State of Washington
Joint Legislative Audit and
Review Committee

# K-12 TRANSIT-STYLE SCHOOL BUS STUDY

## Report 96-3

September 18, 1996

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## Appendices

# K-12 TRANSIT-STYLE SCHOOL BUS STUDY

## Summary

Background

During the 1996 Legislative Session, the legislature mandated a study of transit-style school buses. The purpose of this study is to provide information to the legislature and the Office of the Superintendent of Public Instruction (OSPI) to assist in determining whether engine location should be a separate category in the competitive quote process used for purchasing and depreciating transit-style school buses. Under a new law passed in 1995, school districts may purchase buses directly from the dealer with the lowest bid at the quoted price. The state, in turn, uses the low bid in the depreciation formula by which districts are provided funds to replace their buses when they reach the end of their useful lives.

Are rear engine buses less expensive to own and operate?

What about performance?

## THE ISSUE

In the one bid process that has taken place under the new law, front engine buses won the low bids for the three size categories of transit-style buses. Some school districts have argued that rear engine buses cost more to purchase, but that long-term operating savings, and/or performance and safety advantages, justify the higher initial cost. They have advocated for the creation of a separate category for rear engine transit-style buses.

## STUDY CONCLUSIONS

*From a life-cycle cost perspective, the results of this study do not support adding engine location as a separate price quote category for transit-style buses.*

No generic answer to which bus is less expensive to purchase

Rear engine buses are not necessarily more expensive. When, however, school districts do pay more for a rear engine bus, there is no assurance that ongoing operating savings will necessarily occur, or if they do occur, that they will be sufficient to offset the higher initial cost. As the analysis in this study shows, life-cycle operating costs are strongly influenced by the conditions under which a bus is operated, how it is designed and equipped, its purchase price, and its useful life. What this suggests is that there is no generic answer to the question concerning which type of bus is less expensive to own and operate. Furthermore, if there are life-cycle savings to be achieved from purchasing a more expensive bus, the creation of a separate category is not required in order for a school district to realize such savings.

*We found no empirical analyses that addressed the issue of performance or differences in safety between front and rear engine transit-style buses.*

No agreed upon criteria for weighing performance differences

Furthermore, while engine location does produce characteristics that can affect performance and safety under certain conditions, we did not find any standards or agreed upon criteria for weighing relative advantages and disadvantages. If individual performance characteristics were deemed to be desirable enough that they should outweigh cost considerations, it may be possible to incorporate them into the state's bus specifications rather than address them by creating a separate category for engine location. In some cases, however, changes in specifications that might be desirable for some school districts, even if they were cost justified, may not apply to all districts. It should be noted that school districts have the prerogative of specifying additional equipment or features.

## ACKNOWLEDGMENTS

We appreciate the assistance provided by the Office of the Superintendent of Public Instruction and the many individuals we contacted from within the public and private sectors.

This study was conducted by JLARC staff member Martin Chaw. The project supervisor was Bob Thomas, who also participated in the analysis. Technical assistance was provided by the project consultant, Jim Wilkins of Wilkins and Associates.

Cheryle A. Broom
Legislative Auditor

*On September 18, 1996, this report was approved by the Joint Legislative Audit and Review Committee and its distribution authorized.*

Senator Al Bauer, Chair

# BACKGROUND AND INTRODUCTION

## Chapter One

### Overview

This study, mandated in the 1996 Supplemental Operating Budget, examines the comparative costs and advantages of identically equipped front and rear engine transit-style school buses.[1] The purpose of the study is to provide information to the legislature and the Office of the Superintendent of Public Instruction (OSPI) to assist in determining whether engine location should be a separate category in the competitive quote process established by Chapter 10, Laws of 1995.

### OSPI establishes minimum bus specifications and solicits competitive bids

Under this law, the Superintendent of Public Instruction, in consultation with the regional transportation coordinators, establishes bus specifications and the categories of buses for which OSPI will solicit competitive bids. The law requires that the categories be developed so as to produce minimum long-range operating costs. The low bids for each category are used two ways:

- School districts may purchase buses directly from the dealer with the lowest bid at the price quoted; and

- The low bid price is used in the depreciation formula by which school districts are provided funds to replace their buses when they reach the end of their useful lives.[2] Prior to 1995, the state's depreciation formula had been based on the average prices paid by school districts the previous year for each category of bus.

[1] The scope and objectives of this study are included in Appendix 1. Appendix 2 contains the text of the proviso that mandated this study.

[2] The low bid amount also is used in calculating the depreciation payment for contractor-owned school buses. See WAC 392-142-245.

Under the law that came into effect in 1995, school districts may purchase buses from other dealers and at different prices. However, the state's payments for depreciation will be based on the low bid it has received for each category.

Among the current 14 categories of buses, transit-style buses comprise the three categories having the largest seating capacities.[3] In 1995, the first year of the bid process described above, front engine buses won the low bids for all three transit-style categories.[4] No bids for rear engine buses were received for two of the three categories.

In the mandate for this study, JLARC was asked to answer two general questions about identically equipped front and rear engine transit-style buses of the same model year and seating capacities:

## Mandated study questions

1. Are there documented savings in operating costs from either type of bus?

2. Is there a definitive advantage in either type of bus in performance for transporting students to and from school?

Related questions that could be of interest to decision-makers would address such issues as: the degree of savings; the relative importance of performance advantages; and the conditions under which savings and better performance occur.

Below, we have outlined criteria for the creation of a separate category for engine location. The discussion will focus on rear engine buses. Some school districts have argued that rear engine buses cost more to purchase, but that long-term operating savings and/or performance advantages justify the higher initial cost. In the event that rear engine buses do have higher purchase prices, the creation of a separate category for engine location would result in the state paying more in depreciation to replace those buses when they reach the end of their useful lives.

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[3] Type D, Diesel, with seating capacities of 61-84, 78-84 and 85-90.
[4] $58,549 for 61-77 passenger, $61,024 for 78-84 passenger, and $65,793 for 85-90 passenger. These figures exclude sales tax.

# CRITERIA CONCERNING OWNING AND OPERATING COSTS

If a rear engine bus has lower operating costs than an identically equipped front engine bus, this would support creating a separate engine location category provided:

- Rear engine buses are more expensive to purchase;
- By purchasing a rear engine bus, a school district's total life-cycle ownership costs would be reduced. That is, the present value operational savings over the useful life of the vehicle would outweigh its higher purchase price; and
- The creation of a separate rear engine category would be necessary to achieve the lower life-cycle ownership costs.

Consideration should also be given to whether the lower life-cycle ownership costs would occur for all or only some of the school districts. Geography, weather, road conditions, and other factors can affect operating cost. A type of bus that is less expensive to operate under some conditions (e.g., hilly terrain, cold winters) may not have the same cost advantage under other conditions (e.g., flat terrain, moderate winters).

An additional issue for decision-makers has to do with who would benefit and who would pay. Currently, there are two formulas used for state funding of pupil transportation. One is the depreciation formula, described above, that provides funds for the replacement of buses. The other formula is designed to cover operating costs. If the state were to create a category for engine location that would result in an increase in its depreciation payments, there is no mechanism under the present law for the state to share in any potential operating savings.

# CRITERIA CONCERNING PERFORMANCE

If a rear engine bus has definitive advantages in performance (including safety), this would support creating a separate rear engine category provided:

- The performance advantages outweigh any additional life-cycle ownership costs;

- The disadvantages of front engine buses cannot be addressed by adding features or equipment. If, however, this can be done, a separate life-cycle cost analysis would need to be performed comparing the two alternatives; and

- The creation of a separate rear engine category would be necessary to achieve the lower life-cycle ownership costs. If there are definitive performance advantages that would outweigh additional costs, it may be possible to incorporate them into the state's bus specifications rather than address them by creating a separate rear engine category.

Consideration should also be given to the operating conditions under which the definitive advantages might exist.

## HOW THIS REPORT IS ORGANIZED

Based upon the above criteria, the following two sections of this report address the issues about the life-cycle costs and performance of front and rear engine buses in a question-and-answer format. The conclusions of the study are summarized in the last section.

# LIFE-CYCLE COSTS

## Chapter Two

***Do front engine transit-style buses cost more to purchase than identically equipped rear engine buses?***

There is no general answer to this question. Identically equipped rear engine buses usually cost from $2,000 to $3,000 more to manufacture (see Appendix 3). However, higher manufacturing costs do not necessarily translate into higher purchase prices. Many factors can influence the price at which buses are sold. These include competitive factors such as profit margins, cash flows and marketing strategies.

Competitive factors and purchasing practices can influence prices

Local decisions, such as purchasing practices, can also make a difference. As an example, in 1995 the state of South Carolina received a winning bid for 72-passenger, rear engine transit-style buses at a cost of $51,307 per bus, excluding sales tax. The next lowest bid was only $200 more. For Fiscal Year 1995-96, Washington's low bid for a 78-passenger transit-style bus was $58,549, excluding sales tax. This was for a front engine bus. After the South Carolina figure is adjusted for inflation, adding seats, and reflecting what shipping costs would be for Washington, the resulting, comparable figure in 1996 dollars would be $54,887, or about $3,700 less than Washington's low bid.

We obtained two expert's reviews of each state's specifications for these buses. One was conducted by the Washington State Patrol Commercial Vehicle Enforcement Section, and the other by a technical consultant hired to assist in this study. The conclusion of both reviews was that South Carolina's specifications meet, and in most cases exceed, Washington's minimum specifications for this type of school bus (see Appendix 4).

The relatively low price for the quality of bus obtained by South Carolina was achieved by large volume, centralized purchasing, and the issuance of very detailed bus specifications. In 1995, that state ordered 2,000 buses, 1,800 of which were identical transit-style buses. In contrast, school districts in Washington purchase only about 450 buses of all types each year,[1] and these purchases are not combined within one order. According to the technical consultant for this study, a purchaser would likely have to order at least 1,000 identical buses to duplicate the discount received by South Carolina. Alternatively, a purchaser might try to participate in the bid of a large volume purchaser, such as South Carolina which has plans to purchase another 3,800 buses in the next few years. This would require, however, that specifications be identical, that the size of the order be known, and that the large volume purchaser be willing to cooperate.

***Is there information from school districts, other states, or national organizations that documents savings in operating costs of rear engine buses when compared to identically equipped front engine buses of the same model year operating under the same conditions?***

No other studies or information on operating costs available

No. This study attempted to answer this question through a survey of organizations and individuals who might be expected to know of research on this subject, and through a search of published literature. Our list of contacts, and the questions we asked are included in Appendix 5. We found no published studies that documented savings. We received some information from operators, but it did not apply to buses meeting the criteria of having identical equipment, being of the same model year, and operating under the same conditions.

Several respondents suggested that we contact the state of South Carolina. From 1990 to 1993 this state conducted an analysis of the comparative costs and performance advantages of front and rear engine transit-style buses. Five buses of each type were purchased for the study. The results of this analysis may have contributed to South Carolina's decision to purchase its large order of rear engine buses in 1995. Unfortunately the Department of Education in that

[1] Source: OSPI, "*Report on the Evaluation of the Current and Alternative Methods of Purchasing School Buses*," 1993.

state did not keep a record of either the study's methodology or the data used. Therefore, we were unable to reach an independent conclusion about the results of this analysis.

***Is there other information that can be used to estimate the life-cycle cost differences between front and rear engine buses?***

This study compared two identically equipped front and rear engine buses

Yes. A dealer for Blue Bird buses provided bids to the King County Directors' Association in 1996 for identically equipped,[2] 72-passenger front and rear engine buses. The base costs of these buses, including sales tax, were $71,159 and $74,577, respectively.[3] We asked this study's technical consultant to estimate the costs of operating[4] and maintaining these buses under two scenarios for operating conditions. These scenarios assumed different weather, road conditions and terrain, as can be found in this state. The scenarios were provided by OSPI, and were designed to be representative of two general sets of conditions under which the majority of Washington school districts operate. Scenario 1 assumed relatively shorter annual mileage, better roads, and more moderate weather than Scenario 2. In general terms, Scenario 1 can be described as urban, and Scenario 2 as rural. Both scenarios are described in more detail in Appendix 6.

The consultant estimated costs by using manufacturer's maintenance and replacement schedules, market-based parts prices, and operators' cost experiences with maintenance hours and fuel consumption. A description of the methodology and sources used by the consultant is included in Appendix 7.

We were able to use this information to conduct a life-cycle cost analysis.[5] This kind of analysis looks at all costs of the bus alternatives over their useful lives. These costs include the initial

[2] They are identically equipped in all items except those that are related strictly to engine location, such as rear axle capacity and emergency exit location.
[3] During the 1995-96 school year, the King County Director's Association, a buying consortium representing 288 of the 296 school districts in the State, received bids for a 72-passenger capacity bus with prices, including sales tax, ranging from $71,159 to $74,577 for a front engine and rear engine transit-style school bus, respectively.
[4] We did not ask the consultant to include costs, such as drivers' wages, that would be the same for both buses.
[5] A description of the life cycle cost model is included in Appendix 8.

purchase price as well as on-going operating costs. Since these costs occur at different times, a discount rate is used to express future expenditures as present values.

***What were the results of the life-cycle cost analysis?***

The results of the analysis were strongly influenced by the conditions under which the buses were assumed to operate. They were also strongly influenced by the characteristics of the particular buses being compared.

Both buses have cost advantages and disadvantages

Under the two scenarios, both buses have operating cost advantages and disadvantages. For instance, both buses have the same engine, but the front engine bus weighs less, which contributes to its having better fuel efficiency. This advantage of the front engine bus is more than offset by its having higher parts and labor costs. As an example, because its engine is located farther from the rear axle, the front engine bus has more universal joints that must be replaced more often.

Below we discuss outcomes of the analysis for each scenario. The figures shown are estimated annualized present values. They represent the 1996 annualized costs that would increase by inflation each year. More detailed breakdowns of the annualized owning and operating costs of each scenario are included in Appendix 9.

**Scenario 1 – Urban (Good roads, shorter mileage)**

Under the urban operating conditions, the rear engine bus is estimated to have a very slight advantage in operating costs of $57 per year. Over a useful life of 15 years, this is not enough in annual operating savings to outweigh the higher purchase price of the bus, which was $3,418 more than the front engine bus. On an annualized basis the costs of the buses compare as follows:

Scenario 1 Life-Cycle Cost Analysis (1996$$)

| | Front Engine | Rear Engine | FE / RE |
|---|---|---|---|
| Annualized PV | $14,005 | $14,284 | 98% |

### Scenario 2 – Rural (Poorer roads, longer mileage)

The results of the analysis under rural conditions will favor either the front engine or the rear engine bus depending on the assumptions used about useful lives. Assumptions about useful life are very important in the life-cycle analysis because, if a less expensive bus has to be replaced more frequently, it can end up costing more in the long run.

The consultant for this study estimates that ***this particular*** front engine bus will have a shorter maximum useful life (12 years) compared to the rear engine bus (15 years). This is due to a stronger body design for the rear engine bus (see the consultant's discussion in Appendix 7). If another set of buses had been compared, the front engine bus may have been estimated to have the same expected life. Staff from OSPI, who provided technical reviews of this study, were skeptical that there would be such a difference in useful lives. They pointed out that they have not seen evidence of shorter lives for front engine buses in rural settings in this state.

In recognition of the fact that there will be differences of opinion about useful life under scenario 2, and in order to illustrate the importance of the useful life assumption, we have chosen to display the range of results that comes from using different assumptions.

Scenario 2 Life-Cycle Cost Analyses (1996 $$)

| | Front Engine **12 year Life** | Rear Engine **15 year life** | FE / RE |
|---|---|---|---|
| Annualized PV | $16,025 | $15,066 | 106% |

| | Front Engine **15 year Life** | Rear Engine **15 year life** | FE / RE |
|---|---|---|---|
| Annualized PV | $14,754 | $15,066 | 98% |

***What does this analysis say in general about the comparative life-cycle costs of front versus rear engine buses?***

No generic answer about costs

What this analysis suggests is that there is no generic answer to the question concerning which type of bus is less expensive to own and operate. As the two scenarios indicate, much depends on the conditions under which the buses will operate, how they are designed and equipped, their purchase prices, and their useful lives. It should also be noted that the conditions under which buses operate may not remain static over more than a decade of use. Road conditions can improve or deteriorate over time, and school districts may not operate their buses over the same routes over their entire useful lives.

Operating savings will not likely offset higher purchase cost

***What other conclusions can be drawn from the life-cycle cost analysis?***

For identically equipped front and rear engine buses, operating savings related strictly to engine location will not likely offset more than marginally higher purchase prices. This is because most operating costs will be similar or the same for both vehicles.[6]

***If a rear engine bus were less expensive to operate, would the creation of a separate rear engine category be required in order to reduce total life-cycle costs?***

Separate category not needed to capture savings

No. Currently a school district may pay more than the low bid amount for any bus in order to achieve savings on the operating side. If the life-cycle costs of this alternative are actually lower than for purchasing the state's low bid bus, the operational savings can be applied toward the (potential) additional cost of replacing the more expensive bus. This is true regardless of whether the more expensive bus is rear engine or front engine.

Here is an example of what might happen. The state's low bid bus has a purchase price of $66,000. The paint on this bus is of a quality that may require repainting after eight years at a present value of $2,400. For a bus with an expected life of 15 years, this would be a necessary expenditure. A school district could decide to specify a higher grade paint that would last 15 years, thereby raising the initial bus purchase price by $1,500. In this example, the district would have enough money to replace the more expensive bus and still have $900 left over. It would keep the $900 because, under present law, there is no mechanism by which the state would share in operating savings. The state's allocation for district operating costs would not go down.

[6] See Appendix 9.

# PERFORMANCE

## Chapter Three

***Is there information from school districts, other states, or national organizations that show definitive performance advantages, including better safety, of rear engine buses when compared to identically equipped front engine buses of the same model year operating under the same conditions?***

No other studies or information on performance

No. This study attempted to answer this question through a survey of organizations and individuals who might be expected to know of research on this subject, and through a search of published literature. Our list of contacts, and the questions we asked, are included in Appendix 5. We found no published, empirical analyses of this issue. We did, however, receive comments from many individuals expressing their opinions about the relative merits of front and rear engine buses. We compiled a list of these opinions and submitted them to our technical consultant in the form of questions that might be answered from an engineering point of view. The questions are listed and the answers are summarized in Appendix 10.

The difficulty of comparing performance can be illustrated with some examples.

- The rear engine bus will have less "tail swing" than a front engine bus because its axles are located farther apart. While this may be an advantage in some situations, it can also be a disadvantage because this axle configuration results in a greater turning radius. (The importance that a school district might place on this performance characteristic could depend on the operating conditions existing in the district — for example, congested city streets versus country roads.)

- In a front engine bus, the location of an emergency exit door at the rear may afford the driver better visibility of the area behind the bus. However, in the event of a rear-end collision, the glass in this door could shatter. Rear engine buses do not have a door at the same location.

The information contained in Appendix 10 may assist individuals to reach their own conclusions about the comparative performance of front and rear engine buses. We have not found any standards or agreed-upon criteria for saying how these performance differences should be weighed, or for determining how performance advantages, if shown to be definitive, should be compared to any additional life-cycle costs.

Also, it should be noted that if it can be determined that there are definitive performance advantages that would outweigh cost considerations, it may be possible to incorporate them into the state's bus specifications rather than address them by creating a separate category for engine location.

Disadvantages can be offset by adding equipment

. . . but at a cost

***Can disadvantages of one type of bus be addressed by adding features or equipment?***

Yes, sometimes. For example, front and rear engine buses both have more weight over the rear axle than the front axle. Since the rear axle is the drive axle, this helps with traction. However, the rear engine buses have relatively more weight distributed to the rear axle, with the result that they have somewhat better traction. This can be an advantage under certain conditions, such as icy roads. In this instance, the rear engine bus may have the advantage.

Nevertheless, the front engine bus (and the rear engine bus also) can be equipped with an automatic sanding device at an additional cost. Use of this device might mitigate or overcome the disadvantage of having less weight over the rear axle. The additional cost of this device would have to be included in the life-cycle cost analysis of the alternatives. As previously discussed, if the results of the analysis were to show life-cycle cost savings with the rear engine bus, the creation of a separate category would not be necessary in order for a school district to capture these savings.

***Can cost and performance issues be addressed at the same time by changing specifications?***

This may also be possible. According to this study's technical consultant, both the front and the rear engine buses used in our life cycle cost analysis would be only marginally powered for mountainous applications.[1] They are identically equipped with 210 horsepower engines, whereas a minimum 250 horsepower engine would be desirable. At steep grades, the 210 horsepower engine would result in very sluggish ascents. Both buses would also experience poor fuel efficiency, with the situation being worse for the rear engine bus because of its additional weight.

While the purchase of a bus with a higher horsepower engine would add to the initial cost of a bus, under the mountainous conditions used in this illustration the long term operating savings from better fuel mileage might mitigate or outweigh this additional initial cost. This could be true for both buses, but with even more of an advantage for the rear engine bus. At the same time, both buses would see improvements in performance.

In this case, a change in specifications might be appropriate for an individual school district. Since the same operating conditions do not apply to all districts, a change in state-wide specifications might not be appropriate.

[1] See the discussion in Appendix 7.

# CONCLUSIONS

## Chapter Four

From a life-cycle cost perspective, the results of the study do not support adding engine location as a separate price quote category for transit-style buses. Rear engine buses are not necessarily more expensive. When, however, school districts do pay more for a rear engine bus, there is no general assurance that ongoing operating savings will necessarily occur, or if they do occur, that they will be sufficient to offset the higher initial cost. As our analysis has shown, life-cycle operating costs are strongly influenced by the conditions under which a bus is operated, how it is designed and equipped, its purchase price, and its useful life. Furthermore, if there are life-cycle savings to be achieved from purchasing a more expensive bus, the creation of a separate category is not required in order for a school district to realize such savings.

Creation of a separate category not supported by our analysis

Neither the responses to our survey nor our search of published studies revealed any empirical analyses that addressed the issue of performance or differences in safety between front and rear engine transit-style buses. While engine location does produce characteristics that can affect performance and safety under certain conditions, we did not find any standards or agreed upon criteria for weighing relative advantages and disadvantages. If individual performance characteristics were deemed to be desirable enough that they should outweigh cost considerations, it may be possible to incorporate them into the state's bus specifications rather than address them by creating a separate category for engine location. In some cases, however, changes in specifications that might be desirable for some school districts, even if they were cost justified, may not apply to all districts.

# SCOPE AND OBJECTIVES

## Appendix 1

### *SCOPE*

This mandated study will examine the costs and advantages of owning and operating front and rear engine transit-style school buses.

### *OBJECTIVES*

Provide information to the legislature and the Office of the Superintendent of Public Instruction (OSPI) to assist in determining whether engine location should be a separate category in the competitive price quote process under RCW 28A.160.195.

#### *Task 1*

Determine if studies have demonstrated that either front or rear engine transit buses, that meet the same specifications and are similarly equipped, result in lower ownership costs over the life of the vehicle.

If studies are not available or not conclusive, determine if data are available that would permit a comparative life cycle cost analysis of front end and rear end transit style bus alternatives; and conduct a comparative analysis if possible within the time constraints of the study.

#### *Task 2*

Determine if studies have demonstrated that either front or rear engine transit buses, that meet the same specifications and are similarly equipped, are superior in terms of safety, capabilities, and/or other qualitative factors.

If studies are not available or not conclusive, determine if data are available that would permit a comparative qualitative analysis of front end and rear end transit style bus alternatives if possible within the time constraints of the study.

### *Task 3*

Determine whether the existing categories for transit-style buses fulfill the legislature's intent, as specified in RCW 28A.160.200(1), of producing minimum long-range operating costs, including costs of equipment and all costs in operating the vehicles.

If the existing categories do not fulfill the legislature's intent of producing minimum long-range operating costs, determine what modifications would be necessary to achieve this intent.

# STUDY MANDATE (C283, L96, SEC. 103 (6))

## Appendix 2

**STUDY MANDATE**
**(C283, L96, Sec. 103 (6))**

$10,000 is provided for a study to determine if a category for rear engine transit-style school buses should be added to the competitive price quote process under RCW 28A.160.195. The study shall compare identically equipped front engine and rear engine transit-style school buses of the same model year and the same capacity to determine if there is a definitive advantage in either type of bus in performance for transporting students to and from school and if there are documented savings in operating costs. The study shall include information from other states and national data regarding the use of front engine and rear engine transit-style school buses. The study shall also include information from private contractors' fleets as well as publicly owned and operated fleets. In addition, the study shall identify the cost differences, as provided by the manufacturer of the school buses, of identically equipped front engine and rear engine transit-style school buses of the same capacity. The study shall be submitted to the fiscal committees of the legislature and the superintendent of public instruction by August 1, 1996.

# MANUFACTURING COST DIFFERENCES ESTIMATED BY CONSULTANT[1]

## Appendix 3

The specifications for the buses used in support of the state of Washington Transit Style School Buses study were provided by the King County Directors' Association and meet the state of Washington minimum school bus specification requirements.

Bids were received for these buses on January 12, 1996. The front engine bus was bid at $71,159 and $74,577 for the rear engine bus. Both figures include sales tax at 8.2 percent. The price difference between the two buses is $3,418 including sales tax. With the sales tax deleted, the cost difference is $3,158.

From a specification point of view, these two particular Blue Bird buses are very similar in design and construction. Two of the major power train components, the engine and automatic transmission, are identical in both buses. The front axle is also the same size on both buses, but the rear axle size on the front engine bus is rated at 19,000 pounds capacity while the rear axle size on the rear engine bus is rated at 21,000 pounds capacity. The front and rear brake sizes are also the same on both buses, as well as the front and rear tire and wheel sizes.

The size of the frame rails are the same on both buses and the type of cross-members used are also the same. Both buses have a single 65 gallon size fuel tank. The chassis front and rear suspension systems, if not identical, are very similar in design on both buses.

There are some differences in the design and construction of the two vehicles. The front engine bus has a much longer length multiple piece drive line and U-joint system. This adds to the manufacturing cost of this type vehicle. On the front engine bus, the entire power steering system is located in the very front part of the chassis. On the rear engine bus, the pump and reservoir for the power steering hydraulic oil are located in the rear of the bus in the engine area. However, the power gear must be located up front close to the steer axle. This requires running two full length high pressure hydraulic hoses or lines from the rear to the front of the chassis to supply oil to the power gear. This adds to the manufacturing costs of the rear engine bus.

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[1] Jim Wilkins of Wilkins and Associates. See page 18 for a statement of the consultant's qualifications.

The radiator in the rear engine bus is larger in order to cool higher horsepower engines. Also, on the rear engine bus, the fan drive is hydraulically driven with a system design that is shared with the power steering system. Therefore, the cooling system on the rear engine bus is more expensive to manufacture than that used on the front engine bus.

The bodies on these two buses are identical in passenger capacity rating and each is equipped with three heater cores of identical BTU output ratings. However, while the bodies are similar in appearance they are actually quite different in construction design.

The body of an industry Type D forward control transit body style bus is similar in design to that of an industry Type C conventional body in terms of emergency door placements. There is an emergency door on the left side of the body in the center and a second emergency door located in the rear of the body at the end of the center aisle.

On a rear engine bus, the rear of the body has to be designed to accommodate the engine compartment. This requires relocating the emergency exit, additional structural reinforcing of the body and considerable insulation to keep the engine heat and noise out of the passenger area. All of this adds to the manufacturing cost of the rear engine body.

In terms of dollars between these two Blue Bird bus products, estimated manufacturing cost differences are as follows:

| | |
|---|---|
| 19,000 lb. versus 21,000 lb. Rear Axle: | $ 400. more for rear engine. |
| 19,000 lb. versus 21,000 lb. Rear Suspension: | $ 50. more for rear engine. |
| Radiator water core size: | $ 110. more for rear engine. |
| Fan drive system: | $ 440. more for rear engine. |
| Longer Power Steering hoses: | $ 370. more for rear engine. |
| Rear engine electrical control service box: | $ 385. more for rear engine. |
| Body design and construction: | $ 830. more for rear engine. |
| Total: | $2,585. |
| | |
| Drivelines/U-joints, Front versus Rear Engine: | $ 310. more for front engine |
| Total Difference, Front versus Rear Engine: | $2,275. more for rear engine. |

It should be emphasized that the above dollars represent only differences in product engineering design and manufacturing. The $3,158 cost difference in the King County Director's Association bid is typical of identically equipped buses such as these. Where the remainder of the dollars are as compared to the above estimate are probably in sales and marketing and possibly some slight additional profit margin in the rear engine coach.

## About the Consultant

Mr. Jim Wilkins is a 1970 graduate of California State Polytechnic University in San Luis Obispo, California. His work experience includes several positions with major Original Equipment Manufacturers (OEM) that produce products for the Bus, Fire Apparatus, and Public Works industries. This experience includes engineering, engineering management, project design, and product sales management. He is a guest editor with School Transportation News and has won the state of Wisconsin Governor's New Product Design Award in 1986 for an innovative new truck cab and chassis product.

In addition to consulting, Mr. Wilkins also teaches training session seminars in basic heavy vehicle design, cost control and specifications, including how to write bid specifications that will result in obtaining good, cost effective vehicles. These seminars also include vehicle costs and how to both address and control them when writing bid specifications.

# COMPARISON OF THE DIFFERENCES BETWEEN WASHINGTON AND SOUTH CAROLINA SCHOOL BUS SPECIFICATIONS

## Appendix 4

Not available online. Request hard copy from JLARC office.

# CONTACTS AND INTERVIEW QUESTIONS

## Appendix 5

| Name | Title | Address |
|---|---|---|
| Industry Publications | | |
| Steve Hirano | Managing Editor | School Bus Fleet Magazine |
| Bill Paul | Publisher and Editor | School Transportation News |
| School Bus Manufacturers & Distributors | | |
| Nancy Conrad | General Manager | Durham Transportation |
| Wayne Cope | Director of Marketing | School Bus Services |
| Charles W. Carpenter | Vice President | Larson Bus Sales, Inc. |
| Lisa Thatcher | Lobbyist | Boldt/Thatcher |
| Cal Hull | Manager | Ryder Student Transportation Services |
| Tony Ward | Regional Manager | Am Tran |
| Verna Borders | Western Regional Sales Manager | Bluebird Body Co. |
| Danny Pearcy | Vice-President of Sales | Carpenter Mfg. |
| Ron Dillard | Western Regional Manager | Thomas Built Buses, Inc. |
| Mike McConnel | Marketing Representative | Freightliner Custom Chassis Corp. |
| Bill Middlekauff | Assistant General Sales and Service Manager | Chevrolet Motors Division and GMC Truck |
| Glenn Vick | National Account Manager | Ford Truck Operations |
| Ron Peter | Sales Manager | Transi-Corp. Incorporation |
| Jim Marrs | Sales Administration Manager | Crane Carrier Co. |

| | | |
|---|---|---|
| Randall Ray | Business Marketing Manager | Navistar International Corporation |

National Organizations

| | | |
|---|---|---|
| Mike Martin | Executive Director | The National Association for Pupil Transportation |
| Charles Gauthier | Executive Director | The National Association of State Directors of Pupil Transportation Service |
| Karen Finkle | Executive Director | The National School Transportation Association |
| Charles Hott | Pupil Transportation Specialist | The National Highway Traffic Safety Administration |
| Will Blount | Office of Motor Carriers | The Federal Highway Administration |
| Jan Hazelett | Public Policy Officer | The National Safety Council |
| Jane Williams | | Office of Special Education Programs, US Department of Education |

Other States

| | | |
|---|---|---|
| Don Touter | Director of Student Transportation | State of South Carolina Department of Education |
| Marshall Casey | Director of Maintenance and Training | State of South Carolina Department of Education |
| Ron Kinney | Supervisor of School Transportation | California Dept. of Education |

Private Carriers

| | | |
|---|---|---|
| Kevin Mest | Director of Operations | Laidlaw Transit, Inc. Northwest Area Office |
| Michael Griffus | Regional Vice-President of Operations | Laidlaw Transit |

| | | |
|---|---|---|
| Pete McCue | Division Manager | Mayflower/Laidlaw |
| Don Carnahan | Regional Director of Business Development | Laidlaw Transit, Inc. Northwest Area Office |

State Education and School District Contacts

| | | |
|---|---|---|
| Elisa Benson | Fiscal Analyst | House Appropriations Committee |
| Jack Daray | Sr. Fiscal Analyst | House Appropriations Committee |
| Bill Freund | Sr. Fiscal Analyst | Senate Ways and Means Committee |
| Roger Eastman | Director of Transportation | Office of the Superintendent of Public Instruction |
| Dick Fischer | Regional Transportation Coordinator | Region II Puget Sound Educational Service District 121 |
| Claudia Otey | Regional Transportation Coordinator | Region III Puget Sound Educational Service District 121 |
| Mike Kenney | Regional Transportation Coordinator | Region IV Educational Service District 105 |
| Roy Flitton | Regional Transportation Coordinator | Region V Educational Service District 101 |
| Donald Walkup | Supervisor of Transportation | Kent School District |
| Bonnie Catton | Transportation Manager | Kent School District |
| John Byrne | Transportation Director | Peninsula School District |
| Dr. Raymond P. Reid | Superintendent | Stanwood School District |
| Tal Johnson | Transportation Director | Stanwood School District |
| Dr. Richard Schulte | Superintendent | Oak Harbor School District |
| Dr. Dennis S. Couch | Superintendent | Educational Service District #189 |

| | | |
|---|---|---|
| Dr. J. Clifton Ernst | Superintendent | Riverview School District |
| Dr. Sharon Hill | Superintendent | Anacortes School District |
| Gary Wargo | Executive Associate | Anacortes School District |
| Dr. Gene Sharatt | Superintendent | Educational Service District #171 |
| Dr. Walt Bigby | Superintendent | Eastmont School District |
| Ken Martin | Supervisor/Driver Trainer | Eastmont School District |
| Dr. Richard L. Langum | Superintendent | Cashmere School District |
| Dr. Marilyn Baker | Superintendent | Cascade School District |
| Lee Heinrichs | Transportation Manager | Cascade School District |
| Gary Thomsen | Supervisor | Evergreen School District |
| G. (Reg) Clarke | Program Director | Edmonds School District |
| Carol Crain | Acting Supervisor | Vancouver School District |
| Tom Prigmore | Supervisor/Driver Trainer | Chehalis/Centralia Co-op |
| Dr. Brian L. Talbott | Superintendent | Educational Service District #101 |
| Larry Wise | Superintendent | Educational Service District #113 |
| Steve Yantzer | Purchasing Agent | King County Director's Association |
| Ronald L. Ricketts | General Manager | King County Director's Association |

**Interview Questions**

1. Are you aware of any studies which have analyzed the differences in either cost or performance of front versus rear engine, transit style school buses?

2. Are you aware of any studies which have analyzed, from a life cycle cost perspective, the costs of owning and operating front versus rear engine, transit style school buses?

3. Can you suggest any other agencies, contacts, or other persons with whom we can speak regarding this subject?

# DESCRIPTION OF SECNARIOS 1 AND 2

## Appendix 6

In order to develop estimated operating and maintenance costs for identically equipped transit style buses, a standard set of operating categories was developed by our technical consultant (below). These categories were forwarded to the superintendent's office who in turn provided a set of assumptions used by the technical consultant to estimate O&M costs.

These scenarios were developed by OSPI, and were designed to be representative of two general sets of conditions under which the majority of Washington school districts operate. Scenario 1 assumes relatively shorter annual mileage, better roads and more moderate weather. In general terms, Scenario 1 can be described as urban, and Scenario 2 as rural.

| | Scenario 1 (Urban) | Scenario 2 (Rural) |
|---|---|---|
| **Service Life/Utilization Factor** | | |
| • Anticipated annual mileage | 18,000 miles | 22,000 miles |
| **Street/Road Operating Conditions** | | |
| Percentage of miles vehicle regularly operates on: | | |
| • Freeways in generally good to excellent condition | 11% | -- |
| • Paved streets in generally good to excellent condition | 73% | 87% |
| • Paved streets in generally poor to fair condition | 10% | 3% |
| • Unpaved roads in generally fair to good condition | -- | 8% |
| • Unpaved roads in generally poor to fair condition | 6% | 2% |
| **Terrain** | | |
| Percentage of miles vehicle regularly operates on: | | |
| • Relatively flat streets, roads, or highways | 17% | 72% |
| • Gentle rolling hills, streets, roads, or highways | 62% | 20% |
| • Mountainous roads or highways | 21% | 8% |
| • Maximum above grade angle vehicle will climb and descend daily | Over six degrees | Three degrees or less |
| • Average length of above grade | 0.9 miles | 2.1 miles |
| **Altitude Range Vehicle Will Operate in Daily** | | |
| • Low | +500 feet | -100 feet |
| • High | +3,000 feet | +500 feet |

| | | |
|---|---|---|
| **Weather/Environment** | | |
| Temperature range vehicle will regularly operate in | | |
| • Winter Low | 28 degrees F | -10 degrees F |
| • Summer High | 95 degrees F | 95 degrees F |
| • Maximum summer humidity rating vehicle will be operated in | 30% | 10% |
| **Dust/Visibility** | | |
| • Will vehicle be operated in either occasionally or regularly in extremely dusty conditions? | No | Yes |
| • Will vehicle be operated occasionally in thick, heavy, winter fog? | Yes | No |
| • Will vehicle be exposed to fog with salt in its content? | Yes | No |
| **Snow and Ice** | | |
| • Will vehicle be operated in snow and ice conditions? | Yes | Yes |
| • If yes, is salt used on roads? | No | No |
| **Garaging/Storage** | | |
| • Will vehicle be parked at night in a garage? | No | No |
| • Will vehicle be parked at night in an open space? | Yes | Yes |
| • Will vehicle be parked at night close to a chemical manufacturing plant, wastewater treatment facility, or large body of salt water? | No | No |
| **Preventative Maintenance Service** | | |
| • Will vehicle receive manufacturers recommended or required services? | Yes | Yes |

# SUMMARY OF TECHNICAL ANALYSIS AND SOURCES OF INFORMATION USED BY CONSULTANT

## Appendix 7

### Technical Analysis

A vehicle life-cycle cost analysis involves a detailed comparison of two or more vehicles usually of different design or with different components using a defined operational application. In the case of the state of Washington transit style school bus study, two different operational applications were used involving two identically equipped Blue Bird Type D transit body style school buses. Both buses have 72-passenger capacity ratings and are equipped with the Cummins model B5.9 diesel powered engine rated at 210 horsepower. These buses are identically equipped in all items except those that are related strictly to engine location.

Operational applications were defined for two scenarios. An operational application establishes the parameters and expected operating conditions under which the buses would operate. The assumptions used for these two scenarios is included under Appendix 6.

Scenario 1 is primarily city/urban driving conditions with a utilization factor of 18,000 miles per year.

Scenario 2 is more rural, involving some mountains and unpaved roads with a utilization factor of 22,000 miles per year. In this scenario, both buses are marginally powered for mountain applications. To adequately meet the needs of the defined operational application, a minimum of 250 horsepower with a minimum of 800 ft.-lbs. of Peak Torque would be much more desirable for mountain applications. Larger size front and rear brake shoes and drums would also be more desirable for the mountains.

A 15 year service life was desired and used for the life cycle analysis. With consideration of the construction and specifications of the two buses being evaluated, a 15 year service is an absolute possible maximum. The bus with the engine located in the front of the chassis may have a service life of 25 percent less than its rear engine counterpart, or a 12 year maximum service life. This is due to the use of a stronger body design in a rear engine bus to afford the large, full width engine compartment. This stronger body can better withstand the rougher roads expected in an unpaved operational application.

The cost efficiency of one vehicle compared to another in the defined operational application is the primary purpose of the Lifecycle Cost Analysis. This involves a thorough examination of all costs required to operate a vehicle over its projected service life in a defined operational application. This requires making a series of assumptions about the vehicle including its engineering design and major components.

The costs shown in the study, including engine overhaul costs, were received from the dealers of the applicable products and do include Washington state sales tax of 8.2 percent. It was found by this consultant that prices do vary by a rather considerable margin between dealers. Parts costs were averaged to account for these variances.

The Cummins Engine Company, like all component manufacturers, has occasionally made claims of an engine life before overhaul of 300,000 miles minimum for their model B5.9 diesel engine. However, given the features identified in the two operational applications, it is expected that the 210 horsepower engine will not last as long as intended and that an engine overhaul is estimated at the 170,000 mile point in the service life. It should be mentioned that the figures used to overhaul the Cummins B5.9 engine can and will vary with other makes and/or model diesel engines.

These particular buses were equipped with the Allison model MD 3060 fully electronically controlled automatic transmission. This transmission also features automatic torque converter lock-up. The electronic control and automatic torque converter lock-up features contribute to maximum fuel economy as compared to other model Allison such as the AT Series that has neither of these features or the MT Series that has only the automatic torque converter lock-up feature. The MD 3060 is an excellent transmission that will help contribute to maximum fuel economy.

Today, projected fuel economy is something that can vary depending on a great number of factors. The engine, transmission, and rear axle ratio the vehicle is equipped with is an important place to start. The operational application the vehicle will work in on a daily basis is another important consideration. The driver is another varying factor in the projected MPG equation. An engine operating in tune to manufacturer specification will achieve a higher MPG than an engine that is out of tune. Fuel economy also starts to fall as an engine gets closer to requiring an overhaul since the internal parts get “looser”. Tolerances are not what they were when they were new.

It should also be pointed out that school buses of this size equipped with larger, minimum 250 horsepower size engines that produce a minimum of 650 ft.-lbs. of Peak Torque frequently have MPG rates of 1 to 1.5 MPG higher than those of the engine furnished in these two buses. Such diesel powered engines would include the larger Cummins model C8.3, Caterpillar model 3116 and 3126 and the Navistar model DT 466E.

The reason this exists is that the larger size engine is working easier with more reserve power capacity than the smaller size Cummins model B5.9 engine. Yes, in this case, larger size diesel engines use less fuel. Paying a higher initial purchase price for a larger size engine would reduce operating cost by going to an engine that would provide increased fuel economy and eliminate the major maintenance cost of an engine overhaul or replacement. The additional cost of a larger size engine can frequently be cost justified.

The range for projected MPG can be quite broad depending on a combination of some or all of the above factors. Projected fuel MPG figures selected for this study accounted for the G.V.W. ratings of the chassis, type of body (transit style with high drag coefficient), make, model and horsepower rating of the engine, make and model, of the transmission, tire size and the use of steel-belted radial tires. The study also assumes fuel consumption based on what a good, experienced driver would achieve and an engine which is in tune to manufacturer specification. With this information and data, the two different defined operational applications were then evaluated to determine the projected MPG.

It is assumed that two potential major maintenance items, the Allison model MD 3060 automatic transmission and the rear axle, should not require either an overhaul or replacement over the service life of the vehicle in either operational application.

In school buses, tire wear and tread life is usually determined by continual turning of the steer axle tires and continual acceleration and braking of the drive axle tires. On a 72-passenger size or larger bus, tire tread wear life for 11R22.5 size tires is almost always the same for either a front or rear engine Type D bus.

Service intervals shown in the study are per the recommendations of the various manufacturers. Parts replacement intervals were established by interviewing experienced maintenance people with a detailed knowledge of the school bus industry. Replacement of parts is frequently performed in one of two different ways. One way is to replace a part when it actually fails. This method may, on occasion, require field calls due to a road failure. The second method is to replace a part on a schedule that anticipates when replacement will be required. This method eliminates the potential additional expense of a road service call and is used in this study.

In the study, one parts replacement item, lighting, is typically replaced as required when a failure occurs. It was assumed in this study that every lamp would fail on a five year interval. This is considered a typical average time and parts and labor costing for this item was made on this basis.

Another assumption made concerns paint. Blue Bird and Thomas both use as standard a premium grade polyester reinforced polyurethane enamel type exterior paint. With this quality of paint, the bus should not require repainting over the 15 year service life. If the bus were any other make than these two, a $3,500 bus repainting would have been scheduled at the nine year point in the service life.

To achieve maximum operating cost efficiency, it is common industry practice to immediately replace the four new tires on the rear axle with recaps. The new rear axle tires are then used in the fleet as replacement front axle tires as required. Using recaps on the rear axle reduces tire costs an average of 50 percent as compared to using new rear tires. In this study, for costing purposes, it is assumed that recaps are used on the rear axle over the life of the bus.

## Sources of Information

Bus Maintenance and Repairs, Parts and Component Life:

This also includes labor repair and/or replacement time.

Mr. Don Dickerson
Gillig Corporation
Hayward, CA

Mr. Dennis MacNeill
Bus Maintenance Consultant
Simi Valley, CA

Background for both of the above people: Mr Dickerson is a retired Marine Corps Major who maintained large equipment fleets in the Marine Corps. He has been employed by Gillig for the past 15 years and has taught maintenance and service seminars for Gillig the last eight years. Mr. MacNeill is a former superintendent of fleet maintenance for ARA Services who was a large Los Angeles based school bus contractor. ARA sold out to Laidlaw a number of years ago. Mr. MacNeill is currently working in Atlanta supervising seven bus maintenance shops set up especially for the Olympic Games. He also did this in 1984 for the Olympic Games held in Los Angeles.

Parts and Component Costs:

The following companies were sources for current part and component costing. When variances for the same item were found, which was common, averages were used in the study.

A-Z Bus Sales
Blue Bird Bus Dealer
Colton, CA

California Bus Sales
Thomas Bus Dealer
Fresno, CA

Gibbs International
Amtran Bus Dealer
Oxnard, CA

Published Component Maintenance Manuals:

*Cummins B Series Engines*
Cummins Engine Company
Columbus, IN

*Allison World Transmission*
Allison Transmission
Indianapolis, IN

The above publications were sources for service intervals and other service recommendations for these two key power train components.

Tires, Fuel, Labor, and Inflation:

Tire costs were obtained from the County of Santa Barbara from their current tire contract. Fuel costs were from the State of Washington Joint Legislative Audit and Review Committee (JLARC) staff. The labor cost of $45.00 per hour was researched by Jim Wilkins and approved for use in the study by LARC staff. Inflation and cost of money factors used in the study were selected by JLARC staff.

# DESCRIPTION OF LIFE-CYCLE COST MODEL

## Appendix 8

Life-cycle cost analysis looks at costs of alternatives over time and, since the same dollars to be spent in the future have less value than they would if spent today, uses present value calculations to compare all costs on a current cost basis.

This appendix lists and summarizes the following individual components and assumptions used in the life-cycle cost analysis for this study.

A copy of the life-cycle cost spreadsheet used for this study is available upon request.

| Assumption | |
|---|---|
| Gross Discount Rate | 8.12% |
| General Inflation | 3.12% |
| Parts Inflation | 2.30% |
| Labor Inflation | 3.66% |
| Fuel Inflation | 0.83% |
| Useful Life - Yrs | |
| Scenario 1 | |
| Front & Rear engine | 15 years |
| Scenario 2 | |
| Front engine | 12 - 15 years |
| Rear engine | 15 years |
| Purchase Price (base cost, including sales tax of 8.2 percent) | |
| Front engine | $71,159 |
| Rear engine | $74,577 |
| Miles per Year | |
| Scenario 1 (urban operating conditions) | 18,000 |
| Scenario 2 (rural operating conditions) | 22,000 |
| Miles per Gallon Fuel[1] | |
| Front engine bus | 7.0 - 7.6 |
| Rear engine bus | 6.7 - 7.3 |
| Fuel $/Gallon | $1.00 |
| Insurance $/Yr | $528.50 |
| Routine Labor $/Hr | $45.00 |
| Residual Value | per WAC rules |

1 The estimated fuel economy varied depending on the operating scenario and also on the overall number of miles traveled. After 150,000 miles, the estimated MPG decreased under both scenarios.

**Gross discount rate (General inflation plus 5 percent)**- This rate represents the pre-tax cost of capital to the public.

**General inflation** - This rate is based on the forecasted, long term consumer price index and price deflator for the Puget Sound region.

**Parts inflation** - This rate is based on the forecasted, long term inflation rate for motor vehicles and parts as provided by the Governor's Forecast Council. An individual rate for motor vehicle parts was not available.

**Labor inflation** - This rate is based on the forecasted, long term inflation rate for salaries as provided by the Governor's Forecast Council.

**Fuel inflation** - This rate is based on the forecasted, long term inflation rate for diesel fuel as provided by the Governor's Forecast Council.

**Useful life** - The useful lives were developed with the assistance of the technical consultant and OSPI and was based on the expected first line service and reserve service lifetimes for school buses provided by OSPI.

**Purchase price** - The base cost, including sales tax at 8.2 percent, was based on the bid prices received by the King County Directors' Association, Purchasing Department. The KCDA acts as a purchasing agent for 288 school districts around the state.

**Miles per year** - The anticipated miles per year traveled under each scenario were developed by OSPI and was based on the actual operating experience of school districts around the state.

**Miles per gallon of fuel** - These figures were developed by the technical consultant and represents the anticipated fuel efficiency of front and rear engine buses operating under the conditions specified in Appendix 6 of this report.

**Fuel cost per gallon** - This figure represents the wholesale price of bulk diesel fuel purchased by school districts.

**Insurance cost per year** - This figure represents the anticipated liability and physical damage insurance premium as provided by Puget Sound Districts Risk Management Pool.

**Routine labor cost per hour** - This figure represents a typical hourly staff rate for maintenance personnel, including benefits. This figure was based on conversations with school districts, private sector fleet maintenance managers, and the technical consultant.

**Residual value** - This value, which represents the anticipated salvage value of school a bus at the end of its useful life, was based on the formula as prescribed by the Washington Administrative Code (WAC).

# ANNUALIZED OWNING AND OPERATING COSTS

## Appendix 9

**SCENARIO 2**
**Annualized Owning and Operating Costs**
**Useful lives are different**

| Engine Location | Front | Rear | Difference |
|---|---|---|---|
| Expected Useful Life | 12 Years | 15 Years | 3 Years |
| | | | |
| Purchase Price | $ 8,209 | $ 7,334 | $ 875 |
| Preventative Maintenance -- Parts | $ 1,563 | $ 1,512 | $ 51 |
| Preventative Maintenance -- Labor | $ 1,403 | $ 1,421 | $ (18) |
| Fuel | $ 2,975 | $ 3,038 | $ (63) |
| Insurance | $ 571 | $ 571 | $ - |
| Residual Value | $ (67) | $ (38) | $ (29) |
| Major Maintenance -- Parts | $ 1,016 | $ 919 | $ 97 |
| Major Maintenance -- Labor | $ 355 | $ 308 | $ 47 |
| | | | |
| Total Annualized Cost | $ 16,025 | $ 15,066 | $ 959 |
| Total Minus Purchase Price | $ 7,816 | $ 7,732 | $ 84 |

**SCENARIO 2**
**Annualized Owning and Operating Costs**
**Useful lives are the same**

| Engine Location | Front | Rear | Difference |
|---|---|---|---|
| Expected Useful Life | 15 Years | 15 Years | |
| | | | |
| Purchase Price | $ 6,997 | $ 7,334 | $ (336) |
| Preventative Maintenance -- Parts | $ 1,565 | $ 1,512 | $ 53 |
| Preventative Maintenance -- Labor | $ 1,421 | $ 1,421 | $ 0 |
| Fuel | $ 2,911 | $ 3,038 | $ (127) |
| Insurance | $ 571 | $ 571 | $ - |
| Residual Value | $ (36) | $ (38) | $ 2 |
| Major Maintenance -- Parts | $ 985 | $ 919 | $ 66 |
| Major Maintenance -- Labor | $ 338 | $ 308 | $ 30 |
| | | | |
| Total Annualized Cost | $ 14,754 | $ 15,066 | $ (312) |
| Total Minus Purchase Price | $ 7,756 | $ 7,732 | $ 24 |

**SCENARIO 1**
**Annualized Owning and Operating Costs**

| Engine Location | Front | Rear | Difference |
|---|---|---|---|
| Expected Useful Life | 15 Years | 15 Years | 0 |
| | | | |
| Purchase Price | $ 6,997 | $ 7,334 | $ (336) |
| Preventative Maintenance -- Parts | $ 1,526 | $ 1,473 | $ 53 |
| Preventative Maintenance -- Labor | $ 1,375 | $ 1,375 | $ 0 |
| Fuel | $ 2,273 | $ 2,368 | $ (95) |
| Insurance | $ 571 | $ 571 | $ - |
| Residual Value | $ (36) | $ (38) | $ 2 |
| Major Maintenance -- Parts | $ 967 | $ 900 | $ 67 |
| Major Maintenance -- Labor | $ 331 | $ 301 | $ 30 |
| | | | |
| Total Annualized Cost | $ 14,005 | $ 14,284 | $ (279) |
| Total Minus Purchase Price | $ 7,008 | $ 6,950 | $ 57 |

# ADVANTAGES AND DISADVANTAGES OF FRONT AND REAR ENGINE TRANSIT-STYLE BUSES

## Appendix 10

The following matrix was developed to allow a comparison of the nonquantifiable differences between a front and rear engine transit style bus. These factors, presented in a question and answer type format, are a compilation of the opinions we received from the respondents of our survey of individuals and organizations who had experience in maintaining and operating front and/or rear engine transit style buses. The answers provided in this matrix were developed with the assistance of the technical consultant retained for this study.

## Summary of the Differences Between a Front and Rear Engine Transit-Style School Bus

| Category | Question | Front Engine | Rear Engine | JLARC Staff Notes |
|---|---|---|---|---|
| ***Driver Area Design*** | | | | |
| Noise from engine | Are drivers of front engine buses more affected by engine noise due to their location to the engine? | For front engine buses, there is a higher noise level near the driver area (85 decibels). | For rear engine buses, there is a lower noise level near the driver (77 decibels). | Engine noise can be reduced by installing insulated ceiling panels, using a insulated front engine cover, and using plywood overlays on the floor. The amount of engine noise is also directly associated with the capacity, or output, of the engine. |
| Heat emitted from the engine | Are drivers of front engine buses more affected by engine heat due to their proximity to the engine? | Warmer due to proximity to the driver. May be preferable in winter but not welcomed in summer. | Opposite of a front engine configuration. | None. |
| Engine housing cover | Does the engine cover (known as a "doghouse") obstruct students and drivers as they enter and exit the bus? | Cover can serve as an obstacle to children and driver entering and exiting vehicle. | No obstructions. | Older buses used a larger cover (about knee height). The size of the cover on newer buses is not as significant as the cover rises about 6 inches off floor. |
| Visibility through lower window of rear emergency exit | Does the fact that drivers of front engine buses can see through the lower window of the rear emergency exit increase driver awareness and safety? | Although a rear window available through the emergency exit door, the driver may not be able to see through it due to children, schoolbags, and distance. | No lower rear window as there is no rear emergency exit. | The ability for a driver to see directly behind the bus is assisted by a series of mirrors mounted on the sides and rear of the bus, thus the significance of a rear window is not as great. |
| Visibility through front window | Is there a difference in the visibility through the front windshield between a front and rear engine bus? | The front windshield is about 64 inches from the ground. | The front windshield is about 59 - 60 inches from the ground. | Although there is a 4 - 5 inch difference, this difference has not been mentioned as a material disadvantage in front engine buses. |
| ***Steering/Handling*** | | | | |
| Ease of steering. | Is a front engine bus relatively more difficult to turn due to the weight of the engine over the steering axle? | Due to weight distribution over front axle, the axle will be loaded to maximum capacity when the bus is full, thus making steering more difficult. | Due to greater weight distribution over rear axle, maximum loading of front axle not as great, thus turning is relatively easier | Resistance in steering can be compensated by a higher capacity steering gear box and power assisted steering. |
| Turning radius | Do front engine buses have a tighter turning radius? | Shorter wheelbase resulting in a tighter turning radius. | Longer wheelbase resulting in a greater turning radius. | Although a shorter wheel base results in tighter turning radius, it also results in a larger tail swing. See next line. |
| Amount of tail swing during turns | Do front engine buses have a wider tail swing? | Larger tail swing due to a shorter wheelbase. | Smaller tail swing due to a longer wheelbase. | A shorter tail swing requires a longer wheel base, in turn requiring a larger turning radius. |
| Traction under inclement conditions | Do rear engine buses have greater traction as the weight of the engine is over the drive axle? | Due to a more equal weight distribution over front (45%) and rear (55%) axles, traction under inclement conditions may not be as great. | Due to a greater weight distribution over the rear (65%) axle, traction under inclement conditions (snow/ice) is better than a front engine. | The differences in traction can be compensated by the use of automatic sanders and power driven tire chains. |

| ***Maintenance/Componentry*** | | | | |
|---|---|---|---|---|
| Air intake and air filter maintenance | Do the air filters for a front engine bus remain cleaner for a longer period due to the direct air flow received as the vehicle is moving? | Air coming in to the engine through the front of the bus is usually cleaner, thus cleaner filter and engine compartment. | On rear engine buses, air swirls around the back of the bus as it is traveling. This air picks up road dust and dirt, thus the filter and engine compartment needs cleaning more often. | None. |
| Engine cooling system (radiator) | Since a front engine receives direct air flow, does it require a smaller radiator? | Radiator size is directly related to engine output capacity. Thus a larger engine requires a larger radiator. Direct air flow has little to do with affecting the size of the radiator. | See front engine discussion. | Recent advancements have compensated for accessibility issues by having a swing out radiator which allows for improved access to the front o the engine in front-engine applications. |
| Drive train maintenance | Does the drive train on a front engine bus require more maintenance as the drive shaft is longer? Does this length also result in a loss of torque? | Depending upon the length of a wheel base, the drive train can consist of up to three drive shafts (up to 30 feet in length). This does increase maintenance. Torque may also be diminished, but this should be almost unnoticeable. | The drive shaft is typically 10 to 16 inches long, much shorter than its front engine counterpart. This results in a very simple mechanism to maintain and operates relatively efficiently. | None. |
| Service access to engine compartment | Is accessibility to the engine in a front engine configuration relatively more difficult, thus increasing labor time and costs? | Access to the engine in a front engine bus is more difficult relative to its rear engine counterpart. | Access to the engine in a rear engine bus is easier relative to its front engine counterpart. | None. |
| Weight of the engine and tire life | Does the weight of the power train over the front tires in a front engine cause the tires to wear faster? | With proper alighment, the weight of the power train should not affect tire life. Tire life on the steering axle will be shorter due to continual turning of the tires. | See front engine discussion. | Tire life is directly related to th amount of turning and stops required. These factors are n specific to any one bus configuration. |

| ***Student Safety/Seating*** | | | | |
|---|---|---|---|---|
| Stairwell accessibility | Does the engine cover (commonly known as the "doghouse") serve as an obstacle for students and driver entering and exiting the bus? | See "Driver Area Design, Engine Housing Cover" above. | See "Driver Area Design, Engine Housing Cover" above. | None. |
| Availability of luggage and storage space | Does a front engine bus offer an equal amount of luggage space as in its rear engine counterparts? | Due to the full length drive shaft, luggage space is limited. | Luggage space can be of a side-to-side pass through design as drive shafts do not block the area underneath the bus. | None. |
| Fuel tank safety | Is there a safety difference in the location of the fuel tank between a front and rear engine configuration? | Fuel tank is located behind the rear axle, between the frame rails. There is no evidence that position is unsafe. | Fuel tank is located between the axles and frame rails. This position is considered very safe. | Federal standards require cage surround the fuel tan tank is located outside the rails. |
| Fire safety | Is there a safety difference between a front and rear engine transit style bus in the event of an engine fire? | In the event of a fire in the engine compartment, smoke could enter the bus from underneath the body skirt or through the engine cover if it were to structurally fail due to the heat. | The fire would not be fed by direct incoming air. Smoke and flames may blow behind the bus while it is moving. One manufacturer uses a double steel firewall type construction with fire resisistant insulation, increasing safety and reducing noise. | Due to the proximity of the from the rear engine compartment, in the event fire, the driver may take lo notice as compared to a fr engine bus. |
| Student seating | Is there a difference in safety for children riding in a front or rear engine bus? | Children seated at the rear of the bus body are not afforded the additional structural protection from the engine compartment in a rear engine configuration. | See front engine discussion. | None. |
| Floor height | Is there a difference in safety for children riding in a front or rear engine bus? | The floor height is typically 40 - 42 inches off the ground. | The floor height is typically 44 - 46 inches off the ground. This additional heighth may afford additional protection for passengers in the event of a side impact crash. | |
| Rear exit door glass | Does the glass of the rear exit door pose a risk to passengers in the event of a rear end collision? | In the event of a rear end collision, the glass in the exit door may shatter and fly into the passenger compartment. | The rear windows of a rear engine bus are located about 7 feet off the ground, reducing the chances of breakage in the event of a rear end collision. | |
| Exhaust system | In the event of a failure in the exhaust system could exhaust gases/smoke enter the passenger area? | Exhaust gas/smoke could enter the passenger area in the event of a leak. | The entire exhaust system is located in the engine compartment, thus any leaks will exit behind the bus while it is moving. | |