$600	$775	$3,800	$12,045	$73,950	$91,170
Less: Sales Revenue	—	—	—	—	58,500	58,500
Net Funding Required	$600	$775	$3,800	$12,045	$15,450	$32,670

Table C-8
Operating Expenses
(Dollars in Millions)

Category	5	6	7
Selling			
Sales & Marketing	$ 1.0	$ 2.0	$ 2.0
Salaries	1.0	1.0	1.0
General & Administrative			
General	4.3	4.4	4.4
Corporate Allocation	0.7	3.1	3.2
Salaries	7.5	7.8	7.8
Total	$14.5	$18.3	$18.4

Table C-9
Debt Service
(Dollars in Millions)

	Year									
Category	1	2	3	4	5	6	7	8	9	10
Principal Payments										
Building & Land	—	—	—	—	1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1	$ 1.1
Equipment	—	—	—	—	—	1.1	1.3	1.3	1.3	1.3
Tooling	—	—	—	—	—	7.2	7.2	7.2	7.2	7.2
Working Capital	—	—	—	—	—	5.8	5.8	5.8	5.8	5.8
Subtotal	—	—	—	—	—	$15.4	$15.4	$15.4	$15.8	$15.4
Interest Payments										
Building & Land	—	—	0.1	1.8	4.0	$ 3.8	$ 3.7	$ 3.6	$ 3.5	$ 3.5
Equipment	—	—	—	—	2.2	2.3	2.2	2.0	1.8	1.6
Tooling	—	—	—	0.4	3.9	4.3	3.5	2.6	1.7	0.9
Working Capital	—	—	—	—	0.3	7.0	6.3	5.6	4.9	4.2
Subtotal	—	—	0.1	2.2	10.4	$17.4	$15.7	$13.8	$11.9	$10.1

Table C-10
Principal Price Variables

	Value	
Variable	Conservative	Optimistic
Material Cost per Bus	$78,000	$74,000
Hourly Labor Rate	$15.00	$13.00
Direct Labor Hours per Bus—Steady State	1,200	1,000
Direct Labor Hours—First Bus	4,500	4,500
Number of Buses to Reach Steady State	1,000	1,000

Table C-11
Cost of Goods Sold
(Dollars in Millions)

	Year		
Category	5	6	7
Direct Labor	$14.8	$ 37.4	$ 37.4
Indirect Labor	4.9	12.5	12.5
Material	30.4	151.2	156.0
Manufacturing Overhead	10.2	19.3	19.7
Depreciation	4.8	9.6	9.6
	$65.1	$230.0	$235.2

Appendix D
Comparisons Between Transbus and the ADB Specifications

Table D-1
Specification Comparison—
Advanced Design Bus versus Transbus

Criterion	Comparison
Weight	Slightly lower weight required for Transbus (26,500 lbs versus 26,000 lbs)
Reliability	Same for both buses
Maintainability	Same for both buses
Safety	Same for both buses
Cost	Higher for Transbus
Performance	Better performance required for Transbus—see additional chart

Table D-2
Performance Comparison—ADB versus Transbus

Criterion	ADB	Transbus
Service Life	Twelve years or 500,000 miles	Fifteen years or 600.000 miles
Floor height (before kneeling)	Thirty inches maximum	Twenty-two inches maximum at front door; twenty-four inches maximum at rear door
(After kneeling)	Twenty-four inches maximum	Eighteen inches maximum at front door
Floor Strength	Withstand 150 lbs through a ¼ inch rod	Withstand 150 lbs through a ½ inch rod
Wheel housing material	No specific requirement	Stainless steel
Capacity	Forty-seven seated	Forty-six seated (no wheelchairs)
Front Door Width	Thirty inches minimum	Forty-four inches minimum
Axle Clearance	Six inches minimum	Six and one-half inches minimum
Wheelchair Facilities	Optional	Wheelchair locks and turning room required on each bus
Towing	Towing only from the rear	Towing and lifting from the rear
Curb Visibility	Driver see a six-inch high curb when twelve inches from curb	Driver see a six-inch high curb when six inches from curb
Side Window Material	Acrylic in accord with ANSI Z26.1-1966	In accord with ANSI Z26.1-1977 for AS-3 tempered glass
Seat Fabric Flammability	No requirement	In accord with FAA Regulation 25.853(b)
Fuel Economy	No requirement	3.5 miles per gallon minimum
Passenger Compartment	Twenty feet^3 per minimum per passenger	Twenty-five feet^3 per minimum per passenger

All other performance parameters are the same for each bus.

Appendix E
Persons Interviewed by MITRE

General Motors Corporation, Truck and Coach Division

E. R. Stokel, Director of Public Transportation
Fred Brede, Chief Engineer
J. R. Prior, Staff Engineer
Mel Pullin, General Services
John Sibley, Legal Services

Grumman Flxible Corporation

R. G. Landon, President
W. Aaron, Vice President, Sales and Marketing
E. Kravitz, Vice President, Engineering
G. Prytula, Director, Washington Operations

Firestone Tire and Rubber Company

A. F. Weber, Division Manager, Advanced, Private and International Tire Engineering
Stan Cooper, Project Engineer

Goodyear Tire and Rubber Company

G. E. Stigle, Manager, Heavy Tire, Airplane and Race Tires
J. J. Hunter, Manager, Highway Transportation Department
G. E. McDaniel, Chief Engineer, Field Operations

Rockwell International

G. Flannery, Director of Government Planning
G. DeClaire, Director of Research and Development

Detroit Diesel Allison

R. A. Pejean, Washington Representative
E. F. Lutz, Manager of Market Research
J. L. Trotter, Applications Engineer

DeLorean Motor Company

J. Z. DeLorean, Chairman of the Board
D. L. Manning, Chief Engineer
W. F. Haddad, Planning Vice President
O. Schultz, Engineering
R. Schultz, Engineering

Booz-Allen Applied Research, Inc.

J. Wing, Senior Vice President
M. Buckel, Senior Associate
R. Ross, Engineering Director
J. Mateyka, Vice President

Urban Mass Transportation Administration, United States Department of Transportation

G. J. Pastor, Associate Administrator for Technology Development and Deployment
C. J. Daniels, Chief of Bus Technology Development
W. E. Hare, Director, Office of Program Support Office of Transit Assistance
J. P. McCullagh, Office of Transit Assistance Management Support Division

American Public Transit Association

S. G. Feinsod, Executive Director, Policy Programs
J. B. Schnell, Technical Service Department

Washington Metropolitan Area Transit Authority

R. S. Page, General Manager (formerly Administrator, Urban Mass Transportation Administration, 1977-79)