NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

Report 1

Transit Bus Energy Efficiency And Productivity

Bus Equipment Selection Handbook

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NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

Report 1

Transit Bus Energy Efficiency And Productivity

Bus Equipment Selection Handbook

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Booz, Allen & Hamilton, Inc.
Bethesda, Maryland

AREAS OF INTEREST
User Needs
Energy and Environment
Vehicle Characteristics
(Public Transit)

RESEARCH SPONSORED BY THE URBAN MASS TRANSPORTATION ADMINISTRATION OF THE U.S. DEPARTMENT OF TRANSPORTATION

TRANSPORTATION RESEARCH BOARD
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NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

Administrators, engineers, and many others in the transit industry are faced with a multitude of complex problems that range between local, regional, and national in their prevalence. How they might be solved is open to a variety of approaches; however, it is an established fact that a highly effective approach to problems of widespread commonality is one in which operating agencies join cooperatively to support, both in financial and other participatory respects, systematic research that is well designed, practically oriented, and carried out by highly competent researchers. As problems grow rapidly in number and escalate in complexity, the value of an orderly, high-quality cooperative endeavor likewise escalates.

Recognizing this in light of the many needs of the transit industry at large, the Urban Mass Transportation Administration, U.S. Department of Transportation, got under way in 1980 the National Cooperative Transit Research & Development Program (NCTRP). This is an objective national program that provides a mechanism by which UMTA's principal client groups across the nation can join cooperatively in an attempt to solve near-term public transportation problems through applied research, development, test, and evaluation. The client groups thereby have a channel through which they can directly influence a portion of UMTA's annual activities in transit technology development and deployment. Although present funding of the NCTRP is entirely from UMTA's Section 6 funds, the planning leading to inception of the Program envisioned that UMTA's client groups would join ultimately in providing additional support, thereby enabling the Program to address a large number of problems each year.

The NCTRP operates by means of agreements between UMTA as the sponsor and (1) the National Academy of Sciences, a private, nonprofit institution, as the Primary Technical Contractor (PTC) responsible for administrative and technical services, (2) the American Public Transit Association, responsible for operation of a Technical Steering Group (TSG) comprised of representatives of transit operators, local government officials, State DOT officials, and officials from UMTA's Office of Technology Development and Deployment, and (3) the Urban Consortium for Technology Initiatives/Public Technology, Inc., responsible for providing the local government officials for the Technical Steering Group.

Research Programs for the NCTRP are developed annually by the Technical Steering Group, which identifies key problems, ranks them in order of priority, and establishes programs of projects for UMTA approval. Once approved, they are referred to the National Academy of Sciences for acceptance and administration through the Transportation Research Board.

Research projects addressing the problems referred from UMTA are defined by panels of experts established by the Board to provide technical guidance and counsel in the problem areas. The projects are advertised widely for proposals, and qualified agencies are selected on the basis of research plans offering the greatest probabilities of success. The research is carried out by these agencies under contract to the Academy, and administration and surveillance of the contract work are the responsibilities of the Academy and Board.

The needs for transit research are many, and the National Cooperative Transit Research & Development Program is a mechanism for deriving timely solutions for transportation problems of mutual concern to many responsible groups. In doing so, the Program operates complementary to, rather than as a substitute for or duplicate of, other transit research programs.

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The project that is the subject of this report was a part of the National Cooperative Transit Research & Development Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

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The Transportation Research Board evolved from the 54-year-old Highway Research Board. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

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FOREWORD

By Staff
Transportation
Research Board

Individuals involved in the selection and specification of buses for transit properties will find this report of special interest. Bus manufacturers can also use the research results to develop information that will be applicable to the specific needs of a property. The handbook included in the Appendix is designed as a guide for the comparison of bus equipment and components with primary emphasis on fuel consumption and performance considerations. Computer simulations of various operating conditions, using sample data from several bus manufacturers, serve as the basis for the handbook.

This report is the first in the NCTRP regular publication series and, quite appropriately, deals with one of the most fundamental problems confronting the transit industry—how to select the "best" bus for a given locale and operation. In the specification of a bus, transit properties are concerned with both cost and performance considerations. One of the major cost components is fuel, and the tradeoffs between fuel savings and performance are often difficult to determine. The objective of this research was to develop a handbook suitable for use by transit property managers in specifying a new bus, giving appropriate attention to the energy efficiency and productivity of different bus types, equipment, and options.

Bus equipment and options that were considered in this research included power train features (e.g., transmission shift schedule and converters, axle gear ratios, engine size and power rating); standard component options (e.g., type of heating/air conditioning systems, tire size and type); and basic design and safety features (e.g., overall weight, seating plan, weight of wheelchair lifts and safety bumpers). Estimates of the relative energy consumption levels of the various items of equipment and options were developed. A baseline equipment configuration was specified for each bus type and size, and the energy-consumption characteristics of each option were related to this baseline. An approach was developed for estimating energy-efficiency characteristics of standard and articulated buses over the full range of operating environments (e.g., terrain, maximum operating speed, number of stops per mile).

Information provided in the handbook (included in the Appendix to this report) was developed through computer simulation using a model that had been developed previously by Booz, Allen & Hamilton, Inc. Simulations were run on three different types of bus routes, using sample data on bus characteristics collected from several manufacturers, to compare energy efficiency vs. performance under various operating conditions. The results of the simulation runs are provided in the handbook to illustrate the tradeoffs that need to be considered in selecting a bus.

The term "handbook" often connotes the impression of a stand-alone document that provides all of the essential information needed to reach a decision. Unfortunately, selection of the "best" bus involves so many considerations (e.g., the introduction of newer bus equipment, site-specific conditions, etc.) that such a handbook is not feasible. Further, all of the interactions between bus equipment items and components as related to energy efficiency and performance cannot be completely replicated through computer simulation, and actual field tests for this purpose would be prohibitively expensive. Thus, neither the "handbook" included in this report nor any other single document should be viewed as the sole source of information of this type. The handbook should serve as a useful guide in identifying the types and relative importance of information that should be considered in the selection process. Bus-specific sample data are included primarily to provide a clear and meaningful presentation of the information to help the user understand the concepts, but the user should recognize that these data do not cover the full range of equipment and options (i.e., only a limited amount of the existing equipment could be included in this research, and new equipment is constantly being introduced). Therefore, the handbook should be used in conjunction with site-specific information and current vehicle data when selecting or specifying a bus.

CONTENTS

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TRANSIT BUS ENERGY EFFICIENCY AND PRODUCTIVITY

BUS EQUIPMENT SELECTION HANDBOOK

SUMMARY

NCTRP Project 54-1 addresses the effects of the various power train equipment being offered for sale in the United States for heavy-duty standard-size and articulated transit buses. The objective of this project is to make the transit bus operator/manager aware of the trade-offs between bus performance and bus fuel economy. Understanding of these trade-offs should result in the purchase of buses and bus equipment that best suit the operational and financial needs of individual properties.

This document is instructional in nature. The findings are based on computer-simulated data, which are to be used to make vehicle comparisons only within the context of this report.

Computer-simulated fuel economy data are predicated on a number of assumptions about vehicle operations that differ from real life conditions. Each component of the vehicle's systems—engine, transmission, axles, and others—is mathematically represented in a set of equations. The complex interactions among vehicle components to variations in time and environment are not modeled. For example, because the variations in engine power caused by age or state of repair are not measured, the computer model of an engine will always exhibit the same performance level. This ideal engine data can be used to determine the factors that affect performance in a real engine; however, no computer model of an engine can exactly duplicate a real engine over time.

Another variation exists in the actual weight of each delivered vehicle. Actual weight will be a function of the total package selected: engine size, fuel tank capacity, number of passenger seats, wheelchair lift, etc. The weight used in this program is not the weight of an actual vehicle, but is the manufacturer-estimated curb weight for that bus model. An attempt was made to use weight information associated with the baseline bus for each manufacturer. This led to some inconsistencies when comparing the fuel economy and performance of different manufacturers' buses. For example, the Flxible 870 bus included 750 pounds for a wheelchair lift; no other buses are shown with this additional weight.

Another variation between computer-simulated data and operational data is the driving pattern. Even on the same scheduled route, a bus driver could not exactly duplicate this previous trip. He would not stop at the same traffic lights or at the same bus stops, or carry the same number of passengers. However, the computer-simulated data are duplicated every time the model is run. The real life variations in average speed, number of stops per mile, and number of passengers can make very sizable differences in fuel economy from day to day (up to 50 percent), but these variations are not modeled. This is another reason for not directly comparing the absolute values of real life fuel economy or performance to computer-simulated data found in this report.

Lastly, it should be mentioned that production tolerances in each vehicle ensure that no two vehicles will perform exactly the same. Small variations in

engine horsepower or fuel injector calibration will affect the overall fuel economy and performance of each vehicle. The computer simulation makes no allowance for these variations.

Even though one must be aware of many precautions when using computer-simulated data, this methodology is the most cost-effective approach to quantifying the differences between various bus types and power train options. Fuel economy testing of each bus and power train option at a test track would, indeed, improve the accuracy of the data. However, the method is very expensive, and the data would still be particular to the driving pattern used in the tests and would be representative only of the buses used at the test track, not all buses in the field.

The findings and the conclusions drawn from the computer-simulated data in this report are useful for understanding the systems, and their functions and interactions, which combine to produce overall vehicle fuel economy and performance results. This report is useful for comparing the performance effects of basic differences among buses of different types. For example, the newer and heavier Advanced Design Buses experience some fuel economy penalty compared to their New Look counterparts. This is traded-off for their increased strength, passenger comfort, and safety. The reduced fuel economy of the articulated buses is traded-off for a sizable increase in passenger-carrying capacity. Future bus selections can be based on knowledge of the real world trade-offs that are found to exist in any complex system such as a bus.

The computer model in this report used bus power train data furnished by the transit bus manufacturers and exercised the buses over six simulated routes or duty cycles. Some of the data furnished by the manufacturers have already changed because of product improvements and equipment substitutions. Even though the use of current bus equipment was desirable, it was not absolutely necessary to produce the findings in this report. Likewise, as new-technology components are introduced in the industry, the basic conclusions drawn from the findings in this report will still be useful as long as the general principles are understood and used properly.

From these computer-simulated data a Bus Equipment Selection Handbook was developed for transit property managers to use in comparing the relative performance of different bus configurations operated under the same conditions. It is important to note that *computer-estimated miles per gallon will differ from on-the-road mileages, so estimates in the handbook should not be used to predict actual fuel economy for a transit property.*

Data in the handbook includes the following general and component-specific findings:

1. Duty Cycle—The duty cycle was the most important factor influencing fuel economy. It accounted for the largest variations in the fuel economy results. Fuel economy variations of more than 100 percent as a result of the duty cycles were noted in this study.

2. Air Conditioning—A second major factor determining fuel economy was air conditioning. Degradation of fuel economy in this study ranged from 8 to 20 percent, while 0 to 30-MPH acceleration performance was degraded about 18 percent. The fuel economy results, however, were representative of worst-case conditions in that the compressor load, which varies with engine speed, was assumed to be at full power throughout the test cycle. In cases where a separate diesel engine was used to power the air conditioner, the fuel economy results reflect the fuel consumed by the engine operating at full capacity and the performance results indicate that vehicle acceleration was not degraded.

3. Bus Weight—The buses in this study experienced an approximate 2 to 3 percent increase in fuel consumption over the ADB cycle for each 1,000 lb of increased bus weight. The heavier Advanced Design Buses experienced as much as a 13 percent increase in fuel consumption over the other standard-size buses because of their increased curb weight. The larger articulated buses experienced a 25 percent increase in fuel consumption for the same reason.

4. Engines—Turbocharged engines yielded up to 12.5 percent better fuel economy and 89 percent better 0 to 30-MPH acceleration time performance than the naturally aspirated engines in this study.

5. Transmissions—Four-speed transmissions yielded 1 to 6 percent better fuel economy than the three-speed transmission because they allowed better matching of the engine, torque converter, and axle ratio.

6. Torque Converters—Torque converters had little direct effect on fuel economy, but they improved acceleration performance by as much as 20 percent.

7. Axle Ratios—Axle ratios were selected to limit the top speed of the bus to a predetermined value. In some cases, the higher the numerical axle ratio the lower the top speed, and the better the fuel economy and performance. This would be beneficial for properties where cruising speeds of over 45 MPH are not required. On commuter cycles, though, lower numerical axle ratios allowed the bus engine to operate at a lower speed, which saved fuel by reducing the engine frictional losses that are experienced at high engine speeds.

The study concludes that transit buses can be optimized to achieve the goals of high fuel economy or good performance. Although the fuel economy improvements demonstrated in this study were small (6.4 percent over the composite ADB cycle), performance improvements measured by the 0 to 30-MPH acceleration time ranged up to 89 percent over the baseline buses.

The power train components that were simulated in this study are interactive components within the total vehicle system. Because they act together as a whole, it is important that they be selected and organized into the final vehicle under a set of guidelines for *vehicle* fuel economy and performance, not component performance.

It cannot be overemphasized that while computer-generated results are good for detecting trends in overall vehicle fuel economy and performance, it must be stressed that many assumptions about the conditions under which the computer-modeled buses operate may be different from real bus data. As long as the results are viewed in this light, the handbook can be beneficial to transit property managers.

The handbook (included in the appendix to this report) can be used as a basic resource for understanding the factors determining bus performance and fuel economy. Because of its common operation of the vehicles over the same duty cycles, it can be used to make "gross" comparisons among the various bus models being offered for sale. Finally, it can be used to indicate the fuel economy and performance effects of specific component changes so that a property may tailor a particular bus model to its operational and functional needs.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

This research project was designed to provide transit property managers with data on the trade-offs between bus fuel economy and bus performance. The research addressed the fuel economy and performance effects of the various power train equipment being offered for sale in the United States for heavy-duty transit buses in both standard and articulated lengths.

The specific objective of the project was to develop a Bus Equipment Selection Handbook (presented in the appendix to this report) that transit property managers could use in selecting transit buses and power train options that are technically and economically suited to their property.

The first step in accomplishing this objective was to determine what transit bus equipment was available for sale and to gather vehicle and component data from the bus manufacturers. These data were collected over several months through the mail and by telephone interviews. Back-up data included engine maps, marketing brochures, and vehicle specifications. In all cases, the information furnished by the bus manufacturer was used without validation or test by the contractor.

One of the program requirements was to obtain enough technical data from the manufacturers to proceed. In all cases but one, enough essential data were obtained. M.A.N., a German manufacturer whose product was new to the American marketplace, considered some of the required information proprietary and thereby excluded itself from inclusion in the handbook.

Even though "essential" data were received from the manufacturers, it was sometimes necessary to make assumptions for missing data, such as computing the rolling radius of the tires based on tire size. These assumptions are not on the individual manufacturer-furnished data sheets. Variations between these assumptions and their real world figures will affect fuel economy, so the computer-generated results should be used only for comparisons within this study. For example, differences in the rolling radius figures of ±10 could account for as much as a ±6 percent variation in the fuel economy results. On the other hand, the assumption of a 0.7 drag coefficient instead of 0.55 would vary the fuel economy of a standard-size bus, over the ADB cycle, by only ±1.5 percent.

Duty cycle characteristics account for the largest variations in fuel economy for a given bus; therefore, it was important to evaluate the buses over a variety of simulated duty cycles. The cycles selected consisted of two actual routes taken from existing properties and the Advanced Design Bus (ADB) duty cycle, a weighted composite of three representative cycles—a central business district (CBD) cycle, an arterial (ART) cycle, and a commuter (COM) cycle.

The ADB cycle is run over completely flat terrain and requires about 2.7 horsepower-hours of energy per mile at the wheels of a bus with a running weight of 29,500 lb, with the air conditioner switched off, and with 20 passengers on board. The J-4 and the Zoo routes are run over grades. The J-4 is moderately hilly, contains 20 uphill and 20 downhill grades ranging in severity from 0.9 to 10 percent. The J-4 route requires about 3.9 horsepower-hours of energy per mile under the same vehicle operating conditions, which makes it 44 percent more severe than the ADB cycle. The Zoo route is flat except for four slopes. The three uphill grades range from 9.5 to 14.2 percent and the downhill grade is −2 percent. The Zoo route requires about 2.9 horsepower-hours of energy per mile under the same vehicle operating conditions, which makes it 8 percent more severe than the ADB cycle.

The gradeability estimates shown in this report are determined by measuring the level road acceleration capability of the bus. The acceleration values are then translated into a gradeability estimate. A peak in this estimate is experienced while starting up in first gear, and is typically obtained at speeds between 5 and 10 miles per hour. The magnitude of the peak is directly related to the weight-to-horsepower ratio of the bus and to its powertrain characteristics. It was subjectively determined that the maximum practical gradeability of a bus would be limited to a value close to the peak value measured by this method. A comparative graph showing an acceleration trace (i.e., "practical gradeability") and the theoretical gradeability limit of the same bus is shown in Figure 1.

Next, the new duty cycles, J-4 and Zoo, were incorporated into the Booz, Allen digital computer simulation model, which had been selected to evaluate the various buses and power train equipment. The bus simulation model was based on, and calibrated against, actual test and operational data. Inputs to the model were the manufacturer-furnished bus data supplemented with the few bus-specific assumptions.

General assumptions necessary to operate the model were also made. They included environmental and traffic conditions as well as such operational parameters as full throttle

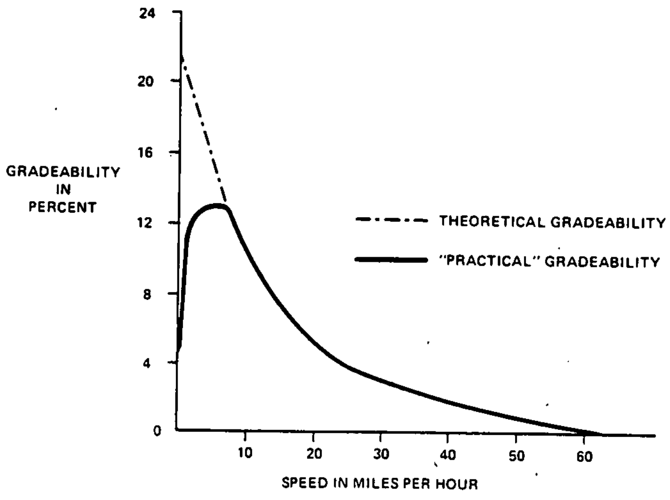

Figure 1. Practical gradeability vs. theoretical gradeability.

acceleration, constant deceleration rates, and full-power air-conditioner compressor load throughout the test cycle. All of these assumptions influenced the results. Air conditioner data represent worst-case operation. Because the fuel consumed by the air conditioner is proportional to the time it is in use and if in the real world it is "on" only 50 percent of the time, the fuel economy of the bus should equal approximately the average between the nonair-conditioned bus data and the fully "on" air-conditioned bus data in this report.

The data resulting from simulating operation of the bus equipment over the six duty cycles were summarized on individual bus model run sheets. From this information a comparison of all the baseline configurations was developed: for empty buses, for 20-passenger loads, and for seated load capacities. Another comparison was the baseline bus versus buses with selected fuel economy and performance options. All of these data are included in the Bus Equipment Selection Handbook.

CHAPTER TWO

FINDINGS

The findings presented in this chapter were extracted from the results of all the computer simulation runs completed in this study. Although the simulated configurations do not constitute the entire range of possible combinations of vehicles and power trains available in the marketplace, they are highly representative based on the manufacturer-supplied data obtained for this project. The findings are grouped into general findings and component-specific findings.

GENERAL FINDINGS

1. For an individual bus, fuel economy variations of more than 100 percent were possible among the six duty cycles used in the study.

2. The variations in horsepower-hours of work per mile were unique to the operation of the vehicles on each of the six cycles, and were highly correlated with the resulting fuel consumption of the bus.

3. The average fuel economies of the stated baseline buses (without passengers) were:

Cycle	MPG	RANGE
CBD	3.68	2.74 to 4.00
ART	4.07	3.21 to 4.30
COM	5.43	4.47 to 5.87
ADB	4.14	3.24 to 4.41
J-4	2.59	1.96 to 3.08
Zoo	3.32	2.57 to 3.83

4. The average performance values of the stated baseline buses (without passengers) were:

- 0-15 MPH time—4.8 sec (3.7 to 6.9 range)
- 0-30 MPH time—14.4 sec (9.9 to 23.2 range)
- Gradeability estimate in low gear from standing start at bottom of hill—20.9 percent (12.8 to 23.5 range)
- Gradeability estimate in top gear from standing start at bottom of hill—2.7 percent (1.46 to 3.86 range)
- Maximum speed or legal limit—53.2 MPH (48.2 to 55.0 range)

5. With increased loads, both fuel economy and performance suffered. The performance degradation in the average 0 to 30-MPH acceleration time of a standard-size bus on level ground with 20 passengers on board was 13 percent (14.4 to 16.3 sec) and at seated load was 34 percent (14.4 to 19.3 sec). The average degradations in fuel economy with increased passenger load were:

	0 Passengers	20 Passengers		Seated Load	
Cycle	MPG	MPG	Percent Degradation	MPG	Percent Degradation
CBD	3.68	3.44	6.5	3.17	13.9
ART	4.07	3.73	8.4	3.29	19.2
COM	5.43	5.19	4.4	4.89	9.9
ADB	4.14	3.87	6.5	3.54	14.5
J-4	2.59	2.39	7.7	2.06	20.5
Zoo	3.32	3.10	6.6	2.79	16.0

COMPONENT-SPECIFIC FINDINGS

1. Air conditioning reduced fuel economy. It is important to note that in this study the compressor load, which varies with engine speed, was assumed to be at full-power draw throughout the simulated cycle. Because this is much more severe than the normal operating conditions experienced by most properties on average throughout the year, these computer calculations are examples of an upper limit on fuel economy losses of an unloaded vehicle while the air conditioner is switched on. The average degradations in fuel economy for empty baseline buses using the manufacturer-reported, air-condtioning system horsepower requirement were:

Cycle	Percent Degradation
CBD	20.4
ART	17.2
COM	8.1
ABD	18.4
J-4	18.2
Zoo	18.7

2. Engine selection affected both fuel economy and performance. In most cases, the 6V-92TA engine gave improved fuel economy over the 8V-71 engine even though they have approximately the same power. The 6V-92TA is turbocharged and aftercooled (more efficient than the naturally aspirated 8V-71). On the basis of the results in the Flyer D901 bus, the Cummins VTB-903 engine gave fuel economy comparable to the 6V-92TA engine. The VTB-903 is a turbocharged eight-cylinder, four-cycle diesel engine. The 6V-71 engine gave better fuel economy than the other engines in low-speed, stop-and-go duty cycles and less fuel economy in the commuter and arterial cycles.

3. Transmission and torque converter selections affected fuel economy performance. The best fuel economy generally resulted from the baseline torque converter, while acceleration performance was most influenced (up to a 20 percent improvement) by switching torque converters. Shifting the transmission into the highest possible gear for the 20-, 40-, and 55-MPH cruise modes of the ADB cycle produced the highest overall fuel economy (up to a 6 percent improvement).

4. Lower numerical axle ratios improved fuel economy from 1 to 6 percent over the COM cycle. The fuel economy effects of axle ratio changes over the other cycles were not consistent. The interaction of the other power train components affected fuel economy for the CBD, ART, ADB, J-4, and Zoo cycles. Performance in both acceleration time and gradeability was improved by using higher numerical axle ratios.

CHAPTER THREE

INTERPRETATION, APPRAISAL, APPLICATION

This chapter discusses the significance of the project findings in their practical application—increasing transit property managers' awareness of the trade-offs between bus fuel economy and performance.

INTERPRETATION

The power train components that were simulated in this study are interactive components that function as a total vehicle system. Because they act together, it is important that they be selected under a set of guidelines for *vehicle* fuel economy and performance, not component performance. The overall matching of components to achieve this system goal is called power train optimization. Tools such as computer simulations allow a sufficient number of tests to be run to develop causal relationships between the various power train line-ups and the final performance and fuel economy of a given vehicle. The performance and fuel economy trends discussed in the Bus Equipment Selection Handbook are based on a computer simulation.

Even though computer-generated results are good for detecting trends in overall vehicle fuel economy and performance, it must be stressed that many assumptions about the conditions under which the computer-modeled buses operate may be different from real bus data. For example, the routes used in the computer model are "perfectly" repeatable. The simulated bus will achieve the same miles-per-gallon figure every time it travels the same route. This is not true for a real bus because traffic conditions, weather conditions, driver habits, and many other factors can change the resulting fuel economy or performance of the bus on any given day.

APPRAISAL

This research study is oriented toward power train optimization of heavy-duty standard-size and articulated buses. Its purpose is to make transit property managers aware of the many factors that affect bus fuel economy and performance. Some are vehicle-dependent and cannot be changed, such as the curb weight and aerodynamic drag. Other factors are component-related and their selection can be tailored to meet specific environmental and operational needs. For example, in the relatively cool, flat plains of Nebraska where gradeability is not important, a transit property may improve fuel economy by purchasing low power option, nonair-conditioned buses. By understanding the various trade-offs, a property will be better able to choose power train systems that get the best fuel economy for particular duty cycle requirements.

The best method for determining the trade-offs among various power train options of a single manufacturer and of all the manufacturers is a controlled test program that operates all of the equipment under the same conditions. Such a test would be very expensive and time-consuming.

A viable alternative to a test program is a computer simulation. It will not yield actual data, but it will indicate data trends and will make gross comparisons of the various equipment operated under the simulated driving conditions. This particular computer simulation has been developed over a 7-year period and is quite sophisticated in its ability to model each component's function.

APPLICATION

The primary product of this project, the Bus Equipment Selection Handbook, is useful to both transit properties and transit bus manufacturers. Transit property managers can use the handbook as a basic resource for understanding the factors determining bus performance and fuel economy. They can also use it, because of its common operation of various vehicles over the same duty cycles, to make gross comparisons among the various bus models being offered for sale. Manufacturers can use it with properties to show the fuel economy and performance effects of specific component changes as they tailor a particular bus model to a property's operational and financial needs.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

Transit buses can be optimized to achieve the goals of high fuel economy or good performance. Although fuel economy improvements were demonstrated in this study, they were small. The fuel economy variations were small because the diesel engine is already a very efficient power plant for this heavy-duty application. The ability to improve fuel economy for particular applications, such as a commuter cycle, does exist; but over more typical cycles, such as the ADB cycle, the current baseline buses are already achieving good fuel economy. It will require the introduction of new technologies, such as regenerative braking systems or light weight bus designs, to significantly improve current bus fuel economy. Performance, on the other hand, is a function of the engine's horsepower rating. Larger and more powerful engines will yield superior performance.

The following conclusions have been drawn from the project findings to identify the parameters important to a transit property in selecting the optimal new bus for improved fuel economy and performance.

1. Duty Cycle—The duty cycle is the most important factor influencing fuel economy. It accounts for the largest variations in the fuel economy results, so it is important to compare all manufacturer claims over the same duty cycle. In addition, fuel economy data collection at each property should be correlated with the types of service encountered. This information would be helpful in future bus procurements, where accurate life-cycle cost information may be required.
2. Air Conditioning—A second major factor determining fuel economy is air conditioning. Air conditioning units draw energy from the engine, requiring the engine to work harder and spend more fuel. Because each engine is rated at a fixed horsepower level, the work spent operating the air conditioner is not available to accelerate the vehicle and performance suffers. Air conditioning should be purchased only when needed, and the engine should be sized to handle the increased load so that performance does not also suffer.
3. Bus Weight—Fuel economy is inversely proportional to bus weight. Heavier standard-size buses will yield lower fuel economy results. Heavier articulated buses will also yield lower fuel economy, but because of their increased passenger capacity, loaded articulated buses can achieve lower operating costs on a per passenger basis.
4. Engines—Turbocharged engines generally yield better fuel economy and performance than the standard 8V-71 engines. However, under certain conditions, such as low-speed operation in areas that do not require air conditioning, the smaller 6V-71 engine can be more fuel efficient.
5. Transmissions—Four-speed transmissions yield better fuel economy than the three-speeds because they allow better matching of engine, torque converter, and axle ratio.
6. Torque Converters—Torque converters have little direct effect on fuel economy, but they do improve acceleration performance and allow for the proper matching of the engine with the transmission. The manufacturer is usually the best source of information for torque converters.
7. Axle Ratios—Axle ratios are selected to limit the top speed of the bus to a predetermined value. In some cases, the higher the numerical axle ratio the lower the top speed, and the better the fuel economy and performance. This could be beneficial for properties where cruising speeds of over 45 MPH are not required. On commuter cycles, though, lower numerical axle ratios allow the bus engine to operate at a lower speed, which saves fuel by reducing the engine's frictional losses that are experienced at high engine speeds.

SUGGESTED RESEARCH

The research suggested as a follow-on to this assignment is future updating of the Bus Equipment Selection Handbook as changes are introduced into the marketplace. Updates will be necessary only when new, significant technological changes affecting transit bus fuel economy or performance are commercialized. The handbook user should be able to evaluate all current technology available from the industry using the data in the original handbook.

When new developments are commercialized, another research project should be commissioned. It should evaluate any fuel economy and performance effects so that transit property managers can perform cost/benefit analyses of the new technologies.

To update the data, it will be necessary to use a computer model. The model would need to be calibrated against the baselines shown in the handbook before any variations are run in order to assure confidence in the results. Then, the new information should be simulated over the six specified duty cycles.

The resulting data should be incorporated approximately in the various charts, the impacts analyzed and discussed in the text, and a revised edition of the handbook printed and distributed.

APPENDIX

BUS EQUIPMENT SELECTION HANDBOOK

CONTENTS

INTRODUCTION

This handbook is oriented toward power train optimization of heavy-duty standard-size and articulated buses. Its purpose is to make transit property managers aware of the trade-offs between bus performance and bus fuel economy. By understanding these trade-offs, the property will be better able to choose a system that suits its operational demands from the available buses and bus power train options.

For example, for certain properties hill-climbing capability may be very important, while another property may be operating on completely flat terrain. There are power train options available to increase fuel economy on flat terrain where gradeability is not important. If a property owner/operator in the flat plains of Nebraska understands this fact, he will be able to purchase vehicles that achieve a higher level of fuel economy. It is in this instructional sense that the handbook is most helpful.

The primary tool used in this study was a transit bus computer simulation model. The program simulated each major power train and bus component and calculated the fuel consumed, power used, transit time, and distance traveled in each mode of operation. The overall vehicle fuel economy and performance was computed by entering the manufacturer-supplied engineering data for each engine selected.

> **Note:** ***The computer-estimated miles per gallon will differ from on the road mileages because of differencs in individual driver, bus, and route profiles. These estimated miles per gallon are not to be used to predict actual fuel economy for your property. They are meant only to compare the relative performance of different vehicle configurations driven under the same conditions.***

GUIDELINES FOR POWER TRAIN SELECTION

The guidelines were designed to help you achieve the best fuel economy or performance considering the operating conditions of your property. By using the guidelines, you will be better equipped to work with the bus manufacturers to ensure that your most important goals are satisfied.

Determine Your Primary Objective

Transit properties face diverse, often conflicting goals when selecting new bus equipment. You may need to:

1. Increase the fuel efficiency of the fleet.
2. Decrease schedule times.
3. Increase bus reliability and availability.
4. Increase bus scheduling flexibility.

This handbook cannot help you decide on your objectives, but once they have been made it can make you aware of the possible fuel economy and performance trade-offs you will have to make to meet these objectives. This handbook should also be of assistance in tailoring your specifications for new equipment to your most important needs and goals.

Familiarize Yourself with the Analysis Procedures Used in This Handbook

Begin by reviewing Attachment 1, which describes the duty cycles used for bus comparisons in the computer simulation. Determine which ones most completely match your own property. You may want to use Table A-1 to help you choose which computer duty cycle best fits your property's situation. First read through the route descriptions across the top row of the chart to find a route that describes the intended service. Probably none will be an exact fit, so select the one that "most closely" fits. Next read down the left-hand column and select the "best" description of the intended terrain. The duty cycle identified at the juncture of the selected row and column is the cycle you should note as you examine the computer fuel economy and performance results on the charts in the other attachments to this handbook.

It may be that one cycle best represents only 60 or 70 percent of your routes and that another cycle best represents the rest. If this is the case, you may have to specify two types of buses in the future in order to obtain your overall goals.

Table A-1. Duty cycle selection chart.

Route Description / Terrain Description	25 MPH or Less Speed Limit/ 5 or More Stops per Mile	40 MPH or Less Speed Limit/ 4 or Less Stops per Mile	55 MPH Speed Limit/1 Stop Or Less per 4 Miles	Composite of Three Previous Routes
Flat	CBD	ART	COM	ADB
Mostly flat some grades	Zoo**	ADB*	ADB*	ADB*
Mostly hilly some steep grades	J-4	ADB*	ADB*	ADB*

* Although the ADB route does not contain any grades, it can be used as an estimate of bus performance under these conditions.

** Zoo route has a limiting grade of 14.2 percent

Be aware, of course, that this may reduce bus scheduling flexibility.

Familiarize Yourself with the Assumptions and Limitations Associated With the Computer Simulation Technique

Next review Attachments 2 and 3 to become aware of the simulation model and the assumptions that went into its design. All the data presented in this handbook are the result of computer simulations, not actual vehicle testing. Directional trends in fuel economy and performance can be simulated using a computer, but absolute values depend on actual operating conditions at a property. For example, some of the conditions that will affect results are: summer versus winter operation, #1 diesel fuel versus #2 diesel fuel, driver habits, and actual route deviations from the simulated duty cycles. The data in this book are to be used to determine expected trends, not as a prediction or comparative estimate for various bus types.

Familiarize Yourself with the Assumptions and Limitations Associated with the Manufacturer-Supplied Data

Review Attachment 4, which lists all the information supplied by the manufacturers for use in the simulation model. In some cases, it was assumed that certain components operated in an average manner because the manufacturer could not supply specific test data. In others, the manufacturer may have supplied data that were outside the normal range of expectations for the component, such as the power requirement to operate the air conditioner. In all cases, manufacturer-supplied data were used, and no judgment was made on the accuracy of the data. It is, therefore, important when you review the fuel economy results that you keep in mind the limitations associated with the supplied data and the assumptions that were made.

Familiarize Yourself with the Computer Simulation Results

Review Attachment 5, which lists all of the computer runs that were made based on the assumptions and manufacturer-supplied data. A number of conclusions can be drawn from the data in these charts:

1. Duty Cycle—The duty cycle is the most important factor influencing fuel economy.
2. Air Conditioning—A second major factor determining fuel economy is air conditioning.
3. Bus Weight—Fuel economy is inversely proportional to the weight of the vehicle.
4. Engines—Turbocharged engines yield both improved fuel economy and performance.
5. Transmissions—Four-speed transmissions yield better fuel economy than three-speeds.
6. Torque Converter—Torque converters have little direct effect on fuel economy although they do improve acceleration.
7. Axle Ratio—Axle ratios are selected to limit the top speed of the bus to a predetermined value, which can improve fuel economy and performance.

Examine the charts of each manufacturer, noting especially the relative fuel economies for the duty cycle that you have decided most closely resembles the intended service of your new equipment. The circles in each column represent the best results among the power train groupings. Also examine the effects of adding air conditioning; a different power train grouping may yield better results when air conditioning is required.

Familiarize Yourself with the Constant Mission Data

Review Attachment 6, which lists the data computed from buses that the manufacturer considered to be the most standard configuration, with 0, 20, and the maximum number of seated passengers on board. These runs were performed to give some trend data on what passenger loads do to affect fuel economy and performance.

The average fuel economies of the stated standard buses were:

Cycle	0 Passengers MPG	20 Passengers MPG	Seated Load MPG
CBD	3.68	3.44	3.17
ART	4.07	3.73	3.29
COM	5.43	5.19	4.89
ADB	4.14	3.87	3.54
J-4	2.59	2.39	2.06
Zoó	3.32	3.10	2.79

The average performances of the standard buses to accelerate from 0 to 30 MPH were:

Terrain	0 Passengers	20 Passengers	Seated Load
Level	14.4 sec	16.3 sec	19.3 sec

At this point it is important to understand the concept of bus productivity because both standard and articulated bus data are presented on the same charts. Bus productivity data need to be used along with fuel economy and performance values in determining the desirability of one bus size over another. Inasmuch as a standardized method for calculating bus productivity is not generally accepted, productivity was not included in the computer model. It is possible, however, to infer from the 0 to 15-MPH and 0 to 30-MPH acceleration times the possible productivity capabilities of the buses.

The basic hypothesis is that if a bus can consistently complete a route in less time than competing buses, that bus is more productive than the others. Theoretically, a fleet of fast buses could have shorter scheduled route times than slow buses and, therefore, move the same number of people with fewer buses. This difference in productivity between a faster and slower bus is calculated as the difference in overall route efficiency. An example of this type of analysis computing passenger-mile per driver-hour is shown in Figure A-1, which shows that the high power option bus completes the cycle in 3½ min less than the baseline bus. This time savings can be converted into increased productivity by revising the run schedule.

Calculating bus efficiency can also be a useful tool for comparing the desirability of alternative buses or power train options. A standardized method for calculating bus efficiency is not available, but a possible equation that calculates bus efficiency in terms of passenger-miles per gallon is presented in Figure A-2.

Data on a typical baseline bus and one with a performance option are shown below:

Bus	Time To Complete ADB Cycle (sec)	Acceleration Times	
		0-15 MPH	0-30 MPH
Baseline	3,115	6.6	21.0
High-Power Option	2,907	4.4	12.2

In this example, the baseline option takes 7 percent (208 seconds) longer to complete the ADB cycle than the performance option. The cause of the slower route time is slower acceleration time—the baseline option takes 50 percent longer to accelerate from 0 to 15 MPH, and 72 percent longer to accelerate from 0 to 30 MPH. Thus, the high power option is the speedier, and more productive option.

Note: Although "time to complete the ADB route" data are not provided in the appendices, it can be inferred that high-performance buses will offer improved overall schedule times and therefore improve productivity.

Figure A-1. Analysis of the effect of bus speed on productivity.

CALCULATE PASSENGER MILES PER GALLON *

Bus efficiency, E, expressed as passenger miles per gallon, is calculated as:

$$E = N \times M$$

where:

N = the number of passengers on the bus

M = the average number of miles traveled per gallon of fuel

A sample efficiency comparison using performance data for two buses, each at their seated load weight, and operated on the ADB cycle is presented below:

	Articulated Bus	Standard Bus
Engine	6V-92TA	6V-92TA
Transmission	HT-740	V-730
Curb Weight	36,200 lb.	26,000 lb.
Duty Cycle	ADB	ADB
Number of Passengers (N):	74	49
Miles per Gallon (M):	2.70	3.30
	$E = 74 \times 2.70$ $= 200$ (more efficient)	$E = 49 \times 3.30$ $= 162$ (less efficient)

Using this example the higher efficiency rating is attached to the bus with the highest passenger capacity. Efficiency should be calculated using the expected passenger load and the representative fuel economy at that load.

* Data needed to calculate bus efficiency is provided in Attachment 6.

Figure A-2. Method for calculating bus efficiency.

Select the Options that Best Suit Your Objectives

The previous steps have presented a large amount of detailed data. It is no simple task to decide what is important to your operations—fuel economy or performance—and then to use the data given in this report to meet your objectives. It will take a number of hours spent reviewing the material in order to develop a feel for the complex interactions among the power-train-selections vehicle sizes and capacities and duty cycles. The manufacturers are aware of optimization problems and have tried to provide enough power train options to suit different types of properties. There is no simple method for balancing the hundreds of variables that affect fuel economy and performance. The only approach is that you work with the manufacturers to choose the best type of buses for your property and its specific operational needs. The information in this report will serve as a good starting point in the process of choosing a particular bus type.

Attachment 7 contains a sample selection of high fuel economy and high performance option packages for each manufacturer. The data used were from the ADB cycle only on runs with no passengers on board. The steps outlined in this handbook can be used by you to select the best economy or performance option for the other routes which may be important to your particular operation.

ATTACHMENT 1—DESCRIPTION OF DUTY CYCLES

This attachment describes the three duty cycles that were used in the bus fuel economy model. The three duty cycles are the ADB duty cycle, the WMATA J-4 route duty cycle, and the Tri-Met (Portland) Zoo route duty cycle.

ADB DUTY CYCLE

The ADB duty cycle was developed by Booz, Allen for the Urban Mass Transportation Administration and the American Public Transit Association. This duty cycle has been accepted and used for bus testing throughout the bus manufacturing and transit industries. The cycle consists of a combination of three phases as follows: central business district (CBD), arterial (ART), and commuter (COM).

The CBD phase consists of 14 consecutive 0 to 20-MPH accelerations and stops over 2 miles. This phase simulates the boarding and exiting of passengers in a business district where frequent stops must be made and heavy traffic is encountered.

The ART phase consists of four 0 to 40-MPH accelerations and stops over 2 miles. This phase simulates the passenger activity in less congested area where traffic is lighter and higher vehicle speed is attainable. Only 2 stops per mile are made in this phase compared to 7 stops per mile in the CBD phase.

The COM phase consists of one 0 to 55-MPH acceleration and 4 miles of interstate speed operation. This phase simulates boarding of passengers in suburban areas and transporting them to a metropolitan area.

Table 1-1 gives the key characteristics of the ADB duty cycle, and Figure 1-1 shows the three phases of the cycle.

The total ADB cycle of 14 miles is run over completely flat terrain and requires about 2.7 horsepower-hours of energy per mile at the wheels of a standard-size bus with a running weight of 29,500 lb.

WMATA J-4 ROUTE

The second duty cycle is the J-4 route operated by the Washington Metropolitan Area Transit Authority (WMATA). This bus route runs from Friendship Heights, an outlying area of the District of Columbia, to the Metro (subway) station in Silver Spring, Maryland, and returns to Friendship Heights over the same route. The round trip covers 10.2 miles and 50 stops, with a total transit time of 48 min, excluding dwell times at the origin and destination points. The boarding and alighting of a constant number of passengers at every stop are assumed.

The average distance between stops on this route is two-tenths of a mile. The top speed is 25 MPH, with an average cruising time between the stops of 23 sec and an average cruising distance of one-seventh of a mile. At two locations on the route, the bus does not reach cruising speed between stops because of normal traffic congestion. The maximum cruising distance is two-thirds of a mile, which occurs between stops 31 and 32.

The round trip contains 20 uphill and 20 downhill grades. The average grade is 4 percent, with a range of 0.9 percent to 10 percent. The overall route is moderately hilly with a grade occurring between 80 percent of the stops.

Table 1-2 gives a summary of the J-4 duty cycle. Figure 1-2 shows the grade heights along the route, and Figure 1-3 provides a frequency distribution of the grade percentage.

It can be seen by the number and sensitivity of the grades that this route requires a great deal of full throttle operation. The J-4 route is the most severe cycle shown for comparison in this report. Although routes in San Francisco may be even more severe, it is assumed that most properties will have very few routes that demand more energy consumption than this route.

For comparison purposes, a bus with a running weight of about 29,500 lb would expend about 3.9 horsepower-hours of energy per mile at the wheels of a standard-size bus to complete this cycle. By this measure, the WMATA J-4 cycle is 44 percent more severe than the ADB cycle.

TRI-MET (PORTLAND) ZOO ROUTE

The third duty cycle is based on bus route number 63

Table 1-1. Key characteristics of ADB duty cycle.

Phase	Stops/Miles	Top Speed (mph)	Miles	Approximate Acceleration Distance (ft)	Approximate Acceleration Time (sec)	Approximate Cruise Distance (ft)	Approximate Cruise Time (sec)	Approximate Deceleration Rate (fpsps)	Approximate Deceleration Distance (ft)	Approximate Deceleration Time (sec)	Approximate Dwell Time (sec)	Approximate Cycle Time (min-sec)	Total Stops
CBD	7	20	2	155	10	540	18.5	6.78	60	4.5	7	9-20	14
Idle	-	-	-	-	-	-	-	-	-	-	-	5-0	-
Arterial	2	40	2	1035	29	1350	22.5	6.78	25.5	9	7	4-10	4
CBD	7	20	2	155	10	510	18.5	6.78	60	4.5	7	9-20	14
Arterial	2	40	2	1035	35	1350	22.5	6.78	255	9	7	4-10	4
CBD	7	20	2	155	10	510	18.5	6.78	60	4.5	7	9-20	14
Commuter	1 stop for phase	Maximum or 55	4	5500	90	2 mile + 4580 feet	188	6.78	480	12	20	5-10	1
Total			14									47-10	51

Approximate Average Speed 17.8 mph

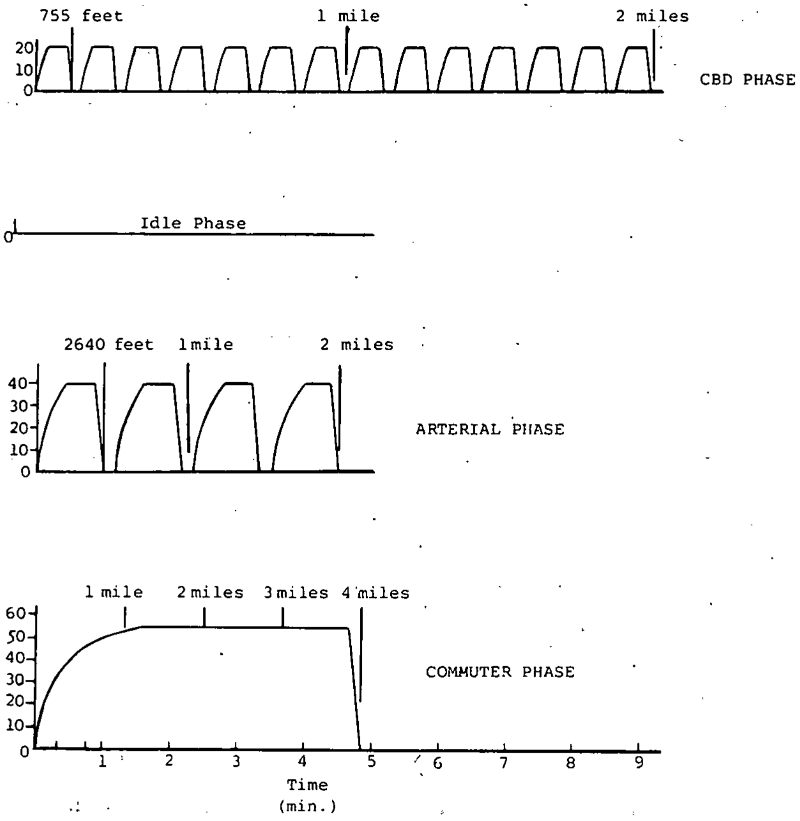

Figure 1-1. Graphical representation of ADB duty cycle.

operated by the Tri-County Metropolitan Transportation District (Tri-Met) of Portland, Oregon. This 8.4-mile route runs from downtown Portland at 6th and Morrison Streets through Washington Park to the Zoo and back. A round-trip transit time of 32 min is assumed, excluding the normal longer dwell times at the origin and destination points on the routes.

The top speed along the route is 25 MPH, with an average cruising time between stops of 31 sec and an average cruising distance of one-fifth of a mile. The shortest cruising distance is 70 ft (before stop 11) and the longest is three-fourths of a mile (before stop 15).

The first leg of the route to the Zoo contains three uphill grades and one slight downhill grade. The uphill grades are 14.2 percent, 11.4 percent, and 9.5 percent; and the downhill grade is −2 percent. On the second leg, the bus returns over the same route with the direction of the grades reversed. With the exception of these four slopes, the bus route covers flat ground.

Table 1-3 gives a summary of the Tri-Met Zoo route. Figure 1-4 shows the height of the grades along the route, and Figure 1-5 presents a frequency distribution of the grade percentages.

This route is considered to be a slightly more difficult route than the ADB cycle. The steep grades in the route require the diesel engine to work very hard, but the number of grades is low compared to the WMATA J-4 route.

For comparison purposes, a standard-size bus with a running weight of 29,500 lb would expend about 2.9 horsepower-hours of energy per mile at the wheels of the bus to complete this cycle. By this measure, the "Zoo" cycle is 8 percent more severe than the ADB cycle.

Table 1-2. Key characteristics of the WMATA J-4 route duty cycle.

Stop	Stops/ Mile	Top Speed (mph)	Miles	Accel. Distance (ft)	Accel. Time (sec)	Cruise Distance (ft)	Cruise Time (sec)	Decel. Rate (fpsps)	Decel. Distance (ft)	Decel. Time (sec)	Stop Time (sec)	Transit Time (sec)	Total Stops
1	10	25	.10	235	15.3	194	5.3	6.78	99	5.4	7.6	33.6	1
2	10	25	.10	118	6.5	308	8.4	6.78	102	5.5	7.6	27.9	1
3	5	25	.20	154	8.9	803	21.9	6.78	99	5.4	7.5	43.7	1
4	2	25	.50	257	17.6	2,284	62.3	6.78	99	5.4	7.5	92.9	1
5	4	25	.25	198	12.2	1,023	27.9	6.78	99	5.4	7.5	53.0	1
6	10	25	.10	198	12.2	231	6.3	6.78	99	5.4	7.5	31.4	1
7	20	24	.05	172	11.3	0	0	6.78	92	5.2	7.5	24.0	1
O 8	7	25	.15	231	15.2	462	12.6	6.78	99	5.4	7.6	40.8	1
U 9	10	25	.10	205	12.2	231	6.3	6.78	92	5.2	7.5	31.4	1
T 10	20	24	.05	165	11.3	0	0	6.78	99	5.4	7.5	24.0	1
B 11	10	25	.10	187	11.2	242	6.6	6.78	99	5.4	7.5	30.7	1
O 12	10	25	.10	231	15.2	198	5.4	6.78	99	5.4	7.6	33.6	1
U 13	3	25	.30	121	6.5	1,364	37.2	6.78	99	5.4	7.6	56.8	1
N 14	3	13	.30	218	65.2	1,338	70.2	6.78	28	2.9	7.6	146.0	1
D 15	10	25	.10	128	7.1	301	8.2	6.78	99	5.4	7.6	28.3	1
S 16	10	25	.10	253	17.6	176	4.8	6.78	99	5.4	7.5	35.3	1
17	10	25	.10	169	9.6	260	7.1	6.78	99	5.4	7.5	29.7	1
18	2	25	.50	165	9.7	2,376	64.8	6.78	99	5.4	7.5	87.4	1
19	1	23	.70	110	79.5	3,218	95.4	6.78	88	5.1	7.5	187.5	1
20	2	25	.50	139	7.9	24,02	65.6	6.78	99	5.4	7.6	86.4	1
21	3	20	.30	277	81.5	1,244	42.4	6.78	63	4.3	7.6	135.8	1
22	10	25	.10	176	10.3	253	6.9	6.78	99	5.4	7.6	30.2	1
23	10	25	.10	176	8.9	274	7.5	6.78	99	5.4	7.6	29.4	1
24	10	25	.10	231	15.2	198	5.4	6.78	99	5.4	7.6	33.6	1
Metro 25	10	25	.10	231	15.2	198	5.4	6.78	99	5.4	7.5	33.5	1

Table 1-2. (Continued)

Stop	Stops/ Mile	Top Speed (mph)	Miles	Accel. Distance (ft)	Accel. Time (sec)	Cruise Distance (ft)	Cruise Time (sec)	Decel. Rate (fpsps)	Decel. Distance (ft)	Decel. Time (sec)	Stop Time (sec)	Transit Time (sec)	Total Stops
INBOUND 26	10	25	.10	176	10.3	253	6.9	6.78	99	5.4	7.6	30.3	1
27	10	25	.10	176	10.3	253	6.9	6.78	99	5.4	7.6	30.2	1
28	10	25	.10	283	21.3	146	4.0	6.78	99	5.4	7.5	38.2	1
29	10	25	.10	231	15.2	198	5.4	6.78	99	5.4	7.5	33.5	1
30	3	25	.30	128	7.1	1,357	37.0	6.78	99	5.4	7.5	57.1	1
31	2	25	.50	393	132.8	2,152	58.7	6.78	95	5.3	7.5	204.3	1
32	1	25	.70	139	7.8	3,454	94.2	6.78	103	5.5	7.5	115.0	1
33	2	25	.50	249	17.0	2,292	62.5	6.78	99	5.4	7.5	92.5	1
34	10	25	.10	253	1,761.4	176	4.8	6.78	99	5.4	7.6	35.4	1
35	10	25	.10	169	9.8	260	7.1	6.78	99	5.4	7.6	29.8	1
36	10	20	.10	280	81.8	185	6.3	6.78	63	4.3	7.6	100.1	1
37	3	25	.30	110	6.0	1,371	37.4	6.78	103	5.5	7.6	56.4	1
38	3	17	.30	191	74.6	1,349	54.1	6.78	44	3.6	7.6	139.9	1
39	10	25	.10	176	10.3	253	6.9	6.78	99	5.4	7.6	30.2	1
40	10	25	.10	213	13.5	216	5.9	6.78	99	5.4	7.6	32.4	1
41	20	24	.05	172	11.3	0	0	6.78	92	5.2	7.6	24.0	1
42	10	25	.10	198	12.2	231	6.3	6.78	99	5.4	7.6	31.5	1
43	7	25	.15	176	10.3	517	14.1	6.78	99	5.4	7.6	37.4	1
44	20	24	.05	172	11.3	0	0	6.78	92	5.2	7.6	24.0	1
45	10	25	.10	198	12.2	231	6.3	6.78	99	5.4	7.5	31.4	1
46	4	25	.25	202	12.2	1,019	27.8	6.78	99	5.4	7.5	53.0	1
47	2	25	.50	169	9.6	2,372	64.7	6.78	99	5.4	7.6	87.4	1
48	5	25	.20	282	21.3	675	18.4	6.78	99	5.4	7.6	52.6	1
49	10	17	.10	215	74.6	269	10.8	6.78	44	3.6	7.5	96.5	1
F.H. 50	10	25	.10	176	10.3	253	6.9	6.78	99	5.4	7.6	30.2	1
TOTAL												2,880 sec or 48 min	50

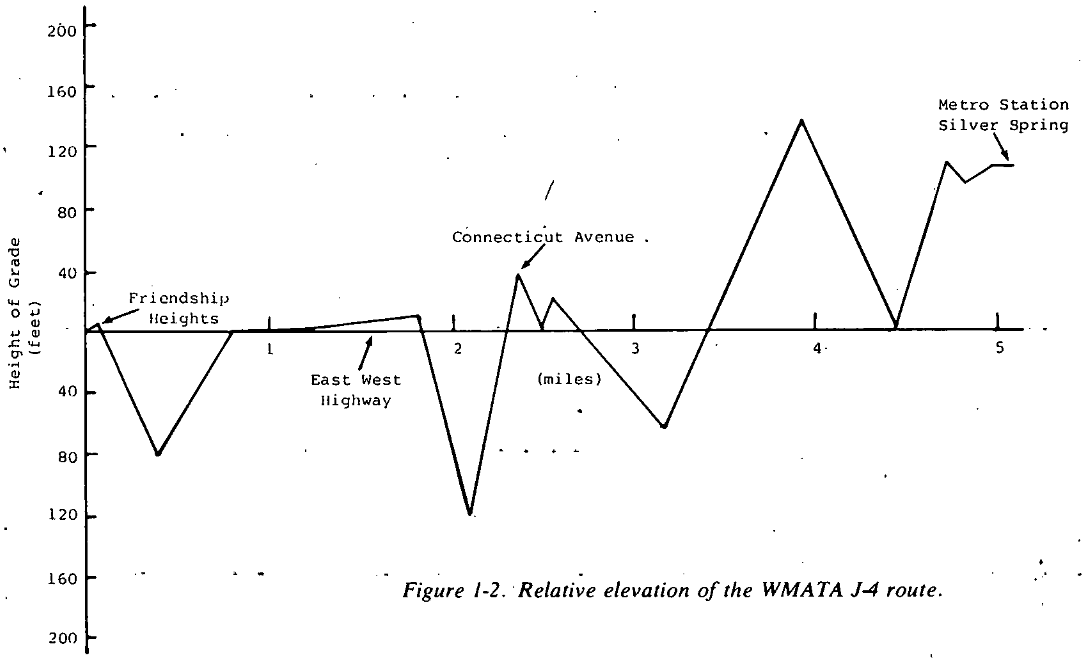

Figure 1-2. Relative elevation of the WMATA J-4 route.

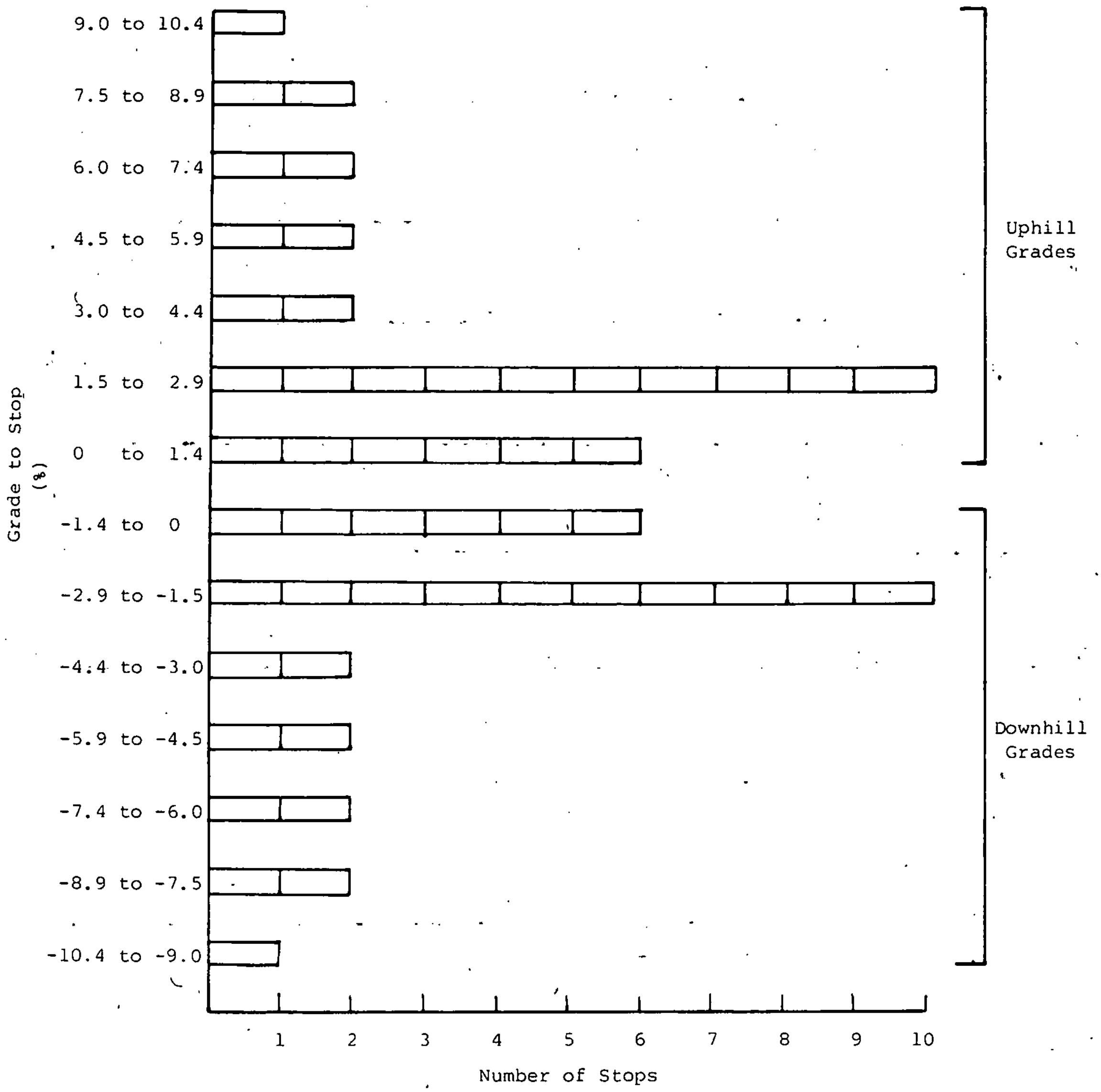

Figure 1-3. Distribution of grade percentages on the WMATA J-4 route.

Table 1-3. Key characteristics of the Tri-Met Zoo route duty cycle.

Stop	Stops/ Mile	Top Speed (mph)	Miles	Accel. Distance (ft)	Accel. Time (sec)	Cruise Distance (ft)	Cruise Time (sec)	Decel. Rate (fpsps)	Decel. Distance (ft)	Decel. Time (sec)	Stop Time (sec)	Transit Time (sec)	Total Stops
1	7	25	.13	198	12.2	389	10.6	6.78	99	5.4	7.6	35.8	1
2	11	25	.09	200	12.2	176	4.8	6.78	99	5.4	7.6	30.1	1
3	7	25	.09	200	12.2	176	4.8	6.78	99	5.4	7.6	30.0	1
4	5	25	.20	198	12.2	759	20.7	6.78	99	5.4	7.6	45.9	1
5	4	8	.25	139	48.4	1,175	100.1	6.78	10	1.7	7.5	157.6	1
O 6	7	25	.13	195	12.1	392	10.7	6.78	99	5.4	7.5	35.7	1
U 7	6	12	.16	146	56.7	676	38.4	6.78	23	2.6	7.6	105.2	1
T 8	4	25	.27	198	12.2	1,129	30.8	6.78	99	5.4	7.6	55.6	1
B 9	2	25	.40	195	12.2	1,815	49.5	6.78	102	5.5	7.5	74.7	1
O 10	1	25	.07	201	12.2	70	1.9	6.78	99	5.4	7.5	27.1	1
U 11	1	25	.73	198	12.2	3,557	97.0	6.78	99	5.4	7.6	122.2	1
N 12	5	15	.19	203	69.0	763	34.7	6.78	37	3.3	7.6	114.5	1
D 13	12	25	.08	198	12.2	125	3.4	6.78	99	5.4	7.6	28.6	1
14	1	25	.80	202	12.2	3,923	107.0	6.78	99	5.4	7.5	132.3	1
15	4	25	.24	171	10.0	997	27.2	6.78	99	5.4	7.5	50.2	1
16	6	25	.17	202	12.2	597	16.3	6.78	99	5.4	7.6	41.6	1
ZOO 17	5	25	.20	198	12.2	759	20.7	6.78	99	5.4	7.6	45.9	1
18	5	25	.20	198	12.2	759	20.7	6.78	99	5.4	7.6	45.9	1
19	6	25	.17	201	12.2	598	16.3	6.78	99	5.4	7.6	41.5	1
20	4	25	.24	237	15.8	931	25.4	6.78	99	5.4	7.5	54.2	1
21	1	25	.80	198	12.2	3,927	107.1	6.78	99	5.4	7.5	132.2	1
22	12	25	.08	198	12.2	125	3.4	6.78	99	5.4	7.6	28.6	1
23	5	25	.19	112	6.2	792	21.6	6.78	99	5.4	7.5	40.7	1
I 24	1	25	.73	198	12.2	3,557	97.0	6.78	99	5.4	7.6	122.2	1
N 25	14	25	.07	201	12.2	70	1.9	6.78	99	5.4	7.6	27.1	11
B 26	2	25	.40	198	12.2	1,815	49.5	6.78	99	5.4	7.5	74.6	1
O 27	4	25	.27	201	12.2	1,126	30.7	6.78	99	5.4	7.6	56.0	1
U 28	6	25	.16	105	5.7	638	17.4	6.78	102	5.5	7.5	36.1	1
N 29	7	25	.13	198	12.2	389	10.6	6.78	99	5.4	7.6	35.8	1
D 30	4	25	.25	99	5.1	1,122	30.6	6.78	99	5.5	7.6	48.8	1
31	5	25	.20	198	12.2	759	20.7	6.78	99	5.4	7.6	45.9	1
32	11	25	.09	200	12.2	176	4.8	6.78	99	5.4	7.5	29.9	1
33	11	25	.09	200	12.2	176	4.8	6.78	99	5.4	7.6	30.0	1
34	7	25	.13	198	12.2	389	10.6	6.78	99	5.4	7.6	35.8	1
			8.4									1,927 sec or 32 min	34

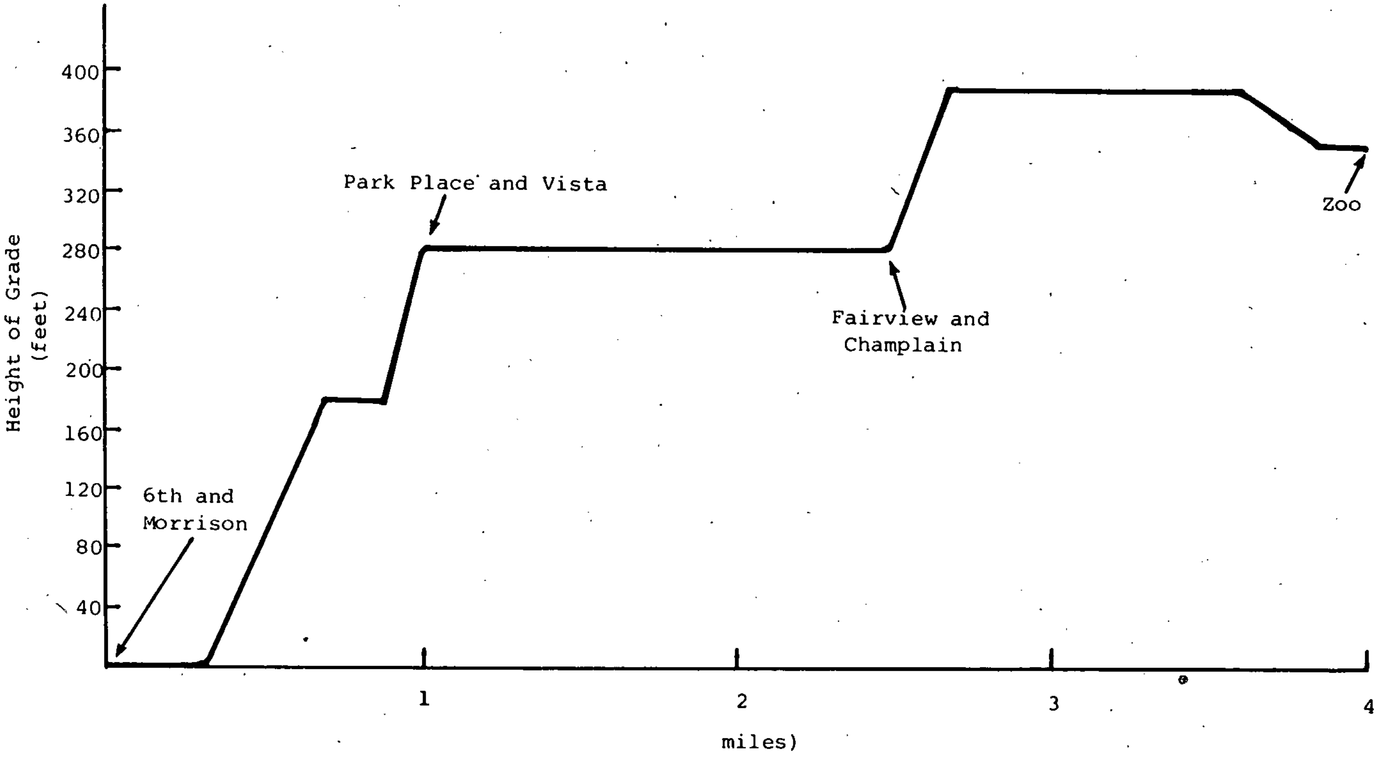

Figure 1-4. Relative elevation of the Tri-Met Zoo route.

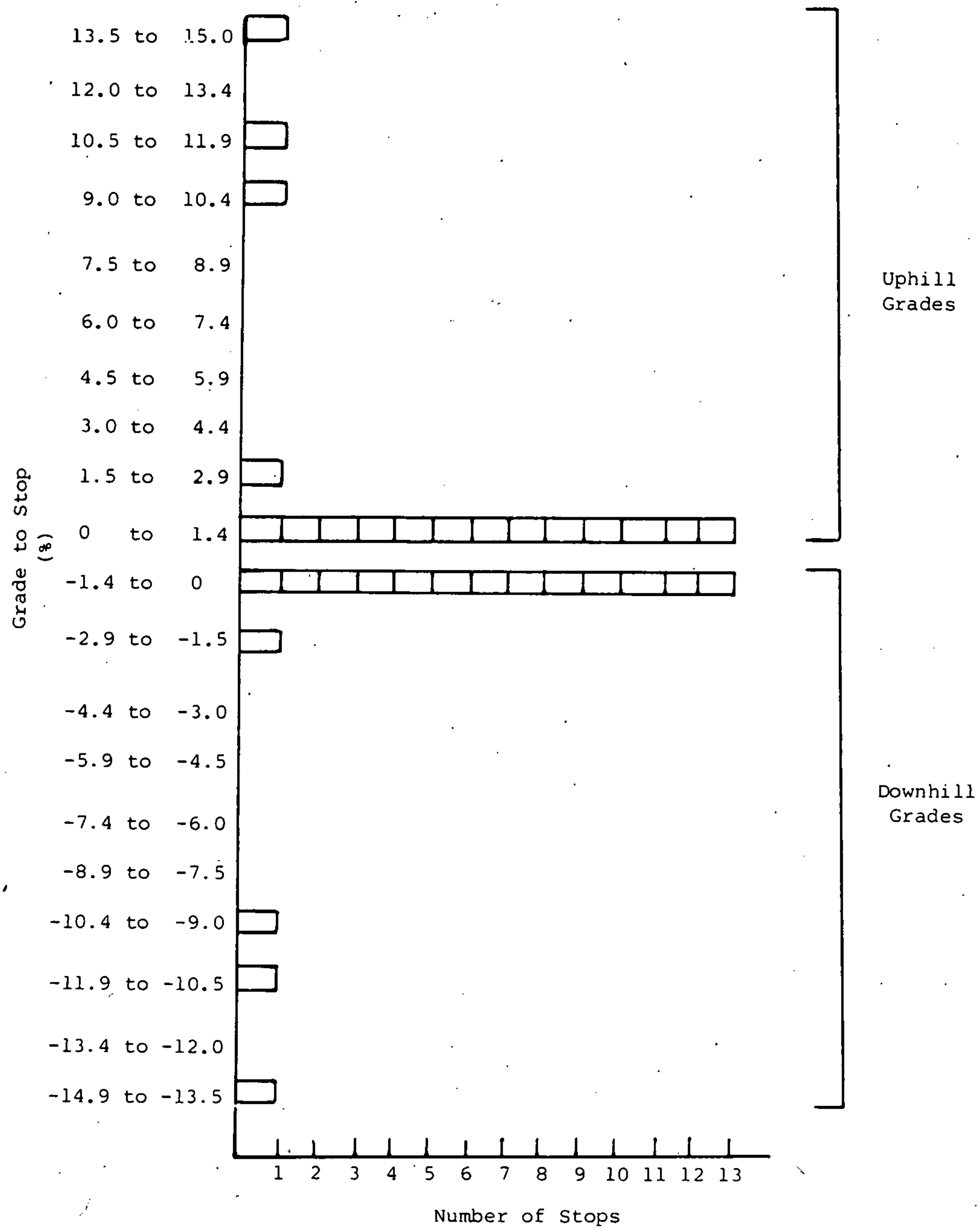

Figure 1-5. Distribution of grade percentages on the Tri-Met Zoo route.

ATTACHMENT 2—DESCRIPTION OF SIMULATION MODEL

The assessment technique used for this assignment was the Booz, Allen transit bus computer simulation model which has evolved over a period of years to its current capability of assessing the performance and fuel consumption of transit vehicles under various operating conditions and with various existing or experimental power trains. The model, in addition, generates the energy distribution within the power train for any synthesized vehicle design over any specified driving duty cycle, such as the Advanced Design Bus (ADB), Environmental Protection Agency (EPA), or Urban Mass Transportation Administration (UMTA) cycles.

The Booz, Allen program models each major power train and vehicle component and calculates the fuel consumed, power used, time consumed, and distance traveled, for each mode of operation. During the acceleration mode, the engine drives the coach to the limits of its capabilities and in conformance with the specified driving cycle. During the cruise and deceleration modes, the vehicle power required by that phase of the cycle is used to calculate the appropriate engine operating conditions.

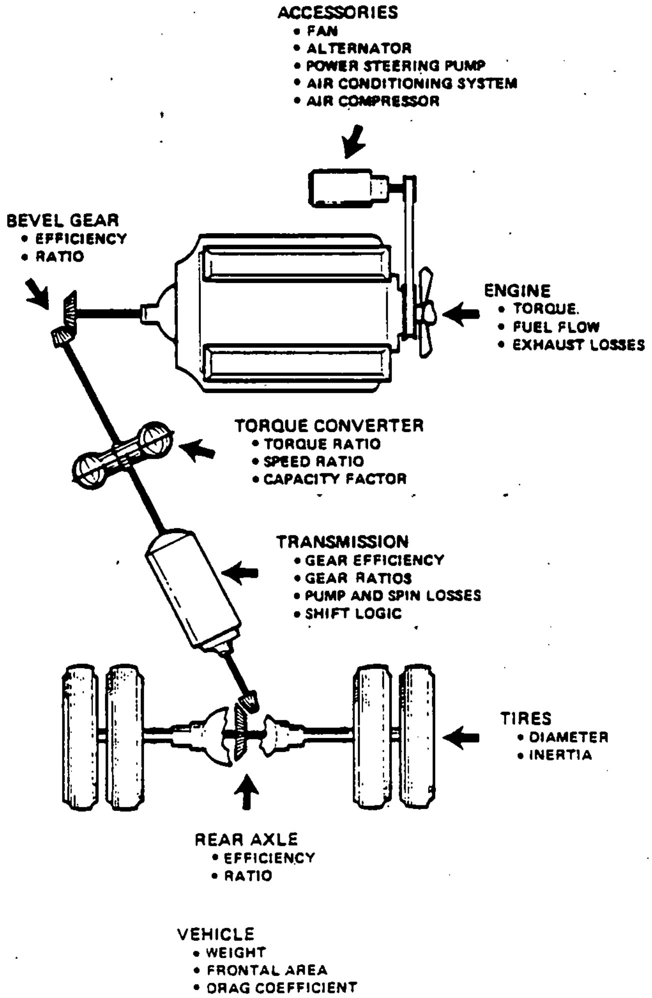

Figure 2-1. Inputs required for Booz, Allen & Hamilton Model.

The general method of calculation is as follows (an example of inputs to the model is shown in Figure 2-1):

- The model starts calculations with engine in idle mode (idle torque and fuel consumption). The idle-start vehicle-acceleration calculation considers the initial engine speed to be idle RPM and vehicle speed to be zero. At time equals zero, engine full throttle net torque begins accelerating the rotating inertias connected directly to the engine (engine, flywheel, accessories, fans, transmission input components, and converter pump). The torque available to accelerate these components is the full throttle torque of the engine minus whatever torque is absorbed by the converter pump, and with appropriate deductions for transmission input losses.

- For each tenth of a second thereafter, the model calculates full throttle acceleration torque, subtracts accessory losses, and calculates the resulting torque supplied to the bevel gear (if one is being used). With an engine idle start, engine torque must be used to overcome the torque of the rotating inertias in the engine, transmission, and converter pump system. When the lockup clutch shift occurs, the engine speed decreases and a portion of this inertia torque is recovered, accelerating the vehicle slightly. In order to compute the additional vehicle weight associated with rotational inertia, the inertia for each component must be determined and transferred to the engine.

- All parasitic and heat losses are accounted for during each 0.1-sec calculation. Appropriate deductions are made for transmission and drive line efficiencies and for the vehicle rolling, wind, and grade resistances. The calculation further assumes that the vehicle does not begin accelerating until such time as the tractive effort has increased to a value sufficient to overcome rolling resistance. The resistances that are accounted for are:

Duty cycle characteristics—stops per mile, grades
Frictional losses—tire rolling resistances, wind and drive train efficiency
Engine accessories—air conditioning compressor, air compressor, power steering pump, alternator, cooling fan
Rotating inertias—engine, drive line and both input and output transmission inertias

- The torque supplied to the transmission is calculated. Using the published torque converter characteristics and the engine inertia, the engine is accelerated to the next RPM level. The torque absorbed by the converter pump, together with the instantaneous value of converter speed ratio, is used to calculate turbine (output) torque. The output torque accelerates the rotating inertias of the turbine, transmission, drive line, vehicle roadwheels, and resulting tractive effort available for vehicle acceleration at the road surface.
- The acceleration of all components turning in relation to engine speed is thus independent of the acceleration of components whose speed is related to vehicle speed. Torque is transmitted from one accelerating system to the other through the torque converter. As the turbine speed increases, the lockup clutch begins transmitting the torque, which tends to decelerate the engine and accelerate the vehicle. As this occurs, converter pump and turbine speeds approach each other and finally become equal. At this point the slip of the lockup clutch is zero and the shift to lockup is complete. From this time on, the engine, converter pump, turbine, transmission, etc., accelerate as a single rather than dual system.
- Fuel consumed during each tenth of a second of the acceleration mode is computed using the engine brake specific fuel curves (BSFC) at wide open and part throttle.
- During the cruise and deceleration modes, the engine requirements are calculated from the duty cycle specifications. The fuel consumed is calculated based on the specified time remaining in that mode. The total fuel consumed during the cycle is summed and used to calculate the resulting overall fuel economy.

The standard output of the model includes both the results of the simulation (detail and summary) and listings of output data (raw and formatted).

ATTACHMENT 3—SUMMARY OF MODELING/RUN ASSUMPTIONS

In any simulation model a certain number of general assumptions have to be made. The following is a list of some of the more important assumptions made for this project's model:

1. Engine altitude and temperature adjustment factors are defined by SAE J270 where altitude is 500 ft and temperature is 85 F.
2. Effective frontal area is computed as: (height −0.75) × width.
3. Air resistance is based on DOT/SAE Report P-59 (2.C.20).
4. Fuel density of #2 diesel is 7.365.
5. Fuel density of #1 diesel is 6.879.
6. Passenger weight (and driver) is 150 lb.
7. Vehicle operates on dry concrete with no head/tail wind.
8. No accounting for road traffic congestion.
9. Grade is constant between stops.
10. Weight per time is 120 lb.
11. No tire expansion as a function of vehicle speed is used.
12. Rolling resistance is based on SAE 690108 where the rolling resistances in lb/ 10^3 lb GVW at 30 MPH are:

    13.4 for bias conventional
    13.8 for bias belted
    12.6 for bias low profile
    12.3 for radial belted

13. Full throttle acceleration is used up to cruise speed.
14. Engine accelerates from idle RPM.
15. Fan, air brake compressor, steering pump, and air conditioner accessory loads are a power function of engine speed.
16. Generator load is a constant.
17. Automatic transmission with instantaneous gear change is used.
18. Constant deceleration rate is 6.78 ft/sec^2.
19. Idle fuel consumption is used while decelerating.
20. There is no downshifting while decelerating.

Differences between these assumptions and actual operating environments may account for significant variations in the fuel economy and performance figures. Therefore, the computer-simulated results should be used only within the context of this report.

ATTACHMENT 4—DESCRIPTION OF BUS EQUIPMENT

The charts (4A through 4I) included in this attachment are summaries of the bus equipment data obtained from the transit bus manufacturers currently bidding or selling standard and articulated buses in the United States. There is a data chart for each bus model (but not each size) being marketed by each manufacturer. For instance, Neoplan is marketing three bus models: the Atlantis (a New Look model), the N412 (an Advanced Design Bus model), and the N421 (an Articulated model). For each one of these models, there is a chart listing the components basic to the model.

If a particular model comes in different lengths or widths, the smaller configuration is listed as an option. Any other alternative equipment being offered, which may include engines, torque converters, axle ratios, and air conditioning, are also listed as options. Where data were not available, and it was possible to make reasonable assumptions, it is so noted.

Chart 4A
Manufacturer-Provided Bus Data

Manufacturer Flxible
Bus Model 870 (ADB)

Vehicle Characteristics	Base	Options**	Assumptions
Length	40'	35'	
Height	120"		
Width	102"	96"	
Drag Coefficient			0.55
Gross Weight			
Curb Weight (includes 750 lb lift)	26,000 lb	25,050 lb (35' model)	
Passenger Seats	49	38 (35' model)	
Fuel Tank	135 gal	126 gal	
Tires (total)			6
Tire Size (rating)	12.0 x 22.5G		
Tire Radius			20.1"
Tire Ply	bias		
Power Train Characteristics			
Engine	6V-92TA(7G75)294HP	6V-71N(7E60)200HP 8V-71N(7E60)280HP	
Transmission	V-730		
Torque Converter	490 (6V-92TA 8V-71N)	470(6V-71N)	
Axle Ratio	4.556	5.857(6V-71N)	
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)	28 (6V-92TA 8V-71N)	20 (6V-71N)	
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)	4.5		
Steering Pump (HP @ 2100 RPM)			1.4
A/C (HP @ 2100 RPM)	30-35HP @ max cool		32.5

** Options available with all models except where noted.

Chart 4B
Manufacturer-Provided Bus Data

Manufacturer Flyer
Bus Model D901 (New Look)

Vehicle Characteristics	Base	Options**	Assumptions
Length	40'	35'	
Height	120"		
Width	102"		
Drag Coefficient			0.7
Gross Weight	36,000 lb		
Curb Weight	22,900 lb	21,000 lb (35' model)	
Passenger Seats	51	43 (35' model)	
Fuel Tank	138 gal	100 gal	
Tires (total)			6
Tire Size (rating)	12.0 x 22.5		
Tire Radius			20.1"
Tire Ply	radial/bias		bias
Power Train Characteristics			
Engine	6V-71N(C55)170HP	6V-92TA(7G65)239HP with #1 fuel VTB903—275HP	
Transmission	V-730		
Torque Converter	470		
Axle Ratio	5.375	5.125(VTB903)	
Fuel Type	#1	#2	run with wgt. of #2
Accessories			
Fan (HP @ 2100 RPM)	20.4		
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)	15 CFM @ 2100 RPM		2.3
Steering Pump (HP @ 2100 RPM)			
A/C *(HP @ 2100 RPM)		24.8	

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* Trane (10 ton)

** Options available with all models except where noted

Chart 4C
Manufacturer-Provided Bus Data

Manufacturer Gillig
Bus Model Phantom (ADB/New Look)

Vehicle Characteristics	Base	Options**	Assumptions
Length	40'	35'	
Height	119"		
Width	96"		
Drag Coefficient	0.55		
Gross Weight	37,600 lb	34,000 lb (35' model)	
Curb Weight (includes driver)	24,000 lb	22,250 lb (35' model)	22,930 lb
Passenger Seats	49	41	
Fuel Tank	125 gal		
Tires (total)			6
Tire Size (rating)	11.0 x 22.5		
Tire Radius			19.7"
Tire Ply	bias		
Power Train Characteristics			
Engine	6V-92TA(7G65)253HP		
Transmission	HT-740		
Torque Converter	470		
Axle Ratio	4.11	4.62, 4.87 5.28, 6.29, 7.17	Deleted 6.29 and 7.17—ratio too high
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)	22 @ 2160		
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)	2.3 @ 2450		
Steering Pump (HP @ 2100 RPM)			1.4
A/C*(HP @ 2100 RPM)		16.8 @ 3000 (compressor speed)	

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* Trane (10 ton)

** Options available with all models except where noted

Chart 4D
Manufacturer-Provided Bus Data

Manufacturer GM of Canada

Bus Model 5307 (New Look)

Vehicle Characteristics	**Base**	**Options****	**Assumptions**
Length	40'	35'	
Height	119.25"		
Width	102"	96"	
Drag Coefficient	.558		0.553
Gross Weight	34,000 lb	30,500 lb (35' model)	
Curb Weight	20,700 lb	19,425 lb (35' model)	
Passenger Seats	53	45 (35' model)	
Fuel Tank	95 gal	125 gal	
Tires (total)			6
Tire Size (rating)	11 x 20G		
Tire Radius			20.1"
Tire Ply	bias		
Power Train Characteristics			
Engine	6V-71N(E50)	8V-71N(E50) 6V-92TA(7G65)	
Transmission	V-730		
Torque Converter	470	490(8V-71N)	
Axle Ratio	5.375	4.1,4.556,5.125, 5.857	
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)	19 @ 1600		
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)	15.5 CFM @ 1250RPM		3.5
Steering Pump (HP @ 2100 RPM)	-		
A/C*(HP @ 2100 RPM)	25		

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* Trane (10 ton)

** Options available with all models except where noted

Chart 4E
Manufacturer-Provided Bus Data

Manufacturer GMC
Bus Model RTS (ADB)

Vehicle Characteristics	**Base**	**Options****	**Assumptions**
Length	40'	35'	
Height	118.5"		
Width	102"	96"	
Drag Coefficient	0.55		
Gross Weight	36,900 lb	35,000 lb (35' model)	
Curb Weight (includes 700 lb lift)	26,600 lb	25,100 lb (35' model)	
Passenger Seats	47		
Fuel Tank	125 gal	95 gal	
Tires (total)			6
Tire Size (rating)	12.5 x 22.5	12.0 x 22.5 (35' model)	
Tire Radius			20.1"
Tire Ply	bias		
Power Train Characteristics			
Engine	6V-92TA(7G70)277HP	6V-71N(7E60)200HP 6V-92TA(7G65)253HP 6V-92TAC(9E65)240HP	
Transmission	V-730		
Torque Converter	470		
Axle Ratio	5.375	5.857(6V-71)	
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)			20
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)	15.5 CFM @ 1250 RPM		4.5
Steering Pump (HP @ 2100 RPM)			1.4
A/C*(HP @ 2100 RPM)			25

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* Trane (10 ton)
** Options available with all models except where noted

Chart 4F
Manufacturer-Provided Bus Data

Manufacturer Neoplan
Bus Model Atlantis (New Look)

Vehicle Characteristics	**Base**	**Options****	**Assumptions**
Length	40'	35'	
Height	117"		
Width	102"	96"	
Drag Coefficient	0.55		
Gross Weight	34,200 lb		
Curb Weight			22,780 lb
Passenger Seats	up to 48		42
Fuel Tank	125 gal		
Tires (total)			6
Tire Size (rating)			
Tire Radius	21.922"		
Tire Ply	bias		
Power Train Characteristics			
Engine	6V-92TA(7G65)277HP		
Transmission	V-730		
Torque Converter	470		
Axle Ratio	5.125		
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)	23.5		
Generator (HP @ 2100 RPM)	1.4		
Compressor (HP @ 2100 RPM)			1.4
Steering Pump (HP @ 2100 RPM)	1.4		
A/C*(HP @ 2100 RPM)	30.0		

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* Trane

** Options available with all models except where noted

Chart 4G
Manufacturer-Provided Bus Data

Manufacturer Neoplan
Bus Model N412 (ADB)

Vehicle Characteristics	Base	Options**	Assumptions
Length	40'	35'	
Height	10'		
Width	102"	96"	
Drag Coefficient	0.55		
Gross Weight	34,000 lb		
Curb Weight			22,580 lb
Passenger Seats	42	35 (35' model)	
Fuel Tank	125 gal		
Tires (total)			6
Tire Size (rating)	12.5 x 22.5H		
Tire Radius	21.922		
Tire Ply	bias		
Power Train Characteristics			
Engine	6V-92TA(7G75)277HP		
Transmission	HT-740		
Torque Converter	495		
Axle Ratio	4.629		
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)	23.5		
Generator (HP @ 2100 RPM)	1.4		
Compressor (HP @ 2100 RPM)	1.4		
Steering Pump (HP @ 2100 RPM)	1.4		
A/C* (HP @ 2100 RPM)	-	30	

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* Optional Manufacturer

** Options available with all models except where noted

Chart 4H
Manufacturer-Provided Bus Data

Manufacturer Neoplan
Bus Model N421 (Articulated)

Vehicle Characteristics	**Base**	**Options******	**Assumptions**
Length	60'	55'	
Height	125"		
Width	102"	96"	
Drag Coefficient			0.7
Gross Weight			
Curb Weight	36,000 lb		
Passenger Seats	59		
Fuel Tank	150 gal		
Tires (total)			10
Tire Size (rating)	12.5 x 22.5		
Tire Radius			20.1"
Tire Ply			bias
Power Train Characteristics			
Engine	6V-92TA(7G75)		
Transmission	HT-740		
Torque Converter	D.B. Ho7		TC 495
Axle Ratio			5.22, 4.639, 5.94
Fuel Type	#2		
Accessories			
Fan (HP @ 2100 RPM)			23.5
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)			1.4
Steering Pump (HP @ 2100 RPM)			1.4
A/C (HP @ 2100 RPM)			30.0

** Options available with all models except where noted

Chart 41
Manufacturer-Provided Bus Data

Manufacturer Crown-Ikarus
Bus Model 286 (Articulated)

Vehicle Characteristics	**Base**	**Options** **	**Assumptions**
Length	60'		
Height	124"		
Width	102"		
Drag Coefficient			0.7
Gross Weight	54,000 lb		
Curb Weight (includes A/C. wheelchair lift, driver)	38,000 lb		36,200 lb
Passenger Seats	74	69	
Fuel Tank	125 gal	100 gal	
Tires (total)			8
Tire Size (rating)	315/75E	315/80	
Tire Radius	22.5"		21.9"
Tire Ply	radial		
Power Train Characteristics			
Engine	NHHTC-290 @ 2100	NHHTC-290 @ 1900 NHHTC-320 @ 1900 NHHTC-350 @ 2100	
Transmission	HT-740		
Torque Converter	495	499	
Axle Ratio	4.110	3.9,4.33,4.63,4.8	
Fuel Type			#2
Accessories			
Fan (HP @ 2100 RPM)	27	30,34	
Generator (HP @ 2100 RPM)			1.4
Compressor (HP @ 2100 RPM)	2.8		
Steering Pump (HP @ 2100 RPM)			1.4
A/C* (HP @ 2100 RPM)	(separate engine)		

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* Carrier-Transicold with Mitsubishi engine.

** Options available with all models except where noted

ATTACHMENT 5—SUMMARY OF SIMULATION RESULTS

This attachment provides, in summary format (see Tables 5-1 through 5-11), the findings or results of the simulations conducted on each manufacturer's bus(es). The data are presented in matrix format for each bus model.

Each matrix chart is organized in the following manner. The manufacturer and bus model are listed at the top. The column headings are:

- Pass. = number of passengers on board
- Eng. = engine and injectors
- A/C = horsepower draw of air conditioner at maximum cooling
- Trans. = transmission
- T.C. = torque converter
- RAR = rear axle ratio
- Fuel Economy = miles per gallon on duty cycles
  - CBD (central business district)
  - ART (arterial)
  - COM (commuter)
  - ADB (weighted average of above 3 cycles)
  - J-4 (actual route in Washington, D.C.)
  - Zoo (actual route in Portland, Oregon)
- Performance = acceleration in seconds, grades attainable in percents from a standing start at the bottom of the hill, and maximum speed or legal limit attainable in miles per hour
  - 0-15 (acceleration time from 0-15 MPH)
  - 0-30 (acceleration time from 0-30 MPH)
  - 1st Gear (grades attainable from standing start at bottom of hill in first gear)
  - Top Gear (grades attainable from standing start at bottom of hill in first gear)
  - Max Speed or Legal Limit (top speed attainable up to 55 MPH)

The tabular data are presented in two groups. The top grouping shows nonair-conditioned results and the bottom grouping shows air-conditioned results. Within each group, the baseline bus configuration as specified by the manufacturer is presented first (without passengers, with 20 passengers, and with seated load capacity), followed by the same engine with consecutively higher rear axle ratios. When new engine options are introduced, they are presented with the lower axle ratios first.

The reader should refer to the body of the report for cautions pertaining to the use of these data.

ATTACHMENT 6—CONSTANT MISSION DATA

This attachment presents comparisons of the manufacturers' baseline bus selections with and without passengers (Tables 6-1 through 6-3). The runs were performed to give some trend data on what passenger loads do to affect fuel economy and performance.

Table 6-1 gives the results of simulating all of the buses without passengers. Table 6-2 gives the results with 20 passengers aboard each bus. Table 6-3 gives the results with each bus at seated load weight.

The reader should refer to the body of the report for cautions and assumptions pertaining to the use of these data.

Table 5-1. Summary of simulation results—Flxible 870 bus model.

	Input to Computer Model						Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air-Conditioned	0	6V-92TA 7G75	0	V-730	490	4.556	3.21	3.75	5.42	3.78	2.39	2.87	4.40	12.20	18.30	2.86	55.0
	20	6V-92TA 7G75	0	V-730	490	4.556	3.06	3.47	5.11	3.57	2.10	2.73	4.80	13.60	16.88	2.44	55.0
	49	6V-92TA 7G75	0	V-730	490	4.556	2.88	3.13	4.69	3.30	1.91	2.53	5.40	15.70	15.16	1.96	55.0
	0	6V-92TA 7G75	0	V-730	490	5.857	3.25	4.03	5.19	3.85	2.36	2.87	4.10	12.10	20.33	4.64	49.1
	0	8V-71N 7E60	0	V-730	490	4.556	3.41	3.53	5.19	3.80	2.33	2.87	4.90	13.60	16.43	2.42	55.0
	0	8V-71N 7E60	0	V-730	490	5.857	3.47	3.80	5.08	3.90	2.17	2.98	4.60	13.40	18.10	4.09	49.1
	0	6V-71N 7E60	0	V-730	490	4.556	3.60	3.28	4.73	3.73	2.18	3.20	6.60	21.00	12.99	1.09	53.3
	0	6V-71N 7E60	0	V-730	490	5.857	3.72	3.54	5.05	3.94	2.22	3.15	6.30	20.50	13.82	2.39	49.1
Air Conditioned	0	6V-92TA 7G75	32.5	V-730	490	4.556	2.73	3.16	4.66	3.16	1.93	2.51	5.00	14.50	16.13	2.27	55.0
	20	6V-92TA 7G75	32.5	V-730	490	4.556	2.59	2.93	4.37	2.98	1.79	2.39	5.50	16.20	14.88	1.91	55.0
	49	6V-92TA 7G75	32.5	V-730	490	4.556	2.43	2.64	3.96	2.74	1.60	2.20	6.20	18.80	13.38	1.49	55.0
	0	6V-92TA 7G75	32.5	V-730	490	5.857	2.78	3.39	4.45	3.22	1.98	2.45	4.70	14.30	17.81	3.90	49.1
	0	8V-71N 7E60	32.5	V-730	490	4.556	2.59	2.82	4.10	2.92	1.79	2.37	5.70	16.80	14.12	1.81	55.0
	0	8V-71N 7E60	32.5	V-730	490	5.857	2.72	3.16	4.29	3.13	1.50	2.46	5.40	16.20	15.35	3.34	49.1
	0	6V-71N 7E60	32.5	V-730	490	4.556	2.67	2.46	4.81	2.92	1.66	-	8.40	28.90	10.42	0.51	46.1
	0	6V-71N 7E60	32.5	V-730	490	5.857	2.78	2.67	4.04	2.96	1.57	2.50	8.20	27.50	10.99	1.64	47.6

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-2. Summary of simulation results—Flyer D901 bus model.

	Input to Computer Model						Fuel Economy						Performance				
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	Max. Speed or Legal Limit
Non-Air-Conditioned	0	6V-71N C55	0	V-730	470	5.375	4.00	3.89	5.23	4.24	2.35	3.83	6.90	23.20	12.75	1.54	48.8
	20	6V-71N C55	0	V-730	470	5.375	3.70	3.44	5.21	3.92	2.24	3.50	7.60	26.70	11.84	1.22	47.0
	51	6V-71N C55	0	V-730	470	5.375	3.28	2.79	5.20	3.46	1.87	-	8.80	32.70	10.67	0.85	44.0
	0	6V-71N C55	0	V-730	470	5.125	4.07	3.91	5.43	4.31	2.29	3.85	6.90	23.40	12.61	1.28	48.5
	0	6V-92TA 7G65	0	V-730	470	5.125	3.40	4.48	5.13	4.05	2.83	3.23	4.20	12.20	19.94	3.43	55.0
	0	6V-92TA 7G65	0	V-730	470	5.375	3.33	4.45	5.20	4.02	2.67	3.33	4.10	12.30	20.13	3.80	53.5
	0	VTB903	0	V-730	470	5.125	3.42	4.62	5.36	4.13	2.71	3.36	4.30	11.80	18.26	3.46	55.0
Air Conditioned	0	6V-71N C55	24.8	V-730	470	5.375	3.06	2.87	5.23	3.35	2.01	-	8.70	30.60	10.49	0.96	43.4
	20	6V-71N C55	24.8	V-730	470	5.375	2.85	2.44	5.25	3.06	1.92	-	9.60	35.50	9.75	0.70	41.4
	51	6V-71N C55	24.8	V-730	470	5.375	2.57	2.15	5.33	2.80	-	-	11.20	44.80	8.80	0.41	38.1
	0	6V-71N C55	24.8	V-730	470	5.125	3.13	2.90	5.48	3.42	1.88	-	8.70	30.70	10.39	0.71	43.0
	0	6V-92TA 7G65	24.8	V-730	470	5.125	2.93	3.88	4.45	3.45	2.23	2.90	4.60	14.20	17.93	2.86	55.0
	0	6V-92TA 7G65	24.8	V-730	470	5.375	2.88	3.85	4.53	3.43	2.18	2.87	4.60	14.20	18.09	3.20	53.5
	0	VTB903	24.8	V-730	470	5.125	3.03	3.97	4.72	3.57	2.11	2.85	5.00	13.80	15.64	2.90	55.0

\- Unable to operate on grades

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-3. Summary of simulation results—Gillig Phantom bus model.

Input to Computer Model							Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air-Conditioned	0	6V-92TA 7G65	0	HT-740	470	4.110	3.88	4.29	5.87	4.40	2.85	3.26	4.40	11.40	18.64	2.97	55.0
	20	6V-92TA 7G65	0	HT-740	470	4.110	3.63	3.97	5.51	4.11	2.63	2.92	4.80	12.80	17.22	2.49	55.0
	49	6V-92TA 7G65	0	HT-740	470	4.110	3.33	3.57	5.02	3.74	2.27	2.68	5.50	14.90	15.51	1.96	55.0
	0	6V-92TA 7G65	0	HT-740	470	4.620	3.66	4.75	5.60	4.35	2.84	3.16	4.30	11.30	19.25	3.82	53.4
	0	6V-92TA 7G65	0	HT-740	470	4.870	3.55	4.65	5.72	4.28	3.42	3.86	4.30	11.20	19.46	4.20	50.6
	0	6V-92TA 7G65	0	HT-740	470	5.280	3.38	4.48	5.80	4.15	3.37	3.71	4.20	11.00	19.73	4.81	46.7
	0	6V-92TA 7G65	0	HT-740	470	5.860	3.18	4.25	5.80	3.96	3.27	3.81	4.10	10.90	19.94	5.62	42.2
Air Conditioned	0	6V-92TA 7G65	16.8	HT-740	470	4.110	3.45	3.88	5.37	3.91	2.59	2.79	4.70	12.40	17.47	2.61	55.0
	20	6V-92TA 7G65	16.8	HT-740	470	4.110	3.28	3.60	5.02	3.68	2.23	2.66	5.20	14.00	16.14	2.17	55.0
	49	6V-92TA 7G65	16.8	HT-740	470	4.110	3.05	3.24	4.55	3.38	1.91	2.47	5.90	16.40	14.54	1.68	55.0
	0	6V-92TA 7G65	16.8	HT-740	470	4.620	3.36	4.27	5.12	3.92	2.48	2.79	4.60	12.30	18.02	3.41	53.4
	0	6V-92TA 7G65	16.8	HT-740	470	4.870	3.26	4.20	5.23	3.86	3.06	3.37	4.60	12.20	18.23	3.77	50.6
	0	6V-92TA 7G65	16.8	HT-740	470	5.280	3.05	4.06	5.31	3.71	2.99	3.45	4.50	12.00	18.47	4.35	46.7
	0	6V-92TA 7G65	16.8	HT-740	470	5.860	2.78	3.85	5.27	3.48	2.85	3.25	4.40	11.90	18.65	5.11	42.1

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-4. Summary of simulation results—GM of Canada 5307N bus model.

	Input to Computer Model						Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air-Conditioned	0	6V-71N 7E50	0	V-730	470	5.375	4.16	4.30	4.97	4.38	2.72	3.94	5.60	18.70	15.80	2.30	53.2
	20	6V-71N 7E50	0	V-730	470	5.375	3.81	3.82	4.89	4.05	2.52	3.61	6.20	21.60	14.53	1.86	51.3
	53	6V-71N 7E50	0	V-730	470	5.375	3.34	3.14	4.79	3.57	2.05	3.10	7.30	27.00	12.85	1.33	48.2
	0	6V-71N 7E50	0	V-730	470	4.100	4.48	3.82	5.90	4.55	2.62	3.72	5.80	18.50	14.50	0.67	51.7
	0	6V-71N 7E50	0	V-730	470	4.556	4.42	3.92	5.47	4.48	2.53	3.93	5.70	18.70	15.07	1.32	52.8
	0	6V-71N 7E50	0	V-730	470	5.125	4.26	4.32	5.09	4.46	2.94	3.97	5.60	18.70	15.60	2.02	53.2
	0	6V-71N 7E50	0	V-730	470	5.857	4.51	4.23	5.58	4.66	2.82	3.89	5.60	18.50	16.09	2.81	49.1
	0	6V-92TA 7G65	0	V-730	470	5.375	3.40	4.69	5.44	4.14	2.76	3.46	4.00	11.70	20.21	4.22	53.3
	0	6V-92TA 7G65	0	V-730	470	4.100	3.74	4.13	6.28	4.33	2.70	3.17	4.20	11.60	19.14	2.22	55.0
	0	6V-92TA 7G65	0	V-730	470	4.556	3.60	4.25	5.91	4.23	2.71	3.23	4.10	11.60	19.59	2.94	55.0
	0	6V-92TA 7G65	0	V-730	470	5.125	3.45	4.74	5.45	4.19	2.83	3.42	4.10	11.70	20.08	3.84	55.0
	0	6V-92TA 7G65	0	V-730	470	5.857	3.59	4.58	5.62	4.26	2.81	3.21	4.00	11.70	20.39	4.88	49.1

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-5. Summary of simulation results—GM of Canada 5307A bus model.

Input to Computer Model							Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Air Conditioned	0	8V-71N E50	25	V-730	490	5.375	2.54	3.21	3.82	2.94	1.93	2.66	6.40	19.80	12.94	2.22	52.5
	20	8V-71N E50	25	V-730	490	5.375	2.41	2.89	3.77	2.77	1.77	2.48	7.10	22.70	11.97	1.82	50.9
	53	8V-71N E50	25	V-730	490	5.375	2.21	2.42	3.70	2.52	1.52	-	8.20	28.00	10.62	1.33	48.3
	0	8V-71N E50	25	V-730	490	4.100	2.86	2.93	4.52	3.14	1.84	-	6.80	20.10	11.71	0.66	52.0
	0	8V-71N E50	25	V-730	490	4.556	2.78	2.95	4.21	3.06	1.79	2.61	6.60	20.20	12.30	1.27	53.0
	0	8V-71N E50	25	V-730	490	5.125	2.63	3.22	3.92	3.01	2.09	2.68	6.40	19.90	12.80	1.95	52.9
	0	8V-71N E50	25	V-730	490	5.857	2.82	3.15	4.09	3.12	2.02	2.62	6.40	19.50	13.15	2.72	49.1
	0	6V-92TA 7G65	25	V-730	470	4.100	3.07	3.36	5.18	3.49	2.06	2.69	5.10	14.70	16.13	1.41	55.0
	0	6V-92TA 7G65	25	V-730	470	4.556	2.99	3.47	4.98	3.45	2.12	2.79	5.00	14.60	16.63	2.11	55.0
	0	6V-92TA 7G65	25	V-730	470	5.125	2.85	3.83	4.59	3.40	2.33	2.85	4.90	14.70	17.06	2.89	55.0
	0	6V-92TA 7G65	25	V-730	470	5.375	2.79	3.80	4.62	3.36	2.15	2.82	4.80	14.70	17.19	3.21	53.5
	0	6V-92TA 7G65	25	V-730	470	5.857	3.00	3.73	4.79	3.50	2.21	2.75	4.80	14.60	17.34	3.79	49.1

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-6. Summary of simulation results—GM of Canada 4523N bus model.

	Input to Computer Model						Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air-Conditioned	0	6V-71N C50	0	V-730	470	5.429	3.91	4.21	5.01	4.26	2.80	3.89	5.80	19.50	15.61	2.25	51.9
	20	6V-71N C50	0	V-730	470	5.429	3.58	3.79	4.94	3.92	2.17	3.55	6.50	22.90	14.29	1.79	50.0
	53	6V-71N C50	0	V-730	470	5.429	3.15	2.99	4.84	3.44	1.99	-	7.70	29.00	12.57	1.25	46.8
	0	6V-71N C50	0	V-730	470	4.10	4.43	3.77	6.94	4.67	2.61	3.62	5.90	19.40	14.29	0.27	47.8
	0	6V-71N C50	0	V-730	470	4.556	4.27	3.84	5.56	4.41	2.56	3.85	5.80	19.50	14.86	1.23	51.8
	0	6V-71N C50	0	V-730	470	5.125	4.03	4.23	5.18	4.36	2.91	3.94	5.70	19.60	15.39	1.91	52.1
	0	6V-71N C50	0	V-730	470	4.444	4.31	3.85	5.66	4.45	2.55	3.72	5.80	19.50	14.73	1.09	51.7

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-7. Summary of simulation results—GMC RTS bus model.

Input to Computer Model							Fuel Economy						Performance				
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	Max. Speed or Legal Limit
Non-Air-Conditioned	0	6V-92TA 7G70	0	V-730	470	5.375	3.01	4.00	4.98	3.66	2.11	2.84	4.40	13.20	19.21	3.52	53.5
	20	6V-92TA 7G70	0	V-730	470	5.375	2.85	3.69	4.73	3.45	2.03	2.72	4.80	14.70	17.98	3.06	53.5
	47	6V-92TA 7G70	0	V-730	470	5.375	2.68	3.32	4.40	3.20	1.75	2.55	5.30	16.30	16.59	2.55	53.5
	0	6V-92TA 7G70	0	V-730	470	5.857	3.17	3.91	5.19	3.77	2.13	2.90	4.30	13.10	19.55	4.10	49.1
	0	6V-92TA 7G65	0	V-730	470	5.375	3.06	3.94	4.92	3.67	2.23	2.97	4.70	14.70	18.04	3.13	53.5
	0	6V-92TA 7G65	0	V-730	470	5.857	3.28	3.86	5.13	3.82	2.15	2.90	4.70	14.70	18.38	3.68	49.1
	0	6V-92TAC 9E65	0	V-730	470	5.375	2.93	3.77	4.55	3.49	2.14	2.87	4.60	14.90	18.78	3.13	53.4
	0	6V-92TAC 9E65	0	V-730	470	5.857	3.17	3.69	4.77	3.65	2.02	2.81	4.60	14.80	19.20	3.73	49.1
	0	6V-71N 7E60	0	V-730	470	5.375	3.31	3.51	4.48	3.62	2.30	3.18	6.50	21.30	13.44	1.89	53.4
	0	6V-71N 7E60	0	V-730	470	5.857	3.65	3.49	5.01	3.88	2.21	3.11	6.40	20.90	13.67	2.33	49.1
Air Conditioned	0	6V-92TA 7G70	25	V-730	470	5.375	2.57	3.48	4.39	3.12	1.90	2.58	4.90	15.30	17.33	3.01	53.5
	20	6V-92TA 7G70	25	V-730	470	5.375	2.46	3.22	4.16	2.96	1.69	2.45	5.30	17.00	16.23	2.59	53.5
	47	6V-92TA 7G70	25	V-730	470	5.375	2.33	2.89	3.83	2.75	1.69	2.30	5.90	19.50	14.99	2.13	53.4
	0	6V-92TA 7G70	25	V-730	470	5.857	2.75	3.42	4.56	3.24	1.81	2.53	4.90	15.20	17.61	3.54	49.1
	0	6V-92TA 7G65	25	V-730	470	5.375	2.60	3.41	4.25	3.10	1.85	2.65	5.30	17.20	16.17	2.61	53.4
	0	6V-92TA 7G65	25	V-730	470	5.857	2.82	3.34	4.49	3.25	1.94	2.60	5.30	17.10	16.45	3.11	49.1
	0	6V-92TAC 9E65	25	V-730	470	5.375	2.53	3.24	3.88	2.97	1.81	2.57	5.20	17.30	17.03	2.66	53.4
	0	6V-92TAC 9E65	25	V-730	470	5.857	2.74	3.18	4.15	3.12	1.87	2.52	5.10	17.20	17.41	3.16	49.1
	0	6V-71N 7E60	25	V-730	470	5.375	2.61	2.83	4.24	2.96	1.69	1.91	7.80	26.60	11.38	1.37	49.1
	0	6V-71N 7E60	25	V-730	470	5.857	2.89	2.82	4.05	3.07	1.64	2.60	7.80	26.10	11.55	1.76	49.0

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-8. Summary of simulation results—Neoplan Atlantis bus model.

	Input to Computer Model						Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air-Conditioned	0	6V-92TA 7G65	0	V-730	470	5.125	3.48	4.08	5.78	4.10	2.63	3.24	4.20	12.20	19.49	2.99	55.0
	20	6V-92TA 7G65	0	V-730	470	5.125	3.32	3.77	5.41	3.86	2.43	3.08	4.70	13.80	18.04	2.51	55.0
	42	6V-92TA 7G65	0	V-730	470	5.125	3.17	3.46	5.03	3.62	2.07	2.92	5.10	15.60	16.67	2.09	55.0
Air Conditioned	0	6V-92TA 7G65	30	V-730	470	5.125	2.94	3.42	4.92	3.40	2.07	2.83	4.90	14.60	17.13	2.36	55.0
	20	6V-92TA 7G65	30	V-730	470	5.125	2.79	3.16	4.57	3.19	1.96	2.70	5.30	16.50	15.86	1.95	55.0
	42	6V-92TA 7G65	30	V-370	470	5.125	2.65	2.90	4.16	2.98	1.75	2.53	5.90	18.80	14.68	1.58	55.0

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-9. Summary of simulation results—Neoplan N412 bus model.

	Input to Computer Model						Fuel Economy						Performance				
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	Max. Speed or Legal Limit
Non-Air-Conditioned	0	6V-92TA 7G75	0	HT-740	495	4.629	3.98	4.21	5.75	4.41	3.08	3.29	3.70	9.90	23.51	3.86	55.0
	20	6V-92TA 7G75	0	HT-740	495	4.629	3.74	3.93	5.44	4.14	2.76	3.13	3.90	11.00	22.16	3.29	55.0
	42	6V-92TA 7G75	0	HT-740	495	4.629	3.51	3.64	5.12	3.88	2.52	2.94	4.20	12.20	20.80	2.79	55.0
Air Conditioned	0	6V-92TA 7G75	30	HT-740	495	4.629	3.22	3.57	6.53	3.79	2.44	2.81	4.20	11.30	20.85	0.27	42.9
	20	6V-92TA 7G75	30	HT-740	495	4.629	3.08	3.34	6.23	3.60	2.25	2.51	4.40	12.60	19.68	0.08	42.9
	42	6V-92TA 7G75	30	HT-740	495	4.629	2.95	3.11	5.93	3.42	1.99	2.45	4.80	14.00	18.51	4.42	42.9

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-10. Summary of simulation results—Neoplan N421 bus model.

	Input to Computer Model						Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air Conditioned	0	6V-92TA 7G75	0	HT-740	495	5.220	2.89	3.26	4.47	3.32	2.46	2.97	4.60	14.30	19.65	3.00	48.2
	20	6V-92TA 7G75	0	HT-740	495	5.220	2.79	3.06	4.30	3.18	2.25	2.76	4.90	15.60	18.79	2.69	48.2
	59	6V-92TA 7G75	0	HT-740	495	5.220	2.61	2.71	3.97	2.92	1.98	2.54	5.50	18.20	17.42	2.18	48.2
	0	6V-92TA 7G75	0	HT-740	495	4.639	3.05	3.37	4.07	3.37	1.96	2.43	4.70	14.60	19.35	2.31	54.2
	0	6V-92TA 7G75	0	HT-740	495	5.940	2.45	3.13	4.67	3.05	2.40	2.85	4.50	14.00	19.54	3.80	42.4
Air Conditioned	0	6V-92TA 7G75	30	HT-740	495	5.220	2.42	2.78	3.88	2.78	1.93	2.49	5.30	16.60	17.40	2.49	48.2
	20	6V-92TA 7G75	30	HT-740	495	5.220	2.33	2.60	3.72	2.65	1.90	2.38	5.60	18.10	16.74	2.21	48.2
	59	6V-92TA 7G75	30	HT-740	495	5.220	2.18	2.29	3.40	2.43	1.68	2.22	6.30	21.20	15.52	1.76	48.1
	0	6V-92TA 7G75	30	HT-740	495	4.639	2.59	2.86	3.39	2.81	1.75	2.18	5.30	16.90	17.25	1.85	54.2
	0	6V-92TA 7G75	30	HT-740	495	5.940	2.22	2.65	4.04	2.65	2.04	2.44	5.10	16.30	17.25	3.21	42.4

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 5-11. Summary of simulation results—Crown-Ikarus 286 bus model.

	Input to Computer Model						Fuel Economy						Performance				Max. Speed or Legal Limit
	Pass.	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	
Non-Air-Conditioned	0	NHHTC290 @ 2100	0	HT-740	495	4.110	2.74	3.21	4.70	3.24	1.96	2.57	4.90	14.10	19.52	1.46	55.0
	20	NHHTC290 @ 2100	0	HT-740	495	4.110	2.63	3.01	4.45	3.08	1.60	2.50	5.20	15.30	18.50	1.26	55.0
	74	NHHTC290 @ 2100	0	HT-740	495	4.110	2.36	2.56	3.81	2.70	1.48	2.22	6.00	18.70	16.14	0.84	55.0
	0	NHHTC290 @ 1900	0	HT-740	495	3.900	1.31	1.26	2.67	1.51	-	1.21	4.90	15.00	18.83	1.17	55.0
	0	NHHTC320 @ 1900	0	HT-740	499	4.330	2.59	3.12	4.54	3.10	1.77	2.45	4.10	13.10	21.47	2.29	55.0
	0	NHHTC320 @ 1900	0	HT-740	499	4.630	2.50	3.09	4.52	3.03	1.87	2.26	4.10	13.20	21.84	2.70	53.5
	0	NHHTC350 @ 2100	0	HT-740	495	4.800	2.36	3.01	4.34	2.90	2.07	2.45	4.00	11.80	23.74	3.02	55.0
Air Conditioned	0	NHHTC290 @ 2100	23	HT-740	495	4.110	2.18	2.76	4.16	2.63	1.67	2.13	4.90	14.10	19.52	1.46	55.0
	20	NHHTC290 @ 2100	23	HT-740	495	4.110	2.11	2.61	3.95	2.52	1.38	2.07	5.20	15.30	18.50	1.26	55.0
	74	NHHTC290 @ 2100	23	HT-740	495	4.110	1.92	2.24	3.41	2.25	1.29	1.87	6.00	18.70	16.14	0.84	55.0
	0	NHHTC290 @ 1900	23	HT-740	495	3.900	1.17	1.18	2.48	1.36	-	1.10	4.90	15.00	18.83	1.17	55.0
	0	NHHTC320 @ 1900	23	HT-740	499	4.330	2.09	2.70	4.04	2.54	1.53	2.05	4.10	13.10	21.47	2.29	55.0
	0	NHHTC320 @ 1900	23	HT-740	499	4.630	2.03	2.68	4.03	2.50	1.60	1.91	4.10	13.20	21.84	2.70	53.5
	0	NHHTC350 @ 2100	23	HT-740	495	4.800	1.94	2.63	3.89	2.41	1.77	2.06	4.00	11.80	23.74	3.02	55.0

\- Unable to operate on grades

Note: Circles indicate best results in each column. Reader should refer to the body of the report for cautions and assumptions pertaining to use of this data.

Source: Booz, Allen & Hamilton transit bus computer simulation.

Table 6-1. Baseline bus comparisons with no passengers.

Input to Computer Model								Fuel Economy						Performance				Max. Speed or Legal Limit	
	Manf.	Model	Eng.	A/C	Trans.	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear		Pass.
Non-Air-Conditioned	Flxible	870	6V-92TA 7G75	0	V-730	490	4.556	3.21	3.75	5.42	3.78	2.39	2.87	4.40	12.20	18.30	2.86	55.0	0
	Flyer	D901	6V-71N C55	0	V-730	470	5.375	4.00	3.89	5.23	4.24	2.35	3.83	6.90	23.20	12.75	1.54	48.8	0
	Gillig	Phantom	6V-92TA 7G65	0	HT-740	470	4.110	3.88	4.29	5.87	4.40	2.85	3.26	4.40	11.40	18.64	2.97	55.0	0
	GM-Canada[a]	5307N	6V-71N 7E50	0	V-730	470	5.375	4.16	4.30	4.97	4.38	2.72	3.94	5.60	18.70	15.80	2.30	53.2	0
	GMC	RTS	6V-92TA 7G70	0	V-730	470	5.375	3.01	4.00	4.98	3.66	2.11	2.84	4.40	13.20	19.21	3.52	53.5	0
	Neoplan	Atlantis	6V-92TA 7G65	0	V-730	470	5.125	3.48	4.08	5.78	4.10	2.63	3.24	4.20	12.20	19.49	2.99	55.0	0
	Neoplan	N412	6V-92TA 7G75	0	HT-740	495	4.629	3.98	4.21	5.75	4.41	3.08	3.29	3.70	9.90	23.51	3.86	55.0	0
	Neoplan	N421	6V-92TA 7G75	0	HT-740	495	5.220	2.89	3.26	4.47	3.32	2.46	2.97	4.60	14.30	19.65	3.00	48.2	0
	Crown-Ikarus	286	NHHTC290 @ 2100	0	HT-740	495	4.110	2.74	3.21	4.70	3.24	1.96	2.57	4.90	14.10	19.52	1.46	55.0	0
Air Conditioned	Flxible	870	6V-92TA 7G75	32.5	V-730	490	4.556	2.73	3.16	4.66	3.16	1.93	2.51	5.00	14.50	16.13	2.27	55.0	0
	Flyer	D901	6V-71N C55	24.8	V-730	470	5.375	3.06	2.87	5.23	3.35	2.01	-	8.70	30.60	10.49	0.96	43.4	0
	Gillig	Phantom	6V-92TA 7G65	16.8	HT-740	470	4.110	3.45	3.88	5.37	3.91	2.59	2.79	4.70	12.40	17.47	2.61	55.0	0
	GM-Canada[a]	5307A	8V-71N E50	25.0	V-730	490	5.375	2.54	3.21	3.82	2.94	1.93	2.66	6.40	19.80	12.94	2.22	52.5	0
	GMC	RTS	6V-92TA 7G70	25.0	V-730	470	5.375	2.57	3.48	4.39	3.12	1.90	2.58	4.90	15.30	17.33	3.01	53.5	0
	Neoplan	Atlantis	6V-92TA 7G65	30.0	V-730	470	5.125	2.94	3.42	4.92	3.40	2.07	2.83	4.90	14.60	17.13	2.36	55.0	0
	Neoplan	N412	6V-92TA 7G75	30.0	HT-740	495	4.629	3.22	3.57	6.53	3.79	2.44	2.81	4.20	11.30	20.85	0.27	42.9	0
	Neoplan	N421	6V-92TA 7G75	30.0	HT-740	495	5.220	2.42	2.78	3.88	2.78	1.93	2.49	5.30	16.60	17.40	2.49	48.2	0
	Crown-Ikarus	286	NHHTC290 @ 2100	23.0[b]	HT-740	495	4.110	2.18	2.76	4.16	2.63	1.67	2.13	4.90	14.10	19.52	1.46	55.0	0

a. Data not directly comparable since A/C available only with larger 8V-71 engine.

b. Separate engine.

Table 6-2. Baseline bus comparisons with 20 passengers.

	Input to Computer Model							Fuel Economy						Performance				Max. Speed	
	Manf	Model	Eng.	A/C	Trans	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	or Legal Limit	Pass.
Non-Air-Conditioned	Flxible	870	6V-92TA 7G75	0	V-730	490	4.556	3.06	3.47	5.11	3.57	2.10	2.73	4.80	13.60	16.88	2.44	55.0	20
	Flyer	D901	6V-71N C55	0	V-730	470	5.375	3.70	3.44	5.21	3.92	2.24	3.50	7.60	26.70	11.84	1.22	47.0	20
	Gillig	Phantom	6V-92TA 7G65	0	HT-740	470	4.110	3.63	3.97	5.51	4.11	2.63	2.92	4.80	12.80	17.22	2.49	55.0	20
	GM-Canada[a]	5307N	6V-71N 7E50	0	V-730	470	5.375	3.81	3.82	4.89	4.05	2.52	3.61	6.20	21.60	14.53	1.86	51.3	20
	GMC	RTS	6V-92TA 7G70	0	V-730	470	5.375	2.85	3.69	4.73	3.45	2.03	2.72	4.80	14.70	17.98	3.06	53.5	20
	Neoplan	Atlantis	6V-92TA 7G65	0	V-730	470	5.125	3.32	3.77	5.41	3.86	2.43	3.08	4.70	13.80	18.04	2.51	55.0	20
	Neoplan	N412	6V-92TA 7G75	0	HT-740	495	4.629	3.74	3.93	5.44	4.14	2.76	3.14	3.90	11.00	22.16	3.29	55.0	20
	Neoplan	N421	6V-92TA 7G75	0	HT-740	495	5.220	**2.79**	**3.06**	**4.30**	**3.18**	**2.25**	**2.76**	**4.90**	**15.60**	**18.79**	**2.69**	48.2	20
	Crown-Ikarus	286	NHHTC290 @ 2100	0	HT-740	495	4.110	**2.63**	**3.01**	**4.45**	**3.08**	**1.60**	**2.50**	5.20	15.30	18.50	1.26	55.0	20
Air Conditioned	Flxible	870	6V-92TA 7G75	32.5	V-730	490	4.556	2.59	2.93	4.37	2.98	1.79	2.39	5.50	16.20	14.88	1.91	55.0	20
	Flyer	D901	6V-71N C55	24.8	V-730	470	5.375	2.85	2.44	5.25	3.06	-[b]	-	9.60	35.50	9.75	0.70	41.4	20
	Gillig	Phantom	6V-92TA 7G65	16.8	HT-740	470	4.110	3.28	3.60	5.02	3.68	2.23	2.66	5.20	14.00	16.14	2.17	55.0	20
	GM-Canada[a]	5307A	8V-71N E50	25.0	V-730	490	5.375	2.41	2.89	3.77	2.77	1.77	2.48	7.10	22.70	11.97	1.82	50.9	20
	GMC	RTS	6V-92TA 7G70	25.0	V-730	470	5.375	2.46	3.22	4.16	2.96	1.69	2.45	5.30	17.00	16.23	2.59	53.5	20
	Neoplan	Atlantis	6V-92TA 7G65	30.0	V-730	470	5.125	2.79	3.16	4.57	3.19	1.96	2.70	5.30	16.50	15.86	1.95	55.0	20
	Neoplan	N412	6V-92TA 7G75	30.0	HT-740	495	4.629	3.08	3.34	6.23	3.60	2.25	2.51	4.40	12.60	19.68	0.08	42.9	20
	Neoplan	N421	6V-92TA 7G75	30.0	HT-740	495	5.220	**2.33**	**2.60**	**3.72**	**2.65**	**1.90**	**2.38**	**5.60**	**18.10**	**16.74**	**2.21**	48.2	20
	Crown-Ikarus	286	NHHTC290 @ 2100	23.0[c]	HT-740	495	4.110	2.11	2.61	3.95	2.52	1.38	2.07	5.20	15.30	18.50	1.26	55.0	20

a. Data not directly comparable since A/C available only with larger 8V-71 engine.

b. Unable to operate on grades.

c. Separate engine.

Table 6-3. Baseline bus comparisons with seated capacities.

	Input to Computer Model							Fuel Economy						Performance					
	Manf.	Model	Eng.	A/C	Trans	T.C.	RAR	CBD	ART	COM	ADB	J-4	Zoo	0-15 MPH	0-30 MPH	1st Gear	Top Gear	Top Speed	Pass.
Non-Air-Conditioned	Flxible	870	6V-92TA 7G75	0	V-730	490	4.556	2.88	3.13	4.69	3.30	1.91	2.53	5.40	15.70	15.16	1.96	55.0	49
	Flyer	D901	6V-71N C55	0	V-730	470	5.375	3.28	2.79	5.20	3.46	1.87	–[a]	8.80	32.70	10.67	0.85	44.0	51
	Gillig	Phantom	6V-92TA 7G65	0	HT-740	470	4.110	3.33	3.57	5.02	3.74	2.27	2.68	5.50	14.90	15.51	1.96	55.0	49
	GM-Canada[b]	5307N	6V-71N 7E50	0	V-730	470	5.375	3.34	3.14	4.79	3.57	2.05	3.10	7.30	27.00	12.85	1.33	48.2	53
	GMC	RTS	6V-92TA 7G70	0	V-730	470	5.375	2.68	3.32	4.40	3.20	1.75	2.55	5.30	16.80	16.59	2.55	53.5	47
	Neoplan	Atlantis	6V-92TA 7G65	0	V-730	470	5.125	3.17	3.46	5.03	3.62	2.07	2.92	5.10	15.60	16.67	2.09	55.0	42
	Neoplan	N412	6V-92TA 7G75	0	HT-740	495	4.629	3.51	3.64	5.12	3.88	2.52	2.94	4.20	12.20	20.80	2.79	55.0	42
	Neoplan	N421	6V-92TA 7G75	0	HT-740	495	5.220	2.61	2.71	3.97	2.92	1.98	2.54	5.50	18.20	17.42	2.18	48.2	59
	Crown-Ikarus	286	NHHTC290 @ 2100	0	HT-740	495	4.110	2.36	2.56	3.81	2.70	1.48	2.22	6.00	18.70	16.14	0.84	55.0	74
Air Conditioned	Flxible	870	6V-92TA 7G75	32.5	V-730	490	4.556	2.43	2.64	3.96	2.74	1.60	2.20	6.20	18.80	13.38	1.49	55.0	49
	Flyer	D901	6V-71N C55	24.8	V-730	470	5.375	2.57	2.15	5.33	2.80	-	-	11.20	44.80	8.80	0.41	38.1	51
	Gillig	Phantom	6V-92TA 7G65	16.8	HT-740	470	4.110	3.05	3.24	4.55	3.38	1.91	2.47	5.90	16.40	14.54	1.68	55.0	49
	GM-Canada[b]	5307A	8V-71N E50	25.0	V-730	490	5.375	2.21	2.42	3.70	2.52	1.52	-	8.20	28.00	10.62	1.33	48.3	53
	GMC	RTS	6V-92TA 7G70	25.0	V-730	470	5.375	2.33	2.89	3.83	2.75	1.69	2.30	5.90	19.50	14.99	2.13	53.4	47
	Neoplan	Atlantis	6V-92TA 7G65	30.0	V-730	470	5.125	2.65	2.90	4.16	2.98	1.75	2.53	5.90	18.80	14.68	1.58	55.0	42
	Neoplan	N412	6V-92TA 7G75	30.0	HT-740	495	4.629	2.95	3.11	5.93	3.42	1.99	2.45	4.80	14.00	18.51	+[c]	42.9	42
	Neoplan	N421	6V-92TA 7G75	30.0	HT-740	495	5.220	2.18	2.29	3.40	2.43	1.68	2.22	6.30	21.20	15.52	1.76	48.1	59
	Crown-Ikarus	286	NHHTC290 @ 2100	30.0[d]	HT-740	495	4.110	1.92	2.24	3.41	2.25	1.29	1.87	6.00	18.70	16.14	0.84	55.0	74

a. Unable to operate on grades.

b. Data not directly comparable since A/C available only with larger 8V-71 engine.

c. Separate engine.

d. Insufficient data at this time.

ATTACHMENT 7—COMPARISONS OF POSSIBLE BUS SELECTIONS

This attachment presents a series of charts (7A through 7H) that show fuel economy-oriented and performance-oriented power train configurations. The charts reduce all the supplied manufacturers' data that were run through the computer simulation to a small selection of optimum power trains. These configurations may not be available to you at this time and do not present the current best selection from the manufacturers. They only represent our selections from the data supplied at the time of the study.

These selections were made by choosing the most fuel-efficient or best-performing power trains from data run over the ADB cycle with no passengers aboard. The ADB route was selected for the comparison because it is the accepted average bus duty cycle. The no-passenger load condition was selected to keep the comparisons on an equal basis among manufacturers. The data should be used to make "gross" comparisons among the manufacturers' bus equipment.

The reader should refer to the body of the report for cautions and assumptions pertaining to the use of these data.

Chart 7A
Flxible 370 (ADB)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer
Fuel Economy Option = Selected from computer simulation results
Performance Option = Selected from computer simulation results
Data = Computer simulation results (not based on actual test and operational data)

Versions	Description	Fuel Econ.	Performance				
		Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	Max. Speed or Legal Limit
Baseline	Eng. 6V-92TA Inj. 7G75 Trans. V-730 T.C. 490 RAR 4.556	3.78	4.4	12.2	18.3	2.9	55
Fuel Economy Option	Eng. 6V-71N Inj. 7E60 Trans. V-730 T.C. 490 RAR 5.857	3.94	6.3	20.5	13.8	2.4	49
Performance Option	Eng. 6V-92TA Inj. 7G75 Trans. V-730 T.C. 490 RAR 5.857	3.85	4.1	12.1	20.3	4.6	49

Chart 7B
Flyer-D901 (New Look)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer

Fuel Economy Option = Selected from computer simulation results

Performance Option = Selected from computer simulation results

Data = Computer simulation results (not based on actual test and operational data)

		Fuel Econ.	Performance				
Versions	Description	Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	Max. Speed or Legal Limit
Baseline	**Eng.** 6V-71N **Inj.** C55 **Trans.** V-730 **T.C.** 470 **RAR** 5.375	4.24	6.9	23.2	12.8	1.5	49
Fuel Economy Option	**Eng.** 6V-71N **Inj.** C55 **Trans.** V-730 **T.C.** 470 **RAR** 5.125	4.31	6.9	23.4	12.6	1.3	49
Performance Option	**Eng.** 6V-92TA **Inj.** 7G65 **Trans.** V-730 **T.C.** 470 **RAR** 5.375	4.02	4.1	12.3	20.1	3.8	54

Chart 7C
Gillig-Phantom (ADB/New Look)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer
Fuel Economy Option = Selected from computer simulation results
Performance Option = Selected from computer simulation results
Data = Computer simulation results (not based on actual test and operational data)

		Fuel Econ.	Performance				
Versions	Description	Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	Max. Speed or Legal Limit
Baseline	Eng. 6V-92TA Inj. 7G65 Trans. HT-740 T.C. 470 RAR 4.11	4.40	4.4	11.4	18.6	3.0	55
Fuel Economy Option	Eng. 6V-92TA Inj. 7G65 Trans. HT-740 T.C. 470 RAR 4.11	4.40	4.4	11.4	18.6	3.0	55
Performance Option	Eng. 6V-92TA Inj. 7G65 Trans. HT-740 T.C. 470 RAR 5.86	3.96	4.1	10.9	19.9	5.6	42

Chart 7D
GM of Canada 5307 (New Look)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer

Fuel Economy Option = Selected from computer simulation results

Performance Option = Selected from computer simulation results

Data = Computer simulation results (not based on actual test and operational data)

		Fuel Econ.	Performance				
Versions	**Description**	Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	Max. Speed or Legal Limit
Baseline	**Eng.** 6V-71N **Inj.** 7E50 **Trans.** V-730 **T.C.** 470 **RAR** 5.375	4.38	5.6	18.7	15.8	2.3	53
Fuel Economy Option	**Eng.** 6V-71N **Inj.** 7E50 **Trans.** V-730 **T.C.** 470 **RAR** 5.857	4.66	5.6	18.5	16.1	2.8	49
Performance Option	**Eng.** 6V-92TA **Inj.** 7G65 **Trans.** V-730 **T.C.** 470 **RAR** 5.375	4.14	4.0	11.7	20.2	4.2	54

Chart 7E
GMC RTS (ADB)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer

Fuel Economy Option = Selected from computer simulation results

Performance Option = Selected from computer simulation results

Data = Computer simulation results (not based on actual test and operational data)

Versions	Description	Fuel Econ.	Performance				Max. Speed or Legal Limit
		Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	
Baseline	**Eng.** 6V-92TA **Inj.** 7G70 **Trans.** V-730 **T.C.** 470 **RAR** 5.375	3.66	4.4	13.2	19.2	3.5	54
Fuel Economy Option	**Eng.** 6V-71N **Inj.** 7E60 **Trans.** V-730 **T.C.** 470 **RAR** 5.857	3.88	6.4	20.9	13.7	2.3	49
Performance Option	**Eng.** 6V-92TA **Inj.** 7G70 **Trans.** V-730 **T.C.** 470 **RAR** 5.857	3.77	4.3	13.1	19.6	4.1	49

Chart 7F
Neoplan-Atlantic (New Look) and
N412 (ADB)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer

Fuel Economy Option = Selected from computer simulation results

Performance Option = Selected from computer simulation results

Data = Computer simulation results (not based on actual test and operational data)

Versions	Description	Fuel Econ.	Performance				
		Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	Max. Speed or Legal Limit
Baseline Atlantis (New Look)	**Eng.** 6V-92TA **Inj.** 7G65 **Trans.** V-730 **T.C.** 470 **RAR** 5.125	4.10	4.2	12.2	19.5	3.0	55
Baseline N412 (ADB)	**Eng.** 6V-92TA **Inj.** 7G65 **Trans.** HT-740 **T.C.** 495 **RAR** 4.629	4.41	3.7	9.9	23.5	3.9	55

Chart 7G
Neoplan N421 (Articulated)

KEY:

Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:

Baseline Version = As defined by the manufacturer
Fuel Economy Option = Selected from computer simulation results
Performance Option = Selected from computer simulation results
Data = Computer simulation results (not based on actual test and operational data)

		Fuel Econ.	Performance				
Versions	Description	Miles/Gal (ADB cycle)	0-15 mph (sec)	0-30 mph (sec)	1st Gear (% grade)	Top Gear (% grade)	Max. Speed or Legal Limit
Baseline	Eng. 6V-92TA Inj. 7G75 Trans. HT-740 T.C. 495 RAR 5.22	3.32	4.6	14.3	19.7	3.0	48.2
Fuel Economy Option	Eng. 6V-92TA Inj. 7G75 Trans. HT-740 T.C. 495 RAR 4.639	3.37	4.7	14.6	19.4	2.3	54
Performance Option	Eng. 6V-92TA Inj. 7G75 Trans. HT-740 T.C. 495 RAR 5.94	3.05	4.5	14.0	19.5	3.8	42

Chart 7H
Crown-Ikarus 286 (Articulated)

KEY:
Eng. = Engine
Inj. = Injectors
Trans. = Transmission
T.C. = Torque Converter
RAR = Rear Axle Ratio

NOTE:
Baseline Version = As defined by the manufacturer
Fuel Economy Option = Selected from computer simulation results
Performance Option = Selected from computer simulation results
Data = Computer simulation results (not based on actual test and operational data)

		Fuel Econ.	Performance				
Versions	**Description**	**Miles/Gal** (ADB cycle)	**0-15 mph (sec)**	**0-30 mph (sec)**	**1st Gear (% grade)**	**Top Gear (% grade)**	Max. Speed or Legal Limit
Baseline	**Eng.** NHHTC-290 @ 2100RPM **Inj.** **Trans.** HT-740 **T.C.** 495 **RAR** 4.11	3.24	4.9	14.1	19.5	1.5	55
Fuel Economy Option	**Eng.** NHHTC-290 @ 2100 RPM **Inj.** **Trans.** HT-740 **T.C.** 495 **RAR** 4.11	3.24	4.9	14.1	19.5	1.5	55
Performance Option	**Eng.** NHHTC-350 @ 2100RPM **Inj.** **Trans.** HT-740 **T.C.** 495 **RAR** 4.8	2.90	4.0	11.8	23.7	3.0	55

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