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Buses

EPA 550/9-77-201

NOISE EMISSION STANDARDS
FOR TRANSPORTATION EQUIPMENT

PROPOSED BUS NOISE EMISSION REGULATION

PART 1.
DRAFT ENVIRONMENTAL IMPACT STATEMENT

PART 2.
BACKGROUND DOCUMENT

AUGUST 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

EPA 550/9-77-201

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AUGUST 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

UNITED STATES

ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF NOISE ABATEMENT AND CONTROL

DRAFT

ENVIRONMENTAL IMPACT STATEMENT

for the

PROPOSED BUS NOISE EMISSION REGULATION

August 1977

This document has been approved for general availability.
It does not constitute a standard, specification or regulation.

SUMMARY SHEETS
FOR
DRAFT ENVIRONMENTAL IMPACT STATEMENT

Prepared By

OFFICE OF NOISE ABATEMENT AND CONTROL
U.S. ENVIRONMENTAL PROTECTION AGENCY

1. Title of Action: Regulation of Noise Emissions for intercity, school and urban transit buses. This is an Administrative Action.

2. Description of Action: The Environmental Protection Agency's proposed regulation is intended to reduce the level of noise emitted from intercity, school and urban transit buses. The regulation is also intended to establish a uniform national standard for such vehicles distributed in commerce, thereby eliminating inconsistent state and local noise source emission regulations that may impose an undue burden on the bus manufacturing industry. The recommended action proposes to establish noise emission standards for newly manufactured buses and to establish enforcement procedures to ensure that these vehicles comply with the standard.

The proposed regulation is based on anticipated health and welfare benefits to the public by reducing noise emission from buses. In arriving at the proposed regulation, the Environmental Protection Agency investigated in detail the bus manufacturing industry, noise control technology, noise measurement methodologies, and costs of compliance. Three major issues were identified requiring resolution: (1) identification of vehicles to be regulated, (2) noise measurement methodologies to be employed, and (3) noise levels and effective dates.

All newly manufactured school buses, transit buses and intercity buses are subject to the proposed regulation. Included are both gasoline and diesel powered buses.

Incremental reductions in vehicle noise levels were concluded to be preferable to a one-step requirement that all vehicles meet the most stringent levels achievable and desirable. To minimize market impacts from substitution of unregulated vehicles, identical effective dates were set for all vehicles subject to the standard.

3. Environmental Impact: Compliance with the proposed exterior noise standards for buses, should result in a reduction of approximately 48.2 percent in potential speech interference impacts due to buses, a 39.5 percent reduction in potential sleep awakening impacts due to buses and a 33.4 percent reduction in potential sleep disturbance impacts due to buses by the year 2000.

Compliance with the proposed standards for interior noise levels would result in a 42.7 percent decrease in potential passenger speech interference impacts due to buses, a 92.4 percent decrease in potential hearing loss risk for passengers exposed to 60 dBA prior to bus transit, a decrease of 68.8 percent in potential hearing loss risk for passengers exposed to a 70 dBA prior to bus transit and a reduction of 2.6 percent in potential hearing loss risk for passengers exposed to an 80 dBA level prior to bus transit. Similar percentage impact reductions will occur for bus operators.

List price increases to quiet new buses to the most stringent level (77 dBA) are estimated to range from 1.8 percent to 8.8 percent, depending on the bus type and size. The average list price increase for all buses considered is estimated to be 3.2 percent.

The maximum impact of the proposed regulation on transit and intercity bus fares would occur if the total costs of the regulation were to be financed entirely by fare increases. This is an extreme case since transit systems and intercity bus carriers typically try to absorb costs in order to forestall fare increases. Utilizing such an (worst case) assumption, the Agency projects a maximum of a 1.0 to 1.7 percent fare increase as a result of this regulation.

Annualized costs to users of all buses beginning in 1979 through the year 2000 are expected to increase nearly $69 million as a result of bus manufacture cost pass throughs plus normal markups as a result of meeting the interior and exterior noise level limits.

Air quality, water quality, land use, solid waste disposal requirements, employment, regional economics, foreign trade, national GNP and energy consumption are not expected to be significantly impacted by the noise levels proposed. Fuel (energy) consumption of buses is expected to increase by no more than an average of 3% with the implementation of the proposed levels.

Persons wishing to obtain copies of the Draft Environmental Impact Statement and the Background Document for the Proposed Bus Noise Emission Regulation or the Proposed Regulation itself may receive them on request from:

EPA Public Information Center (PM-215)
Room M2194D, Waterside Mall
U.S. Environmental Protection Agency
Washington, D.C. 20460.

Persons wishing to comment on the Draft Environmental Impact Statement, the Background Document or on the Proposed Regulation, should write to:

Director, Standards and Regulations Division
Office of Noise Abatement and Control (AW-471)
Attn: Bus Noise Regulation Docket Number ONAC 77-6
U.S. Environmental Protection Agency
Washington, D.C. 20460.

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PART I

DRAFT ENVIRONMENTAL IMPACT STATEMENT

PROPOSED BUS NOISE EMISSION REGULATION

DRAFT

ENVIRONMENTAL IMPACT STATEMENT

ABSTRACT

This Draft Environmental Impact Statement addresses a proposed noise emission regulation for buses. In arriving at the proposed regulation, the Agency carried out detailed investigations of bus design and manufacturing and assembly processes, bus noise measurement methodologies, available bus noise control technology, costs attendant to bus noise control methods, costs to test vehicles for compliance, costs of record keeping, possible economic impacts due to increased costs, and the potential environmental and health and welfare benefits associated with the application of various noise control measures. Data and information generated as a result of these investigations are the basis for the statements made in Part I of this document. Part I has been designed to present, in the simplest form, all relevant information regarding the environmental impact expected to result from the proposed action. Where greater detail is required, the Agency encourages perusal of Part II, the Background Document.

INTRODUCTION

Congress passed the Noise Control Act (NCA) of 1972, in part, as a result of their findings that inadequately controlled noise presents a growing danger to the health and welfare of the nation's population, particularly in urban areas. For this and other reasons, the Congress established a national policy to "promote an environment for all Americans free from noise that jeopardizes their health or welfare." To further this policy, the NCA provides for the establishment of Federal noise emission standards for products distributed in commerce and specified four categories of important noise sources for regulation, of which surface transportation is one.

Approximately 93 million Americans are exposed to levels of urban traffic noise which may jeopardize their health and welfare. Although a small component of the urban noise problem, bus noise is perceived by many as a major concern in comparison with noise from other vehicles.

Inasmuch as bus noise is only a part of urban traffic noise, quieting buses alone is not sufficient to reduce traffic noise to a level requisite to protect health and welfare. Accordingly, noise emissions from medium and heavy duty trucks have already been regulated and noise regulation levels for motorcycles are currently being developed.

Pursuant to the mandate of the NCA and EPA's approach to the control of surface transportation noise, noise emission regulations for medium and heavy trucks (41 CFR 15538) were promulgated on April 13, 1976.

The Agency determined that regulation of all buses meeting the following definition is requisite to protect the public health and welfare:

A bus is defined as any motor vehicle with a Gross Vehicle Weight Rating (GVWR) in excess of 10,000 lbs, designed for the transportation of passengers on a street or highway, and includes a partially or fully enclosed engine compartment, and an enclosed passenger compartment. Details regarding identification of these vehicles as candidates for regulation, their design features and functional characteristics are contained in Sections 1, 2 and 5 of Part II, the Background Document.

PROPOSED NOISE REGULATION

This proposed regulation is intended to reduce the level of noise emitted from buses. It also establishes a uniform national standard for these vehicles when they are distributed in commerce, thereby eliminating differing State and local noise control source emission regulations which may impose a burden on the bus manufacturing industry.

Statutory Basis The proposed action establishes noise emission standards for newly manufactured buses and enforcement procedures to ensure that this equipment complies with the standard. This proposed rulemaking is issued under the authority of the Noise Control Act of 1972 (Pub. L. 92-574, 86 Stat. 1236).

Alternatives Considered The alternatives to the proposed regulation available to EPA are the proposing of different regulatory levels and effective dates, taking no regulatory action at all and labeling. The latter two actions may be taken only if (a) the product does not contribute to the detriment of the public health and welfare, or (b) in the Administrator's judgement, regulation is not feasible.

In Tables 6-1 and 6-2 (Section 6 of Part II the Background Document) and Tables E-1 and E-2 (Appendix E of Part II, the Background Document) are presented 15 alternative regulatory actions, for both exterior and interior bus noise, the Agency considered as possible regulatory levels. The regulatory alternatives presented for both exterior and interior bus noise ranged from no action at all (Schedule 1) to a theoretical maximum action (Schedule 15). In point of fact, the Agency considered many more possible regulatory alternatives, however, detailed information regarding health and welfare benefits (Section 6) and economic impact (Section 7 and Appendix E) are presented only for the 15 exterior and 15 interior regulatory schedules outlined in the above tables.

Pursuant to section 5(b)(1) of the Noise Control Act, buses were identified as major noise sources in May 1975. Subsequent to this identification, comprehensive studies were performed to evaluate bus noise emission levels requisite to protect the public health and welfare, taking into account the magnitude and condition of use of buses, the degree of bus noise reduction achievable through application of the best available technology and the cost of compliance.

Representatives of the Agency carried our extensive interviews with key members of firms in the bus industry to gain firsthand knowledge of the industry and its products and to obtain and verify technological and financial information. Similar interviews were conducted with key persons in intercity bus companies, transit authorities, school districts, and bus industry trade associations as well as officials of various Federal agencies including the U.S. Department of Transportation.

The results of the above studies show that the regulation of bus noise is feasible through available technology taking into account the cost of compliance. Accordingly, the Act permits no alternative action to be taken other than regulation.

It should be noted, however, that if information is received during the Notice of Proposed Rulemaking (NPRM) public comment period which indicates either (1) buses should be regulated to different standards or (2) buses do not constitute a major source of noise, then in the first case the proposed standards should be revised or in the second case the standards should not be issued.

Proposed Regulatory Schedules

The proposed noise emission standards and effective dates are shown in Table 1.

Table 1
Proposed Noise Emission Standards
Average A-Weighted Sound Level (dBA)

	1979	1983	1985
Exterior Bus Noise	83	80	77
Interior Bus Noise	86	83	80

Exterior bus noise levels are measured at a distance of 50 feet. Interior bus noise levels are measured at the noisiest seat location nearest the main body of the engine.

The proposed regulatory levels for exterior bus noise are represented by Option 10 in Tables 6-1 and E-1 of Part II, while the proposed regulatory levels for interior bus noise are represented by Option 11 in Tables 6-2 and E-2 of Part II.

The above standards are required to be met by each product distributed in commerce. To assure 100% compliance with such not-to-exceed standards EPA predicts that manufacturers will design products some two to three decibels below the standards.

To eliminate designs which may fail rapidly when in use, the proposed regulation also requires an acoustical assurance period, a period over which manufacturers will be held responsible for designing and building their products such that the sound control performance of the manufactured vehicles will not deteriorate above the applicable standards. For buses, this period is two years or 200,000 miles, whichever occurs first.

Enforcement The EPA will use the following two methods to determine whether buses comply with the acceptable noise emission standard:

- Production verification - Prior to distribution into commerce of any bus, as defined in this regulation, a manufacturer must submit information to EPA which demonstrates that the product conforms to the standards.
- Selective enforcement auditing - Pursuant to an administrative request, a statistical sample of buses may be tested to determine if the units, as they are produced, meet the standard.

Relationship with Other Federal, State, and Local Government Agencies The proposed regulation will affect several other government regulatory efforts. It will also require supplementary actions by State and local governments.

Federal Government Agencies - The General Services Administration (GSA) currently has set no regulations on maximum sound emission levels for bus vehicles. With the promulgation of this proposed regulation, all bus vehicles procured by the Federal Government after the date of implementation would have to comply with the standards.

State and Local Governments - Although the Noise Control Act prohibits any State or political subdivision thereof from adopting or enforcing any law or regulation which sets a limit on noise emission from such new products, or components of such new products, not identical to the standard prescribed by the Federal regulation, primary responsibility for control of noise still rests with State and local governments.

Nothing in the Act precludes or denies the right of any State or political subdivision thereof from establishing and enforcing controls on environmental noise through the licensing, regulation or restriction of the use, operation or movement of any product or combination of products.

The noise controls which are reserved to State and local authority include, but are not limited to, the following:

1. Controls on the manner of operations of products.
2. Controls on the time in which products may be operated.
3. Controls on the places in which products may be operated.
4. Controls on the number of products which may be operated together.
5. Controls on noise emissions from the property on which products are used.
6. Controls on the licensing of products.
7. Controls on environmental noise levels.

By use of the noise controls reserved to them, state and local governments are able to supplement Federal noise emission standards and to effect near-term relief from traffic noise. The EPA has developed a model ordinance to indicate the form and content of an instrument whereby state and local governments may control transportation equipment noise in the absence of Federal regulation or in the time frame before Federal regulations become effective. The model ordinance is contained in Appendix G of Part II, the "Background Document."

ENVIRONMENTAL IMPACT

Impact on the Population of the United States

Assessment of the intrusive nature of bus noise impact led the Agency to a single event passby noise exposure analysis for assessing the health and welfare impact of bus noise control for exterior noise exposure. Measures of the three indicators of intrusiveness (sleep awakening, sleep disturbance, and speech interference) were used for the single event analysis. Compliance with the proposed standards for exterior bus noise would result in a 39.5 percent reduction in potential sleep awakening impacts due to buses, a 33.4 percent reduction in potential sleep disturbance impacts due to buses, a 52 percent reduction in potential speech interference impacts for people indoors due to buses, a 39.3 percent reduction in potential pedestrian speech interference impacts due to buses and a 49.8 percent reduction in potential speech interference impacts for people outdoors due to buses.

The health and welfare effects from the reduction of interior bus noise were assessed in terms of potential passenger and operator hearing loss risk and passenger speech interference. Compliance with the proposed standards for interior noise levels for buses would result in an average of a 42.7 percent decrease in potential passenger speech interference impacts. In terms of the reduction of hearing loss risk due to lower interior bus noise levels the reductions will range from a 92.4 percent decrease in potential hearing loss for passengers exposed to 60 dBA prior to bus transit to a reduction of 2.6 percent in potential hearing loss risk for those exposed to an 80 dBA level prior to bus transit. Similar percentage impact reductions will occur for bus operators. These reductions are percentages taken from present day impacts to those that will be realized in the year 2000.

For a detailed discussion of the analysis employed to assess the health and welfare benefits due to bus noise regulation refer to Section 6 of Part II, the Background Document.

Impact on Other Environmental Considerations

Energy Conservation Additional weight, increased cooling system capacities and possible greater muffler back pressures are expected to negatively impact the fuel economy of buses by an overall figure of about 3%. Incorporated into this estimate are the fuel savings expected by the implementation of viscous fan clutch technology, which will most probably be used to reduce fan noise on various bus vehicles. The 3% estimate translates into about a 1800 barrel daily increase in fuel consumption for all buses as a result of the proposed regulation. This estimate is based on industry submitted data. The actual impact on bus fuel consumption will be a function of the design changes manufacturers implement to comply with the standards.

Land Use The proposed regulation will have no adverse impact on land use.

Water Quality The proposed regulation will have no adverse impact on water quality or supply.

Air Quality The proposed regulation will have no adverse impact on air quality.

Solid Waste Disposal Requirements The proposed regulation will have no adverse effects on solid waste disposal requirements.

Wildlife Although wildlife may possibly benefit from reduced noise levels of transportation vehicles, not enough is known to conclude to what extent any benefit on wildlife may result from the noise reduction achieved from the proposed regulation.

EPA 550/9-77-201

NOISE EMISSION STANDARDS FOR
TRANSPORTATION EQUIPMENT

PROPOSED
BUS NOISE
EMISSION REGULATION

PART 2
BACKGROUND DOCUMENT

AUGUST 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

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Summary

The subjects addressed in this document are intended to provide background information on various aspects associated with the development of regulations relative to the noise emissions from newly manufactured buses.

Section 1 - "Prologue." sets forth the legal basis for the regulations which may be promulgated under the Noise Control Act of 1972, the procedure followed in the promulgation of such regulations, and a brief statement relative to preemption of state and local regulations by Federal regulations.

Section 2 - "Identification of Buses as a Major Source of Noise." This section addresses the reasons for the classification of buses as a major source of noise.

Section 3 - "The Bus Industry." This section presents general information about the U.S. Bus Industry. It covers industry growth statistics, descriptions of intercity, transit and school bus systems, bus classifications, product life cycle estimates and other useful descriptive material.

Section 4 - "Bus Noise Data Base." This section details the results of exterior and interior bus noise level measurements conducted by EPA on school, transit, and intercity buses. Bus noise data from existing studies and from industry submissions are also presented.

Section 5 - "Noise Abatement Technology." In order to establish regulations restricting bus noise emissions, it was necessary to determine what constitutes the "best available technology" for bus noise reduction. Section 5 reviews the various components of exterior bus noise: noise radiated from the engine surface, fan, intake, exhaust

system and chassis. In addition to the exterior noise generating components, the interior noise of buses is also discussed along with the associated technology needed to reduce bus interior noise levels.

Consideration is given to the total bus noise problem. The technology is examined to determine what modifications or redesign work might be performed on buses in order to quiet them to levels below those which presently exist.

Section 6 - "Potential Impact of Proposed Bus Noise Regulation Schedules on the Environment." This section describes what health and welfare benefits would accrue from the institution of various regulatory standards for exterior and interior bus noise. The percentage of the population affected by noise and the extent of the effect is measured by the Equivalent Noise Impact (ENI) method. The reduction of potential equivalent impacts of sleep disturbances, sleep awakenings, and speech interferences from the lowering of exterior bus noise are detailed. In addition, the reduction of potential equivalent impacts of hearing loss risk and speech interference effects from a lowering of interior bus noise are presented.

Section 7 - "Economic Impact of Bus Noise Control." In this section, the economic impact of increased bus costs due to the basic engineering changes (outlined in Section 5) that are believed to be required to achieve various levels of interior and exterior bus noise is presented. The economic impacts on the three main types (intercity, transit, and school) of bus manufacturers and bus operators are evaluated.

Section 8 - "Measurement Methodology" This section reviews and examines the various test procedures that have been used to determine noise levels for buses. The EPA recommended procedures for the measurement of exterior and interior bus noise emissions are presented.

Section 9 - "Enforcement." Enforcement of new product noise emission standards applicable to buses is discussed in terms of production verification testing of vehicle configurations, assembly line testing using selective enforcement auditing procedures or continuous testing of production vehicles, and in-use compliance provisions.

Section 10 - "Existing Noise Regulations Applicable to Buses." This section presents existing bus noise regulations, both foreign and domestic, and the history of such regulations.

Appendix A - "Foreign Technology Buses." This appendix presents a description of urban transit buses produced by European bus manufacturers which are claimed to be considerably quieter than any similar transit bus produced in the United States.

Appendix B - "New Technology Buses." This appendix looks at new technological designs of quiet buses.

Appendix C - "Bus Noise Abatement Costs." Presented in this appendix are the estimated cost increases and decreases required to manufacture quieter buses, as compared to currently produced buses, for the various technology levels discussed in Section 5. In addition, the lead time estimates believed necessary for the industry to comply with the various technology levels are presented.

Appendix D - "Estimates of Demand Elasticities for Urban Bus Transit and Intercity Bus Transportation." This appendix reviews some of the pertinent economic literature and reports estimates made of the fare elasticity of demand for both transit (intracity) and intercity bus riders.

Appendix E - "Uniform Annualized Cost of Bus Noise Abatement." This appendix presents the annualized costs of various bus noise abatement regulatory schedules. The costs are presented in terms of capital costs and operating and maintenance costs due to the application of additional noise abatement equipment to buses.

Appendix F - "Additional Supporting Information for Health and Welfare Analysis (Section 6)." This appendix provides various tables and figures in support of the health and welfare analysis presented in Section 6.

Appendix G - "Model Noise Ordinance." This appendix provides information for State and local governments to aid them in preparing local noise ordinances for bus noise abatement.

SECTION 1

PROLOGUE

Statutory Basis for Action

Through the Noise Control Act of 1972 (86 Stat. 1234), Congress established a national policy "to promote an environment for all Americans free from noise that jeopardizes their health and welfare." In pursuit of that policy, Congress stated, in section 2 of the Act, "that, while primary responsibility for control of noise rests with State and local governments, Federal action is essential to deal with major noise sources in commerce, control of which requires national uniformity of treatment." As part of that essential Federal action, subsection 5(b)(1) requires the Administrator, after consultation with appropriate Federal agencies, to publish a report or series of reports "identifying products (or classes of products) which in his judgement are major sources of noise." Further, section 6 of the Act requires the Administrator to publish proposed regulations for each product, which is identified or which is part of a product class identified as a major source of noise, where in his judgement noise standards are feasible and when such products fall into various categories of which transportation equipment (including recreational vehicles and related equipment) is one.

On May 28, 1975, pursuant to subsection 5(b)(1), the Administrator published a report which identified, among other new products, new buses as a major source of noise. As required by section 6, the Administrator has proposed regulations for buses, which are "requisite to protect the public health and welfare, taking into account the magnitude and conditions of use of such product (alone or in combination with other noise sources), the degree of noise reduction achievable through the application of the best available technology and the cost of compliance."

Preemption

Under subsection 6(e)(1) of the Noise Control Act, after the effective date of a regulation under section 6 of noise emissions from a new product, no State or political subdivision thereof may adopt or enforce any law or regulation which sets a limit of noise emissions from such new product, or components of such new product, which is not identical to the standard prescribed by the Federal regulation. Subsection 6(e)(2), however, provides that nothing in Section 6 precludes or denies the right of any State or any political subdivision thereof to establish and enforce controls on environmental noise (or one or more sources thereof) through the licensing, regulation or restriction of the use, operation or movement of any product or combination of products.

The noise controls which are reserved to State and local authority by subsection 6(e)(2) include, but are not limited to, the following:

(1) Controls on the manner of operation of products.

(2) Controls on the time during which products may be operated.

(3) Controls on the places at which products may be operated

(4) Controls on the number of products which may be operated together.

(5) Controls on noise emissions from the property on which products are used.

(6) Controls on the licensing of products.

(7) Controls on environmental noise levels.

Federal regulations promulgated under section 6 preempt State or local regulations which set limits on permissible noise emissions from the new products covered by the Federal regulations at the time of sale of such products, if they differ from Federal regulations.

Conversely, State and Local authorities are free to enact regulations on new products offered for sale which are identical to Federal regulations.

SECTION 2

IDENTIFICATION OF BUSES AS A MAJOR SOURCE OF NOISE

In pursuit of subsection 5(b) of the Noise Control Act of 1972, the Administrator has published a report (Federal Register, Vol. 40, No. 103, pp. 23105-7) which identified buses as a major source of noise.

The following paragraphs will briefly describe the basis on which buses were identified as such a noise source.

LEGISLATIVE BASIS

Subsection 6(a) of the Noise Control Act set forth four categories of products for which a noise emission standard can be proposed for each product identified as a major source of noise. The categories are:

1. Construction equipment
2. Transportation equipment (including recreational vehicles and related equipment)
3. Any motor or engine (including any equipment of which an engine or motor is an integral part)
4. Electrical or electronic equipment

PRIORITY BASIS

The criteria developed by EPA to identify products which are major sources of noise and for which noise emission standards are requisite to protect the public health and welfare stipulate that at this time first priority be given to products that contribute to community noise exposure. (Medium and heavy duty trucks have been classified in this category and have already been regulated.) Community noise exposure is that exposure experienced by the community as a whole as a result of the operation of a product as opposed to that exposure experienced solely by the users of the product. To determine which sources ought to be identified for regulation, EPA consideres their functionally weighted noise impact. This measure includes both the intensity (loudness) and extensity (population affected) of noise source impact.

DAY-NIGHT AVERAGE SOUND LEVEL BASIS

The day-night average sound level, L_{dn}, has been specifically developed as a measure of community noise. Since it is a cumulative energy measure, it can be used to identify areas where noise sources operate continuously or where sources operate intermittently but are present enough of the time to emit a substantial amount of sound energy in a 24 hour period.

EPA has identified an outdoor L_{dn} of 55 dB as the day-night average sound level requisite to protect the public from all long-term adverse health and welfare effects in residential areas, and an L_{eq} (24) of 70 dB as the threshold of hearing impairment.

An abbreviated summary of the identified levels is given in Table 1.

TABLE 1

NOISE LEVELS PROTECTIVE OF HEALTH AND WELFARE

Human Response	Leq	Ldn
Hearing Loss (8 hours)	75	--
Hearing Loss (24 hours)	70	--
Outdoor Interference and Annoyance	--	55
Indoor Interference and Annoyance	--	45

The fractional impact of a noise environment on an individual as used by EPA is proportional to the amount (in decibels) that the noise level exceeds the appropriate level identified in the "Levels Document" as shown in Table 1. The fractional impact is zero when the noise level is at or below the identified level. The fractional impact rises to 1.0 at 20 decibels above the identified level and can exceed unity in situations in which the noise level exceeds 20 decibels above the identified level. The range from zero to 20 decibels above the criterion level represents the range between those noise levels that are totally acceptable and those noise levels that are totally unacceptable to the individual in terms of annoyance responses. The total Equivalent Noise Impact (ENI) is then determined by summing the individual fractional impacts for all people affected by the environment.

Thus, two people exposed to 10 decibels above the identified level (fractional impact = 0.5) would be equivalent to one person exposed to 20 decibels above the identified level (fractional impact =1.0).

OTHER PRE-REGULATION CONSIDERATIONS

The drawing-up of regulations necessitates other considerations. Included among these other factors are available noise reduction technology, voluntary industry noise standards, the interrelationship of regulations, lead time necessary for the development of a regulation, economic impact, and the relative availability of data. All these factors have been considered in the development of the proposed regulatory noise levels for buses.

SECTION 3

THE BUS INDUSTRY

GENERAL INDUSTRY BACKGROUND

Early buses, many of which utilized steam power, were designed and constructed in Europe and America at various times during the 1800's. Although some of these primitive buses were effective in passenger transportation, none of them were used for more than short periods of time. Reasons for their lack of success included poor roads, competition from railroads and stagecoaches, and the unreliable operating characteristics of the units themselves.

Bus transportation, as it is now perceived, began to take form in the early 1900's following the development of the internal combustion engine. Bus service was started in New York City and on the Pacific Coast in 1905. In many cases the vehicles used were ordinary passenger touring cars.

Development and improvement of bus design and construction were begun early and have continued to the present time. Touring car chassis were elongated to provide somewhat larger passenger carrying capacity and eventually passenger carrying bodies were mounted on truck chassis to provide the basis for the modern bus. During the middle 1930's, transit and intercity bus manufacturers began combining the chassis and body, utilizing principles of airplane construction. At the same time, it became common to mount the engine at the rear of the bus or under the floor instead of the traditional underhood mounting at the front. These developments resulted in greater strength and longer wear of buses, as well as greater comfort and safety for passengers, better driving vision, greater passenger capacity, and improved riding qualities.

The most significant development in the bus industry in recent years is the Transbus Program. Performance specifications for a revolutionary transit coach were established by the U.S. Department of Transportation's (DOT) Urban Mass Transit Administration. Three different prototypes were built by AM General, GMC Truck & Coach Division, and Rohr Industries' Flxible Company. The three buses underwent a year-long series of tests involving engineering, performance, and public acceptance. Upon completion and evaluation, a "composite" bus incorporating the most significant features of each of the three prototypes was to have been built for further testing.

The purpose of the DOT-funded program was to build and evaluate buses incorporating new design and mechanical features. As a result, the present three prototypes are experimental and do not represent the current state-of-the-art. For example, totally new powertrains and suspensions are used. In an effort to make the buses more attractive to senior citizens, low curb height with the ability to "stoop" to pick up handicapped people and wheelchairs was included in the specifications. A floor height of less than 20 inches was achieved by using specially developed low-profile tires, revolutionary suspensions, and chassis-mounted differentials with swing axles. Other specifications called for noise and odor levels to be 90% below current levels and emission levels that meet the 1975 California standards.

Given the above historical perspective, the following facts from the Motor Vehicle Manufacturers Association exemplify the present size of the bus industry:

- 1975 bus registrations = 470,000
- 1975 bus sales = 40,530

The general structure of the bus industry is schematically outlined in Figure 3-1. The figure illustrates:

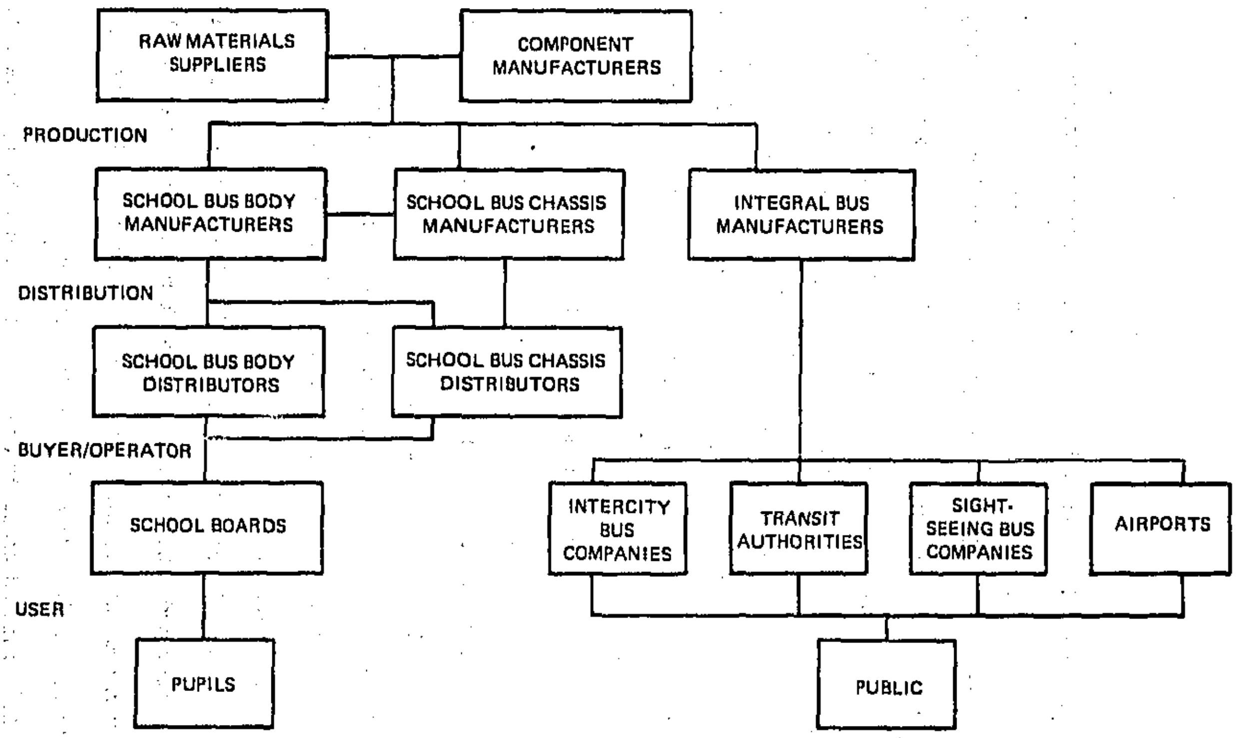
1. Bus manufacturing operations obtain raw materials and components used in the manufacturing process from raw materials suppliers and component manufacturers.

2. Channels of distribution differ from integral (transit and intercity) buses and school buses. Integral bus manufacturers deal directly with end-users, while the distribution channel for most school buses is through body and/or chassis distributors.

3. Finished products are sold to school boards, intercity bus companies, transit authorities, sightseeing bus companies, or airports for

Figure 3-1

STRUCTURE OF THE BUS INDUSTRY



SOURCE: INDUSTRY INTERVIEWS

passenger transportation.

It should be stressed that Figure 3-1 is an overview of the structure of the industry and not all buyer/operators of buses are represented. Most significant of those excluded are government departments and agencies. Also, some integrally constructed buses are used as school buses.

THE BUS MARKET

The bus market is comprised of bus users and operators who provide multiple passenger transporation to the public. The bus market includes the following:

- Commercial Intercity Class 1, 2 and 3 Carriers
- Local or Regional Transit Systems
- School Boards or Administrations
- Churches, private schools and related organizations
- Federal, State and Local Government Agencies and Departments
- All Other
    - o Airports
    - o Hotels
    - o Demand Response Agencies or Organizations
    - o Social Services

A brief overview of the most significant end-users is presented below. In 1974, the following three market segments, intercity, transit and school boards, accounted for approximately 75% of the buses in use.

(a) Commercial Intercity
Class 1, 2, 3 Carriers[1]

The intercity bus operation in the United States is performed by approximately 950 operating companies utilizing some 20,500 motor coaches (Figure 3-2). They provide regularly scheduled service over 270,000 miles of highway and employ an estimated 46,600 people. Intercity bus operations service over 15,000 cities and towns and are the only public intercity transportation service available to some 14,000 of them. In 1975, an estimated 354 million trips were taken by passengers traveling a total of 25.6 billion passenger miles.

Operating revenue from intercity bus lines was $1,165.4 million in 1975, up 29.3% from the 1970 level. During this same period, miles operated and the number of revenue passengers declined 7.4% and 11.7% respectively. In 1976, net operating revenues before income taxes declined 24.3% of the 1970 figure.

(b) Transit Systems

Some 941 transit systems utilized 50,811 buses in 1975. They transported 4,080.9 million passengers and employed almost 160,000 individuals (See Figure 3-3). Operating revenue attributed to motor bus operations reached $1,437.7 million in 1975.

Inspection of the total industry figures indicates that in spite of continued increases in revenue, transit systems have shown operating losses through the last six years. These revenues have increased 17.3% while losses are 5.9 times larger than they were in 1970. These losses were $1,703.5 million in 1975 and $288.2 million in 1970.

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1 Class designations are formed using annual revenue dollars.
Class 1 Carriers have revenues of $1,000,000 or more.
Class 2 Carriers have revenues between $300,000 and $1,000,000.
Class 3 Carriers have revenues less than $300,000.

Figure 3-2

INTERCITY BUS INDUSTRY OPERATING PROFILE

	1970	1971	1972	1973	1974	1975
Number of Operating Companies	1,000	1,000	1,000	1,000	950	950
Number of Buses	22,000	21,900	21,400	20,800	20,600	20,500
Number of Employees	49,500	50,200	49,100	48,400	49,000	46,600
Miles Operated (Millions)	1,209	1,202	1,182	1,178	1,187	1,120
Revenue Passengers (Millions)	401	395	393	381	380	354
Operating Revenues ($ Millions)	901.4	953.2	974.4	1,022.7	1,144.9	1,165.4
Operating Expenses ($ Millions)	812.2	851.8	882.1	937.9	1,062.7	1,097.9
Net Operating Revenues, Before Income Taxes ($ Millions)	89.2	101.4	92.3	84.8	82.2	67.5

Source: National Association of Motor Bus Owners, One-Half Century of Service to America, 1976.

Figure 3-3

TRANSIT BUS INDUSTRY OPERATING PROFILE

	1970	1971	1972	1973	1974	1975
Number of Systems Utilizing Buses	1,075	1,059	1,040	N.A.	941	941
Number of Buses	49,700	49,150	49,075	48,286	48,700	50,811
Number of Employees(1)	138,040	139,120	138,420	140,700	153,100	159,800
Passenger Vehicle Miles Operated (Millions)	1,409.3	1,375.5	1,308.0	1,370.4	1,431.0	1,528.0
Revenue Passengers (Millions)	4,058.3	3,734.8	3,560.8	3,652.8	3,977.6	4,080.9
Operating Revenues ($ Millions)	1,236.3	1,280.2	1,230.1	1,262.9	1,377.3	1,437.7
All Transit Systems(1)						
Operating Revenue ($ Millions)	1,707.4	1,740.7	1,728.5	1,797.6	1,939.7	2,002.4
Operating Expenses ($ Millions)	1,891.7	2,040.5	2,128.2	2,419.8	3,102.4	3,534.9
Net Operating Revenue (Loss)($ Millions)	(184.3)	(299.8)	(399.7)	(622.2)	(1,162.7)	(1,532.5)
All Taxes ($ Millions)	103.9	111.6	113.4	116.3	137.0	171.0
Net Operating Revenue (Loss) After Taxes ($ Millions)	(288.2)	(411.4)	(513.1)	(738.5)	(1,299.7)	(1,703.5)

Source: American Public Transit Association, 1975/1976 Transit Fact Book

(1) All Transit-Includes 6 Rail and 13 Multimode Systems

(c) School Boards or Administrations

Pupil transporation is provided by public school operations for both public and private school children. These operations of the transportation systems are either assumed by local boards or contracted to independent operators. School bus operations are primarily funded with public monies, although certain private schools receive no funding. Depending on the local tax base and the area covered by the school districts, these funds are allocated on a per capita pupil basis or miles driven by the school bus fleet.

In the 1973/74 school year, 21,969,060 public and non-public school children were transported by 267,704 buses at an operating cost of $1,858.1 million. Figure 3-4 shows the average cost of a pupil transported at public expense during the 1973/74 school year to be $87.04. This average figure reflects a significant upward trend in the cost of pupil transportation since the 1959/60 school year when the average cost per pupil was $39.78.

PRODUCT CLASSIFICATION AND CHARACTERISTICS

The most common bus classification is by end use which generally determines the manufacturing process and the finished product. Four general classifications exist:

- Intercity
- Intracity or Transit
- School
- Special Purpose

Figure 3-4

NUMBER AND PERCENT OF PUBLIC SCHOOL PUPILS TRANSPORTED AT PUBLIC EXPENSE, AND CURRENT EXPENDITURES FOR TRANSPORTATION: UNITED STATES, 1959-60 TO 1973-74

		Pupils transported at public expense		Expenditure of public funds	
School Year	Total Enrollment	Number	Percent of total Enrollment	Total, excluding capital outlay (in thousands)	Average Cost per pupil transported
1959-60	32,477,440	12,225,142	37.6	$ 486,338	$39.78
1961-62	34,682,340	13,222,667	38.1	576,361	43.59
1963-64	37,405,058	14,475,778	38.7	673,845	46.55
1965-66	39,154,497	15,536,567	39.7	787,348	50.68
1967-68	40,827,965	17,130,873	42.0	981,006	57.27
1969-70	41,934,376	18,198,577	43.4	1,218,557	66.96
1971-72	42,254,272	19,474,355	46.1	1,507,830	77.43
1973-74	41,438,054	21,347,039	51.5	1,858,141	87.04

Note: All Enrollment and Pupil Figures are Average Daily Attendance.

Source: U.S. Department of Health, Education and Welfare, National Center for Education Statistics, Statistics of State School Systems.

(a) Intercity Buses

Intercity buses are integrally constructed vehicles combining body and chassis into a single unit. Size of these vehicles are determined by practical limitations and state restrictions (Figure 3-5).

As shown in Figure 3-6 there are five principal producers of intercity buses who, combined, offer some fifteen models. The most popular of these have passenger capacities of 41 or 49 passengers with a complete vehicle weight of between 20,000 lbs. and 29,000 lbs. However, large intercity carriers will generally order buses with restroom facilities which reduces passenger capacity by six seats. Depending on the size of the vehicle, two or three axles are utilized. Intercity buses usually have one door for passenger boarding and exit. Product features generally include reclining seats, individual reading lamps, air conditioning, and adequate storage space under the floor of the passenger compartment.

The typical intercity bus is utilized by a company engaged primarily in providing passenger transportation over regular intercity routes with regular time schedules. Approximately 90 percent of the total bus miles in the country are generated in regular route service. Charter and special service travel also play an important part in the industry's operation. In addition, sightseeing bus operations and airports utilize a significant number of intercity buses.

Figure 3-5

SPACE LIMITS ON BUS SIZE

	Alabama	Alaska	Arizona	Arkansas	California	Colorado	Connecticut	Delaware	District of Columbia	Florida	Georgia	Hawaii	Idaho	Illinois	Indiana	Iowa	Kansas
Height (Ft)	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	12-1/2	13-1/2	13-1/2	13-1/2	14	13-1/2	13-1/2	13-1/2	13-1/2
Width (In)	96	96	96	96	96	96	102	96	96	96	96	96	96	96	96	96	96
Length (Ft)	40	40	40	40	40	40	55	42	40	40	55	40	40	42	40	40	42-1/2

	Kentucky	Louisiana	Maine	Maryland	Massachu-setts	Michigan	Minnesota	Mississippi	Missouri	Montana	Nebraska	Nevada	New Hampshire	New Jersey	New Mexico	New York	North Carolina
Height (Ft)	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	14	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2
Width (In)	96	96	102	96	96	96	96	96	96	96	96	96	96	96	96	96	96
Length (Ft)	40	40	56-1/2	55	40	40	40	40	40	40	40	40	40	NS	40	35	40

	orth Dakota	Ohio	Oklahoma	Oregon	Pennsyl-vania	Rhode Island	South Carolina	South Dakota	Tennessee	Texas	Utah	Vermont	Virginia	Washington	West Virginia	Wisconsin	Wyoming
Height (Ft)	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	14	13-1/2	13-1/2	13-1/2	13-1/2	13-1/2	14
Width (In)	102	96	102	96	96	102	96	96	96	96	96	96	96	96	96	96	102
Length (Ft)	40	40	45	35	40	40	40	40	40	45	45	55	40	40	40	40	50

Source: Commercial Car Journal, April, 1975.

Figure 3-6

INTERCITY BUS SPECIFICATIONS

Make and Model	Passenger Rating	Standard Wheelbase (In.)	No. of Axles	Length (Ft.)	Width (In.)	Complete Vehicle Weight Dry (Lbs.)	Engine Make and Model
Crown							
RD-426-11	37-41	260	2	35	96	21,000	Detd 6V-71N
AD-426-11	37-41	232	2	35	96	21,000	Detd 6-71N
RD-568-11	49	251	3	40	96	-	Detd 8V-71N
A-855-11	37-45	232	2	35	95	-	Cum NHH-250
2A-855T-11	49	258	3	40	96	-	Cum NHHT-335
GMC							
P8M-4108-A	41	259-1/2	2	35	96	20,342	Detd 8V-71N
P8M-4904-A	49	318-35/64	3(1)	40	96	23,027	Detd 8V-71N
Motor Coach Industries							
MC-5B(Challenger)	41	261	2	35	96	20,500	Detd 8V-71C
MC-8(Crusader)	49	285	3(2)	40	96	26,760	Detd 8V-71C
Prevost							
TS 47	47,49,51	280	3(2)	40	96	28,300	Detd 8V-71N
TS 102	47,49,51	280	3(2)	40	102	-	Detd 8V-71N
Prestige TS 47	47,49,51	280	3(2)	40	96	28,800	Detd 8V-71N
Prestige TS 102	47,49,51	280	3(2)	40	102	-	Detd 8V-71N
Silver Eagle							
0-5	49	285-1/2	3(2)	40	96	26,500	Detd 8V-71N

Abbreviations and Notes:

(1) Optional third axle is air operated retractable single wheel.
(2) Third axle is a single non-drive bogie.

Cum - Cummings
Detd - Detroit Diesel

Silver Eagle is manufactured and distributed by Eagle International, Inc.
Prevost models Prestige TS 47 and Prestige TS 102 are also marketed as sightseeing buses.

Source: Manufacturer product literature; Commercial Car Journal, October, 1975.

(b) Intracity or Transit Buses

Intracity or transit buses are similar to intercity buses in that both are integrally constructed vehicles. Intracity bus vehicle size and weight are determined by practical limitation and state restrictions. In 1975, as shown in Figure 3-7, four domestic manufacturers produced some twenty-six models of transit buses. However, Highway Products has ceased manufacturing operations for its Twin Coach line of transit and suburban buses. The most popular transit buses seat between 44 and 53 passengers with a complete vehicle weight of between 17,500 lbs. and 23,800 lbs. Transit buses generally have two axles and utilize two doors for passenger boarding and exit. Product features include seats designed for both durability and comfort, and capacity for standing passengers about equal to seating capacity.

The typical intracity bus is utilized by a transit company engaged primarily in providing passenger transportation over regular local routes with regular time schedules. Charter and special service travel play a relatively minor role in the total intracity operation.

Suburban buses are very similar to intracity or transit buses in construction and design. For this reason suburbans are generally not considered as a separate bus classification. General Motors offers two models of its suburban bus to the industry (Figure 3-8). As noted above, Twin Coach suburban buses are no longer manufactured. Suburban

Figure 3-7

TRANSIT BUS SPECIFICATIONS

Make and Model	Passenger Rating	Standard Wheelbase (In.)	No. of Axles	Length (Ft.)	Width (In.)	Complete Vehicle Weight Dry (Lbs.)	Engine Make and Model
AM General							
9635-6	44	224-3/4	2	35	96	17,559	Detd 6V-71N
9635-8	44	224-3/4	2	35	96	17,994	Detd 8V-71N
10235-6	44	224-3/4	2	35	102	18,497	Detd 6V-71N
10235-8	44	224-3/4	2	35	102	18,932	Detd 8V-71N
9640-6	53	284-3/4	2	40	96	19,285	Detd 6V-71N
9640-8	53	284-3/4	2	40	96	19,720	Detd 8V-71N
10240-6	53	284-3/4	2	40	102	20,362	Detd 6V-71N
10240-8	53	284-3/4	2	40	102	20,797	Detd 8V-71N
Flxible							
35096-6	35	175	2	30	96	20,400	Detd 6V-71N
45096-6	45	225	2	35	96	21,000	Detd 6V-71N
45096-8	45	225	2	35	96	21,400	Detd 8V-71N
45102-6	45	225	2	35	102	21,700	Detd 6V-71N
45102-8	45	225	2	35	102	22,700	Detd 8V-71N
53096-6	53	285	2	40	96	22,000	Detd 6V-71N
53096-8	53	285	2	40	96	22,800	Detd 8V-71N
53102-6	53	285	2	40	102	23,200	Detd 6V-71N
53102-8	53	285	2	40	102	23,800	Detd 8V-71N
GMC							
T6H-4523-N	45	235	2	35	96	18,331	Detd 6V-71N
T6H-4523-A	45	235	2	35	96	19,411	Detd 6V-71N
T6H-5307-N	53	284-3/4	2	40	102	19,606	Detd 6V-71N
T6H-5307-A	53	284-3/4	2	40	102	20,631	Detd 6V-71N
T8H-5307-A	53	284-3/4	2	40	102	21,182	Detd 8V-71N
T6H-5308-A	53	284-3/4	2	40	96	20,451	Detd 6V-71N
T8H-5308-A	53	284-3/4	2	40	96	20,982	Detd 8V-71N
Twin Coach							
TC-25-B-TO	21-29	133	2	25	96	11,000	Chy 413 (1)
TC-31-B-TO	30-34	169	2	28	96	12,000	Detd 4-53N (1)

Abbreviations and Notes:

(1) Gasoline or Diesel engine available.

Chy - Chrysler
Detd - Detroit Diesel

Twin Coach is manufactured by Highway Products.

Source: Manufacturer product literature; Commercial Car Journal, October, 1975.

Figure 3-8

SUBURBAN BUS SPECIFICATIONS

Make and Model	Passenger Rating	Standard Wheelbase (In.)	No. of Axles	Length (Ft.)	Width (In.)	Complete Vehicle Weight Dry (Lbs.)	Engine Make and Model
GMC							
S8H-5304-A	53	284-3/4	2	40	96	22,788	Detd 8V-71N
S8H-5304-A	53	284-3/4	2	40	96	22,828	Detd 8V-71N
Twin Coach							
TC-25-B-SO	21-29	133	2	25	96	10,560	Chy 413(1)
TC-31-B-SO	30-34	169	2	28	96	12,000	Detd 4-53N(1)

Abbreviations and Notes:

(1) Gasoline or Diesel engine available.

Chy - Chrysler
Detd - Detroit Diesel

Source: Manufacturer product literature; Commercial Car Journal, October, 1975.

buses generally have one door for passenger boarding and exit and utilize many features of any intercity bus, such as reclining seats and underfloor baggage compartments. The GMC suburban buses currently being put into service, seat 53 passengers with a complete vehicle weight of around 22,800 lbs.

(c) School Buses

The vast majority of school buses, over 98% in 1974, are manufactured in a two stage process. The chassis, which is primarily the same as a medium-duty truck chassis, is produced by a manufacturer and then shipped as an incomplete vehicle to another manufacturer who assembles the body on it. The chassis manufacturing process utilizes the assembly line concept, while the body manufacturing and assembly process utilizes the station or bay system concept.

Various configurations of two-stage school buses are available. The most popular type, approximately 90% of school bus production in 1974, is the conventional school bus, which has the engine located forward of the driver and passengers. The other two types of two-stage school buses are the forward control type which resembles a transit coach in appearance and the parcel delivery type which utilizes a smaller chassis than does the conventional. Gas or diesel engines are available for the above types of school bus with the exception of the parcel delivery type school buses which are powered by gasoline engines.

The remaining small number of school buses are integrally constructed vehicles. The floor, sides, ends and roof are joined into a one-piece construction to form the bus shell. These units are powered by diesel engines located either at the rear or the mid-point of the bus. Only two firms, Crown Coach and Gillig Brothers presently offer integrally constructed school buses.

The size and weight of all school buses are limited by state and local restrictions. In the case of the two-stage vehicles, the chassis GVWR (Gross Vehicle Weight Rating) is also a determining factor. Figure 3-9 shows representative chassis specifications by manufacturer for the conventional school bus. The most popular school bus models currently being produced utilize chassis with seating capacities of between 30 and 72 passengers and a GVWR of between 16,000 lbs. and 30,200 lbs.

Six firms build school bus bodies which are assembled on the chassis. Bodies are built according to customer specifications, consequently manufacturing flexibility is essential. Figure 3-10 presents the various types of bodies manufactured by the six companies. Only Carpenter and Superior have product offerings in all three types of two-stage school buses.

School bus bodies are designed for occupant safety and for durability. Typically, there is one door for passenger boarding and exit, with an emergency door at the rear.

Figure 3-9

SCHOOL BUS CHASSIS SPECIFICATIONS

Make and Series	Axles	Engines	GVW (Lb.)	Capacity (No. of Pupils)	Cowl to End of Frame (In.)	Overall Length (In.)	Wheelbase (In.)
Chevrolet							
SE 620	4X2	G	19,700-24,000	42 - 48	267-3/4	322-1/4	189
SE 625	4X2	G	19,700-24,000	48 - 54	294-3/4	349-1/4	218
SE 628	4X2	G	19,700-24,000	54 - 60	322-3/4	377-1/4	235
SE 631	4X2	G	19,700-24,000	60 - 66	348-3/4	402-1/4	254
Dodge							
S600	4X2	G	16,500-24,000	36 - 66	172 - 349	236 - 413	157 - 258
S700	4X2	G	19,700-25,500	60 - 72	323 - 349	387 - 413	240 - 279
Ford							
B-500	4X2	G	14,000-19,200	36	210-3/4	274-1/2	156
B-600	4X2	G	16,000-24,000	48 - 60	268-1/4-322-1/4	332 - 386	198-1/2-242-1/2
B-700	4X2	G	19,700-27,250	60 - 72	322-1/4-369-1/4	386 - 433	242-1/2-280-1/2
B-750	4X2	G	21,500-27,250	60 - 72	322-1/4-369-1/4	386 - 433	242-1/2-280-1/2
B-7000	4X2	D	20,200-27,250	60 - 72	322-1/4-369-1/4	386 - 433	242-1/2-280-1/2
GMC							
SE 620	4X2	G	19,700-24,000	42 - 48	267-3/4	322-1/4	189
SE 625	4X2	G	19,700-24,000	48 - 54	294-3/4	349-1/4	218
SE 628	4X2	G	19,700-24,000	54 - 60	322-3/4	377-1/4	235
SE 631	4X2	G	19,700-24,000	60 - 66	348-3/4	403-1/4	254
International							
1603	4X2	G	19,800-26,000	30 - 66	221 - 356-1/2	273-1/2 - 409	151 - 254
1703	4X2	G	19,800-27,500	48 - 66	274 - 356-1/2	326-1/2 - 409	187 - 254
1803	4X2	G	20,200-30,200	60 - 66	274 - 380	326-1/2-432-1/2	187 - 275

Abbreviations:

G - Gas
D - Diesel

Source: Manufacturer product literature; Commercial Car Journal, October, 1975.

Figure 3-10

SCHOOL BUS BODIES BY MANUFACTURER AND TYPE

Manufacturer	Conventional	Forward Control	Parcel Delivery
Blue Bird	X	X	
Carpenter Body	X	X	X
Superior Coach	X	X	X
Thomas	X	X	
Ward	X		
Wayne	X		X

Source: EPA interviews with above manufacturers; Manufacturer's Product Catalogues.

(d) Special Purpose Buses

Manufacturers will often custom build a vehicle for an end-user's specific needs, such as airports, hotels, demand response agencies, amusement parks, or prisons. These buses can be either two-stage or integrally constructed. From the manufacturer's perspective, such vehicles are generally treated in the same manner as their standard units in terms of production and sale statistics. In addition, firms not in the bus industry such as recreational vehicle manufacturers may occasionally convert one of their products to fulfill an end-user's specific needs. Consequently, for the remainder of this overview of the industry, with the exception of the section devoted to end use, these special purpose vehicles will not be treated in a separate and distinct fashion.

SIZE AND GROWTH OF THE INDUSTRY

The demand for bus units is a derived demand based upon user/ operator requirements. This section will develop the current size of the market for buses and identify the growth trends within each principal segment.

(a) Geographic Concentration

In 1974 there were 446,558 buses registered in the United States (Figure 3-11). Over fifty percent of these registrations were concentrated in eleven states.

Figure 3-11

U.S. MOTOR BUS REGISTRATIONS BY STATES-1974

State	Private and Commercial: Commercial Buses(1)	Private and Commercial: School and Other(2)	Publicly Owned: Federal	Publicly Owned: School(3)	Total School Buses	Total Buses
Alabama	1,102	746	15	6,349	7,095	8,212
Alaska	424	378	21	18	396	841
Arizona	568	106	233	1,882	1,988	2,789
Arkansas	393	1,485	7	5,460	6,945	7,345
California	9,586	2,859	89	10,935	13,794	23,469
Colorado	448	818	26	3,568	4,386	4,860
Connecticut	1,784	5,350	4	551	5,901	7,689
Delaware	295	942	-	88	1,030	1,325
Florida	2,301	1,010	53	11,369	12,379	14,733
Georgia	1,203	2,365	37	8,796	11,161	12,401
Hawaii	1,444	326	8	81	407	1,859
Idaho	328	391	141	1,788	2,179	2,648
Illinois	6,569	8,747	33	5,723	14,470	21,072
Indiana	3,204	4,213	24	5,873	10,086	13,314
Iowa	895	732	8	7,596	8,328	9,231
Kansas	299	1,005	5	3,650	4,655	4,959
Kentucky	682	772	45	4,980	5,752	6,479
Louisiana	1,004	10,177	11	3,445	13,622	14,637
Maine	200	578	6	1,180	1,758	1,964
Maryland	2,126	5,576	55	2,950	8,526	10,707
Massachusetts	3,333	4,681	4	450	5,131	8,468
Michigan	2,321	3,363	12	8,437	11,800	14,133
Minnesota	1,615	3,866	10	8,718	12,584	14,209
Mississippi	983	1,829	44	5,018	6,847	7,874
Missouri	750	3,155	38	5,449	8,604	9,392
Montana	323	725	41	643	1,368	1,732
Nebraska	410	479	5	1,915	2,394	2,809
Nevada	159	93	44	652	745	948
New Hampshire	253	760	3	203	963	1,219
New Jersey	3,142	4,277	14	3,497	7,774	10,930
New Mexico	539	2,392	341	284	2,676	3,556
New York	12,077	5,800	39	12,606	18,406	30,522
North Carolina	1,972	6,576	19	15,238	21,814	23,805
North Dakota	63	541	40	1,167	1,708	1,811
Ohio	4,807	3,465	29	12,951	16,416	21,252
Oklahoma	355	1,540	62	6,145	7,685	8,102
Oregon	820	1,498	30	3,998	5,496	6,346
Pennsylvania	7,632	10,729	44	4,240	14,969	22,645
Rhode Island	266	542	2	118	660	928
South Carolina	817	1,421	9	6,859	8,280	9,106
South Dakota	253	401	39	1,320	1,721	2,013
Tennessee	1,420	1,163	34	5,289	6,452	7,906
Texas	2,799	11,743	119	11,784	23,527	26,445
Utah	321	79	40	623	702	1,063
Vermont	99	391	-	555	946	1,045
Virginia	2,101	30	61	8,724	8,754	10,916
Washington	385	3,429	106	6,865	10,294	10,785
West Virginia	744	-	6	1,529	1,529	2,279
Wisconsin	1,491	4,814	10	3,053	7,867	9,363
Wyoming	940	226	2	853	1,079	2,021
Dist. of Columbia	2,027	33	132	193	226	2,385
Total	90,072	128,617	2,200	225,658	354,275	446,547

(1) Includes municipal owned transit buses.
(2) In some instances church, industrial and other private buses are included here; and in other instances privately owned school buses could not be segregated from commercial buses, and are included with the latter.
(3) This column consists primarily of publicly owned school buses but include a few privately owned school institutional and industrial buses registered free or at a reduced rate.

Source: U.S. Federal Highway Administration.

(b) Buses in Service by End Use and Product Classification.

End users generally utilize the type of bus that is manufactured and designed for a specific application. In other words, intercity carriers utilize intercity buses, transit systems utilize transit buses, and school districts, private schools and churches utilize school buses. However, exceptions do exist and an end user may utilize a type of bus which is not necessarily designed for the specific application. According to manufacturers, trade associations, and end users, such situations are rare. Thus, for purposes of analysis, Figure 3-12, which is the basis for the following discussion, treats end use of the three types of bus according to the traditional applications.

1. Total Buses. Bus registrations have increased 27% during the period 1968 to 1974. The size of each segment in 1974 was as follows:

Intercity	4.6%
Transit	10.9%
School	79.4%
Federal Government	0.5%
Others	4.6%

2. Intercity Buses. Intercity buses are primarily utilized by Intercity Class 1, 2 or 3 Carriers, sightseeing bus companies, and firms providing transportation to and from airport locations. The National Association of Motor Bus Owners estimates that in 1974, 20,600 intercity buses were operated by intercity carriers. Robert A. Kay, Director of the

Figure 3-12

BUSES IN SERVICE BY END USE AND PRODUCT CLASSIFICATION

	INTERCITY & TRANSIT BUSES			SCHOOL BUSES[2]				
Year	Intercity Class 1,2,3 Carriers	Transit Systems	Others[1]	Transportation Public Expense	Transportation Private Expense	Total	Federal Government[3]	Total Buses
1974	20,600	48,700	20,772	267,704	86,930	354,634	2,200	446,906
1973	20,800	48,286	20,390	262,579	71,313	333,892	2,159	425,527
1972	21,400	49,075	18,247	260,772	55,649	316,421	1,811	406,954
1971	21,900	49,150	17,566	245,608	61,677	307,285	1,682	397,583
1970	22,000	49,700	17,123	244,337	44,413	288,750	1,448	379,021
1969	21,600	49,600	17,792	238,103	35,871	273,973	1,317	364,282
1968	21,000	50,000	17,182	219,147	43,000	262,204	1,413	351,799

Notes: (a) The numbers given above are EPA estimates based on estimates by several reliable sources of the buses in use. Certain inaccuracies must be acknowledged and are listed below:

(1) End users of intercity and transit buses utilize a very small number of school buses in their operations, such vehicles cannot be easily identified and consequently are included in the Intercity & Transit columns.

(2) As was the case in (a) above, end users of school buses utilize a very small number of intercity and transit buses which are included in the School Bus columns.

(b) The numbers given above are estimates based on state registration data. Buses owned by the Department of Defense are not included. In 1969, DOD buses were estimated to be 11,289.

Footnotes: (1) Intercity buses used in sightseeing and airport operations accounted for an estimated 18,000 units in 1974.

(2) Includes Class II school buses which are estimated to account for approximately 10% of the total.

(3) Includes all types of buses. Only vehicles of the civilian branches of the Federal Government are given.

Source: U.S. Department of Transportation/Federal Highway Administration, Highway Statistics, 1968-1974, Table MV-10; Department of Health, Education, and Welfare, Office of Education, Statistics of State School Systems, 1967-68 to 1973-74; National Association State Directors of Pupil Transportation Services, Growth of School Transportation In the U.S., 1975; National Association of Motor Bus Owners, One-Half Century of Service to America, 1976; American Public Transit Association, Transit Fact Book, 1976; Motor Vehicle Manufacturers Association, Motor Truck Facts, 1970; Federal Highway Administration/Bureau of Motor Carrier Safety, Safe Transport, Intercity Bus Industry in the U.S., 1975.

Bureau of Motor Carrier Safety, Federal Highway Administration, has estimated that in 1974, approximately 18,000 buses were operated by sightseeing and airport bus lines.

The number of intercity buses utilized by Class 1, 2, 3 Carriers has remained rather stable since 1968. However, a downward trend has developed since 1970 when the population reached 22,000. In 1974, the population was estimated to be 20,600, while preliminary estimates for 1975 are 20,500. Influencing this downward trend have been a 5% decline in operating companies, a 7.4% decline in miles operated, and an 11.7% decline in revenue passengers (refer to Figure 3-2).

3. Transit Buses. Transit buses accounted for 10.9% of the total bus population in 1974. In the early 1970's, transit bus population demonstrated a downward trend which reached a low point in 1973 of 48,286 buses in use. The following two years have seen the transit bus population on the rise, 48,700 units in 1974 and 50,811 units in 1975. Influencing this growth situation has been a rise in revenue passengers, 3,560.8 million in 1972 compared with 4,080.9 million in 1975, a growth of some 14.6%. Related to this growth in revenue passengers has been a corresponding growth in operating revenues, from $1,230.1 million in 1972 to $1,437.7 million in 1975, and increase of 16.9%. Despite these growth factors, net operating losses after taxes have continued to mount, $288.2 million in 1970 compared to 1,703.5 million in 1975, an increase in losses of 591%.

4. School Buses. School buses accounted for a significant number, 79.4%, of total buses in 1974. The majority of school buses, are utilized in transportation of students, the handicapped, etc., at public expense. The vehicles used in this function are either owned by a school district (or other public entities) or by a private company which operates under contractual arrangement with a school district. The remaining school buses are privately owned and operated in a variety of situations without public funding. Common examples of users include churches, private schools, and related groups or organizations.

The number of school buses in use has increased dramatically since 1968 when 262,204 vehicles were registered. In 1974, total registrations of school buses had reached 354,634, a growth of some 35% since 1968.

Included within the above school bus figures are vehicles with a GVW of 10,000 lbs. or less and seating capacity of 16 or less. Such vehicles are commonly called "Class II" school buses. Generally, Class II school buses are converted vans or cab cut-a-ways. A converted van is a type of light duty truck which is modified to meet state and local safety regulations for pupil transport. Modifications include reinforcing the floor, raising the ceiling, and adding windows. A cab cut-a-way is also a light duty truck which comes to the body manufacturer with an enclosed cab and a chassis upon which a small school bus body is built according to required safety guidelines.

Station wagons used as school buses along with the above vehicles accounted for approximately 31,282 units according to 1973-74 estimates by the Department of Health, Education, and Welfare's Office of Education. Such vehicles are not included in the scope of this proposed regulation.

According to several manufacturers, these types of school buses have enjoyed increasing popularity over the last few years. However, data to substantiate such opinions cannot be documented from existing published records.

5. Federal Government. Buses used by civilian branches of the Federal Government represent only 0.5% of the total bus population. All three types of bus are utilized by this end use segment. A significant growth rate of almost 57%, 1,413 units in 1968 compared with 2,200 units in 1974, has characterized this market segment.

6. Others. As discussed earlier in the intercity bus section, the majority of vehicles in this end use category are buses used in sightseeing and airport applications. The remaining buses in this category have many and varied applications. For example, amusement parks, hotels, rental car companies, etc., use buses to provide transportation in conjunction with some other activity. This general end use category has grown almost 21% to 20,772 vehicle in 1974 from 17,182 in 1968. From industry interviews with several manufacturers, it can be assumed that some part of the total 20,772 buses in this segment are smaller than

16,000 lbs. GVWR and seat less than 16 passengers.

(c) New Product Shipments

In 1974 manufacturers of buses shipped 35,729 units. Figure 3-13 presents a history of these shipments.

1. Intercity Buses. In 1974 total shipments of intercity buses were 1,350 units, 26.9% above shipments of 1970. Intercity bus shipments show a great deal of variation from year to year.

2. Transit Buses. Transit bus shipments have shown constant growth through the last five years. 1974 shipments of 4,818 units are 3.3 times greater than shipments in 1970.

3. School Buses. In 1974 school bus shipments were 29,561 units, which is a slight decline from the peak level of 30,635 units in 1972. Although the trend in school bus shipments has been upward since 1965, the trend has not been constant with cyclical rises and declines in annual shipments.

PRODUCT LIFE CYCLE

Beyond the end-use industry conditions outlined above, product life cycle dictates the replacement activity within bus fleets. It is very difficult to determine an average product life for the three major types of bus. Product life is contingent on factors such as maintenance routines and procedures, geographic location, miles traveled, and the

Figure 3-13

SHIPMENTS BY YEAR AND BUS CLASSIFICATION BASED ON REGISTRATIONS

Year	Intercity	Transit	School
1974	1,350	4,818	29,561
1973	1,276	3,200	30,039
1972	1,353	2,904	30,635
1971	977	2,514	28,358
1970	1,064	1,442	27,468
1969	NA	2,230	28,064
1968	NA	2,228	29,015
1967	NA	2,500	28,214
1966	NA	3,100	26,419
1965	NA	3,000	24,276

Source: National Association of Motor Bus Owners; American Public Transit Association; Interviews with General Motors and International Harvester.

economic conditions of the end-users. Given this situation, the following are estimated ranges for product life with the original owner:

Intercity - 12 to 15 years

Transit - 10 to 15 years

School - 8 to 12 years

Certain factors can affect these ranges. For example, when a bus is first put into operation it incurs its heaviest utilization. A typical intercity bus will travel 250,000 miles during the first two years of utilization. Transit buses, depending on the geographic location and the attendant route size, will travel between 30,000 and 60,000 miles per year. School buses travel an average of 38 miles per day, but individual mileage totals vary substantially around this mean figure.

NATURE OF THE INDUSTRY

This section will describe the nature of the bus industry in terms of channels of distribution, sales practices, pricing, and resale. It is organized according to the three major product segments of Intercity, Transit, and School Buses.

(a) Intercity Buses

The nature of the intercity bus segment is generally determined by the following:

1. Channels of Distribution. The flow of new intercity buses is incorporated in Figure 3-1. Note that the manufacturer deals directly with the end-user and that a dealer or distribution network does not exist.

All intercity bus prices are F.O.B. factory, and delivery of the vehicle is the responsibility of the end-user. Two alternatives are primarily utilized: end-user personnel are sent to the factory to drive the units to their destination, or an independent bus delivery company will drive the completed unit from the factory to an end-user designated location.

2. Sales Practices. Manufacturers of intercity buses deal directly with intercity operators. Generally, bus requirements and specifications are determined by the end-user, with custom units made in accordance with a variety of special requirements. Each order is separately priced in competitive bids.

Certain exceptions to the above exist. For example, the Greyhound Corporation, the largest Class I Intercity Carrier, purchases its vehicles from a subsidiary, Motor Coach Industries. Continental Trailways, another large end-user, has maintained a purchase agreement with Eagle International.

3. Pricing. The variety of end-user bus requirements and specifications makes the determination of an average price difficult. However, based on interviews with the National Association of Motor Bus Owners, General Motors and Crown Coach, current prices would range between $75,000 and $96,500.

4. Resale/Used Buses. The impact of the resale of used buses on the nature of the intercity bus market is relatively insignificant. Original end-users of intercity buses generally utilize the

vehicle throughout the usable life of the unit. After the useful life of the vehicle is expended, the original end-user will either sell the unit for salvage or strip the unit for useful parts and sell the remainder for salvage or sell the unit to another end-user. Purchasers of used vehicles generally are smaller intercity carriers and usually do not purchase new vehicles.

(b) Transit Buses

The nature of the transit bus segment is generally determined by the following:

1. Channels of Distribution. The flow of new transit buses into distribution as shown in Figure 3-1 is the same as the flow for new intercity buses.

2. Sales Practices. The sales practices utilized in the transit bus market segment are very similar to those practices employed in the intercity segment. In summary, manufacturers deal directly with end-users. Also, transit coaches are custom-made according to customer specifications and each order is separately priced in competitive bids by industry. The significant difference lies in the formality of the bid procedure in the transit market segment. This formal bid procedure is dictated by governmental guidelines which are prerequisite to the awarding of grants and subsidies.

3. Pricing. The most popular transit buses in use are 35 foot and 40 foot vehicles which are manufactured according to customer specifications. Based on interviews with General Motors and several transit

companies, current price ranges for the most popular models are:

35 foot - $55,000 to $68,000

40 foot - $60,000 to $75,000

4. Resale/Used Buses. Transit buses are generally utilized by the original owner throughout their useful life. The original end-user will dispose of a unit by either selling it for salvage or by stripping the useful parts and selling the remainder for salvage, or by selling it to another transit authority or end-user.

Transit authorities may occasionally purchase used buses to fill an unexpected demand, to cover delays in new bus delivery, to obtain parts, or to avoid costs of new bus purchases.

(c) School Buses

The nature of the school bus segment is generally determined by the following:

1. Channels of Distribution. As depicted in Figure 3-1, distribution of conventional school buses differs greatly from that of intercity and transit buses. School bus distribution is a complex two-step distribution process. The difference principally is that either a chassis dealer or a body dealer can sell the complete bus to the end-user. Most orders will typically be handled by the school bus body manufacturer.

The distribution process begins with a bus body builder's pool (inventory) of chassis. Given a local body dealer's order, a chassis is taken from inventory and a body installed to end-user specifications. Typically, when a chassis is used the regional chassis manufacturer representative is notified and credit is given to the local chassis dealer.

In the case where a chassis dealer takes an order for complete buses, the process is similar. The principal difference is that the local body distributer is given commission on the sale of the body. In both cases warranty service is provided on a local dealer basis for the part of the product that each represents.

2. Sales Practices. As expected by the type of distribution, the principal sales of school buses are through dealers. National selling responsibility for each part of the product is maintained by body and chassis manufacturers.

There is a principal difference between the selling efforts of chassis and body manufacturers. Chassis manufacturers view their customers as body builders and principally concentrate their activites at that level, although chassis manufacturers will become involved in large bid situations. Body manufacturers, on the other hand, promote their companies' products and services directly to the school administrations.

The majority of school bus sales are made in public bids to predetermined specifications. As previously noted, these specifications, beyond meeting minimum safety standards, vary greatly from locality to locality.

3. Pricing. Due to the variety of school bus model types, a single price range would not accurately portray the proper perspective. Therefore, the following Table 3-1 presents school bus prices by vehicle type.

4. Resale/Used Buses. School buses find rather a large resale market: Typically, school authorities will sell used buses to brokers. These buses in turn will be sold to such groups as churches, boys' clubs, P.T.A.'s, Y.M.C.A.'s, and a wide variety of other groups.

TABLE 3-1

August, 1976 Prices for
Completed School Buses, by Type of Bus

Type of Bus	Range of Prices	Average Price (1)
Gasoline Powered:		
Conventional	$11,000-18,000	$14,500
Forward Control	$26,000-30,000	$27,000
Parcel Delivery	$10,000-11,500	$11,000
Diesel Powered:		
Conventional	$17,000-25,000	$19,000
Forward Control	$28,000-30,000	$30,000
Integral Mid-engine	$37,000-90,000	$50,000
Integral Rear-engine	$37,000-75,000	$50,000

Note: (1) The average price expressed here is the price given by respondents as closely approximating the mean price paid for units of the respective type.

Source: Telephone interviews conducted between EPA consultants and manufacturers and school bus distributors.

BUS MANUFACTURERS PROFILE

The remainder of this discussion will profile individual bus manufacturers in terms of a general description, financial resources, employment, production facilities, and market share. It is organized into four sections as determined by the basic bus classifications and market segments as follows:

- Intercity Bus Manufacturers
- Transit Bus Manufacturers
- School Bus Chassis Manufacturers
- School Bus Body Manufacturers

The basic information used in this section is developed from composite tables of manufacturers shown in Figure 3-14 and 3-15. Market share data are represented in Figure 3-16 through 3-19.

(a) Intercity Bus Manufacturers

The firms, subsidiaries, or divisions shown below account for the vast majority of intercity bus production:

- Crown Coach Corporation
- Eagle International, Incorporated
- GMC Truck & Coach
- Motor Coach Industries, Limited
- Prevost Car

1. Crown Coach Corporation. Established in 1904, this family controlled business has operated on a profitable basis and has increased

Figure 3-14

BUS MANUFACTURERS FACILITY PROFILE AND EMPLOYMENT ESTIMATES, 1974

Manufacturer	Corporate Headquarters Location	Production Facilities: Location	Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
General Motors Corporation (1)	Detroit, Michigan	Pontiac, Michigan	1,579.1	O	15,000 (2)	School bus chassis Medium duty trucks
		Pontiac, Michigan	NA	O	-	Intercity buses Transit buses
Ford Motor Company	Dearborn, Michigan	Louisville, Kentucky	NA	NA	NA	School bus chassis NA
		Windsor, Ontario, Canada	NA	NA	NA	School bus chassis NA
Chrysler Corporation	Warren, Michigan	Windsor, Ontario, Canada	495	O	NA	School bus chassis Medium duty trucks Motor home chassis
International Harvester Company	Chicago, Illinois	Springfield, Ohio	NA	NA	4,000	School bus chassis Medium duty trucks
Greyhound Corporation (Motor Coach Industries, Ltd.)	Phoenix, Arizona	Winnipeg, Manitoba, Canada	155	O	1,500 (3)	Intercity buses
		Fort Gary, Manitoba, Canada	135	O	-	NA
American Motors Corporation (4) (AM General Corporation)	Southfield, Michigan	Mishawaka, Indiana	350	NA	NA	Transit buses
		Marshall, Texas	NA	NA	NA	Transit bus bodies
Indian Head Incorporated (Wayne Corporation)	New York, New York	Richmond, Indiana	NA	NA	500 - 800	School bus bodies Ambulances Hearses Professional cars
Rohr Industries, Incorporated (The Flxible Company)	Chula Vista, California	Delaware, Ohio	338	NA	NA	Transit buses

Figure 3-14 (cont.)

BUS MANUFACTURERS FACILITY PROFILE AND EMPLOYMENT ESTIMATES, 1974 (CONT'D)

		Production Facilities				
Manufacturer	Corporate Headquarters Location	Location	Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
Sheller-Globe Corporation (Superior Division)	Toledo, Ohio	Lima, Ohio	698	O	1,800	School bus bodies Integral buses Hearses Ambulances Military vehicles
		Kosciusko, Mississippi	NA	NA	NA	School bus bodies Integral buses Specialty vehicles
Thomas Built Buses, Incorporated	High Point, North Carolina	High Point, North Carolina	42.2	O	500	School bus bodies Integral buses Specialty vehicles
		Woodstock, Ontario, Canada	NA	NA	NA	NA
Blue Bird Body Company, Incorporated (5)	Fort Valley, Georgia	Fort Valley, Georgia	500	NA	650	School bus bodies Integral buses Specialty vehicles
		Mount Pleasant, Iowa	NA	NA	NA	NA
		Buena Vista, Virginia	NA	NA	NA	NA
Carpenter Body Works, Incorporated	Mitchell, Indiana	Mitchell, Indiana	375	O	630	School bus bodies Integral buses Specialty vehicles
Ward School Bus Manufacturing, Incorporated (Subsidiary of Ward Industries, Incorporated)	Conway, Arkansas	Conway Arkansas	234	L	500 - 600	School bus bodies
Crown Coach Corporation	Los Angeles, California	Los Angeles, California	65	O	275 - 450	Integral school buses Intercity buses Specialty vehicles
Highway Products, Incorporated (6) (Subsidiary of Midwest Management Corporation)	Chicago, Illinois	Kent, Ohio	250	NA	150	Transit buses Automotive suspension systems

Figure 3-14 (cont.)

BUS MANUFACTURERS FACILITY PROFILE AND EMPLOYMENT ESTIMATES, 1974

Manufacturer	Corporate Headquarters Location	Production Facilities: Location	Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
Gillig Brothers Incorporated (Subsidiary of the S.G. Herrick Corporation)	Hayward, California	Hayward, California	120	O	150	Integral school buses Specialty vehicles
Eagle International, Inc.	Luxembourg (Europe)	Brownsville, Texas	157	L	150	Intercity buses
Prevost Car	Ste. Claire, Dorchester, Quebec, Canada	Ste. Claire, Dorchester, Quebec, Canada	144	O	125-200	Intercity buses Motor Homes Specialty Vehicles

Footnotes: (1) General Motors is refurbishing an existing facility to accommodate production of a new line of transit buses. A new production facility for school bus chassis is being planned.

(2) This figure represents all employees in the two operating facilities. The number of employees involved exclusively in the production of buses is not available.

(3) This figure represents all employees in the two facilities.

(4) AM General Corporation's headquarters are located in Wayne, Michigan.

(5) A bus production facility in Guatemala and a bus production facility in Canada, utilized exclusively for sales of product in their respective countries, have been excluded from the exhibit. A parts manufacturing facility in Fort Valley, Georgia has also been excluded. Total company employment is approximately 1,000.

(6) Production ceased in 1975.

Source: Annual Reports; Dun & Bradstreet; Moody's Industrial Manual; Industry Interviews.

Figure 3-15

BUS MANUFACTURERS
FINANCIAL CHARACTERISTICS, 1974

Year End	Manufacturer	Financial Characteristics ($ Millions) Sales	Net Income	Assets	Principal Bus Products
12/31/74	General Motors Corporation Detroit, Michigan (GMC Truck & Coach Division)	$31,549.5	$950.1	$20,468.1	Intercity and transit buses; school bus chassis
12/31/74	Ford Motor Company Dearborn, Michigan	23,620.6	360.9	14,173.6	School bus chassis
12/31/74	Chrysler Corporation Warren, Michigan	10,971.4	(52.1)	6,732.8	School bus chassis
10/31/74	International Harvester Company Chicago, Illinois	4,965.9	124.1	3,327.0	School bus chassis
12/31/74	Greyhound Corporation Phoenix, Arizona (Motor Coach Industries, Ltd.)	3,469.3	58.0	1,357.3	Intercity buses
9/30/75	American Motors Corporation (1) Southfield, Michigan (AM General Corporation)	2,282.2	(27.5)	1,010.3	Transit buses
11/30/74	Indian Head Incorporated New York, New York (Wayne Corporation)	615.4	22.5	353.5	School bus bodies
7/31/75	Rohr Industries, Incorporated Chula Vista, California (The Flxible Company)	456.3	(7.6)	313.8	Transit buses
9/30/74	Sheller-Globe Corporation Toledo, Ohio (Superior Division)	286.8	7.6	233.7	School bus bodies
3/31/75	Thomas Built Buses, Incorporated High Point, North Carolina	30.0	1.6 (2)	14.6	School bus bodies
12/31/74	Blue Bird Body Company, Incorporated Fort Valley, Georgia	30.0	NA	NA	School bus bodies

Figure 3-15

BUS MANUFACTURERS
FINANCIAL CHARACTERISTICS, 1974 (CONT'D)

Year End	Manufacturer	Financial Characteristics ($ Millions) Sales	Net Income	Assets	Principal Bus Products
12/31/74	Carpenter Body Works, Incorporated Mitchell, Indiana	20.0	NA	9.8[3]	School bus bodies
12/31/74	Ward School Bus Manufacturing, Incorporated, Conway, Arkansas (Subsidiary of Ward Industries Incorporated)	16.0	NA	NA	School bus bodies
12/31/74	Crown Coach Corporation Los Angeles, California	14.0	NA	18.2	Integral school buses; intercity buses
12/31/74	Highway Products, Incorporated[4] Kent, Ohio (Subsidiary of Midwest Management Corporation)	11.7	(.8)	5.4[5]	Transit buses
11/30/72	Gillig Brothers Incorporated Hayward, California (Subsidiary of The S. G. Herrick Corporation)	6.0	NA	4.4	Integral school buses
12/31/74	Prevost Car Ste. Claire, Dorchester, Quebec, Canada	4.5	NA	2.5-3.5	Intercity buses
	Eagle International, Incorporated Brownsville, Texas (Subsidiary of Overseas Inns)	NA	NA	NA	Intercity buses

(1) AM General Corporation's sales totaled $339.3 million with net income of $188,000.

(2) 3/31/74

(3) 12/31/72

(4) Production ceased in 1975.

(5) 3/11/75

Source: Annual Reports, Dun & Bradstreet, Fortune "500" Directory.

Figure 3-16

ESTIMATED FACTORY SHIPMENTS AND MARKET SHARE

INTERCITY BUSES

Manufacturer	1970 Units	1970 Market Share	1971 Units	1971 Market Share	1972 Units	1972 Market Share	1973 Units	1973 Market Share	1974 Units	1974 Market Share
Motor Coach Industries	509	47.8%	497	50.9%	725	53.6%	587	46.0%	620	45.9%
General Motors	241	22.7	155	15.9	280	20.7	346	27.1	434	32.1
Eagle International	291	27.3	300	30.7	300	22.2	283	22.2	236	17.5
All Others (1)	23	2.2	25	2.6	48	3.5	60	4.7	60	4.4
Total	1,064	100%	977	100%	1,353	100%	1,276	100%	1,350	100%*

* Totals do not add up to 100% due to rounding

[1]Footnote: Includes units manufactured by Prevost and Crown Coach.

Source: Interviews with General Motor Corporation and Motor Coach Industries; A.T. Kearney calculations based on information provided in industry interviews.

Figure 3-17

TRANSIT BUS MARKET SHARES

ESTIMATED MARKET SHARES - TRANSIT BUSES
TOTAL TRANSIT BUS FLEET

Manufacturer	Market Share
General Motors	75.2%
Flxible	17.8%
AM General	3.4%
Highway Products	1.1%
All Others*	2.5%

Footnote: *Includes imported buses.

Source: EPA estimates based on data from American Public Transit Association, Fleet Inventory.

ESTIMATED MARKET SHARES - TRANSIT BUSES
NEW EQUIPMENT DELIVERED, 1970-1975

Manufacturer	Market Share
General Motors	65.2%
Flxible	26.9%
AM General	4.2%
Highway Products	1.7%
All Others*	2.5%

Footnote: *Includes imported buses.

Source: EPA estimates based on data from American Public Transit Association, Fleet Inventory.

ESTIMATED MARKET SHARES - TRANSIT BUSES
NEW EQUIPMENT DELIVERED, 1974-75

Manufacturer	Market Share
General Motors	44.6%
AM General	26.3%
Flxible	22.4%
Highway Products	2.7%
All Others*	4.0%

Footnote: *Includes imported buses

Source: EPA estimated based on data from American Public Transit Association, Fleet Inventory.

Figure 3-18

U.S. DOMESTIC FACTORY SALES AND MARKET SHARES

SCHOOL BUS CHASSIS

	1969		1970		1971		1972		1973	
Manufacturer	Units	Market Share	Units	Market Share	Units	Market Share	Units	Market Share	Units	Market Share
Chevrolet	9,105	29.6%	6,945	24.5%	5,294	17.1%	3,879	11.7%	3,793	11.2%
Dodge	1,511	4.9	2,010	7.1	1,676	5.4	1,177	3.6	677	2.0
Ford	6,670	21.7	5,670	20.0	5,503	17.8	8,549	25.9	9,815	29.0
GMC	4,764	15.5	3,989	14.1	5,114	16.6	4,622	14.0	2,455	7.3
IHC	8,117	26.4	8,921	31.5	12,399	41.1	13,575	41.1	15,510	45.9
All Others[(1)]	603	2.0	790	2.8	897	2.9	1,235	3.7	1,580	4.7
Total	30,770	100.0%*	28,325	100.0%*	30,883	100.0%*	33,037	100.0%*	33,820	100.0%*

*Totals do not add up to 100% due to rounding.

Footnote: [(1)]National Chassis Company, Perry, Goergia and Hendrickson Manufacturing Company, Lyons, Illinois account for a significant number of units.

Source: School Bus Fleet; Interviews with General Motors, International Harvester and Chrysler.

Figure 3-19

ESTIMATED FACTORY SHIPMENTS AND MARKET SHARE
SCHOOL BUS BODIES, 1974

Manufacturer	Shipments	Market Share
Blue Bird	6,592	22.3%
Sheller Globe (Superior)	6,592	22.3
Indian Head (Wayne)	5,055	17.1
Thomas	4,257	14.4
Carpenter	3,784	12.8
Ward	2,838	9.6
All Others[(1)]	443	1.5
Total	29,561	100.0%

(1) Crown Coach and Gillig account for the majority with integrally constructed buses. Also includes units manufactured by firms not in the bus industry such as recreational vehicle manufacturers.

Source: EPA compared estimated market share information provided by body manufacturers with Dun & Bradstreet sales estimates.

net worth annually through retained earnings. In 1974, Crown had sales of approximately $14 million, total assets of $18,165,223, and a tangible net worth of $3,755,232. In addition to intercity buses, the firm also manufactures integrally constructed school buses and fire trucks. Crown is also a distributor of coaches and bodies for other manufacturers and operates a coach maintenance division. Crown will employ between 275 and 450 people, depending on demand and seasonal fluctuations, in one production facility of 65,000 square feet located in Los Angeles, California. The firm's integrally constructed vehicles compete primarily in two market segments, intercity and school, and accounted for less than 1% of total sales in each market in 1974.

2. Eagle International, Incorporated. This company, a subsidiary of Overseas Inns, S.A., Luxembourg was founded in 1973 to manufacture buses primarily for Continental Trailways, the second largest U.S. intercity carrier. Prior to 1973, another subsidiary of Overseas Inns manufactured such buses in Belgium. However, with the devaluation of the U.S. dollar, the Belgian units could no longer be competitively priced and Eagle was formed.

As noted above, Eagle was started to manufacture Silver Eagle intercity buses primarily for Continental Trailways under an annual contract. In the second half of 1975 this annual contract expired and had not been renewed as of August 26, 1976. As a result, production has been cut significantly. The number of employees has been reduced from 350 to 150. Finally, on August 12, 1976, a meeting was held with many of the firm's creditors in order to work out a plan for repayment of debts. The firm is maintaining its lease on a 157,000 square foot plant in Brownsville, Texas. In 1974, Eagle accounted for approximately 17.5% of total intercity bus sales.

3. GMC Truck & Coach. In 1943, General Motors Corporation acquired the assets of Yellow Truck & Coach Manufacturing Company and business formerly conducted by that organization is today being carried on by the GMC Truck & Coach Division. In 1974, General Motors had net sales of $31,549,546,126; net income of $950,069,363; total assets of $20,468,099,914; and employed approximately 734,000 individuals. Specific financial information for GMC Truck & Coach Division is not available.

General Motors is primarily an operating corporation, carrying on activities through operating divisions. The firm also owns stock in many other companies. Generally, GM is engaged in manufacture, assembly, and distribution in the United States of various motor driven products most of which relate to transportation equipment. Subsidiaries and associated companies conduct similar operations in Canada and other foreign countries.

Automotive products consist of passenger cars, trucks, buses, motor homes, and their related components, as well as parts and accessories. The greatest portion of such components, parts and accessories is used in the manufacture of GM automotive products. In addition, substantial amounts of such products are sold to outside manufacturers, and are also marketed through distributors, dealers, and jobbers.

In the United States there are 29 major operating divisions, while in Canada, GM manufacturing operations are carried on by a subsidiary. Products are distributed to other world markets through the Overseas Operations Division which has assembly and manufacturing operations in 21 countries.

GMC Truck & Coach Division operates two bus manufacturing facilities in Pontiac, Michigan; one is devoted entirely to the production of intercity and transit buses, while the other manufactures school bus chassis and medium duty trucks. The two plants jointly employ approximately 15,000 people. An existing facility, also in Pontiac, is being refurbished to accomodate production of GMC's new transit bus, the RTS-2. Future plans call for another facility for the manufacture of school bus chassis.

In 1974, GMC's respective estimated market shares were as follows:

Intercity	32.1%
Transit	44.6%
School Bus Chassis	18.5%

4. Motor Coach Industries, Limited. This company is a wholly owned subsidiary of Greyhound Lines of Canada, Ltd. which is both a holding and an operating company. Overall control rests with the Greyhound Corporation, a holding company with numerous subsidiaries whose business activities can be categorized into six general groups: Transportation, Leasing, Consumer Products and Pharmaceuticals, Food, Services, and Food Services. In 1974,

Greyhound Corporation had sales of approximately $3,469,281,000; net income of approximately $57,955,000; total assets of $1,357,328,236 and employed approximately 55,000.

Motor Coach Industries employs approximately 1,500 employees in three plants located in Winnipeg and Fort Gary, Manitoba, Canada and Pembima, North Dakota. Respectively, the two facilities contain 155,000 square feet and 135,000 square feet. In 1974, MCI accounted for 45.9% of total intercity bus sales. Specific financial information is not available.

5. Prevost Car. This Canadian-based manufacturer was formed in 1957. Intercity buses account for approximately 60% of production, motor homes account for 25% and the remaining 15% of production is accounted for by specialty vehicles.

1974 sales were estimated to be $4.5 million with total assets of between $2.5 million and $3.5 million. Two buildings with a total area of 144,000 square feet are owned by the company and used as a manufacturing facility. Employment is estimated at 125-200.

Prevost Car is estimated to have less than a 1% share of the sales of the total United States intercity bus market.

(b) Transit Bus Manufacturers

The following firms, subsidiaries or divisions account for the vast majority of transit bus production:

- AM General Corporation
- The Flxible Company
- GMC Truck & Coach
- Highway Products, Incorporated

1. AM General Corporation. In 1971, American Motors Corporation formed this wholly-owned subsidiary to assume the assets and government contracts of the former general products division. AM General entered the transit bus business in 1972 and has since recorded substantial gains. 1975 sales totaled $339.3 million which represents a 113% increase over 1974. During this same period of time, the subsidiary went from a loss of $9.7 million to a profit of $188,000. Since entering the market, AM General has become a major factor in the transit bus industry. During 1975, AMG was awarded contracts valued at $83.7 million for 1,361 buses by 19 transit authorities. 1974-5 sales accounted for 26.3% of the total market for new transit buses. Bus manufacturing facilities include a 350,000 square foot plant in Mishawaka, Indiana and another plant in Marshall, Texas.

The parent company, American Motors, is an operating corporation with several wholly-owned operating subsidiaries. The company is primarily engaged in the manufacture, assembly, and distribution in the United States and foreign countries of various motor driven products, most of which relate to transportation equipment. Automotive products include passenger cars, utility and recreational vehicles and transit buses.

2. The Flxible Company. This wholly-owned subsidiary of Rohr Industries, Inc. was acquired by the parent company in 1970. Flxible manufactures transit buses in a new 338,000 square foot plant located in Delaware, Ohio. 1974-5 sales accounted for 22.4% of the total transit bus market. Specific employment and financial information is not available.

Rohr is a diversified company organized into two systems groups: Aerospace and Marine Systems Group, and Rail and Industrial Systems Group. The company designs and manufactures the following products: power plant assemblies; thrust reversal systems and other components; motor sections and nozzles for large solid propellant rocket motors; spacecraft tracking and communications antennas; steel and aluminum boats of various kinds; prestressed and precast concrete structural components; automated materials handling and storage systems; rail transit systems; personal transit systems; postal mechanization systems; transit buses, and other aerospace, transportation, and industrial systems. In the year ended July 31, 1975, Rohr had a net loss of $7.6 million on sales of $456.3 million and assets of $313.8 million.

3. GMC Truck & Coach. This General Motors operating division is the most significant factor in the transit bus market. For a profile, refer to the Intercity Bus Manufacturers portion of this section.

4. Highway Products Incorporated. This subsidiary of Midwest Management Corporation ceased operations in 1975. Highway Products had manufactured and marketed transit buses under the Twin Coach product name. In 1974, Highway Products had a net loss of $800,000 on sales of $11.7 million with assets of $5.4 million. The manufacturing facility, located in Kent, Ohio, contains 250,000 square feet. As of July 18, 1975, the company had employment of 150 at the plant location. 1974-75 transit bus market share amounted to 2.7%.

The parent corporation is a holding company which maintains at least six subsidiaries. These companies are involved in manufacturing aluminum doors and windows, railroad hardware equipment, leasing and land development, and travel bureau operations. On December 31, 1973, Midwest Management Corporation had a tangible net worth of $756,096 with finances unbalanced. 1973 sales were $28.2 million with a loss of $361,000.

(c) School Bus Chassis Manufacturers

The following firms or divisions account for the vast majority of school bus chassis production:

- Chrysler Corporation
- Ford Motor Company
- GMC Truck & Coach
- International Harvester Company

1. Chrysler Corporation. Chrysler manufactures and markets its conventional school bus chassis under the Dodge product line. Along

with school bus chassis, the 495,000 square foot plant in Windsor, Ontario, Canada produces medium duty trucks and motor home chassis. In 1973, Chrysler accounted for 2.0% of the total school bus chassis market. Specific employment and financial information is not available.

The parent company and its subsidiaries are engaged primarily in the manufacture, assembly and sale of cars and trucks and related automotive parts and accessories. Other operations include the manufacture and sale of tractors, outboard motors, boats, inboard marine engines, air conditioning, heating and cooling equipment, power metal products, chemical products and defense-space products, including tracked and wheeled vehicles and space boosters. In 1974, Chrysler had a net loss of $52,093,772 on sales of $10,971,415,723 and assets of $6,732,755,557. Employment numbered 25,929.

2. Ford Motor Company. Ford school bus chassis production occurs at plants located in Louisville, Kentucky and Windsor, Ontario, Canada. Ford's 1973 share of the school bus chassis market amounted to 29.0%. Specific financial, employment, manufacturing and marketing data for Ford's school bus chassis production operation are not available.

The corporation is primarily an operating company with several subsidiaries. The manufacture, assembly and sale of cars, trucks and related parts and accessories accounted for approximately 91% of sales in 1974. In the United States, Ford ranks second in the industry in unit factory sales of cars and trucks. Outside the U.S., cars and trucks are manufactured by several subsidiaries throughout the free world. The remaining 9% of sales in 1974 was accounted for by operations dealing with tractors and farm implements, communications and electronic systems, automotive production component materials, the dealer organization, land developments, and public transit "people mover" systems. Total sales for the year amounted to $23.6 billion which generated net income of $360.9 million. Assets total approximately $14.2 billion. In 1974, Ford employed 235,256 workers in this country and 464,731 on a worldwide basis.

3. GMC Truck & Coach. This General Motors operating division markets its school bus chassis under the Chevrolet or GMC product line. For a profile, refer to the Intercity Bus Manufacturers portion of this section.

4. International Harvester. International Harvester manufactures school bus chassis and medium duty trucks in their Springfield, Ohio plant which employs 4,000. In 1973, the company accounted for 45.9% of the total school bus chassis market. Additional specific financial information is not available.

The corporation is primarily an operating company with numerous wholly-owned subsidiaries. International Harvester's principal products are trucks, agricultural/industrial equipment and construction equipment. The company is also a major producer of gasoline and diesel engines for use primarily with its products. International Harvester owns 17 manufacturing plants in the United States, while its subsidiaries own 18 manufacturing plants throughout the free world. As of October 31, 1974, the company had approximately 73,870 U.S. employees and 110,990 total worldwide employees. Sales for the year amounted to $4,965,916,000 with a net income of $124,053,000. Total assets amounted to $3,362,962,000.

(d) School Bus Body Manufacturers

The following firms, subsidiaries or divisions account for the vast majority of school bus body production:

- Blue Bird Body Company
- Carpenter Body Works
- Superior
- Thomas Built Buses
- Ward School Bus
- Wayne Corporation

1. Blue Bird Body Company, Incorporated. A privately owned company, Blue Bird was originally started in 1927. The company wholly-owns five subsidiaries, all of which are associated with the school bus market. Three of the subsidiaries are located in the United States, with one in Canada and the other in Guatamala. The main plant, which is 500,000 square feet, is located in Fort Valley, Georgia. Some 650 of the company°s 1,000 workers are employed in the main plant.

Although Blue Bird is primarily a conventional school bus body manufacturer, it also produces forward control school bus bodies and motor homes. In addition, one U.S. subsidiary manufactures school bus accessories and parts. In 1974, Blue Bird had sales of approximately $30 million which resulted in an estimated 22.3% share of the school bus body market. Additional financial information is not available.

2. Carpenter Body Works, Inc. This privately owned company was founded in 1918. The most significant portion of Carpenter's operation is the manufacture and assembly of conventional school bus bodies; however, the company also builds forward control and parcel delivery school bus bodies mounted on special chassis according to customer specifications. The company's 375,000 square foot production facility employs 630 workers and is the largest employer in Mitchell, Indiana. 1974 sales were reported over $20 million which resulted in approximately a 12.8% share of the total school bus body market.

3. Superior. An operating division of Sheller-Globe Corporation, Superior was acquired in 1969. In addition to conventional school bus bodies, Superior manufactures forward control and parcel delivery school bus bodies, ambulances, funeral hearses and military vans, most of which are mounted on chassis furnished by automotive manufacturers. A 698,000 square foot production facility, employing 1,800, is located in Lima, Ohio. Another plant is located in Kosciusko, Mississippi. The firm's estimated 1974 share of the school bus body market is 22.3%. Additional specific divisional financial information is not available.

The parent corporation, Sheller-Globe, is a diversified operation with its products being classified into one of three categories: automotive parts, assemblies, and related products; vehicles and transportation equipment; and office products. 1974 sales were $286.8 million with a net income of $7.6 million. Assets totaled $233.7 million.

4. Thomas Built Buses. This operating company has two subsidiaries, one in Canada and the other in Ecuador. Conventional school bus bodies represent the most significant portion of the operation. The firm is also engaged in the manufacture and assembly of forward control school bus bodies and other specialized vehicles. The firm employs 500 workers in a 42,200 square foot facility located in High Point, North Carolina. Thomas also operates a plant in Woodstock, Ontario, Canada. For the fiscal year ending March 31, 1975, Thomas reported sales of approximately $30 million and assets of $14.6 million. During the prior fiscal year, net income was reported as $1.6 million. The firm's 1974 estimated share of the market is 14.4%.

5. Ward School Bus Manufacturing, Inc. This family owned business is a subsidiary of Ward Industries, Incorporated which serves as a holding company for three other subsidiaries. Manufacture and assembly of school bus bodies is the primary operation of Ward School Bus Manufacturing. The subsidiary employs between 500 and 600 workers in a 234,000 square foot plant located in Conway, Arkansas. Ward's estimated share of the 1974 school bus body market is 9.6%.

6. Wayne Corporation. A subsidiary of Indian Head, Inc., this corporation manufactures ambulances, hearses, postal delivery vehicles and other speciality vehicles. However, the most significant part of the operation is the manufacture and assembly of school bus bodies. The Wayne Corporation employs 500 to 800 workers at their main plant in Richmond, Indiana. The 1974 estimated share of the market is 17.1%. Additional specific information pertaining to this subsidiary is not available.

The parent corporation, Indian Head, Inc., reported 1974 sales of $615.4 million and net income of $22.5 million. Assets totaled $353.5 million. Indian Head is a diversified company engaged in the manufacture and processing of glass containers, metal and automotive products, specialty textiles, utilities and communications products, and micropublishing.

EXPORTS AND IMPORTS

With regard to all types of buses, the U.S. has experienced a favorable balance of trade situation. In 1975, the U.S. exported a total of 5,673 new and used buses with a value of almost $112.4 million. During the same year, the U.S. imported a total of 881 units valued at $20.1 million.

(a) Exports

Figure 3-20 shows U.S. bus exports in terms of units and value for both new and used buses. New buses figures are listed according to engine type. In 1975, the U.S. exported more buses, 5,673 units valued at $112,360,243,

Figure 3-20

U.S. BUS EXPORTS

	New Buses				Used Buses	
	Gas Engines		Diesel Engines			
Year	Units	Value	Units	Value	Units	Value
1975	4,621	$86,101,082	432	$21,909,768	620	$4,349,393
1974	2,607	15,391,587	455	13,649,000	381	1,545,689
1973	2,068	11,188,240	287	5,830,917	324	1,175,850
1972	2,579	13,179,882	206	4,132,188	266	799,222
1971	3,384	14,435,144	414	4,664,188	355	1,271,542
1970	3,141	11,978,367	359	6,527,308	297	945,006
1969	2,686	11,001,298	190	3,888,541	307	704,549
1968	3,952	19,736,151	371	6,139,753	606	1,637,171

Source: U.S. Bureau of the Census, U.S. Exports, FT 410, Schedule B, Commodity by Country, 1968-1975.

than in any year since 1968 when 4,929 units valued at $27,513,075 were exported.

According to statistics compiled by the Motor Vehicle Manufacturers Association, Ford is the leading exporter accounting for 43.6% of all exports. The following Table 3-2 presents the percentage share of total exports by manufacturer in 1975. It is significant to note that Chrysler's entire bus production was exported rather than utilized domestically.

TABLE 3-2

Percentage Breakdown of Total U.S. Bus Exports by Manufacturer[1]

Manufacturer	% of Total Exports
Ford	43.6%
Chrysler	29.8
General Motors	19.2
International Harvester	7.3
Other	0.1
Total	100.0%

Note:[1] In the case of school buses, data refers only to chassis manufacturers.

Source: Motor Vehicle Manufacturers Association

(b) Imports

Figure 3-21 presents U.S. bus imports in terms of units and value by country of origin. U.S. imports of 881 units in 1975 represent a significant decline of approximately 33% from the prior year's total of 1,319 units and an even larger decline of 38.5% from the peak year of 1972 when the U.S. imported 1,433 units. With the exception of certain Canadian manufacturers identified in prior sections, such as Motor Coach Industries and Prevost Car, only two foreign bus manufacturers have been the source of significant imports to the United States. Mercedes Benz accounts for virtually all buses imported from West Germany and a subsidiary of Overseas Inns (parent company of Eagle International) accounts for all buses imported from Belgium. As discussed in the Bus Manufacturer Profile section, Continental Trailways, the second largest intercity carrier, had maintained bus purchase agreements with Overseas Inns which has a subsidiary with a plant in Belgium. With the devaluation of the U.S. dollar, the manufacture of such units outside the United States became economically unsound and Eagle International was formed in 1973. According to industry sources at the National Association of Motor Bus Owners, production of the Belgian units was gradually phased out in 1975 with Eagle International assuming production of all Continental Trailways buses in the United States. Subsequently, the purchase contract with Eagle has not been renewed by Continental.

RAW MATERIAL - COMPONENT - AFTERMARKET SUPPLIERS

As illustrated in Figure 3-1, bus manufacturers obtain raw materials and components from suppliers and manufacturers. The bus aftermarket is

Figure 3-21

U.S. BUS IMPORTS

Year	Total Imports Units	Total Imports Value	Canada Units	Canada Value	United Kingdom Units	United Kingdom Value	Belgium Units	Belgium Value	West Germany Units	West Germany Value	Others Units	Others Value
1975	881	$20,113,458	545	$7,484,196	40	$116,274	149	$ 8,921,151	141	$3,546,608	6	$ 45,229
1974	1,319	28,504,289	561	6,969,929	24	46,840	262	13,384,153	469	8,033,367	3	70,000
1973	1,230	25,375,908	794	6,316,020	53	66,460	307	17,735,226	72	1,183,276	4	74,926
1972	1,433	23,855,177	779	7,137,549	52	113,633	306	15,154,884	125	1,200,763	171(1)	248,348
1971	959	21,456,271	370	3,342,758	27	26,027	328	15,911,197	234	2,176,289	-	-
1970	752	17,228,225	374	3,581,444	27	64,075	278	13,089,103	72	491,043	1	2,560
1969	478	12,894,227	166	1,393,697	22	50,335	251	10,794,048	38	640,262	1	15,885
1968	433	12,562,821	109	925,521	20	49,764	266	10,745,567	37	839,299	1	2,670

(1) Includes 169 units valued at $181,934 from Japan.

Source: U.S. Bureau of the Census, Imports, FT 135, Schedule A, Commodity by Country.

served by those same firms which are classified as component suppliers. These suppliers and manufacturers also supply the large auto and truck manufacturing industries.

An examination of sales figures developed by the Motor Vehicle Manufacturers Association presents the relative importance of the bus industry to suppliers when compared to the much larger auto and truck industries. In 1975, auto, truck and bus sales are estimated to be 8,985,012 units, of which buses accounted for an estimated 40,530 units or 0.5% of the total. Figure 3-22 lists some suppliers which have been identified during interviews with bus manufacturers.

BASELINE INDUSTRY FORECAST

In order to measure the economic impact of the proposed bus noise emission levels selected for study, a baseline forecast of industry activity was established. Against this forecast, estimated post-regulation activity will be compared so as to measure the change. This section presents the baseline forecast and the methodology utilized in its development. Figures 3-23, 3-24, and 3-25 respectively portray baseline forecasts for intercity, transit, and school buses.

(a) Baseline Forecasts

The Department of Transportation's National Transportation Report estimates that intercity passenger travel expenditures for the period 1975 to 1990 will annually increase 0.5%. During this same period of time, the National Association of Motor Bus Owners estimates that the

Figure 3-22

SELECTED SUPPLIERS TO THE BUS MANUFACTURING INDUSTRY

Manufacturer	1975 Sales ($ Millions)	Manufactured Component
Bendix	$2,481	Engine Accessories
Borg-Warner	1,768	Radiator
Caterpillar	4,082	Engine
Cummins	833	Engine
Dana	1,070	Transmission
Donaldson	120	Air Cleaner, Muffler
Eaton	1,760	Axle
Garlock (Stemco)	151	Muffler
Midland-Ross	415	Engine Accessories, Frame
Modine	128	Radiator
Questor (A P Parts)	384	Muffler
Rockwell International	4,409	Axle, Brake
Wagner Electric	236	Engine Accessories, Brake
Wallace-Murray (Schwitzer)	330	Radiator Fan
Westinghouse	5,799	Engine Accessories
Young Manufacturing	36	Radiator

Source: Interviews with bus manufacturers; Dun & Bradstreet.

Figure 3-23

BASELINE FORECAST
INTERCITY BUSES

Year	Shipments
1976	1,256
1977	1,236
1978	1,256
1979	1,256
1980	1,256
1981	1,256
1982	1,256
1983	1,257
1984	1,257
1985	1,257
1986	1,257
1987	1,257
1988	1,257
1989	1,257
1990	1,257

Source: National Association of Motor Bus Owners estimate for growth rate added to an average annual shipments figure based on the years 1970-1974.

Figure 3-24

BASELINE FORECAST
TRANSIT BUSES

Year	Shipments
1976	7,277
1977	5,880
1978	5,627
1979	4,375
1980	4,209
1981-85	3,861
1986-90	4,023

Source: Mid-points calculated from forecast ranges developed by the American Public Transit Association as described in the publication United States Transit Industry Market Forecast.

Figure 3-25

BASELINE FORECAST
SCHOOL BUSES
BY YEAR AND TYPE OF BUS

	Gasoline			Diesel				
						Integral		
Year	Conventional	Forward Control	Parcel Delivery	Conventional	Forward Control	Mid-Engine	Rear Engine	Total All Bus Types
1976	24,750	205	1,295	1,430	1,140	290	90	29,200
1977	25,260	210	1,320	1,460	1,160	300	90	29,800
1978	27,765	215	1,350	1,490	1,185	305	90	30,400
1979	26,190	215	1,370	1,515	1,205	310	95	30,900
1980	27,885	230	1,460	1,595	1,300	330	100	32,900
1981	28,825	240	1,510	1,665	1,325	340	100	34,000
1982	29,835	245	1,565	1,725	1,375	350	105	35,200
1983	30,770	255	1,610	1,780	1,415	360	110	36,300
1984	31,785	265	1,665	1,835	1,465	375	110	37,500
1985	32,715	270	1,715	1,890	1,505	385	115	38,600
1986	33,650	280	1,760	1,945	1,550	395	120	39,700
1987	34,585	285	1,810	2,000	1,590	410	120	40,800
1988	35,514	295	1,860	2,055	1,635	420	125	41,900
1989	36,445	300	1,910	2,110	1,670	430	130	43,000
1990	37,380	310	1,955	2,160	1,720	440	135	44,100

Source: Forecast of total buses is based on regression analysis on ten year historical relationship between school bus registrations and: population in age group 5-14, disposable personal income, state and local expenditures on education, and Gross National Product. Distribution by type of bus is based on estimates of market share for 1975.

total bus population will increase at an annual rate of 0.25%. Consequently, as shown in Figure 3-23, the annual shipments of intercity buses will remain almost constant, either 1,256 or 1,257, during the period 1976 tp 1990. It is signifcant to note that these annual shipment figures represent approximate mid-points for forecast ranges provided by General Motors.

Figure 3-24 presents a transit bus baseline forecast. The annual shipment figures are based on forecasts developed by the American Public Transit Association in 1976. Transit bus shipments are expected to peak in 1976 at a level of 7,277 units. The period 1977 to 1985 is expected to show continual declines to an annual figure of 3,861 units during the period 1981 to 1985. The period 1986 to 1990 is forecast to have slight annual increases to a level of 4,023 units.

The baseline forecast for school buses is presented in Figure 3-25. The annual shipment figures have been developed by a regression analysis based on ten years of historical data. School bus shipments are expected to show continual annual growth during the period 1976 to 1990.

(b) <u>Methodology</u>

The intercity bus base line forecast was developed by utilizing an estimated growth rate for the intercity bus population of 0.25%. This growth rate was estimated by the National Association of Motor Bus Owners. 0.25% was converted to the actual number by which the entire intercity bus population was expected to increase on an annual basis. The incremental number represented by 0.25% was then added on to an average shipments figure of 1,204 units which is based on actual shipments during the period 1970-1974.

The transit bus baseline forecast was developed by establishing mid-points for forecast ranges development by the American Public Transit Association. The APTA forecast, United States Transit Industry Market Forecast, was published in September, 1976.

The baseline forecast for school buses was based on a regression analysis on a ten year historical relationship between school bus registrations and the following factors: population in the age group 5-14, disposable personal income, state and local expenditures on education, and Gross National Product. The distribution by type of bus is based on market share estimates for 1975.

REFERENCES

Section 3

1.) "A Study to Determine the Economic Impact of Noise Emission Standards in the Bus Manufacturing Industry," Draft Final Report submitted by A.T. Kearney, Inc., under EPA Contract No. 68-01-3512, prepared for the Office of Noise Abatement and Control, September, 1976.

SECTION 4

BUS NOISE EMISSIONS DATA BASE

Noise emissions from school buses, transit buses and inter-city buses were measured by EPA in a series of tests. The following discussion, describes the results of those tests. In addition, sound level data from existing studies and from industry submissions are presented.

For a discussion of the various testing procedures used for the exterior and the interior noise measurements described in this section refer to Section 8 (Measurement Methodologies).

(1) Gasoline-Powered Conventional School Buses

Current Exterior Noise Levels

Measurements taken for EPA of in-service and newly-manufactured gasoline-powered conventional school buses indicate a range of noise levels between 74 dBA and 84 dBA under the SAE J366b acceleration procedure (see Section 8). The data indicate that the noise level depends on engine size and gross vehicle weight rating (GVWR). Table 4-1 presents a summary of all noise tests conducted on in-service school buses.[22] Measurements of noise emissions from new (1976) gasoline engine school buses are shown in Table 4-2.[25]

TABLE 4-1
Summary of Noise Levels, In-Service Gasoline Engine Conventional School Buses

SCHOOL BUS TYPE				ACCELERATION (dBA) (J366b)				PULLAWAY (dBA)				STATIONARY (dBA)				COAST BY (dBA)				INTERIOR (dBA) (J366b)			
GVWR	DATE OF MANUFACTURE	TRANSMISSION	ENGINE SIZE (in^3)	CURBSIDE		STREETSIDE		CURBSIDE		STREETSIDE		CURBSIDE		STREETSIDE		CURBSIDE		STREETSIDE		FRONT		REAR	
				X	S	X	S	X	S	X	S	X	S	X	S	X	S	X	S	X	S	X	S
23,000	1972	Standard	345	80.1	0.95	79.3	1.13	N.A.	N.A.	N.A.	N.A.	84.9	1.85	84.8	1.35	N.A.	N.A.	N.A.	N.A.	85.9	1.61	N.A.	N.A.
23,000	1973	Standard	361	81.0	0.00	80.5	2.70	76.5	I.D.	78.5	I.D.	85.7	0.94	85.0	1.91	65.0	I.D.	69.0	I.D.	84.75	0.75	77.75	I.D.
23,000	1973	Automatic	361	82.0	0.84	83.6	1.36	77.5	0.87	78.6	0.42	85.0	2.26	85.4	2.96	N.A.	N.A.	N.A.	N.A.	83.9	1.22	77.4	1.18
23,000	1975	Automatic	361	83.5	1.50	83.1	0.54	77.8	1.03	77.1	0.55	86.8	1.48	86.3	0.83	N.A.	N.A.	N.A.	N.A.	81.25	1.48	N.A.	N.A.
23,000	1975	Automatic	330	82.0	I.D.	83.0	I.D.	79.0	I.D.	77.5	I.D.	86.5	I.D.	87.0	I.D.	N.A.	N.A.	N.A.	N.A.	82.0	I.D.	N.A.	N.A.
21,200	1975	Standard	330	77.25	0.25	77.25	0.25	N.A.	N.A.	N.A.	N.A.	80.0	1.0	82.0	2.0	N.A.	N.A.	N.A.	N.A.	83.9	0.35	80.75	0.35
21,200	1974	Standard	361	77.0	I.D.	77.5	I.D.	N.A.	N.A.	N.A.	N.A.	82.0	I.D.	81.5	I.D.	N.A.	N.A.	N.A.	N.A.	83.0	I.D.	N.A.	N.A.
19,700	1975	Standard	330	78.0	I.D.	77.0	I.D.	N.A.	N.A.	N.A.	N.A.	76.5	I.D.	75.5	I.D.	N.A.	N.A.	N.A.	N.A.	83.5	I.D.	N.A.	N.A.
17,900	1974	Standard	345	80.3	1.89	81.2	3.06	78.0	I.D.	79.5	I.D.	83.2	2.39	84.7	2.90	N.A.	N.A.	N.A.	N.A.	85.75	0.75	N.A.	N.A.
17,900	1975	Standard	330	76.0	I.D.	77.5	I.D.	N.A.	N.A.	N.A.	N.A.	82.0	I.D.	83.5	I.D.	N.A.	N.A.	N.A.	N.A.	84.0	I.D.	N.A.	N.A.
17,400	1975	Standard	330	79.0	1.0	79.5	0.5	N.A.	N.A.	N.A.	N.A.	83.5	0.5	82.5	3.5	69.5	I.D.	74.0	I.D.	83.0	0.0	81.25	0.35
17,400	1975	Automatic	330	75.0	I.D.	74.0	I.D.	N.A.	N.A.	N.A.	N.A.	76.5	I.D.	76.0	I.D.	N.A.	N.A.	N.A.	N.A.	81.25	I.D.	78.75	I.D.
All Bus Types				79.3	2.65	79.5	2.94	77.8	0.90	78.2	0.95	82.7	3.5	82.9	3.71	67.25	I.D.	71.5	I.D.	83.5	1.53	79.2	1.74

N.A. indicates data was not available for that test.

I.D. indicates there was insufficient data to compute mean or standard deviation.

TABLE 4-3
Summary of Noise Levels for New (1976) Gasoline Engine Conventional School Buses -- Acceleration Test (SAE J366b)

GROSS VEHICLE WEIGHT RATING (POUNDS)	ACCELERATION TEST[1] (SAE J366b)										NO. OF BUSES TESTED/TOTAL NO. OF TESTS
	EXTERIOR NOISE LEVELS*				INTERIOR NOISE LEVELS						
	STREET SIDE		CURB SIDE		FRONT		MIDDLE		REAR		
	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	MEAN	STD. DEV.	
23,660	81.4 (81.0)	0.78 (0.78)	80.2 (80.0)	1.19 (1.13)	89.2 (87.2)	0.50 (1.58)	83.0 (81.3)	0.10 (1.68)	82.1 (80.1)	0.14 (1.97)	3/18
22,000	82.8 (83.4)	2.55 (2.57)	80.0 (79.6)	1.68 (1.56)	87.0 (85.9)	0.28 (0.68)	83.0 (81.4)	0.10 (0.92)	81.2 (79.9)	0.36 (1.13)	7/46
20,500	81.7 (80.9)	0.69 (1.42)	79.7 (78.5)	2.53 (1.42)	84.9 (84.8)	0.00 (0.26)	80.7 (79.8)	0.28 (1.11)	80.6 (78.9)	0.22 (2.01)	2/16
19,700	81.6 (80.0)	0.64 (1.46)	81.1 (79.8)	0.89 (1.57)	87.2 (86.9)	0.36 (0.37)	83.8 (83.3)	0.78 (0.78)	80.8 (80.9)	0.28 (0.20)	2/12
19,200	81.6 (81.0)	1.06 (1.04)	81.4 (81.0)	1.30 (1.62)	89.0 (88.0)	0.14 (1.23)	84.7 (84.2)	0.42 (0.75)	83.4 (32.2)	0.50 (0.34)	2/14
15,700	82.6 (82.5)	0.64 (0.38)	82.8 (82.5)	0.58 (0.30)	88.4* (88.4)*	0.22* (0.22)*	85.7* (85.7)*	0.14* (0.14)*	84.0* (84.0)*	0.22* (0.22)*	1/6
All Buses	82.1 (81.9)	1.80 (1.99)	80.4 (79.8)	1.67 (1.70)	86.6 (86.5)	1.39 (1.34)	82.2 (82.0)	1.94 (1.79)	80.8 (80.6)	1.85 (1.86)	--

*Only one reading was taken.

(1) Top row of numbers are noise level values computed in accordance with SAE Standard J366b, i.e., taking the average of the two highest readings which were within 2dB(A) of each other, for each bus in the GVWR class. Numbers in parentheses were computed by averaging all readings for all buses in each GVWR class. "All Buses" values (last line) were similarly computed.

Source: Reference 25

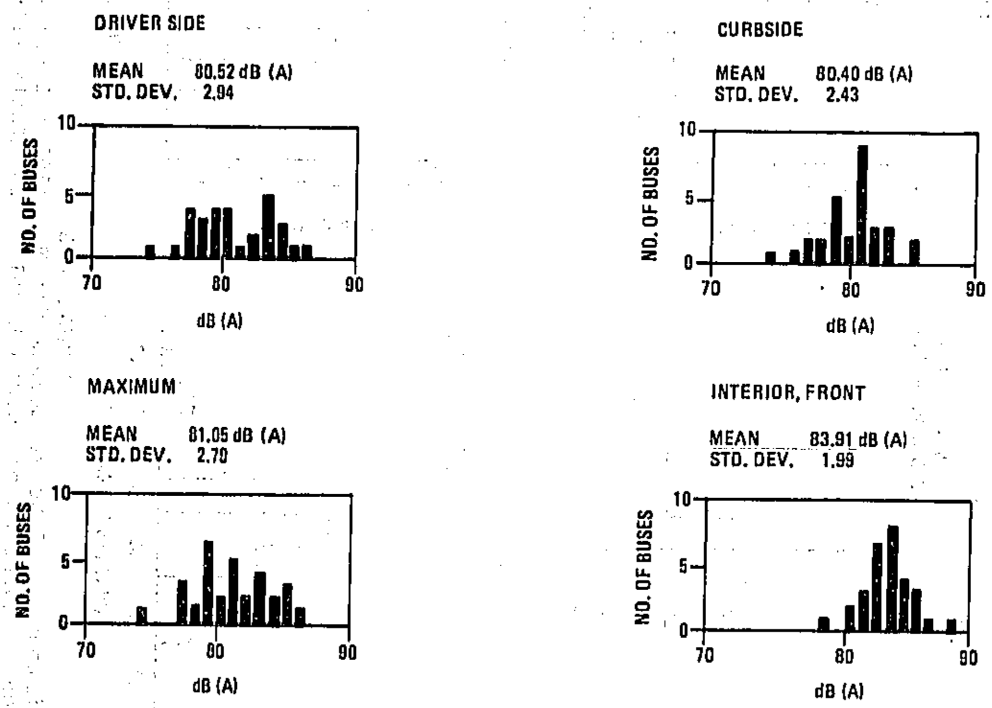
While there is no clear trend as to which side of the older, conventional buses is noisier, exterior measurements from the new school buses tested indicate that the streetside of the buses is generally noisier than the curbside (see Table 4-2). It is believed that the difference in standard deviations between the streetside and the curbside measurements of the older buses indicates that the variation in noise levels is probably a function of the test conditions and the age of the bus rather than bus design itself. These data and past vehicle tests indicate that production buses, if tested under carefully controlled test conditions, will all produce noise levels within four to five decibels of each other. Therefore, an allowance of 2 to 2.5 dB appears appropriate between the mean design noise level and a regulated "not to exceed" level.

Figure 4-1 shows histograms of measured exterior noise levels on each side of the gasoline powered in-service school buses along with interior noise levels at the driver and the maximum levels from all the buses. Figure 4-2 presents the same data for the new 1976 buses. Maximum levels are shown separately because not all buses had higher noise levels on one side.

Octave band spectra for gasoline-powered conventional school bus noise are shown in Figure 4-3.

None of the conventional school bus body manufacturers that were contacted was able to provide noise level data on their current production buses. Chrysler Corporation did provide some noise data based on Dodge gasoline truck chassis that have identical components to their conventional school bus chassis. These data are summarized in Table 4-3.

FIGURE 4-1
Histograms of In-Service Gasoline Engine
Conventional School Bus Noise Levels
(SAE J366b)



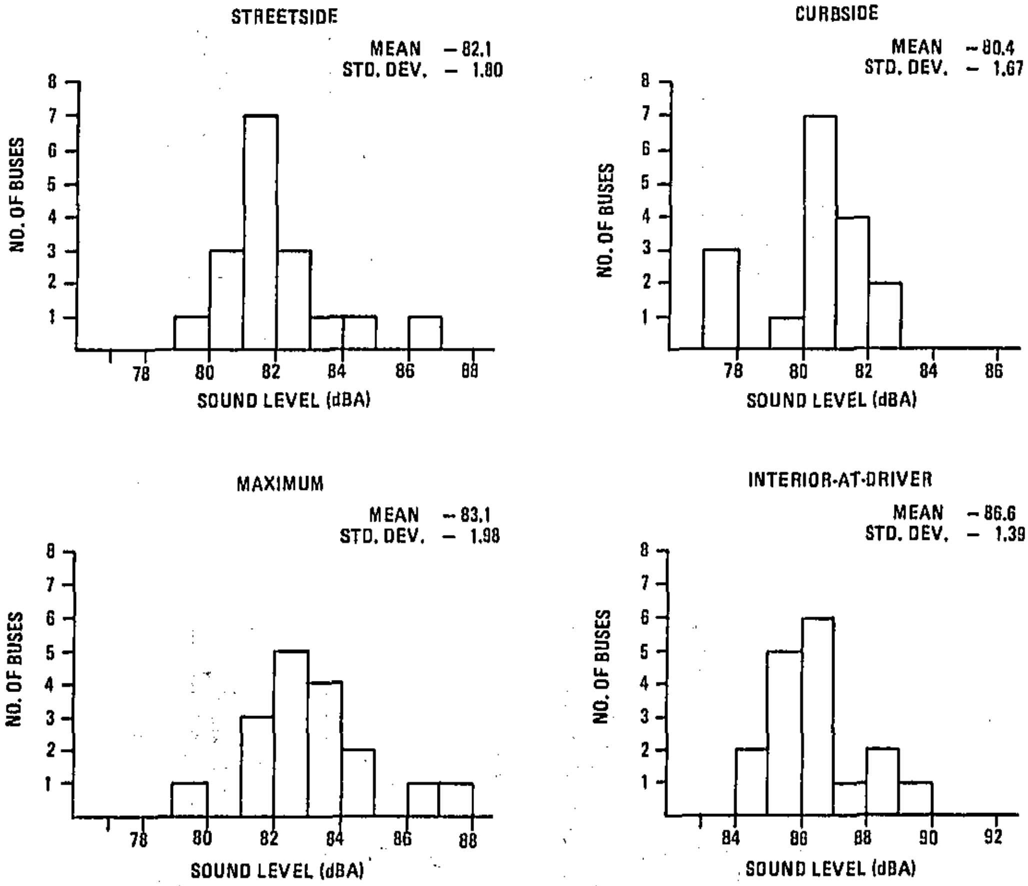


FIGURE 4-2
Histograms of Noise Levels for New (1976) Gasoline Engine Conventional School Buses Acceleration Tests (SAE J366b)

FIGURE 4-3
Typical Octave Band Spectrum of
Gasoline Engine Conventional
School Bus Noise

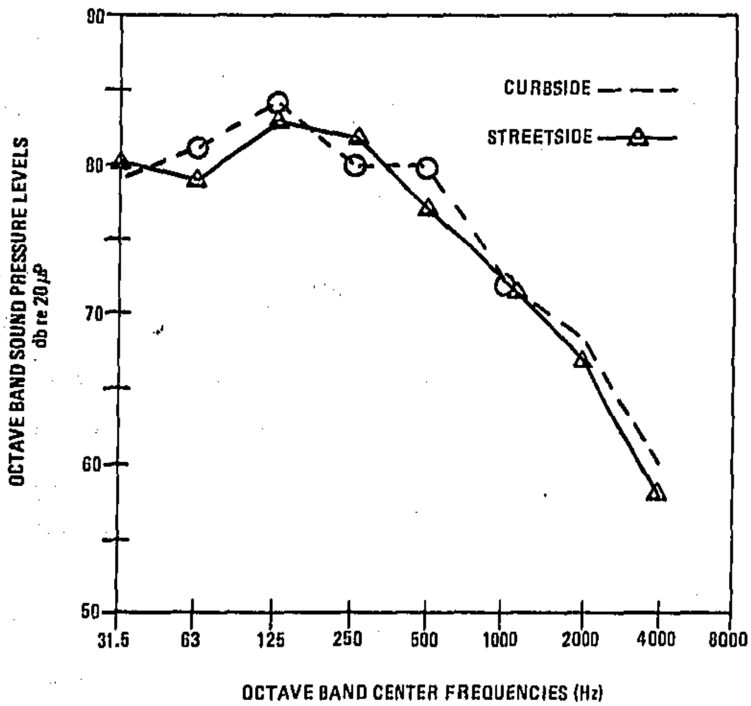


Table 4-3

Noise Data Supplied by
Chrysler Corporation

Model	Equivalent Bus Chassis	Engine Displacement (in^3)	Equivalent School Bus Chassis	Exterior Sound Level (SAE J366b) dBA
D600	S600	318	S600	76.8 to 81.6
D600 & D700	S600 & S700	361	S600 & S700	79.2 to 81.3
D700	S700	413	S700	79.1 to 82.6

Source: Reference 22

Interior Noise Levels

Tests on both in-service and 1976 conventional school buses indicate that the noise levels are significantly higher at the front of the bus as opposed to the rear of the bus. During tests for new buses involving an idling engine only, interior fan accessories only (heating and cooling fans), and then an idling engine and interior fan accessories together, the average noise level difference between the front and rear interior of the buses tested was about 4 dBA (see Table 4-5).

Tests on new buses with all accessories on under maximum acceleration conditions produced a range of interior noise levels from 85 to 89 dBA for the front interior and 81 to 84 dBA in the rear interior. Interior noise levels at the driver's seat for the in-use school buses tested under maximum acceleration conditions with all fan accessories on ranged from 81 to 86 dBA while levels at the rear interior of the buses ranged from 78 to 81 dBA. Full results on interior noise levels are shown in Table 4-1 and 4-2 for both in-use and new conventional gasoline-powered school buses, respectively.

TABLE 4-5
Interior Noise Levels for New (1976) Gasoline Engine
Conventional School Buses -- Engine at Idle Conditions
Stationary Tests (Complete Data for All Buses and All Test Runs)

TEST VEHICLE NUMBER	GROSS VEHICLE WEIGHT RATING (POUNDS)	MANUFACTURER CHASSIS/BODY	TRANSMISSION TYPE	ENGINE SIZE ($IN.^3$)	STATIONARY TEST – INTERIOR NOISE LEVELS: ENGINE ONLY			ACCESSORIES ONLY			ENGINE & ACCESSORIES		
					FRONT	MIDDLE	REAR	FRONT	MIDDLE	REAR	FRONT	MIDDLE	REAR
1	23,660	IHC/Superior	Manual	392	56.9	54.1	55.1	78.4	72.2	71.0	81.2	74.7	73.8
3	23,660	IHC/Superior	Automatic	392	57.3	55.8	53.2	77.4	71.8	71.0	78.9	73.2	72.3
4	23,660	IHC/Superior	Automatic	392	54.7	51.5	53.5	76.8	70.1	69.8	78.2	72.4	71.8
8	22,000	Ford/Superior	Manual	330	55.0	54.0	53.5	77.2	72.7	74.5	78.6	74.3	75.1
9	22,000	Ford/Superior	Manual	330	---	---	---	77.2	72.8	73.7	79.7	75.0	75.6
11	22,000	Ford/Superior	Manual	361	57.5	56.0	56.5	76.4	71.0	71.3	77.3	72.5	72.7
12	22,000	GMC/Superior	Manual	350	---	---	---	77.3	70.7	70.3	77.7	73.0	71.8
13	22,000	GMC/Superior	Manual	350	58.7	56.0	54.0	76.8	72.8	74.2	80.9	76.8	78.2
14	22,000	GMC/Superior	Manual	350	54.3	53.3	51.8	77.2	72.2	74.4	78.2	73.5	74.3
15	22,000	GMC/Superior	Manual	350	60.5	56.6	55.0	77.4	71.1	70.0	80.9	74.6	73.9
16	20,500	Chev/Superior	Manual	350	---	---	---	75.8	71.6	70.6	76.2	72.2	70.6
17	20,500	Chev/Superior	Manual	350	58.7	52.5	51.0	73.7	70.9	72.7	75.8	73.2	75.8
2	19,700	IHC/Superior	Manual	345	---	---	---	76.5	72.2	71.8	79.8	75.4	74.6
6	19,700	IHC/Superior	Manual	345	---	---	---	74.2	68.9	66.4	75.8	72.5	69.3
7	19,200	Ford/Superior	Manual	361	57.5	53.5	52.8	78.5	74.1	75.7	81.0	76.7	78.2
10	19,200	Ford/Superior	Manual	389	---	---	---	73.8	72.2	75.5	75.0	73.2	76.0
5	15,700	IHC/Superior	Automatic	345	57.2	54.0	56.0	76.7	73.0	70.8	79.2	75.1	73.5
All Buses					$\bar{x}$ = 57.1 s = 1.88	$\bar{x}$ = 54.3 s = 1.62	$\bar{x}$ = 53.8 s = 1.69	$\bar{x}$ = 76.5 s = 1.42	$\bar{x}$ = 71.8 s = 1.24	$\bar{x}$ = 72.0 s = 2.44	$\bar{x}$ = 78.5 s = 1.99	$\bar{x}$ = 74.0 s = 1.45	$\bar{x}$ = 74.0 s = 2.44

Current Component Noise Levels

Table 4-4 shows the estimated range of contributed noise levels of conventional gasoline powered school bus major noise components. These estimates are based on component noise levels of medium duty trucks using similar engines[1,2] and estimates made during a previous study.[3] None of the school bus body or chassis manufacturers contacted were able to supply actual measured data for component noise levels of gasoline-engine school buses or of equivalent trucks.

Table 4-4

Range of Component Noise Levels for Current Gasoline Powered Conventional School Bus

Noise Source	Contributed Noise Level, dBA at 50 feet (SAE J366b Procedure)
Engine, including air intake and transmission	69 to 73
Exhaust	75 to 78
Fan	71 to 82.4
Chassis at 30 mph (including accessories)	65 to 73
Total Bus Noise	77 to 84

Source: References 1, 2 and 3

Tire noise is not included in Table 4-4 as a separate noise source since with the use of maximum acceleration noise testing procedures the vehicle does not exceed 35 mph; the velocity at which tire noise becomes a major contributing factor to the overall noise level.

(2) Diesel-Powered Conventional School Buses

Physical dimensions and weight rating for diesel-powered conventional school buses are similar to those for gasoline powered conventional school buses.

A variety of medium duty diesel engines are used in this type of bus including the CAT 3208, the Ford V636, and the IHC D-150, D-170, D-190, and the DT-460.

Current Overall Noise Levels

Very little data are available in the form of direct measurement of noise from conventional diesel school buses. Since diesel powered conventional school buses utilize medium diesel truck chassis, noise levels from such trucks can be considered representative of those of buses. Unfortunately, very little data on noise from medium diesel trucks are available, but noise levels from medium diesel trucks are similar to those from heavy duty diesel trucks with similar size engines. Thus, noise characteristics of a conventional diesel school bus are described in terms of available noise data from conventional diesel school buses as well as from diesel trucks.

None of the conventional diesel school bus manufacturers contacted was able to provide noise test data for their buses. International Harvester (IH) indicated that exterior noise levels measured from all of their school buses were below 86 dBA. Moreover, school buses sold in California and Oregon were said to meet those states' exterior noise level standards of 83 dBA.

Table 4-6 gives the results of a study involving noise measurements from diesel trucks. For school buses, the interior noise levels with closed truck windows would apply (see Section 8). Another study of noise levels from two conventional heavy diesel trucks showed a variation in exterior noise levels from 82.7 dBA to 86.8 dBA, slightly higher than the exterior noise levels for the new gasoline engine school buses (see Table 4-2).

Table 4-6, shown below, suggests that maximum acceleration exterior noise levels for conventional diesel school buses range from 82.7 to 88 dBA at 50 feet. It is not clear from the data which side of the vehicle is noisier. The interior noise levels at the driver's seat range from 88 to 94.5 dBA. Production buses, as evidenced from these data and past tests, will exhibit noise levels within 4 to 6 dB of each other, if tested under carefully controlled conditions. Here again, an allowance of 2 to 2.5 dB between the mean design noise level and the regulated level appears appropriate.

Table 4-6

Overall Noise Levels From Conventional Heavy Diesel Trucks (SAE J366b Test Procedures)

Truck Number	Exterior Sound Level [dBA]		Interior Sound Level [dBA]	
	Curbside	Streetside	Open Window	Closed Window
3	86.5	86.0	92.5	91.0
4	88.0	85.0	94.5	94.0
6	85.5	85.5	94.5	94.0
13	87.5	87.0	90.5	88.0

Source: Reference 4

Current Component Noise Levels

For diesel vehicles, important noise sources are the engine, the exhaust, and cooling fan. The typical range of noise levels from each of these sources is between 75 dBA and 85 dBA.[6]

Another major noise source in diesel engines is the intake noise. Typical unsilenced intake noise levels for diesel truck engines at high idle vary between 70 dBA and 85 dBA, measured at 50 feet from the engine inlet.[7]

(3) Forward Engine Forward Control School Buses

By forward control it is meant that the driver is located as far forward and to the left as possible. The engine which can be either diesel or gasoline is located to the right of the driver, or under the floor between the two axles. This type of bus typically has a flat front end.

Current Overall Noise Levels

Noise characteristics for this type of bus are similar to those of conventional school buses. Current noise levels from forward engine buses made by Blue Bird for states other than California are shown in Table 4-7. These levels are similar to those given in Table 4-6 for conventional diesel trucks. The forward engine forward control school buses sold in California are said to meet the state standard of an 83 dBA exterior level under acceleration.

Concerning interior noise levels, the noise level at the driver for front engine buses may be higher for these buses compared to conventional school buses because of the close proximity of the engine to the driver.

Table 4-7

Noise Levels From Diesel Powered Forward Control Forward Engine Buses by Blue Bird (Sold in States Other Than California)

Type of Engine Used	Sound Levels dBA Exterior (J366b Test)	Interior (BMCS Test)
CAT 3208, 320A	86	90
Cummins V504, 504A	89	90
Detroit Diesel 6V53, 6V53A	92	95

Source: Reference 15

Current Component Noise Levels

Although no data are available for component noise levels from this type of bus, they are expected to be similar to those for conventional school buses.

(4) Parcel Delivery Chassis Buses and Motor Home Chassis Buses

Carpenter Body Works' Cadet "CV" and Sheller-Globe's (Superior) "Pacemaker" models are built from parcel delivery vehicle chassis and motor home chassis. GMC also recently introduced a motor home vehicle that is also offered as a bus, called Transmode.

Current Noise Levels

GMC measured the noise level of one Transmode Bus in accordance with the SAE J366b procedure. This level is reported as 81.7 dBA.[14] No interior noise level data was reported.

Since these buses use the same engines as full size conventional school buses, the exterior and component noise levels are expected to be similar. The interior noise levels at the driver's seat may be higher for these buses as compared to conventional school buses because of the closer proximity of the engine to the driver.

(5) Mid-Engine School Buses (Integral)

The only mid-engine integral school buses available today are made by Gillig Brothers and Crown Coach Corporation.

Current Overall Noise Levels

Although the engine location and engine types for mid-engine buses differ from front and rear-engine school buses, their exterior noise characteristics are not significantly different. However, in contrast to the noise levels inside rear engine buses, the interior noise in a mid-engine bus would be higher in the front of the bus than in the rear because the engine is relatively closer to the front end.

Exterior noise levels from the Gillig buses, which were measured in 1975[10], and Crown buses which were measured in 1973[22], are shown in Table 4-8. These levels range from a low of 80.9 dBA on the curbside to a high of 86.3 dBA on the streetside.

Table 4-8

Exterior Noise Levels From Diesel Powered Mid-Engine school Buses at 50 Feet

Bus Manufacturer	Engine	Exterior Sound Level, dBA Curbside	Exterior Sound Level, dBA Streetside
Gillig	Detroit Diesel 6-71	83.6	86.3
Gillig	Cummins Diesel NHHTC-240 Turbocharged	80.9	82.1
Crown	Detroit Diesel 6-71	82.6	84.9
Crown	Cummins Diesel NHHTC-270 Turbocharged	83.9	85.9

Source: References 10 and 22

For exterior noise considerations, mid-engine buses may be considered to be similar to transit buses rear-engine integral school buses. Interior noise, however, is expected to be higher for mid-engine buses because of the shape and position of the engine compartment. Crown Coach Corporation has indicated that the interior noise level at the driver's seat in their buses is about 87 dBA when measured at 35 mph under full throttle conditions.

Current Component Noise Levels

Data on component noise levels for mid-engine school buses are not available.

In order to meet the California exterior noise standard of 83 dBA, Gillig provides sheet metal covers with noise damping insulation around the complete engine.[10] The muffler is also wrapped with insulation. Fan speeds are said to be as low as their cooling requirements will allow.

Crown Coach Corporation also provides sound absorbing insulation around their engine. Engine compartment doors are lined with 1.5 inch thick acoustical material. Exhaust noise from their turbocharged Cummins engine is said to be sufficiently low. Therefore, no special exhaust noise treatment is provided for that engine. However, for the Detroit Diesel 6-71 engine a heavier gauge muffler shell is used which, when tested, provided the same attenuation as a wrapped muffler. Crown also uses an acoustical floor in its buses. The floor, used since 1964, is made up of one-half inch "Celetex" sandwiched between two 1/4 inch and 5/8 inch thick plywood panels. (Celetex is a fire-resistant material made by Georgia Pacific.)

(6) Rear Engine School Buses (Integral)

Gillig Bros. is the only manufacturer of rear engine integral school buses. Urban transit and intercity buses, which are also integral rear-engine buses, are discussed separately because of differences in engine sizes, engine compartment layout, and ruggedness of construction.

Current Overall Noise Levels

Although the integral rear-engine school buses and the urban transit bus use different types of diesel engines, they have similar noise characteristics. While urban transit buses use Detroit Diesel's naturally aspirated 6V-71 and 8V-71 engines, the rear engine school buses, produced by Gillig use either the naturally aspirated CAT 3208 or the turbocharged Cummins 230 engine. Exterior noise levels for Gillig school buses are shown in Table 4-9.

Table 4-9

Exterior Noise Levels at 50 Feet From
Gillig Integral Rear Engine School Buses
(SAE J366b Test)

	Sound Levels, dBA	
Type of Engine	Curbside	Streetside
Cummins 230 (Turbocharged) -With grille on engine compartment doors	83.7	82.7
CAT 3208 (Naturally aspirated) -With grille on engine doors	84.0	83.5
-With solid engine doors	81.3	82.5

Source: Reference 10

The streetside noise levels from the top two buses in Table 4-9 are slightly lower than those on the curbside because of an additional inner compartment wall on the streetside of the engine compartment. When Gillig replaced the grill on the engine doors with solid panels on the Caterpillar engine powered bus, the noise levels were reduced as seen in the table. Giving the same treatment to the Cummins engine powered bus would probably provide similar reduction. Because of a lack of more detailed test data, the reason for attaining relatively greater noise reduction on the curbside from the Caterpillar engine powered bus with solid engine doors is not clear.

Interior noise levels for rear engine school buses are not available but are expected to be similar to transit bus interior noise levels.

Current Component Noise Levels

No component noise data for rear-engine (integral) school buses are available.

(7) Rear Engine School Buses (Body-on-Chassis)

There is one bus which falls into this category, the Carpenter Corsair and Transit bus which is offered with a front-mounted engine as well as with a rear-mounted engine. No noise level information is presently available for this type of bus.

Exterior, interior and component noise levels are expected to be similar to diesel powered forward control school buses and rear engine (integral) school buses.

(7) Urban Transit Buses

Current Overall Noise Levels

Noise level measurements taken for EPA of 24 in-use urban transit buses along with mean levels and standard deviations are presented in Table 4-10 for various measurement procedures.

The variation in noise levels between in-use buses of identical construction is thought to be due to the following reasons:

- The maximum noise occurs at transmission shift, which does not always occur at the same engine rpm or test location for each test for older buses.
- The rear engine compartment doors for the older buses tend to be ill-fitting and failed to lock on many of the buses tested causing some variation between test runs.

The difference in noise levels between the curbside and streetside of the buses occured because the fan and radiator are located on the streetside of the bus causing higher levels on that side.

Histograms of in-service transit bus exterior noise levels under maximum acceleration, pull-away, and stationary conditions and interior noise levels in the front and rear of the bus under maximum acceleration test conditions are shown in Figures 4-4 and 4-5. It should be noted that in the interior tests involving the front and rear interior of the bus, the higher noise level was measured in the rear location each time.

Noise levels of two GMC transit buses under different operating conditions are given in Tables 4-11 through 4-14.[22] The buses are designated as #440D and #704. Attention should be given to a comparison of the noise levels on the streetside and curbside.

TABLE 4-10
Summary of Exterior and Interior Noise Levels for In-Service Transit Buses

MAKE AND MODEL NO.	TRANSMISSION	EXTERIOR NOISE LEVELS (50 FT.)						(SAE J366b) INTERIOR NOISE REAR
		(SAE J366b)		PULL-AWAY		STATIONARY IMI		
		STREET SIDE	CURB SIDE	STREET SIDE	CURB SIDE	STREET SIDE	CURB SIDE	
GM-6504	Automatic	83 (83)	81 (80.7)	87 (86.5)	79.5 (79.5)	--	--	83 (82.5)
GM-6302	Automatic	82 (81.7)	79.5 (78.7)	82 (82)	79.5 (79.5)	--	--	87.2 (86.6)
GM-6323	Automatic	84 (83.7)	80 (79.7)	85 (85)	77 (77)	--	--	89.5 (88.8)
GM-6610	Automatic	82 (82)	80 (80)	82.5 (82)	76.25 (76.2)	--	--	86.75 (86.4)
GM-6400	Automatic	82 (81.8)	79.7 (79.1)	82 (82)	75.25 (75.2)	--	--	83.5 (83.2)
GM-6401	Automatic	84.25 (84.2)	83.1 (82.4)	85.5 (85.3)	80.5 (80.3)	-- (86.7)	-- (--)	84 (83.7)
GM-6321	Automatic	86.1 (85.7)	81.5 (81.5)	86 (85.8)	82.25 (82)	-- (86)	-- (--)	82 (81.3)
GM-6408	Automatic	79 (78.7)	79.25 (78.8)	81 (80.7)	76.25 (76.75)	-- (--)	-- (--)	83 (82.3)
GM-6616	Automatic	82 (82)	78.25 (78.25)	84.25 (84.17)	79 (79)	86.7 (86.7)	-- (--)	90 (88.4)
GM-6503	Automatic	-- (--)	78.75 (78.5)	81.75 (81.5)	78 (77.7)	86 (86)	-- (--)	87 (85.8)
GM-6703	Automatic	83.5 (83.3)	83.25 (81.8)	89.25 (89.25)	78 (77.5)	87 (87)	74 (74)	85.75 (84.8)
GM-6601	Automatic	82.5 (82.2)	77 (77)	81.5 (81.2)	77 (76.8)	87 (87)	78 (78)	83 (82.8)
FLX-6808	Automatic	81 (80.8)	80 (80)	82.5 (82.3)	78.5 (78.5)	89 (89)	74 (74)	86 (85.8)
FLX-6812	Automatic	80.75 (80.7)	79.5 (79.7)	80.25 (81.25)	76.75 (76.5)	87 (87)	79 (79)	85 (85)
FLX-6826	Automatic	80 (80)	78.75 (78.5)	81.75 (81.7)	76.5 (76.3)	86 (86)	74 (74)	86.75 (85.8)
FLX-6800	Automatic	82.25 (82.17)	81.5 (81.3)	82 (81.7)	81 (81)	91 (91)	75 (75)	85 (84.8)
AM-7110	Automatic	79.75 (79.7)	80.75 (80.7)	83.75 (83.5)	78.25 (78.2)	89 (89)	80 (80)	81 (80.6)
AM-7120	Automatic	80 (80)	80.75 (80.7)	82.5 (82.5)	79.25 (79)	89 (89)	76 (76)	82.75 (82.2)
AM-7130	Automatic	80 (80)	81 (81)	83.5 (83.3)	77.75 (77.5)	88 (88)	74 (74)	80.25 (80)
AM-7135	Automatic	80 (80)	81 (80.8)	82 (82)	77.75 (77.7)	88 (88)	79 (79)	81.25 (79.3)
AM-7540	Automatic	81.75 (81.2)	77.75 (77.5)	80.5 (80.3)	79 (78.7)	83 (83)	75 (75)	80.25 (79.6)
AM-7545	Automatic	77.75 (77.5)	79 (78.3)	79.25 (79.2)	75.5 (75)	83 (83)	80 (80)	83.5 (80.5)
6M-50/51	Standard	78.75 (78.7)	78.75 (78.5)	81 (81)	77 (76.8)	88 (88)	76 (76)	82.75 (79.4)
FLX-6509	Automatic	81 (80.7)	81 (80.8)	82.5 (82.5)	79.5 (79)	88 (88)	76 (76)	85 (81.9)
MEAN		81.5 (81.3)	80.0 (79.8)	82.9 (82.8)	78.1 (78)	87.2 (87.1)	76.4 (76.4)	84.3 (83.4)
STD.		1.96 (1.93)	1.53 (1.44)	2.31 (2.25)	1.75 (1.74)	2.09 (1.98)	2.31 (2.31)	2.67 (2.82)

NOTE: Numbers in parentheses are computed from all data, while numbers not in parentheses are computed from the two highest noise levels.

FIGURE 4-4
Histograms of In-Service Transit Bus Noise Levels
SAE J366b (Acceleration) and Pull-Away Test Levels

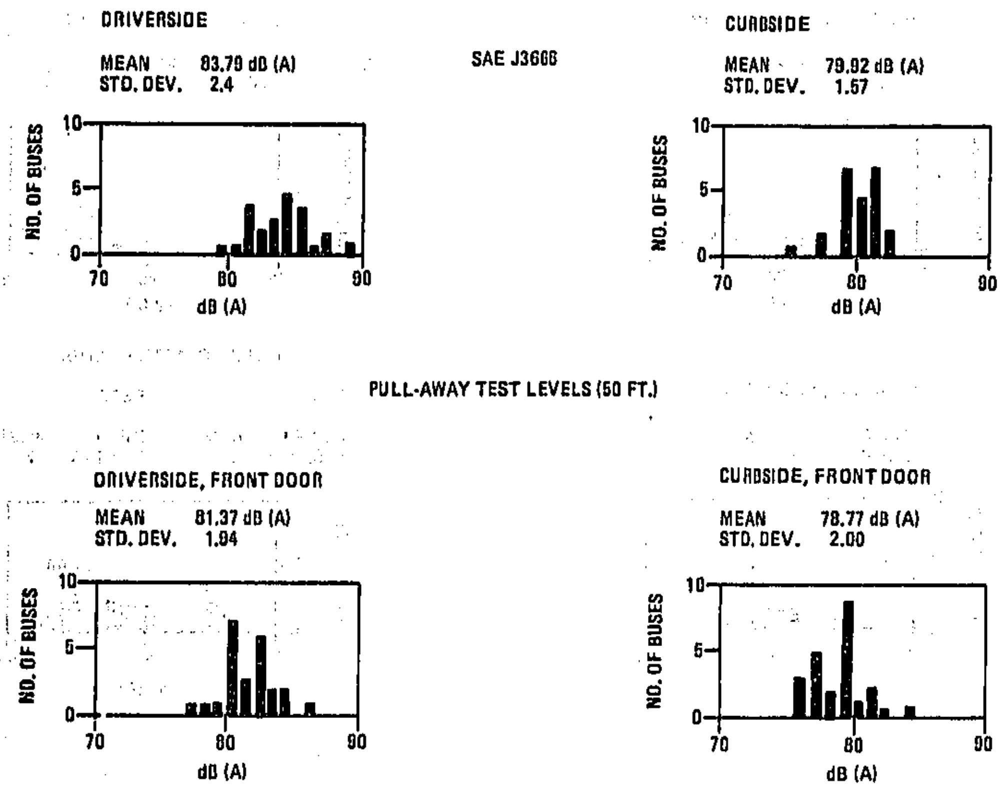


FIGURE 4-5
Histograms of In-Service Transit Bus Noise Level Tests
Stationary Runup Levels (50 ft.)

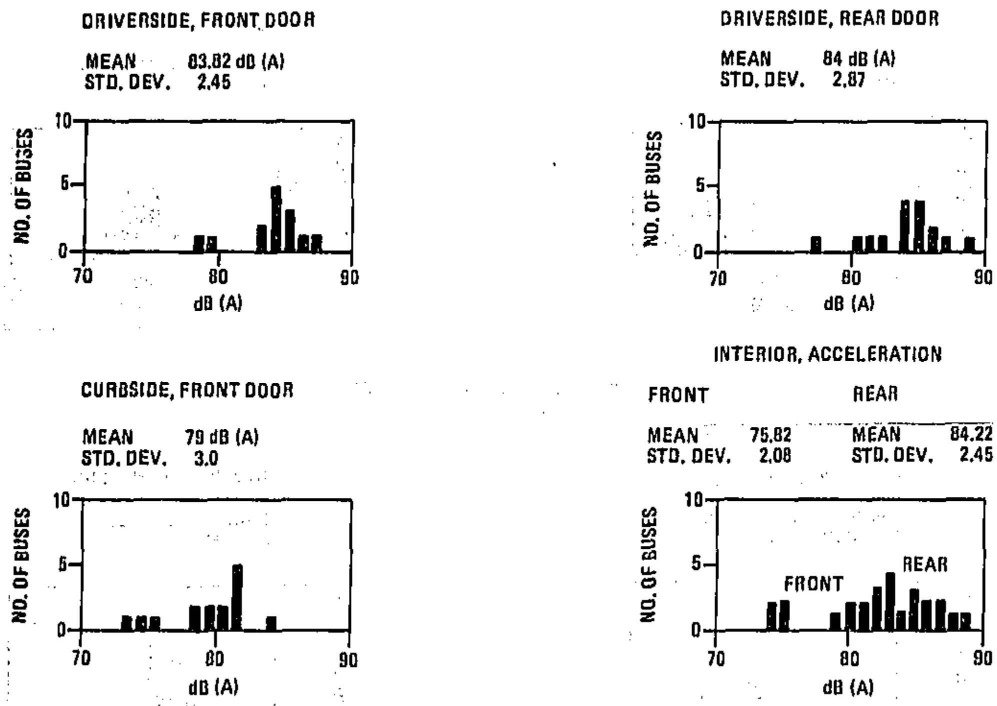


Table 4-11

Exterior Noise Levels, Bus #440D

Test Description	Accessories	Sound Level, dBA			
		Curbside		Streetside	
		25 ft	50 ft	25 ft	50 ft
Acceleration, J366b Test	OFF	81.5	77.5	87.0	84.0
Acceleration, J366b Test	ON	81	77	86	81.5
Deceleration from 30 mph (no brakes)	OFF	70.5	67	74	66
Deceleration from 30 mph (no brakes)	ON	73	70	72	71
Coast-by 30 mph	OFF	72	70	74	71
Coast-by 30 mph (fan off)	ON	-	71	75	71
Coast-by 30 mph (fan off)	OFF	70.5	68	75	70
Coast-by 55 mph	OFF	80	77	83	80
Cruise 30 mph	ON	75	72	80	76

Source: Reference 22

Tables 4-12 and 4-13 indicate that carpeting will lower very slightly the noise level in the interior. Inside the non-carpeted buses, no difference in noise level appears evident from a change in the height of the microphone for noise levels taken at any one measurement location. This indicates that a sitting or standing passenger in the same general area of the bus receives the same noise exposure.

Table 4-12

Exterior Noise Levels, Bus #705

Test Description		Sound Level, dBA	
		Curbside	Streetside
Curb Idle	- 5 ft	77	-
0-5 mph, Wide Open Throttle, Rear Corner	- 5 ft	88	-
0-5 mph, Wide Open Throttle, Rear Door	- 5 ft	90	-
10 mph Drive By	- 50 ft	66	73
30 mph Drive By	- 50 ft	72	78
55 mph Drive By	- 50 ft	78	87
25 mph Acceleration	- 50 ft	75	81
50 mph Acceleration	- 50 ft	78	86
30 mph Deceleration	- 50 ft	71	77
55 mph Deceleration	- 50 ft	77	84
55 mph Coast By	- 50 ft	77	84

Source: Reference 22

Table 4-13

Interior Noise Levels (Empty Bus), Bus #440D

Test Description	Sound Level, dBA			
	Without Carpet		With Carpet	
	Standing	Seated	Standing	Seated
10 mph - Front	68	67	68	67
Middle	70	71	70	70
Rear	74	74	-	75
30 mph - Front	73	72	72	71
Middle	75	76	73	72
Rear	80	81	78	78
55 mph - Driver's Ear	-	77	-	77
Front	79	79	77	75
Middle	79	79	77	77
Rear	84	83	84	83
0-55 Acceleration - Front				
Middle	-	79	77	76
Rear	81	81	79	79
	82	84	84	84
55-0 Deceleration - Front	78	76	75	74
Middle	78	77	77	77
Rear	80	81	81	83
Standing Idle - Accessories Off, Middle	-	63	-	61
Standing Idle - Accessories On, Middle	-	69	-	68
10 mph - Accessories Off, Middle	-	67	-	63
30 mph - Accessories Off, Middle	-	72	-	69
55 mph - Accessories Off, Middle	-	78	-	76

Source: Reference 22

Table 4-14

Interior Noise Levels (Empty Bus), Bus #705

Test Description		Sound Level, dBA Standing	Sound Level, dBA Seated
10 mph -	Front	74	73
	Middle	75	75
	Rear	79	78
30 mph -	Front	75	74
	Middle	77	77
	Rear	85	84
55 mph -	Front	77	78
	Middle	79	80
	Rear	85	85
0-55 Acceleration -	Front	78	78
	Middle	82	81
	Rear	89	86
55-0 Deceleration -	Front	77	76
	Middle	77	79
	Rear	86	85

Source: Reference 22

The Flxible Co.[11] has performed an extensive series of noise measurements on their buses under controlled test conditions. Their measurements are summarized in Table 4-15.

Table 4-15

Summary of Measured Transit Exterior Bus Sound Levels
The Flxible Company

Coach	Engine	No. Tested	Sound Level at 50 Feet, J366b Procedure, dBA — Curbside Mean	Curbside Std. Dev.	Streetside Mean	Streetside Std. Dev.
40'	6V-71	7	80.46	.55	82.25	.69
40'	8V-71	9	80.92	.87	82.05	.73
35'	6V-71	3	82.16	1.26	83.17	.76
35'	8V-71	1	80.50		82.00	

Source: Reference 11

The mean interior noise level measured 24 inches from the rear window under maximum acceleration conditions was 83.5 dBA with a standard deviation of 0.75. Flxible Co. also reports that interior noise levels of some coaches can be 87 dBA at shift point.[12]

AM General reports their exterior bus noise levels to be "in the range of 80 to 86 dBA" when measured according to the existing SAE J366b test procedure.[13]

Based on the above data for new and in-use buses concerning variation in noise level data, the medium design level of new buses should be 2 to 2.5 dBA below a not to exceed standard.

General Motors Corporation has recently initiated a "Quiet Bus Program".[21] For a GMC new-look bus before it was "quieted", Model No.

T8H5307A, GMC reports a mean noise level of 80.5 dBA using a modified SAE J366b test procedure with the fan off, and 83.7 dBA with the fan on. This model is a 40 ft, 53 passenger urban transit bus powered by an 8V-71 diesel engine. GMC also reports that for 15 identical transit coaches, of this model (T8H 5307A) using a modified SAE J366b maximum acceleration procedure a mean noise level of 81.2 dBA with the fan off (standard deviation of 0.43) was measured while a mean level of 83.9 dBA was measured with the fan on (standard deviation 0.75).[9]

In four trials, while using a special dual muffler configuration, GMC was able to lower the noise level of the "quieted coach" to just over 75 dBA under acceleration on the left side of the test coach and less than 71 dBA on the right. GMC indicates this developmental coach would meet a regulated level of 78 dBA. Exact results are shown in Table 4-16. The test used is a modified SAE J366b test with the starting point adjusted so that the transmission shift, and therefore maximum noise, is achieved in the end zone. All cooling fans were running during the test.

Table 4-16

GMC Quiet Bus Program Exterior
Sound Levels SAE J366b

Run	Left Side (dBA)	Right Side (dBA)
1	75.3	71.5
2	74.9	70.0
3	75.8	71.4
4	75.1	70.6

Source: Reference 21

GMC also reported a reduction of interior noise levels for its "Quiet Bus". Measurements were made at ear level in various coach seat positions during a wide open throttle acceleration and maximum sound levels were recorded. Observed data are shown in Table 4-17.

Table 4-17

GMC Quiet Bus Program Interior Sound Level Data at Wide Open Throttle Conditions

Interior Seat Location	Unmodified Coach SAE J366b	Modified Coach SAE J366b
Rear	81 dBA	76 dBA
Center	79 dBA	72 dBA
Driver	73 dBA	70 dBA

Source: Reference 21

Current Component Noise Levels

For diesel powered urban transit buses of current configurations, the important noise sources are the engine exhaust, engine, cooling fan, air intake system, chassis, and tires. (Tire noise becomes important at high speeds and may become the dominant noise source at highway speeds when all the other sources have been quieted.) Data on relative contributions of these sources (minus tire noise) were obtained for a GMC transit bus during tests conducted by EPA.[22] Additional data were obtained from tests conducted for the U.S. Department of Transportation (DOT) by two major transit bus manufacturers.[15, 16] This data is summarized in Table 4-18. All buses were 40 feet long and had Detroit Diesel 8V-71 engines except for the Rohr (Flxible) bus which was a 35 foot bus with a 6V-71 engine. The GMC and Rohr buses demonstrated the potential of feasible retrofit techniques to lower bus noise. The manufacturers' contracts with DOT required them to make these retrofit parts available to transit bus users. (It should be noted that the GMC data in Table 4-18 was not obtained during their "Quiet Bus Program" but rather under the retrofit study for DOT.[15])

An independent estimation of transit bus component noise levels conducted by Wyle Laboratories[3] is also included in Table 4-18.

Table 4-18

Urban Transit Bus Component Exterior Noise Levels, dBA at 50 Feet

	EPA Tests	GMC Standard Bus	GMC Quieted Bus	Rohr Standard Bus	Rohr Quieted Bus	Wyle Estimate
Engine Mechanical	75	73	71	79	75	79-80
Exhaust	80	76	74	79	65	80
Cooling Fan	81	84	73	77	73	78-85
Intake	70					60-75
All Other Sources	70	76	76	65	65	68-73
Overall Sound Level	84.5	85.5	80	83.5	78	84-87.5

Source: References 3, 15, 16 and 22

The main contributor to interior noise for transit buses is the engine. Engine noise is transmitted through the panels by vibration and by flanking paths. The latter two transmission mechanisms are very difficult to control and are thought to be the limiting factor to interior noise reduction. Air conditioning ventilation noise is also a contributing source to interior noise levels. Since all major component noise sources are located in the rear of the bus, it is difficult to diagnose the relative contributions of component sources to interior noise and as such no data is presently available.

(9) Intercity Buses

Exterior and interior noise level data gathered on intercity buses for the three major U. S. intercity bus manufacturers (Eagle International, General Motors Corporation and Motor Coach Industries) are presented below.

Current Exterior Noise Levels

Exterior sound level data, measured by EPA, of 12 newly manufactured intercity buses under various test procedures may be found in Table 4-19. The buses tested emitted average exterior noise levels ranging between 82 and 87 dBA under maximum acceleration conditions (SAEJ366b) with a mean level of 85.5 dBA. In addition, SAE J366b deceleration tests were run on two intercity coaches with engine brakes fully engaged. The buses emitted average maximum noise levels of 89.4 dBA under the SAE J366b deceleration procedure as compared to average maximum noise levels of 87 dBA under the SAE J366b acceleration procedure. The standard deviations exhibited in the data indicate that a 2-2.5 dBA difference between an engineering design level and a "not to exceed" regulatory level appears adequate for intercity buses.

TABLE 4-19
Summary of Exterior Noise Levels for Intercity Buses

BUS SERIAL NO.	MODEL	TRANSMISSION	A-WEIGHTED SOUND LEVELS, dB(A) AT 50 FEET							
			(SAE J366b) MAXIMUM ACCELERATION		PULL-AWAY		STATIONARY IMI		STATIONARY MAXIMUM GOVERNED SPEED	
			STREET SIDE	CURB SIDE	STREET SIDE	CURB SIDE	STREET SIDE	CURB SIDE	STREET SIDE	CURB SIDE
S 12337	MC-8	Standard	86 (85.1)	82.5 (80.6)			86.5 (85.25)	85 (81.50)	79.5 (77.5)	79.5 (77.0)
S 12337	MC-8	Standard	86 (85.2)	83.25 (81.3)			87.5 (85.5)	82.75 (79.80)	80 (78.25)	78 (76)
S 12361	MC-8	Automatic	86.5 (85.7)	83.25 (82.4)	86 (85.63)		88 (85.75)	77.25 (77.25)	80.5 (78.75)	75 (74)
S 12239	MC-8	Automatic	86 (85.5)	84.25 (82.9)	84.75 (84.5)	82.75 (82.63)	86.25 (84.6)	83.75 (80.6)	81 (78.5)	78 (75)
S 12359	MC-8	Automatic	84.5 (84.25)	81 (79.75)	84 (83.88)	81 (80.75)	86.75 (85.4)	81 (78.50)	81.5 (79.25)	78 (75.75)
S 12322	MC-5B	Standard	87.25 (85.2)	81 (79.6)	90.25* (89.33)	83* (82.17)	86 (85.5)	81 (79.25)	79 (78.75)	77 (76)
S 12323	MC-5B	Standard	87 (85.6)	81 (79.5)	89* (88.25)	82.25* (81.0)	85.5 (85.25)	80.25 (78.9)	80 (78.75)	77 (75.5)
19699	05	Standard	85 (84.5)	85.5 (84.5)	--	--	84.8 (82.9)	85.8 (83.3)	82.3 (81.1)	84.5 (81.3)
19704	05	Standard	85.5 (84.3)	86.5 (84.8)	--	--	84 (82.1)	85.8 (85.1)	82.5 (80.6)	84.5 (83.6)
9678	05	Standard	85.3 (84)	85.3 (84)	--	--	84 (82.4)	84.5 (82.1)	83 (80.5)	82.5 (80.3)
9677	05	Standard	84 (83.8)	85.8 (83.8)	--	--	84.8 (82.4)	84.5 (80.4)	83 (82.9)	82.5 (80.6)
--	17	Automatic	82.5 (81.4)	81 (79.9)	--	--	80 (79.4)	79.3 (77.6)	75.8 (75.4)	78.5 (77.3)
Mean	All	All	85.5 (84.6)	83.4 (81.9)	84.9 (84.9)	81.9 (81.7)	85.3 (83.9)	82.6 (80.3)	80.7 (79.2)	79.6 (77.7)
Std. Dev.	All	All	1.33 (1.18)	2.09 (2.05)	1.01 (.89)	1.24 (1.33)	2.11 (2.0)	2.78 (2.23)	2.06 (1.91)	3.14 (3.0)
Mean	MC-8	All	85.8 (85.1)	82.9 (81.4)	84.9 (84.7)	81.9 (81.7)	87 (85.3)	82 (79.6)	80.5 (78.5)	77.7 (75.6)
Std. Dev.	MC-8	All	.76 (.48)	1.21 (1.30)	1.01 (.89)	1.24 (1.33)	.73 (.42)	3.01 (1.70)	.79 (.65)	1.64 (1.12)
Mean	MC-5B	Standard	87.1 (85.4)	81 (79.5)	89.6* (88.8)	82.6* (81.6)	85.8 (85.4)	80.6 (79.1)	95.5 (78.8)	77 (75.8)
Std. Dev.	MC-5B	Standard	.18 (.29)	0 (.06)	.88* (.76)	.53* (.83)	.35 (.18)	.53 (.26)	.71 (0)	0 (.35)
Mean	05	Standard	85 (84.2)	85.8 (84.3)	--	--	84 (82.5)	85.2 (82.5)	82.7 (81.3)	83.5 (81.5)
Std. Dev.	05	Standard	.67 (.31)	.53 (.46)	--	--	.46 (.33)	.75 (1.95)	.36 (1.11)	1.15 (1.49)
Mean	17	Automatic	82.5 (81.4)	81 (79.9)	--	--	80 (79.4)	79.3 (77.6)	75.8 (75.4)	78.5 (77.3)
Std. Dev.	17	Automatic	0 (.78)	0 (.74)	--	--	0 (.58)	.35 (1.41)	.35 (.32)	0 (1.16)

*Deceleration tests with engine brake.
NOTE: Numbers in parentheses are computed from all data, while numbers not in parentheses are computed from the two highest noise levels.

Data measured by using the SAE J366b procedure for a GMC manual transmission production intercity coach Model P8M4905A[14] is shown in Table 4-20.

Table 4-20

GMC Intercity Bus
J366b Test Procedure

Cooling Fan On		Cooling Fan Off	
Streetside	Curbside	Streetside	Curbside
84.2 dBA	81.4 dBA	80.6 dBA	79.1 dBA

Source: Reference 14

In addition, during a demonstration at the GMC noise test track in Pontiac, Michigan, on December 16, 1975, maximum acceleration (SAE J366b) noise levels at 50 feet of 83.4 and 84.1 dBA were measured on the streetside of a GMC intercity coach while 82.8 and 83.2 dBA were measured on the curbside.[22] The test was performed with the transmission in second shift.

Motor Coach Industries (MCI) reports a curbside noise level of 82.5 dBA and a streetside noise level of 85 dBA using the SAE J366b procedure. At 70 mph cruise conditions, the same bus was said to produce 80.5 dBA on the curbside and 82.5 dBA on the streetside.[17]

Wyle Research[3] estimated SAE J366b noise levels for intercity coaches at 84 to 86 dBA, which is about the same as their estimate of 85.5 dBA for urban transit buses with 8V-71 engines.

Under high speed cruise conditions, tire noise levels at 50 feet may reach 75 dBA at 55 mph for rib-type tires used for intercity coaches.[16] This estimate is based on measurements conducted by DOT and the National Bureau of Standards at Wallops Island, Virginia, on a loaded International Harvester Truck (Model No. 1890) of 25,640 pounds GVWR.

Current Interior Noise Levels

Table 4-21 presents interior noise level data for 12 intercity coaches recorded during various testing procedures. It is interesting to note that in certain cases up to a 10 dB difference in noise level is present from the front of the vehicle to the rear of the vehicle.

Besides the data reported in Table 4-22 Eagle International reports levels of 72 to 73 dBA at the rear seat at 50 mph[19], after noise treatment had been added around the engine compartment.

MCI reports levels of 70 to 71 dBA at an unspecified seat location in their MC-5 35-foot coach.[17] MCI also conducted measurements under stationary and cruise conditions at various locations in the coach with and without approximately 90 square feet of sound insulation (Baryfoil #10.25) between the engine compartment and passenger compartment. This insulation was found to have no consistent effect on interior sound levels, which are summarized in Table 4-22.

TABLE 4-21
Summary of Interior Noise Levels for Intercity Buses

BUS SERIAL NO.	MODEL	TRANSMISSION	MEASUREMENT LOCATION	A-WEIGHTED SOUND LEVEL, dB(A) AT 50 FT. (SAE J366b) MAXIMUM ACCELERATION	PULL-AWAY	STATIONARY IMI	STATIONARY MAXIMUM GOVERNED SPEED
S 12327	MC-8	Standard	Front	74.5		74.25	
			Mid	73.25		73	
			Rear	79.25		77.3	74.3
S 12337	MC-8	Standard	Front	73.75		73.5	
			Mid	72		72	
			Rear	78.25		77	75.7
S 12239	MC-8	Automatic	Front	73	73	72.5	
			Mid	72	72	71.7	
			Rear	77.5	77.5	76.6	74.6
S 12239	MC-8	Automatic	Front	73.5	73.75	73.2	
			Mid	74	74.25	72.5	
			Rear	80.25	79	77.5	74
S 12359	MC-8	Automatic	Front	73	73	73	
			Mid	71	71	70.75	
			Rear	77	75.5	74.7	73
S 12322	MC-5B	Standard	Front	74.6	77.25	75.5	
			Mid	78	76.5	78.75	
			Rear	79.75	79.25	78.5	76.75
S 12323	MC-5B	Standard	Front	77.25	75.25	74.5	
			Mid	76.75	74.5	77.75	
			Rear	81	79.5	80.15	79
19699	05	Standard	Front	71.25	—	71.5	70
			Mid	76.5		75.75	—
			Rear	81.75		82	81
19704	05	Standard	Front	69.5	—	72.25	69
			Mid	74.75		72.75	70
			Rear	81		82	81
9678	05	Standard	Front	67.75	—	70	66
			Mid	73		77.25	74.8
			Rear	82		—	80
9677	05	Standard	Front	70.75	—	72	69.5
			Mid	77		76	72.5
			Rear	82		82.5	80
—	17	Automatic	Front	74	—	75.8	72
			Mid	79.25		80.5	77
			Rear	84		84	83
Mean	All	All	Rear	80.3	77.3	79.1	77.7
Std. Dev.	All	All	Rear	2.06	1.76	2.91	3.36
Mean	MC-8	All	Rear	78.5	77.3	76.6	74.3
Std. Dev.	MC-8	All	Rear	1.37	1.76	1.13	.98
Mean	MC-5B	Standard	Rear	80.4	79.4	79.3	77.9
Std. Dev.	MC-5B	Standard	Rear	.88	.18	1.17	1.59
Mean	05	Standard	Rear	81.7	—	82.2	80.5
Std. Dev.	05	Standard	Rear	.47		.29	.58
Mean	17	Automatic	Rear	84	—	84	83
Std. Dev.	17	Automatic	Rear	0		0	0

Table 4-22

Interior Sound Levels in
Rear of MCI MC8 Coach, dBA

	Normal Idle	High Idle	Maximum rpm	60 mph Cruise
Standard Coach	64	65	69	73
Insulated Coach	63	65	72	72

Source: Reference 17

Bray[18] reports average front seat levels for intercity coaches of 74 to 78 dBA and rear seat levels of 70 to 84 dBA.

Levels under normal street acceleration conditions at the rear seat of a new GMC intercity bus ranged from 80 to 84 dBA, compared to 77 dBA at cruise (30 mph) and 72 dBA at idle.[22]

For intercity buses, interior noise levels at pass-bys of 55 mph are more representative of actual driving conditions than the interior noise levels measured under maximum acceleration. However, maximum noise levels are most likely to occur under maximum acceleration conditions.

Current Component Noise Levels

Data on component levels of intercity buses are presently not available but are believed to be closely aligned with Urban Transit Bus component noise levels. This is believed to be true since many of the same noise generating sources (engine, transmission, cooling system) are similar or identical to Urban Transit Buses. Thus, refer to the Urban Transit Bus discussion on component noise levels for intercity bus component levels.

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Section 5

NOISE ABATEMENT TECHNOLOGY

For buses of current configurations, the important noise sources are the engine, exhaust, cooling fan, intake, and chassis. The relative contributions of these sources vary depending on the type of bus and on the type of bus operation.

Engine

Engine noise is the mechanically radiated noise associated with the combustion process and the mechanical components of the engine. This noise is a result of vibration of the engine structure, covers, and accessories. In general, noise from the transmission, turbocharger (if so equipped), and the blower are included in the noise source comprising engine noise. In the case of diesel engines, the air intake is treated as a separate noise source from engine noise. For gasoline engines the air intake noise component is included as part of the engine noise.

Exhaust

Exhaust noise includes the noise produced by the exhaust gases at the tail pipe exit, the noise generated by the vibration of the muffler shell and piping, and the noise caused by leakage of the exhaust system components (muffler, exhaust manifold, exhaust pipe, and tail pipe).

Fan

Fan noise includes the various noise sources of the cooling system. Although the predominant noise source is the fan, the shrouds, radiators, shutters, and grills affect the noise produced by the cooling system.

Intake

In the case of diesel engines, intake noise includes the noise from the air inlet, the air cleaner shell and ducting, and the leakage of the air intake system components.

Chassis

Chassis noise refers to that noise generated by a bus when it is coasting by at approximately 30 m.p.h. with the engine idling and the transmission in neutral. This noise includes any wind or turbulent noise caused by the passage of the bus. It is considered to be the lowest level of noise attainable for a vehicle.

Component Noise Abatement Technologies

(1) Engine Noise

a. Gasoline Engines

In the case of gasoline engines, it is customary to lump engine, air intake, and transmission noise together. This is done because the air intake filter is mounted directly on the engine carburetor, in close proximity to the engine. Transmission noise becomes an important noise contributor on gasoline engine vehicles only after the noise from the engine and the intake have been lowered below 70 dBA.

Intake noise is relatively low in gasoline engines. This is true because of the presence of the carburetor and the inherently quieter air intake process. As a comparison, current intake noise levels for diesel engines, which are considered noisier than gasoline engines, range from 56 to 75 dBA.[1]

Current gasoline bus engine noise levels under acceleration range from 69 to 73 dBA.[2] Chrysler Corporation estimates the combined engine and air cleaner noise levels for their 1976 model school bus chassis at 76 to 79 dBA. The EPA Background Document for Medium and Heavy Truck Regulations[3] estimates that engine noise levels range from 75.7 to 77 dBA for gasoline engines with ratings of 160 to 230 net horsepower.

Several methods are available for lowering the contribution of engine noise to overall bus noise levels. All of these techniques have been successfully tested in the laboratory and, for some, put into practice on diesel engines.[4,5] These techniques, and their expected noise reductions, are summarized below:

	Noise Reduction at 3 Ft.
Covers and panels attached to the engine	3 to 5 dB
Close fitting engine covers	5 to 8 dB
Partial engine enclosures	5 to 10 dB
Complete engine enclosures	Up to 15 dB
Major structural engine modifications	4 to 7 dB

Noise reductions at other distances are expected to be somewhat lower.

Turbocharging of diesel engines results in some engine noise reduction because of its smoothing effect on the rate of combustion pressure rise in the cylinder. This is not expected to be of significant benefit to gasoline engines.

Conventional school bus cowls provide an inherent barrier to some engine noise radiation. Improvements in the cowl design, addition of acoustic materials in the engine compartment, and provision of belly underpans all are beneficial to the overall reduction of engine noise.

Because interior noise levels are mostly controlled by engine noise, both radiated and structurally transmitted, care in the placement of fire-wall acoustical insulation and engine mounting is indicated to reduce interior noise levels.

b. Diesel Engines

Diesel engine noise is the result of forces generated by combustion and the mechanical aspects of the engine.[6] Diesel engine combustion forces are of sufficient magnitude to distort or vibrate the engine block, crankcase and attachments. Primary combustion forces are at engine fundamental firing frequencies. These frequencies are relatively low, but the structure responds to all harmonics of the basic firing frequency. The steep pressure rise inherent in diesel cycle combustion results in the introduction of high-frequency components into the engine structure which are readily radiated by the sides of the block and rocker arm covers. Changes in the character of or reduction of combustion forces have been under investigation by researchers for a number of years.

Precombustion chambers or indirect injection (IDI) can be used effectively to lower combustion rate related noise levels.[7] IDI is commonly used in diesel engines powering light-duty vans and passenger cars. For heavy diesels of the type used in diesel school buses and transit coaches, noise control by retardation of injection timing and turbocharging has proved to be effective. Retardation has been shown to have advantages in terms of power, fuel economy, and emissions,[6] but it also increases exhaust smoke.

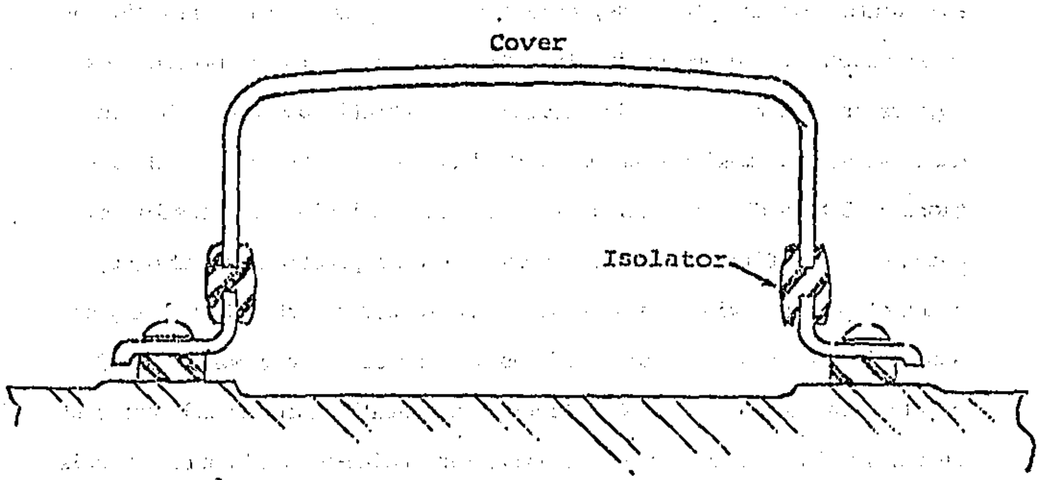
Turbocharging also increases the horsepower output for a given size engine and has advantages from the emissions viewpoint. Turbocharging is not as advantageous for transit buses as it is for trucks. Current transit buses use naturally aspirated engines of adequate power. Additional power would not be very useful because passenger capacities cannot be increased without exceeding overall size and axle weight regulations. The dynamic lag of turbochargers results in little increase in engine power levels until the engine reaches maximum speed. There is, therefore, no gain in dynamic torque and hence no improvement in bus performance in city traffic conditions. However, a tailored combination giving the desired characteristics can be developed.

Another method to lower engine-radiated noise would be to alter the stiffness or increase damping of all structures sufficiently to prevent their response to input forces. The cast iron diesel engine block is inherently damped and added damping has been found to offer little improvement.

Thin walled components such as oil pan, rocker arm covers, and manifolds can be isolated from the cylinder head casting by means of soft gaskets, rubber washers at mounting bolts or, in severe cases, by splitting the cover immediately above its mounting surface and joining together by a bonded, rubber section. This is conceptually shown in Figure 5-1.

A common method of reducing engine radiated noise is by noise barrier panels attached to the engine exterior surfaces. These covers or panels are made of a high-density barrier material lined with an absorbent material, usually sheet metal lined with glass fiber or mineral wool. These shields must be designed specifically for each engine model since proper covering and edge sealing is quite important. Panels generally are attached to and cover each side of the engine block and oil sump. They must be contoured to the engine shape and be attached through isolation mountings. Experience has shown they are more effective on in-line engines than Vee engines because of the greater, flat, radiation area on in line engines. Current practice for urban transit buses is to use Detroit Diesel V-6 or V-8 engines, which makes this method less effective.

Figure 5-1
Isolated Rocker Arm Cover



Engine covers have definite disadvantages and advantages. They restrict engine service operations. The possibility of undetected oil leaks being absorbed by the panel-lining material creates a potential fire hazard as well as destroys the noise absorption characteristics. The engine physical dimensions are increased, making installation in a vehicle more difficult. Heat radiation from engine surfaces is reduced, but experience has shown that this effect is minimal.[6] Quality control must be maintained to assure seal of all panel edges and joints. On the plus side, panels can be applied without redesign or modification of the engine itself. They can be applied to present new engines or even to engines in service as a retrofit package. This is much easier than making changes to the basic engine structure. Reductions of 3 to 8 dBA at 3 ft. in engine noise radiation are possible by means of close-fitting covers. However, from a practical standpoint, a set of panels giving 8 dBA reduction would cover virtually all engine and engine mounted accessory surfaces by many separate complex shaped panels. In general, a 4 dBA reduction in overall engine sound levels at 50 ft. is close to the practical limit for engine-mounted barrier panels.

Sound level reduction due to modified engine structure, reduced piston slap, damping, and isolation can be used in conjunction with barriers to produce overall reductions greater than 4 dBA, although each additional decibel reduction is more difficult to achieve than the preceding one. When the panels are combined with a partial enclosure, the resultant reduction is often less than the sum of the separate reductions due to each method.

The urban transit bus engine compartment already provides some shielding from engine noise, at least on the curb side of the bus. The large opening on the left side for admitting cooling air through the radiator allows much engine and fan noise to escape on that side. Rohr Corporation has experimented with a forward-facing air scoop installed over the radiator and by covering the standard grills with an inverted Vee non-line-of-sight louver.[8] A line-of-sight barrier between the engine and the radiator opening was found to be effective. General improvement of the engine compartment door seals and sound isolation of the existing engine compartment walls can result in additional engine radiated noise reduction. The design of radiator grills to eliminate line-of-sight sound propagation and also to provide sound absorption without excessive increase in cooling system flow resistance is attainable, but will require some developmental work.

Shielding under the engine can be effective if the entire area under the engine is treated. Engine noise reaches the receiver by two routes, via straight line from the engine area and by reflection from the road beneath the vehicle. Belly pans are effective in blocking the reflective path and are currently available for all transit buses. In general, however, belly páns are not specified or used extensively due to the added engine servicing problems, restriction of cooling air exit, and problems associated with sealing. A 2 dB reduction in the engine contributed noise level can be expected by sealed belly pans in the case of buses. This will be especially effective in reducing bystander and pedestrian ear level noise since the reflective sound path from the engine off the road surface toward the side of the bus will be virtually eliminated.

Full engine enclosures are in use for certain European buses. Saab-Scania buses have a completely encapsulated engine, with remotely placed dual radiators and electrically operated fans. The engine enclosure is ventilated by a third fan, with air being admitted through an opening in the roof. European bus technology is discussed in greater detail in Appendix A.

Disadvantages of engine enclosures include reduced accessibility to the engine compartment, added weight, some reduced passenger and freight capacity due to increased engine compartment size, and a greater potential fire hazard.

Transmission noise for diesel buses can be lowered by the application of damping material to reduce resonant amplification at troublesome frequencies, by stiffening or by weakening housing areas to shift resonance frequency components, by decoupling housing areas by slotting or adding mass dampers, and by altering panel geometrics.[9] Engine shields can be extended to include the transmission housing in the case of buses.

Engine mountings are important since engine vibrations can be transmitted to the body framework and to the body panels through the mounts. Engine mount design technology is sufficiently advanced to provide good isolation at high frequencies between the engine and body frame or chassis while allowing the large torque forces to be transmitted to the transmission. Vibration isolation is important because current bus interior noise levels are dominated by floor and body side panel radiated noise which appears to be the result of engine vibration.

(2) Exhaust Noise

a. Gasoline Engines

Gasoline engine school buses, without exception, require the tail pipe outlet to be at the rear of the bus, extending at least five inches beyond the body wall. This results in ample exhaust pipe lengths for adequate engine exhaust noise quieting. Moreover, gasoline engines can tolerate higher back pressures to allow mufflers of greater restriction to be used compared to diesel engines. The average back pressures of current passenger-car mufflers range from 6 to 16 inches Hg.[11] The exhaust systems for gasoline-powered medium trucks are designed for a 3-inch Hg back pressure allowance. Wide open throttle (WOT) operation is common in the case of trucks and high back pressures and ensuing high exhaust valve area temperatures can affect engine durability. However, school bus applications seldom require WOT operation, and if they do, it is limited to a few hours only per day. Thus, higher back pressures may be allowable on bus chassis rather than on comparable truck chassis.

There are a few problems associated with school bus exhaust systems. Even when the exhaust pipe outlet noise is lowered, the long exhaust and tail pipe can still generate noise from the muffler shell and pipe walls. Horizontal muffler and tail pipe systems are inherently noisier than comparable vertical systems because of ground-reflected acoustical energy. The large bus floor undersurface also reflects the sound which escapes from the sides resulting in higher sound levels on both sides of the bus.

The positioning of the muffler in the exhaust system is also critical,[11, 12, 13] and some improvement in exhaust noise levels can be obtained by experimenting with this. Since school bus exhaust systems are optimized for engine cruise conditions, the exhaust noise has a characteristic tinniness during brief periods of high and low engine rpm.

No quantitative information is available for gasoline truck, bus, or automobile exhaust noise levels for the various engine and muffler combinations employed. The EPA Background Document for Medium and

and Heavy Truck Regulations reports that exhaust noise levels of current gasoline trucks under acceleration are around 80 dBA at 50 feet. Chrysler Corporation has estimated the current production school bus exhaust noise levels at 50 feet to be from 75 to 78 dBA under acceleration conditions.

b. Diesel Engines

Naturally aspirated diesel engine exhaust noise levels with currently available mufflers range from about 70 to 82 dBA.[1] Turbocharging results in reduced exhaust noise levels but the selection of a muffler to take advantage of this noise reduction requires care because allowable back pressures are generally lower.

Data is available from manufacturers on the acoustic performance of a given muffler on a given diesel engine. However, changes in pipe routing, installation, etc., can have significant effects. Because of packaging problems, transit bus exhaust pipe often take winding routes between the two manifolds and the horizontal muffler. Newer model buses have a vertical tail pipe routed through the left side of the bus. Older buses have a short horizontal tail pipe exiting at the rear under the engine.

The location of a muffler between the bus floor and pavement worsens the effect of muffler shell radiated noise.

(3) Cooling System Noise

a. Conventional School Buses

The cooling system fan is a major component source of noise for trucks and buses. Sound levels of fan noise at 50 feet vary from near 70 dBA to 85 dBA depending predominantly on fan blade tip speed and the position of radiator shutters. Other components of the cooling system generate noise, but are of secondary importance. Noise from the water pump, belts and pullies, and air flow through the radiator contribute very little to the overall noise level.

Because they are part of the fan environment, the engine, radiator, shroud, cab, and other components all affect the cooling ability of the vehicle. They also affect the noise generated by the fan because of the effect which each component has on the air flow or the flow resistance against which the fan must operate. Studies conducted by two major heavy truck manufacturers under the DOT Quiet Truck Program have indicated that modifications to improve the fan environment are very effective in reducing the fan noise levels by allowing lower fan tip speeds without reduction in cooling ability.[14, 15]

The potential for reducing fan noise hinges on the possibilities for maximizing the cooling rate at a given fan speed, thereby minimizing fan speeds and/or fan-on time. Several approaches to such an optimization have been suggested:

- Fan redesign
- Improved fan shrouds
- Increased cooling system pressures
- Optimized radiator to fan and fan to engine clearance
- Radiator redesign
- Fan clutches
- Ducts and flow deflectors
- Ring shrouds to prevent tip recirculation.

A combination of these techniques has resulted in lowering fan noise levels from 81.5 dBA to 66 dBA on the left, and from 80 dBA to 68 dBA on the right side of an IHC model CF-4070A diesel cab-over truck without reducing the cooling capacity.[14] Similarly, the fan noise level was lowered from 80 dBA to 64 dBA by using a different combination of techniques for a Freight-liner cab-over truck using a Cummins NTC-350 engine.[15]

The following noise reductions have been demonstrated in the laboratory for a 20-inch 5-bladed truck fan:

	Reduction dBA
Sealed shrouds and optimized fan coverage	4.5
Optimum fan-to-radiator distance	.5
Engine mounted air deflector	4.0
Contoured shroud with 1/4-inch tip clearance	7.5
Optimized radiator heat transfer	2.0

These reductions are not always cumulative.

Generally about one-third of the total energy of the fuel used in a gas engine is released as heat to the cooling system. Another one-third is released as heat to the exhaust or radiated away, and the remaining one-third generates useful power. This ratio varies with engine configuration, compression ratio, spark timing, valve timing, engine load, and speed. At idle, for instance, no useful power is developed and all the fuel energy is released as heat. The heat released to the cooling system is released to the atmosphere through the radiator. The fan draws air through the radiator to improve heat transfer.

The noise generated by an engine cooling fan can be decreased by changing the fan drive ratio to reduce the maximum speed. This change will also reduce the speed of the water pump and the fan speed at idle. Both of these changes could cause cooling performance problems. The water pump capacity may be recovered by increasing the diameter of the water pump impeller, which may necessitate redesigning the entire water pump on some engine models. Reducing fan capacity requires a larger radiator to maintain the same cooling performance. Configuration of the front end sheet metal on a bus limits the radiator size, but the sheet metal can be raised on the frame to accommodate a larger radiator. This change impacts bus body mounting, tooling, and driver visibility.

Fortunately, the cooling problem is not critical for conventional school buses. School buses use the same sheet metal as medium-duty trucks, but are seldom fitted with the largest engine that is available in trucks of the same load capacity. This would indicate that larger radiators are available than currently fitted to most school buses. Also, since the majority of school buses do not operate during the hot summer months, the design temperature can be lower for a school bus than for a truck. On the other hand, cooling performance at idle cannot be compromised on a school bus.

Air emission control requirements for gasoline engines also need to be taken into account. Current engine designs require highly retarded ignition timing which increases the exhaust temperatures and heat rejection to the cooling system. The reduced compression ratios and changes in camshaft to delay exhaust valve opening and increase valve overlap also increase the heat rejection. On the other hand, the use of higher temperature thermostats gives some relief.

The chief differences between the diesel truck application and conventional gasoline bus application are summarized in Table 5-1.

It should be noted that the cooling systems of forward control buses require special attention. The technology in the DOT Quiet Truck Program is not directly applicable for such buses.

b. Transit and Intercity Buses

Urban transit buses of current design employ a radiator and fan for engine cooling on the left side of the engine compartment. The arrangement results in uneven flow speeds through the radiator, and thus little or no ram air is obtained from the forward motion of the bus. GMC intercity buses also employ the same arrangement.

MCI intercity buses employ twin radiators with thermostatically controlled centrifugal fans at the top of the engine compartment directly above the engine. The fans are connected to the radiators by ducts. This arrangement results in a quiet cooling system with evenly distributed sound levels on the two sides.

The three DOT Transbus prototypes use different cooling system arrangements. (For a discussion of the DOT Transbus Program see Appendix B.) None of the Transbuses use Detroit Diesel engines.

Table 5-1

Comparison of Cooling Fan Parameters for Gasoline and Diesel Engines

	Diesel Engine Truck	Conventional Gasoline Engine School Bus
Maximum engine rpm	2100	3600-4000
Heat rejection at idle	2 Btu/hp/min	7 Btu/hp/min
Heat rejection at maximum throttle	24 Btu/hp/min	27.5 Btu/hp/min
Load factor	Sustained operation at maximum engine speed	Under 20% of time at maximum engine speed
Fan-on time (when on-off clutches are used)	Under 5%	23-40%
Coolant pressure	Atmospheric	14-16 psig
Shutters	Employed	Generally not employed
Air conditioners	Available	Rarely employed

The AM General Transbus uses a Caterpillar 3406 TAFC turbocharged and aftercooled 6-cylinder in-line diesel for propulsion. The engine cooling radiator and the air conditioning condenser are mounted in series directly above the engine across the rear of the coach. The cooling fan is hydraulically driven, with no speed modulation. The GM Transbus used a gas turbine and hence does not require a water cooling radiator. The oil coolers were on the right side of the engine compartment with a squirrel cage type fan directly driven off the accessory drive system. The evaporators, including the two-speed circulation fans, are mounted in the air conditioning compartment above the engine. The Rohr Industries Transbus uses a Cummins VT-903, V8 turbocharged diesel engine for propulsion. The 1300 in^2 cooling radiator with the transmission oil cooler was located between the left side of the bus and the front of the engine, the conventional location for current design buses. The fan was hydraulically driven with the speed modulated to meet cooling demands by a sensor in the bottom tank of the radiator.

Although it is not certain where the future transit bus cooling systems will be located, for this discussion, it shall be assumed that the radiator and fan will be located in the left hand side rear portion until space considerations dictate relocation.

The advantage of locating the side-facing radiator close to the rear end of the bus is that the radiator air inlet is in the only high pressure area at the rear of the bus. The disadvantage of the rear side-facing placement of the fan is that the air near this section of the bus is relatively dirty. As a result the fan draws this dirt through the radiator and usually deposits it in the engine compartment. MCI reports that on their intercity buses with compromised radiator positioning, during actual operating conditions on the highway, the cooling fan air flow is only 50 percent of the air flow measured during static bus tests.

Current transit bus cooling fan noise levels range from 77 to 85 dBA under acceleration conditions. The fan-on time with viscous fan clutches is on the average higher than for trucks. It depends on the operation cycle of the bus which may range from intermittent city operation to an occasional continuous highway cruise. The GM and Rohr quieted buses used a fan clutch to lower noise levels on the left side of the bus to 73 dBA. Even when the fan is engaged, it does not reach full engine speed under normal operation.

(3) Air Intake Noise

Air intake noise of gasoline engines is included in the engine noise for reasons discussed earlier. The following discussion will be limited mainly to diesel engine intake systems.

Intake noise is produced by the opening and the closing of the inlet valve. When the valve opens, the pressure in the cylinder is usually above atmospheric and a sharp positive pressure pulse sets the air in the inlet passage into oscillation at the natural frequency of the air column. This oscillation is rapidly damped by the changing volume caused by the piston's downward motion. When the inlet valve closes it produces similar pressure oscillations, which are relatively undamped. In the diesel engine, air inlet noise is generally observed in the low to middle frequencies (up to 1000 Hz). (On gasoline engine, this inlet noise may be important at higher octave bands due to the flow noise produced in the carburetor.)

Typical unsilenced intake noise levels for truck diesel engines at high idle vary between 70 dBA and 85 dBA, measured at 50 feet from the engine inlet. Production air filters used on most trucks provide a noise reduction (Insertion Loss) of from 9 to 22 dBA. In the case of eleven trucks with Detroit Diesel Engines and production model intake filters,[17] intake noise exceeded the noise levels from the remaining components in only one case. Six trucks had sufficiently quiet air intake such that further reduction of the intake noise would not be of any benefit to overall vehicle noise levels. The remaining trucks showed overall noise reductions of 0.5 to 3 dBA for a 6 dBA reduction of intake noise. If the noise from remaining components were lowered, intake noise would assume greater importance for a great proportion of trucks.

Intake filters act as silencers because of the sound absorption properties of the filter element and because of the area changes. Additional silencing may be provided by designing flow passages to restrict line-of-sight transmission.

Heavy duty oil bath cleaners used in transit buses are good noise suppressors. Cleaners that have large flat sections of sheet metal can radiate significant amounts of noise from mechanical vibrations. Use of rubber sections such as elbows, tubes or connectors in the air intake piping should be avoided as much as possible. Most rubber sections are not good acoustic barriers and radiate excessive amounts of noise because of their pulsating walls.

For maximum quieting, an additional intake silencer can be installed between the air cleaner and the engine inlet. These devices are not particularly expensive, are easy to install, and will do a good job of absorbing higher frequency noises. The silencer should be installed as close to the engine inlet as possible. The additional space requirement may be a problem in transit and forward control school buses.

With the precautions outlined above, the attainment of intake noise levels under 65 dBA is practicable with available intake filters for diesel engines.

(5) Chassis and Accessory Noise

In the category of chassis noise, the coasting noise of the vehicle with no propulsive power being applied to the vehicle and the noise from the remaining minor sources such as air conditioning and air brake compressors are included.

Motor Industries Research Association (MIRA)[18] has collected data on coasting noise levels for a broad range of vehicles. Coasting noise depends on size or weight of vehicle, conditions of road surface, and road speed. Variations might also be expected due to tire tread pattern and construction, number of axles and tires, axle loadings, and bus body surface area. A useful general relationship for the coasting noise of a vehicle at 30 mph (44 fps) on a smooth, dry surface is given by the equation:

$$dBA = 65 + 7 \log_{10} W$$

where:

W = gross vehicle weight in tons

dBA = sound level 7-1/2 meters from vehicle centerline.

A typical school bus of 23,000 lb GVWR according to this formula will produce 66 dBA at 50 feet while coasting at 30 mph. A vehicle of 10,000 lbs GVWR will produce 64 dBA under the same conditions.

EPA conducted tests on the coasting levels of several school buses of 17,400 lb to 23,000 lb GVW rating chassis.[25] A 23,000 lb GVWR bus measured 65 dBA on the curbside and 69 dBA on the streetside while coasting at 30 mph. A 17,400 lb GVWR bus equipped with snow tires measured 73 dBA on the curbside and 74 dBA on the streetside while coasting at 30 mph. Both tests were conducted with the engine idling, the transmission in neutral, and all accessories on. Hence the measured levels reflect the total chassis noise levels to be expected rather than the coast-by noise alone.

Current school bus chassis noise levels appear to be in the 65 to 74 dBA range at 30 mph with the engine shut off. Coast-by noise levels for conventional school buses (without accessory noise) without snow tires are approximately 64 to 68 dBA. Chassis noise levels can approach these coast-by levels by lowering the contributions from accessories and body vibrations.

Chassis noise levels of current transit buses range from 65 to 76 dBA for 35 ft. and 40 ft coaches.[16] It is felt that chassis noise levels of 70 dBA are achievable on today's 40-foot transit coach.

In the case of integral design transit buses, the outer skin panels are load-carrying members. Hence any road or engine vibrations transmitted through the suspension or engine mounts will be transmitted to the skin as stress and result in vibrations of the panels. These panels are acoustically efficient radiators of sound at audible frequencies. The mounting of accessories will need special care to avoid excitation of the body panels into resonance. The windows of the bus should also receive attention. Apart from rattles, loose window panes also result in large vibrating surfaces and hence chassis noise.

Overall Noise Abatement

The abatement of bus noise is a systems problem. In the following discussion, the classification of buses according to their noise component configurations attempts to make the total universe of buses into a manageable number of systems that are similar from the noise abatement viewpoint. Total bus noise abatement is further broken down into a number of steps or target noise levels. Each targeted noise level may be achieved by combining component noise control measures in a specific way. System compatibility is implicit in the selection of such combinations.

In general, noise control strategy is determined by the source levels of the noisiest and/or most difficult-to-control components. The successive steps in noise reduction invariably require increasingly more complex, and in most cases increasingly expensive, technologies.

(1) Conventional Gasoline-Powered School Buses

Five study levels have been identified for conventional gasoline-powered school buses. Component levels to achieve each study level are indicated in Table 5-2. The production bus noise design levels should be 2 to 3 dBA under the targeted not to exceed noise levels, as shown.

Table 5-2

Component Noise Level Matrix for Gasoline-Powered Conventional School Buses

	Sound Level, SAE J366b Test, dBA				
Bus exterior study level (Not to exceed level)	83	80	77	75	73
Bus design level	80.0	77.5	74.5	72.0	70.5
Engine and intake	77	74	71	68	65
Exhaust	73	69	65	65	64
Cooling fan	73	70	64	64	64
Chassis and accessories	70	70	70	65	65
Interior Study Level (at driver)	83	80	80	75	75

83 dBA Exterior and Interior Study Levels

Engine

No special engine, intake or transmission treatments will be needed.

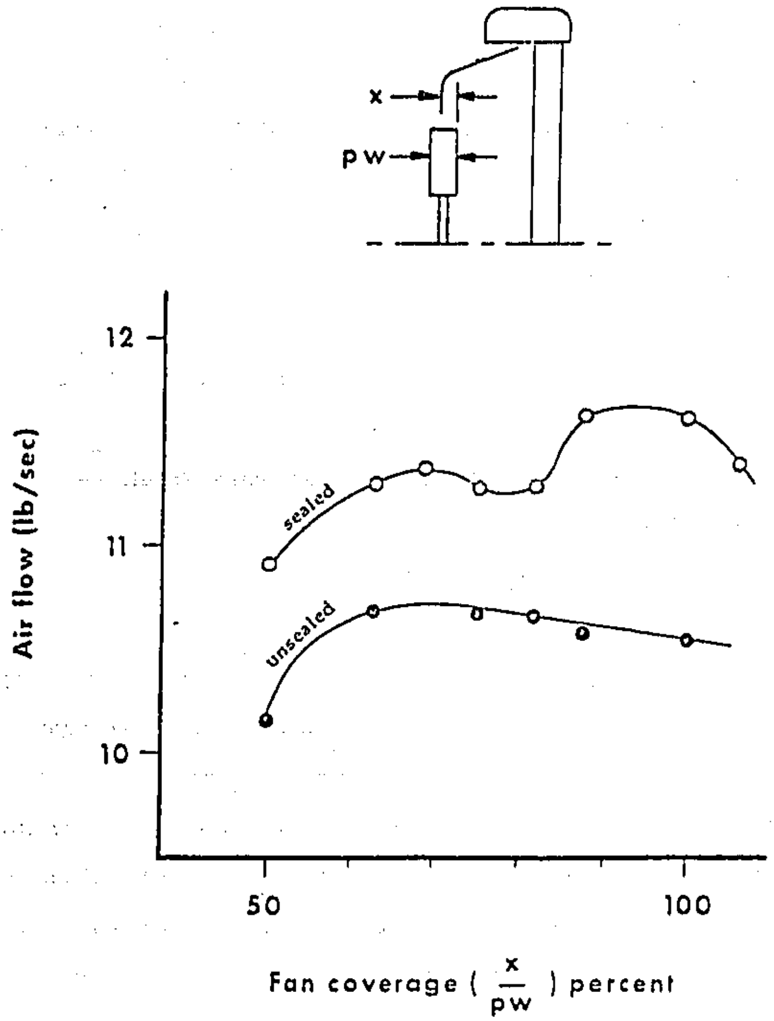
Exhaust System

The use of best available mufflers will be sufficient to obtain 73 dBA exhaust noise levels. The muffler will be located in an optimum position for the school bus exhaust system after the tail pipe length has been adjusted for the body length.

Cooling Fan

To obtain the 73 dBA fan noise level, careful sealing of the shroud to the radiator along with optimization of fan coverage by the shroud will be needed to maximize the air flow. In tests conducted by International Harvester Company, the air flow rate was increased by this method from 10.66 lb/sec to 11.5 lb/sec (see Figure 5-2). Optimum fan coverage for the sealed shroud was obtained at 90 to 100 percent coverage, while the original unsealed shroud gave maximum air flow rates at 65 percent coverage. The increased air flow rate allowed a reduction of fan speed to reduce overall noise level by as much as 5 dBA. Optimization will help only to the extent of the actual departure in the present system. The reduction in fan maximum speed can be obtained by providing a viscous type fan clutch. The latter approach is recommended because it has the advantage of minimizing the fan power requirements when cooling loads are less than maximum. Because there is always some slippage at fan speeds approaching maximum shift speed, the maximum fan speed will be automatically lowered with the usage of a fan clutch.

Figure 5-2
Effect of Fan Coverage on Air Flow
With Shroud Sealed to Radiator



Fan Speed 2520 rpm.

Source: International Harvester Company

An on-off type clutch is not considered to be a feasible solution because it will not lower the maximum fan speed, unless the engine to fan pulley ratio is changed appropriately.

In those cases where the sealing of the shroud and optimizing fan coverage does not result in sufficient noise reductions, flow rates may be increased further by choosing a fan that will allow reduction in shaft speed. This again is dependent on the present fan on the vehicle. In most cases, increasing the number of blades and/or blade twist will result in achieving the air flow at reduced speeds. A shaft speed reduction of ten percent will be sufficient.

Chassis

The required 70 dBA level for chassis and accessories is already attained by most gasoline school buses on the road today.

With the above exterior technologies interior noise should be reduced to the 83 dBA level.

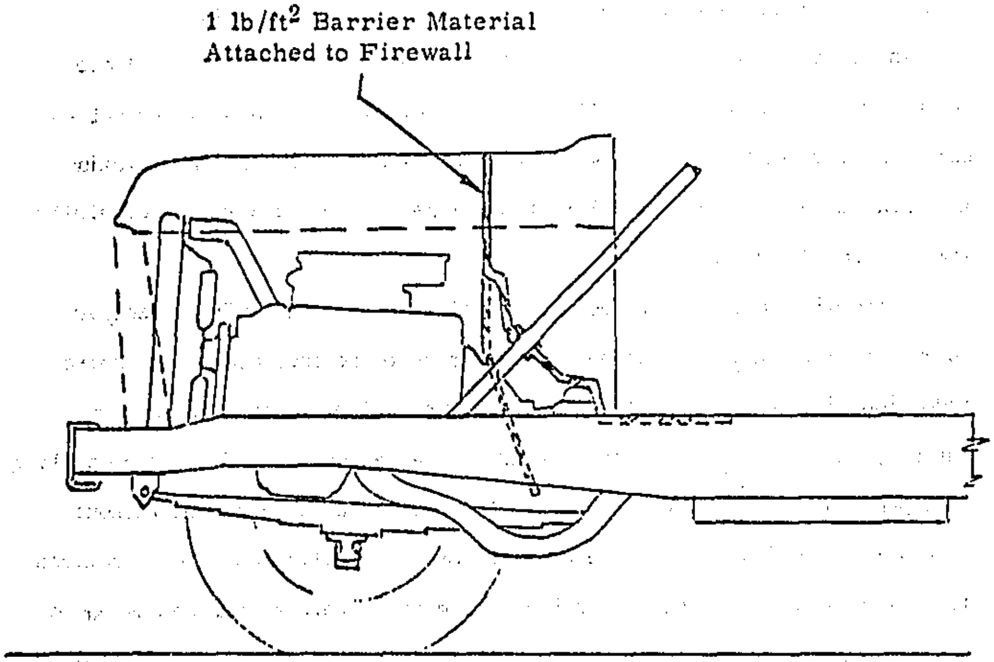
80 dBA Exterior and Interior Study Levels

Engine

Some engines may require the inclusion of acoustic treatment of engine hood. For this, acoustic barrier-cum-absorption material of the type currently used for automobile hood insulation may be added.

To reach the interior noise level of 80 dBA at the driver's location, one layer of barrier-type acoustic insulation weighing 1 lb/ft^2 should be employed at the cowl face and under the floor extending about 5 feet as shown in Figure 5-3. All holes in the firewall for pedal linkages, steering column, etc., should be carefully sealed with heavy rubber boots.

Figure 5-3
Engine Noise Abatement
by Shielding



Approximate Area of Barrier = 25 ft^2

Exhaust

To reduce exhaust noise to 69 dBA, larger, more advanced mufflers will be needed. Careful design of the exhaust system to place the muffler in the optimum position will be necessary. It will also be necessary for the exhaust system designer to specify that the tail pipe length not be altered by anyone adapting the chassis to school bus application.

In April 1973, GMC reported[19] that by using a larger muffler, with the pipes rerouted where possible to lie within the confines of any engine compartment shielding and to avoid conflict with a belly pan installation, the exhaust noise level of a CE 6500 gasoline engine truck was successfully lowered from 83 dBA to 70 dBA.

Automotive mufflers are designed empirically by the muffler manufacturers who work with the engine manufacturers to achieve acceptable noise reduction without loss in performance.[11] For a simple expansion chamber muffler, the transmission loss increases by a maximum of 7 dBA for a doubling of expansion ratio.[20] Increased expansion ratios can be obtained without increasing the thickness of the mufflers by using elliptical cross sections. It is estimated that almost a doubling of muffler volume will be needed to achieve exhaust noise levels of under 69 dBA, which are 4 to 5 dBA below those of currently available mufflers.

Special attention must be given to the support system for the exhaust pipes and muffler under the bus floor to prevent the transmission of vibrations to the chassis. Airborne noise could also excite the floor to radiate noise to the bus interior. Current plywood floor designs appear adequate in reducing floor transmitted exhaust noise to the bus interior.

Cooling Fan

Two alternate approaches are possible for achieving fan noise levels of under 70 dBA.

1. Contoured Shroud with 1/4-Inch Tip Clearance

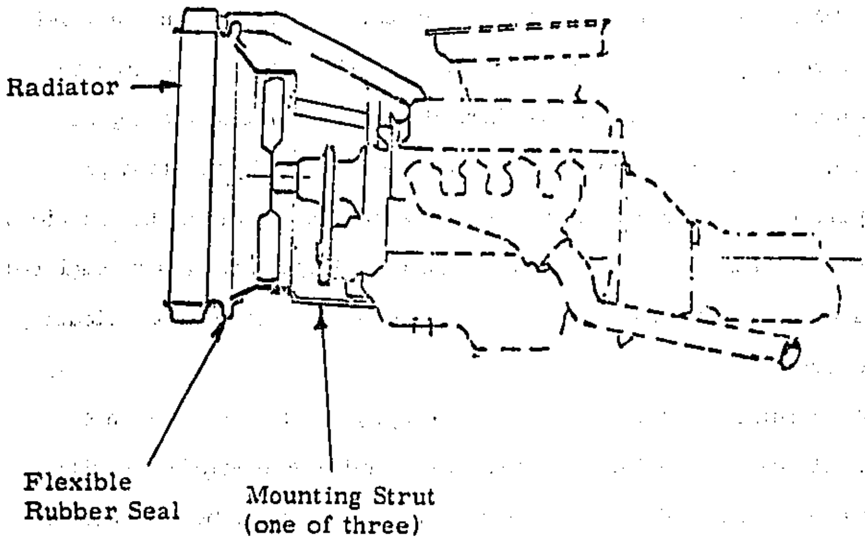
This type of shroud is shown diagrammatically in Figure 5-4. Tests by the International Harvester Company have shown that the use of this shroud resulted in allowing fan speed to be reduced by 6 percent while 3 to 6 dBA noise reduction was obtained in comparison to the noise level of the carefully sealed shroud. The shroud will need to be mounted in such a way as to maintain the 1/4-inch clearance even when the engine moves relative to the radiator. This can be achieved by mounting part of the shroud to the engine and part to the radiator with the two sections connected together by a flexible rubber boot. Recent road tests completed on a truck equipped with such a shroud have demonstrated the practicality of this design.[21]

Total noise reduction expected from using the low tip clearance shroud with careful seals, a viscous clutch and a seven-blade fan will be between 10 and 13 dBA. The maximum fan speed has now been lowered to 79 percent of the original fan speed without sacrificing air flow and hence cooling system performance. The radiator has not been altered in any way.

2. Increased Radiator and Fan Size

Increasing the radiator area can result in significant reduction in fan rpm and noise.[1] Estimates show that by using simple fan laws show that increasing the radiator area by 20 percent and the fan diameter by 10 percent, fan rpm can be lowered by 37 percent without sacrificing

Figure 5-4
Engine-Mounted 1/4 Inch Tip
Clearance Shroud



cooling capacity. This would in turn result in lowering the fan noise level by 8 dBA. Additional noise reduction can be obtained by careful fan and radiator sealing and increasing fan diameter (the larger radiator will allow this).

Chassis and Accessories

Current chassis noise levels are sufficiently low and no treatment will be required.

77 dBA Exterior and 80 dBA Interior Study Levels

Engine

To reach the 71 dBA required engine noise level, additional engine side shields will be required. These may be located as sketched in Figure 5-5. The shield may be made from 20 gauge steel sheets lined on the inside with a 2-inch layer of acoustical glass fiber. To keep the glass fiber from losing its effectiveness from saturation with oil, gasoline, or water, a 2-mil nonflammable plastic barrier should be provided. Finally, a perforated thin (22 gauge) metal cover should be added on the inside to minimize mechanical wear and tear. This is sketched in Figure 5-6. Glass fiber materials are relatively inexpensive. The study of currently available cowl and engine sizes for school buses indicates that sufficient space is available for such shields and no alteration in cowl design will be necessary.

The reduction in open area around the engine may result in some loss of cooling air flow. Thus, in all probability, cooling fan redesign would be needed to achieve the 77 dBA bus regulated level.

Figure 5-5
Engine Side Shields in Position For
77 dBA Overall Bus Noise Levels

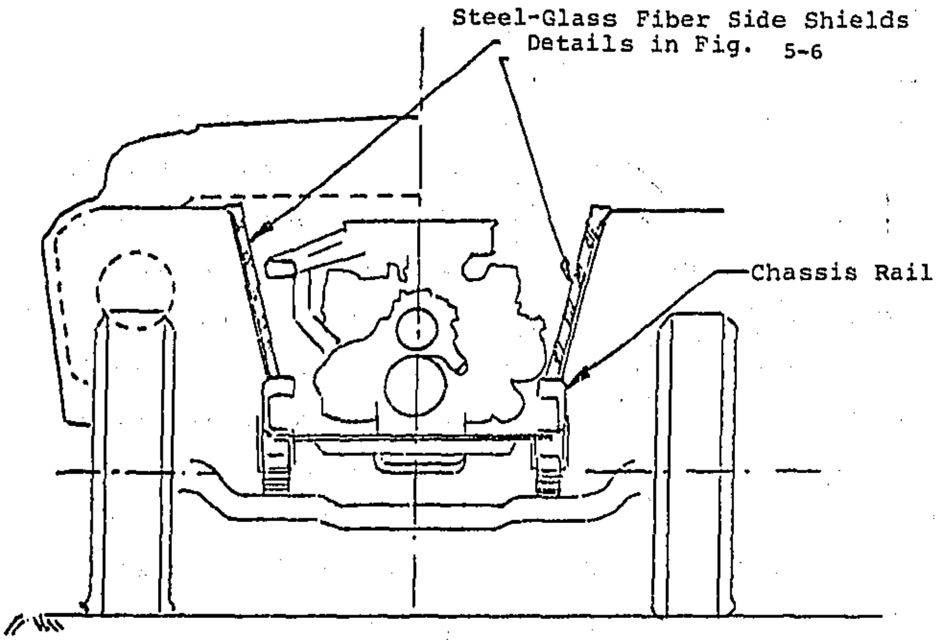
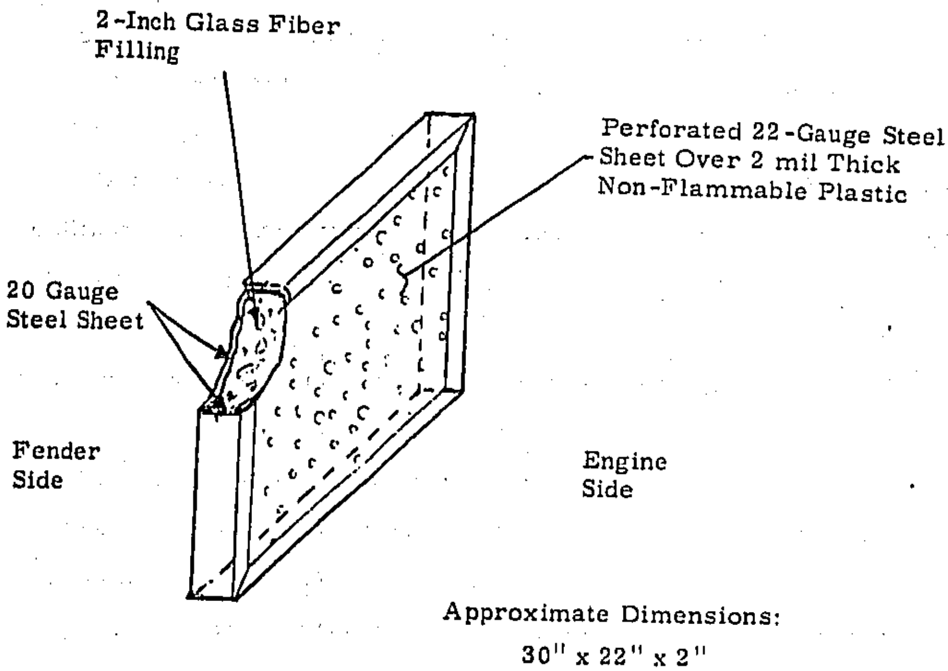


Figure 5-6
Detail of Side Shield Construction



The transmission noise at this level is expected to be sufficiently below engine noise so as not to warrant any attention.

Engine accessibility will be somewhat reduced by the incorporation of side shields.

Exhaust System

To reach exhaust noise levels of 65 dBA will require a carefully designed advanced dual horizontal exhaust system with double walled mufflers and premufflers or resonators to optimize the system under cruise as well as high rpm conditions.

The use of a dual system allows greater expansion volume for the exhaust gases and hence greater reduction of the pulsations which are responsible for exhaust noise. The larger flow areas allowed by dual pipes will also reduce the existing velocity of gases which is responsible for the characteristic hiss of well-silenced exhaust systems of some of the current luxury automobiles.

Heavier gauge exhaust and tail pipes with gastight exhaust joints will be needed to minimize shell radiation and leaks.

The use of premufflers or resonators may not be necessary for all engines. Since insertion loss data for mufflers and resonators designed for the gasoline engines is not available, it is not possible to make any judgments at this time as to which engines may need less treatment.

Double wall mufflers are currently being made available for diesel truck applications by several manufacturers: Donaldson Co., Riker and

Stemco. Donaldson markets the "Silent Partner" muffler wrap which consists of an asbestos blanket held in place by a stainless steel wrap together cover. Although current designs are for diesel truck vertical stack mufflers, little development is expected to be necessary to adapt these techniques to horizontal mufflers for school bus applications.

Cooling Fan

For achieving overall bus noise levels of under 78 dBA, fan design noise levels will need to be lowered to 64 dBA and under. This is 13 to 18 dBA under current gasoline engine bus fan noise levels. These levels have already been demonstrated by International Harvester and Freightliner quiet trucks. International Harvester Company was able to achieve a 66 dBA fan noise level by employing a 1/4-inch tip clearance fan shroud along with an engine enclosure which reduces fan noise level by 2 dB and by replacing the original 4 row, 11 fin-per-inch, plate fin radiator by a 4 row, 14 fin-per-inch, serpentine fin radiator. Freightliner Corporation achieved a 64 dBA estimated fan noise level by replacing the standard 28 inch six-bladed fan with a specially made 31 inch seven-bladed fan featuring staggered blade spacing manufactured by Schwitzer Corporation. The fan speed was lowered from 2100 rpm to 1280 rpm and the standard 1200 in^2 six-row radiator was replaced by a 2000 in^2 four-row radiator.

For current application to gasoline powered school buses, the suggested method of achieving the 64 dBA level is to increase radiator frontal area by 20 percent and fan diameter by approximately 10 percent. An engine-mounted close-fitting shroud should be used along with an advanced serpentine-fin radiator with approximately 30 percent greater heat transfer area than a comparable plate-fin type radiator. The increased core thickness of the serpentine fin radiator will result in a slightly greater pressure drop across the radiator resulting in somewhat greater fan speed. However, the overall effect of all the improvements will allow fan rpm to be lowered to almost 50 percent of the original fan speed.

With this low fan speed, the fan shaft, pulley, and belt system will need to be redesigned. The water pump could be mounted on a separate shaft independent of the fan shaft so as to make its redesign unnecessary.

Chassis and Accessories

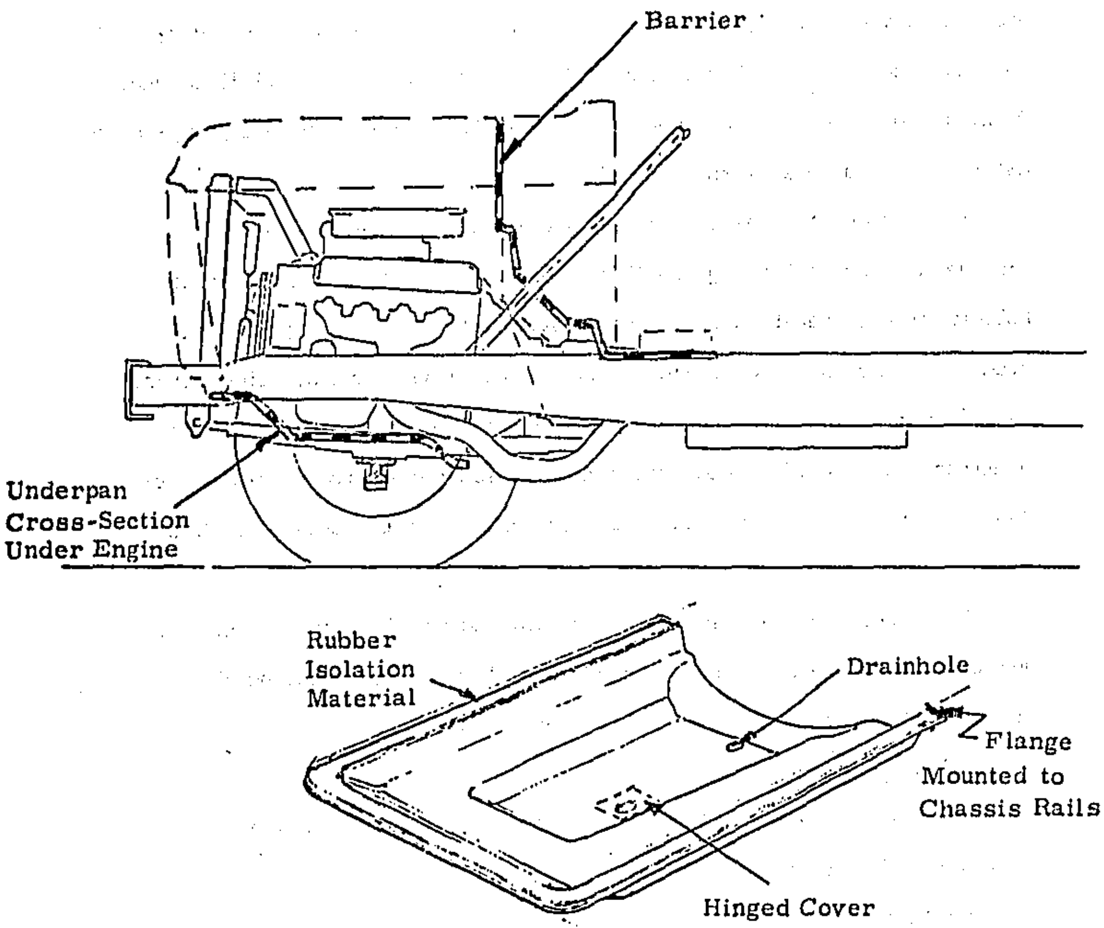
No treatment is anticipated.

75 dBA Exterior and Interior Study Levels

Engine and Intake

To reach the 68 dBA source level, gasoline engines will require the side shields shown in Figure 5-5 and an underpan between the radiator and bell housing. Since gasoline engines require servicing from underneath for regular oil changes, an underpan with small removable panels such as that sketched in Figure 5-7 will be suitable. Some innovative provision

Figure 5-7
Possible Underpan Configuration for
Achieving 75 dBA
Overall Noise Level



is necessary to ensure that the removable panels are always replaced after the routine maintenance or servicing; otherwise, the benefit of the underpan may be greatly reduced. One method to accomplish this would be to hinge the panel so that it cannot be completely removed and discarded. Warning labels could be attached to the panels to make maintenance personnel aware of the purpose of these panels.

Hazards due to fuel or oil collection in the underpan can be minimized by careful design so that the liquid flows to a small drain hole under all operating conditions. Again, the cooling capacity may need to be increased to provide adequate ventilation and air flow rates. This is not expected to increase fan noise since the side shields and underpan will provide sound attenuation to fan noise also. This treatment is expected to lower engine and air intake contribution from 2 to 5 dBA.

To achieve the interior noise levels, engine vibrations transmitted through the chassis will need to be lowered by isolating the engine or by isolating the body from the chassis.

Exhaust

The exhaust system will not need any alteration beyond that required for the previous study level.

Cooling Fan

The cooling system will need readjustment because of the presence of the engine belly pan. The increased flow restriction will require the maximum fan speed to be increased. To maintain the fan source level at 64 dBA, the engine side shield should be redesigned to give some shielding to fan noise escaping from the sides of the cowl.

Chassis and Accessories

To meet the bus noise levels of 75 dBA, the chassis exterior noise design levels will need to be at 65 dBA and under. To approach this noise on buses over 23,000 GVWR will require careful body design to minimize noise radiation from body panels. Some critical body panels may need damping treatment or stiffening to make them inefficient radiators of sound energy at the troublesome frequencies peculiar to the body-chassis combination.

The isolation between the body and chassis will need improvement. School buses employ truck chassis with stiffer suspensions than those employed for automobiles. The number of isolation pads between the chassis and the body should be kept at a minimum since each pad provides a path for some of the chassis vibrations to the body. Doubling the thickness and halving the stiffness of the rubber pads, for example, will lower the critical frequency by a factor of 1.4 and improve the isolation over a greater range of frequencies. Floor insulation in the form of double flooring with isolation material in between has been in use by Crown Coach for reducing road noise inside their diesel buses. This technique will be very helpful in lowering engine contributed interior levels also if the floor and body are carefully isolated from the chassis.

Interior carpeting, fabric covering of roof, and safety padding of seats and bus walls can reduce interior noise levels further if necessary.

73 dBA Exterior and 75 dBA Interior Study Levels

Engine

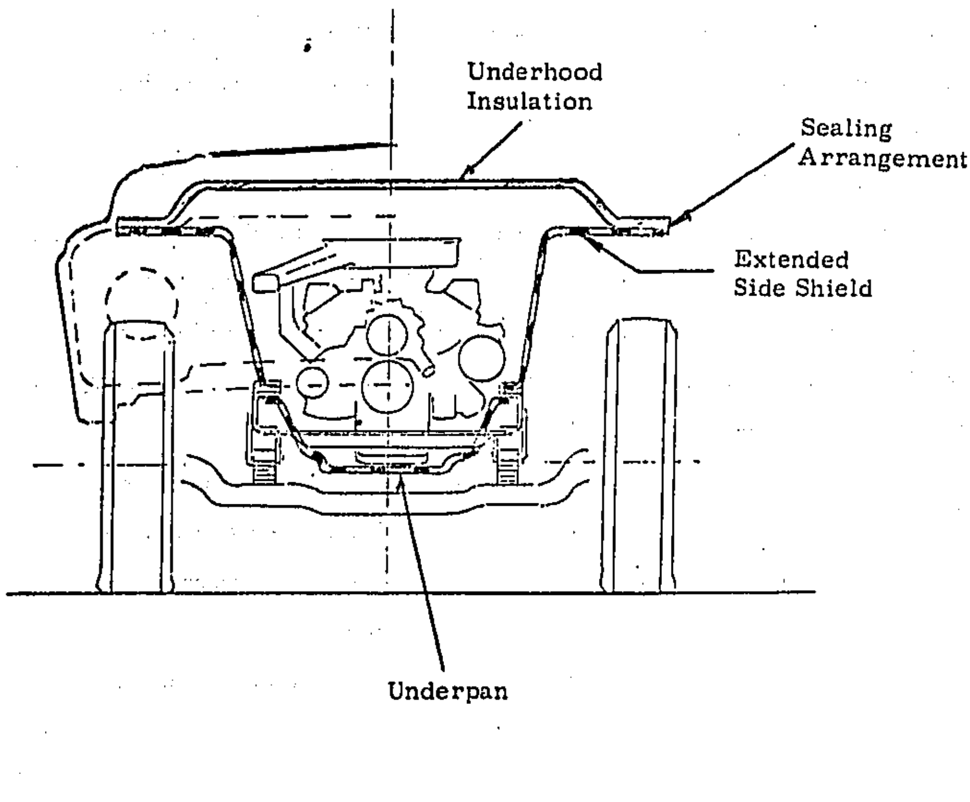
To reach the 65 dBA engine noise level, side shields will need to be extended to include the rerouted exhaust pipes which should be lagged with thermal insulation. The cowl lid will need additional acoustical treatment that will lock into the side shields. The engine will be virtually encapsulated. This is conceptually shown in Figure 5-8.

Enclosure design technology has been demonstrated through experience with the Quiet Truck Program. It should be noted that the enclosure will provide shielding also to the fan noise. The greater heat buildup in the engine compartment and increased restriction to the air-flow will require cooling fan speeds to be increased, which will nullify some of the acoustical benefits of shields. It is anticipated that in spite of this, the enclosure will provide reductions of 5 to 8 dBA to the engine noise and about 2 dBA to the fan noise.

The air intake noise will need further suppression by adding an intake silencer between the carburetor and air filter.

The lowered engine and other component noise levels will require some attention to the transmission casing, which may need to be redesigned.

Figure 5-8
Engine Enclosure for Achieving
73 dBA Overall Bus Noise Level



Approaches to reduce airborne noise radiation by the transmission housing include the application of damping material to reduce resonant amplification, the stiffening, or the weakening of housing areas to shift resonance frequency components out of the range of excitation forces; the decoupling housing areas by slotting or by adding mass dampers, and the altering of panel geometries.[22] Transmission manufacturers are already aware of these techniques and are anticipating future noise reduction needs.

Exhaust System

The achievement of 73 dBA overall bus noise levels will require the reduction of exhaust noise levels to 64 dBA or below. This is only one decibel below the levels for the previous case and will not require any major improvements in exhaust systems. It may be necessary to lag some lengths of the exhaust pipes between the engine and the mufflers to reduce pipe wall radiated noise and to minimize temperatures in the engine enclosure. This section of the exhaust system generally carries the largest pulsations from the engine exhaust. Currently one of the bus exhaust system manufacturers, AP Parts Co., is working on the development of double walled exhaust pipes, and reports promising results.

Cooling Fan System

The cooling system will need readjustment to maintain adequate cooling in the presence of the sealed engine enclosure.

(2) Conventional Diesel Powered School Buses

Based on data from diesel trucks, the attainable exterior noise levels from conventional diesel school buses range from 83 dBA to 75 dBA, which is the lowest study level.

Allowing 2-3 dBA for variation among production buses, the design levels would range from 80.5 dBA to 72.5 dBA. Table 5-3 shows the targeted study "not to exceed" levels and design exterior noise levels along with a set of possible combinations of component levels to achieve the overall noise levels. Other component noise level combinations may be used to achieve the same overall noise levels, but those shown in Table 5-3 appear to be the most logical.

Interior levels ranging from 86 dBA to 75 dBA can be met using similar techiques as discussed for conventional gasoline-powered school buses.

The noise control packages are summarized below:

Table 5-3

Component Noise Level Matrix for Diesel-Powered Conventional School Buses

	Sound Level, SAE J366b Test, dBA			
Bus Exterior Study Level (Not to exceed level)	83	80	77	75
Exterior Design Level	80.5	77.5	74.5	72.5
Engine	77	74	71	68
Exhaust	73	69	68	65
Fan	73	70	64	64
Intake	72	69	65	65
Chassis and Accessories	70	70	65	65
Interior Level at Driver	86	83	80	75

83 dBA Exterior and 86 dBA Interior Study Levels

Engine

Diesel engine noise can be reduced to a source level of 77 dBA by using engine quieting kits. Such kits include covers for the sides of the engine block and oil pan, vibration isolation of the valve covers or air intake manifolds, and cross-overs and possible damping treatment on sheet metal covers.

The engine hood should be lined with acoustical material such as non-flammable felt or glass wool.

No special treatment will be needed to reach the 86 dBA interior level beyond the application of the exterior technology.

Exhaust System

Exhaust noise levels of 73 dBA will need available advanced double-wrapped mufflers. A premuffler may be needed to obtain maximum attenuation over the broad range of frequencies characteristic of engine operation over a wide speed range.

Cooling System

Cooling system design will be similar to that used to achieve 73 dBA source noise levels for gasoline engine buses.

Intake

Air intake noise from most current diesel engines is below 72 dBA with available intake filters.

Chassis

No treatment will be necessary.

80 dBA Exterior and 83 dBA Interior Study Levels

Engine

In order to attain this level, engine noise shields and an underpan would be required. A sketch of side shields is shown in Figure 5-5, whereas a possible underpan configuration is shown in Figure 5-7. The side shields and underpan have been described in detail for gasoline engine buses. The dimensions of the shield will be somewhat larger than those shown in Figure 5-5.

For the interior level technology refer to the 80 dBA interior technology of gasoline-powered conventional school buses.

Exhaust System

Mufflers with exhaust design levels of 70 dBA or lower are currently not available. One way or reducing the exhaust noise is to use a turbocharged engine instead of a naturally aspirated engine. Because of additional expansion of exhaust gases through the turbocharger, the exhaust noise levels should be significantly reduced. Alternately, diesel truck muffler manufacturers currently have several experimental mufflers that could be modified for bus applications to give source levels under 69 dBA.

Cooling System

The cooling system design will be similar to that for attaining 70 dBA source levels for gasoline engine buses described earlier.

Intake

In order to attain the design level of 69 dBA, some noise treatment would be required. On the International Harvester Quiet Truck, the intake noise was reduced from 72 dBA to 69 dBA by replacing the intake rain cap with one with a better design.[10] Thus, it is possible to achieve the intake design level of 69 dBA by using better designed parts for the intake system.

Chassis and Accessories

No treatment will be necessary.

77 dBA Exterior and 80 dBA Interior Study Levels

Engine

Most medium duty truck engines can be quieted to a 71 dBA source level by using side shields and an underpan as mentioned in the control pcakage for 74 dBA. The noisiest engines may require a flow-through engine enclosure with special engine mounts. Figure 5-8 shows such an enclosed engine.

If a turbocharged engine has been substituted for meeting air emission and exhaust noise levels a larger engine cab will be required.

For attaining the interior level refer to the technology for the 75 dBA interior level of conventional gasoline-powered school buses.

Exhaust System

In addition to the exhaust system modifications described for achieving the previous study level, exhaust pipes may need to be wrapped with thermal/acoustical material.

Cooling System

The cooling system design will be the same as that for gasoline engine buses for attaining the same source level.

Intake

An air intake silencer will be required.

Chassis and accessories

The same considerations for gasoline powered buses will be applicable for attaining the 65 dBA chassis and accessory source level.

75 dBA Exterior and Interior Study Levels

Engine

Attainment of 68 dBA source level for diesel engines will be difficult. Engines will be turbocharged and a sealed tunnel type flow-through enclosure will be mandatory. Major redesigns of engine cowl and cooling system will be required.

For attaining the interior 75 dBA level, refer to the technology for the 75 dBA interior level of conventional gasoline powered school buses.

Exhaust System

In order to achieve this level, manifold mufflers or advanced double-walled dual mufflers, double-wall exhaust piping, and pipe joint seals would be required. Exhaust design levels of 65 dBA or lower have been demonstrated on the Freightliner Quiet Truck and the Flxible quieted bus. Quieting exhaust noise to this level would require additional lead time beyond the normal development to production lead times.

Cooling System

The system will be similar to that for gasoline engine buses. However, due to the greater space limitations in engine cab, a redesign from the previous level cooling system will be required.

Chassis and Accessories

No additional treatment beyond the previous level will be required.

(3) Front-Engine Forward Control School Buses, Parcel Delivery Chassis School Buses and Motor Home Chassis Buses

The progression of noise levels and corresponding source levels of these vehicles will be the same as those levels for school buses with conventional chassis powered by gasoline and diesel engines except for the 73 dBA level for gasoline engine vehicles, which is not felt to be applicable to the forward control school buses. The 73 dBA level and its attendant technology is applicable, however, to parcel delivery chassis and motor home chassis buses.

The methods for achieving these levels in forward control, parcel delivery chassis and motor home chassis buses will be identical to conventional school buses using similar engines, except that space constraints will be more severe. Interior noise levels will be more difficult to achieve, while the contribution of the engine to exterior noise levels will be of a lesser extent.

(4) Mid-Engine School Buses

Exterior noise level reduction and component noise levels to achieve the overall noise level reduction for mid-engine school buses are shown in Table 5-4.

It is assumed that the bus will need to be designed to produce a noise level on the average 2 to 3 dBA below the not to exceed level because of the expected spread in production vehicle noise levels.

The noise control packages are summarized below.

86 dBA Exterior and 88 dBA Interior (Over Engine) Study Levels

Existing noise levels generated by this type of bus under acceleration are expected to meet a 83.5 dBA design level without any additional applied technology.

Table 5-4

Component Noise Level Matrix for Mid-Engine School Buses

	Sound Level, SAE J366b, dBA				
Bus Exterior Study Level (Not to exceed)	86	83	80	77	75
Exterior Design Level	83.5	80.5	77.5	75.0	72.5
Engine	79	75	71	71	67
Exhaust	79	75	70	65	65
Cooling Fan	77	76	73	70	65
Intake	65	65	65	65	65
Chassis	70	70	70	65	65
Interior (Over Engine)	88	86	83	80	78

83 dBA Exterior and 86 dBA Interior (Over Engine) Study Levels

To achieve this study noise level, damped engine covers and oil pan will need to be incorporated and engine compartment treated to minimize transmission of engine airborne noises.

Advanced double wall mufflers and premuffler compartments will be needed. (These mufflers have been used in the DOT quiet truck program.)

All leaks between radiator, bus sidewall, and shroud should be sealed and a thermostatically controlled fan clutch incorporated.

These treatments should result in lowering interior noise level above the engine to 86 dBA.

80 dBA Exterior and 83 dBA Interior (Over Engine) Study Levels

To achieve this study noise level, the engine compartment will need belly pans.

The exhaust system will need improvement to achieve 70 dBA for non-turbocharged engines. This can be obtained by adding a large resonator in series with the main muffler. Leaks in exhaust system become very important at this level and consequently must be sealed.

The engine mounts will need improvements to reduce transmission of vibration to floor and body members.

77 dBA Exterior and 80 dBA Interior (Over Engine) Study Levels

To achieve this study level, the exhaust and cooling system will need further improvement. The non-turbocharged engine would have to be replaced with a turbocharged engine and a large resonator would be needed.

Providing a 10 percent greater radiator area and engine mounted contoured shroud with 1/4-inch tip clearance can be expected to reduce the cooling fan noise to 70 dBA. To increase the radiator area, a larger radiator would be required. To reduce the chassis noise to 65 dBA, the body panel design should consider the resonant modes of all body panels. Damping treatment on the inside or outside of the panels may be required. A floating slab floor may also need to be employed to achieve the interior noise level.

75 dBA Exterior and 78 dBA Interior (Over Engine) Study Levels

The achievement of the 75 dBA level has been demonstrated for the rear engine Scania CR 111M bus (see Appendix A).

Total engine encapsulation would be required. To provide adequate engine cooling, two radiators located on either side of the engine might be necessary along with thermostatically controlled fans or blowers.

(5) Rear-Engine School Buses (Integral and Body-on-Chassis)

Exterior noise level reduction and component noise levels to achieve the overall noise level reduction from rear-engine school buses are shown in Table 5-5. Because of variation in noise levels among production buses, the design noise levels are 2-3 dBA below the "not to exceed" levels.

Table 5-5

Component Noise Level Matrix for Rear-Engine School Buses (Integral and Body-on-Chassis)

	J366b Sound Level, dBA					
Bus Exterior Study Level (Not to exceed level)	86	83	81	80	77	75
Bus Exterior Design Level	83.5	80.5	78.5	77.5	75.0	72.5
Engine and Transmission	79	75	75	71	71	65
Exhaust System	79	75	70	70	65	65
Cooling Fan	77	76	73	73	68	65
Intake	65	65	65	65	65	65
Chassis	70	70	70	70	68	68
Interior Level (Rear)	84	83	83	80	80	78

86 dBA Exterior and 84 dBA Interior (Rear) Study Levels

Existing noise levels generated by this type of bus under acceleration are expected to meet the proposed 83.5 dBA design level without any additional applied technology.

83 dBA Exterior and 83 dBA Interior (Rear) Study Levels

Damped engine covers and an oil pan should be incorporated. Engine compartment should be treated to minimize transmission of engine and fan airborne noises.

Double wall or wrapped body mufflers will be needed to produce 75 dBA exhaust noise levels. These mufflers are currently under development by muffler manufacturers.

All leaks between the radiator, the bus sidewall and the fan shroud should be sealed and a thermostatic control fan clutch incorporated.

81 dBA Exterior and 83 dBA Interior (Rear) Study Levels

The engine and transmission treatment remains the same as for previous levels. The exhaust system will need improvement to achieve 70 dBA. This can be obtained either by substituting a turbocharged engine or by adding a large resonator in series with the main muffler. Leaks in the exhaust system become important.

Rectangular cooling fan shrouds should be replaced by contoured shrouds and fan coverage reoptimized. This may need adjustment of fan to radiator distance. Sealing and thermostatic fan speed control will be needed.

80 dBA Exterior and 80 dBA Interior (Rear) Study Levels

The exhaust system remains identical to the previous step. Engine contributed level will be lowered to 71 dBA by providing a sealed belly pan, an acoustically treated exit duct, and a line-of-sight shield between the engine and the fan.

The fan will have to be replaced with one capable of delivering the same airflow as before against a greater total head.

Engine mounts will need improvement. Body panel vibrations in rear area will need to be minimized by damping or isolation or by means of barrier material. Interior reverberations should be minimized with acoustical material.

77 dBA Exterior and 80 dBA Interior (Rear) Study Levels

The exhaust and cooling systems will need further improvement. A turbocharged engine with manifold mufflers or turbocharged engine with improved resonators and a muffler with stack silencers will be needed. Contoured or venturi shroud with 1/4-inch tip clearance will be required along with 10 percent increase in radiator frontal area.

75 dBA Exterior and 78 dBA Interior (Rear) Study Levels

This level will need either total engine encapsulation or an improved flow-through engine enclosure. Both concepts need development and extensive testing. Some passenger seats will most probably be lost. Detailed discussion given for urban transit buses will be applicable. A floating slab floor may be required for attainment of the interior noise level.

(6) Urban Transit Buses

The lowest exterior noise level of integral transit buses studied was 75 dBA at 50 feet, measured according to the Section 8 (recommended) procedure. Current transit bus noise levels with the cooling fan engaged can be under 86 dBA with little difficulty. Step-by-step reduction of noise levels of major contributors can result in four intermediate levels as shown in Table 5-6.

Table 5-6

Component Noise Level Matrix for Diesel Powered Integral Transit Buses

	J366b Sound Level, dBA					
Bus Exterior Study Level (Not to exceed level)	86	83	81	80	77	75
Bus Exterior Design Level	83.5	80.5	78.5	77.5	74.5	72.5
Engine and Transmission	79	75	75	71	71	65
Exhaust System	79	75	70	70	65	65
Cooling Fan	77	76	73	73	68	65
Intake	65	65	65	65	65	65
Chassis	70	70	70	70	68	68
Interior (Rear)	84	83	83	80	80	78

With the application of the exterior noise abatement technologies for transit buses outlined in the following discussion, the interior noise levels at the rear of transit buses should be met. However, in some cases additional treatment may be necessary. Refer to the discussion of interior noise abatement technology for intercity buses for a description of additional interior noise abatement technology which will be applicable to transit buses.

86 dBA Exterior Study and 84 dBA Interior (Rear) Study Levels

Engine

No treatment to the engine or engine compartment is considered necessary for achieving exterior engine source level of 79 dBA. The blocking of all airborne engine noise from the passenger compartment will be essential to achieve the interior level of 84 dBA at the rear seat location.

Exhaust System

No modification to current exhaust systems will be required. When a vertical tail pipe is present, it should be resiliently mounted to prevent transmitting vibrations to the bus body.

Cooling System

These levels will be achievable by installing a viscous clutch between the engine and the fan without any modification to the cooling system. All leaks between the engine compartment sidewall and radiator and between the radiator and the shroud should be carefully sealed to minimize fan-on time. An on-off type fan clutch will also be suitable if the radiator grill is redesigned to minimize line-of-sight transmission of sound.

Intake

Best available air cleaner with careful sealing of all leaks will be adequate.

Chassis and Accessories

The mounting of accessories will need special care to avoid excitation of the body panels into resonance. Air conditioner compressor area may need some acoustical treatment.

83 dBA Exterior and Interior (Rear) Study Levels

Engine

For diesel transit buses, the attainment of 75 dBA engine contributed noise levels will not require any major changes in the engine compartment. Rohr Corporation demonstrated a reduction of 3 dBA on Detroit Diesel 6V-71 engine noise for a 35-foot transit bus by using damped rocker arm covers and acoustical material on existing parts of the hood, engine compartment sidewall, and forward bulkhead.

Detroit Diesel has developed such damped covers for retrofit purposes.[17] It is possible that such covers or similar improved covers would be offered as standard equipment for future bus engines to comply with 83 dBA exterior levels.

It is expected that sealed underpans will not be necessary to reach this level.

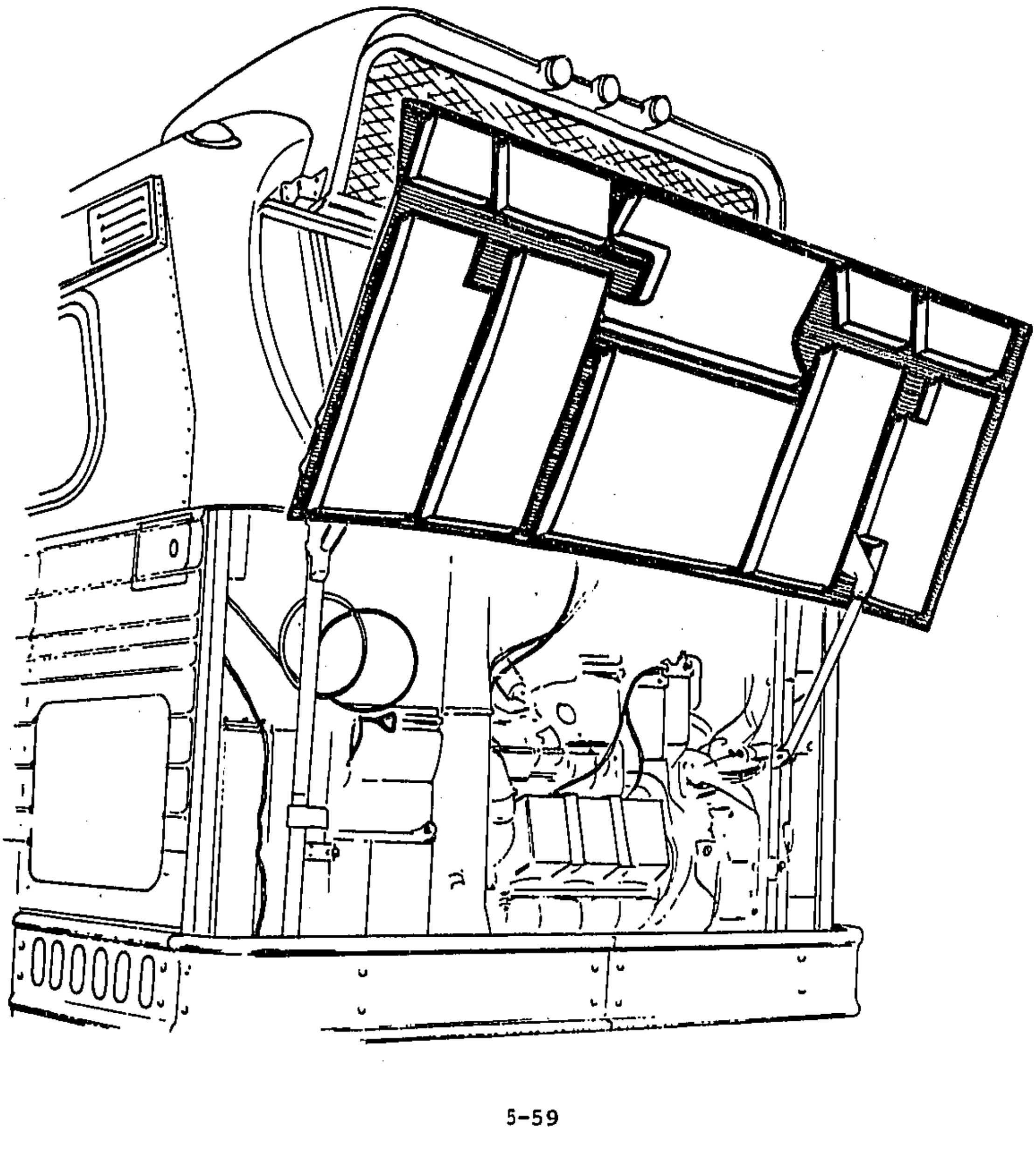
The engine contributed level on the street side of the bus is generally higher because of the radiator opening. Design of the radiator grill to prevent line-of-sight sound transmission while maintaining adequate cooling is one method of curbing streetside radiated noise.

All other engine compartment holes should be carefully sealed, and the entire compartment lined with sound absorbent material. Thin metal panels such as hood and sidewalls will require sound barrier type material, such as 1 lb/sq foot lead-lined vinyl. Alternatively, mylar-faced acoustical foam with lead septum and an insulation layer between the septum and panel can be used for the entire area. This treatment is illustrated in Figure 5-9.

Exhaust System

This level can be achieved by substituting single wall mufflers with advanced double-wrapped body mufflers. These mufflers are

Figure 5-9
Acoustic Treatment of Engine
Hood on a Flexible Busrd Bus



already available for both 6V-71 and 8V-71 engines.* The design noise level of this muffler with an MAM09—104 Wye connection is 75 dBA for 5-inch systems on the 8V-71 engine, giving a back pressure of only 3.4-inch Hg. Transit bus applications permit higher back pressures (up to 6-inch Hg.). The larger number of bends in the exhaust pipes will not cause any penalty for naturally aspirated engines.

GMC achieved exhaust noise levels of under 75 dBA without exceeding the back pressure limitation on their T8H5305 coach by replacing the standard Nelson muffler with a Nelson T13680 muffler.

Exhaust noise should not present any difficulty for turbocharged engines.

Cooling System, Intake, Chassis, and Accessories

The same treatments as for the previous level will be sufficient.

81 dBA Exterior Study and 83 dBA Interior (Rear) Study Levels

Engine

No treatment beyond the previous level is indicated, unless the option of turbocharged engine is adopted for achieving lower exhaust noise levels.

Exhaust System

70 dBA exhaust source noise level will be necessary to achieve overall bus median noise levels of 78.5 and 77.5 dBA. It appears that at present mufflers with exhaust design levels of 70 dBA are not available for naturally aspirated two-stroke Detroit Diesel engines.

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* Donaldson Co. Part No. MCM 12-0189.

There are two alternatives available to achieve 70 dBA exhaust noise levels.

(1) Turbocharged Engine - A turbocharged six cylinder engine may be substituted in place of a naturally aspirated eight cylinder engine to obtain the same amount of power. Because of the inherently low exhaust noise levels of turbocharged engines, currently available mufflers or modifications thereof to allow for the greater air flow rates can be employed to obtain the 70 dBA exhaust noise levels.
Stemco Mfg. Co. has currently available dual horizontal mufflers, part No. 9428, producing 73.5 dBA which can be treated to yield 70 dBA noise levels on the 8V-71T engine.

(2) Adding a Resonator - Optimum exhaust system design to provide adequate muffling under low as well as high engine rpm conditions requires the whole system to be designed with a resonator (or premuffler) in series with the main muffler. This allows a smaller size muffler than if the entire silencing were to be achieved from a single muffler.
Because of the allowable 6-inch Hg. back pressure at full load for naturally aspirated engines, a single resonator and muffler, with a vertical stack, should be sufficient. The absence of any leaks in this type of exhaust system become a necessity at the 70 dBA exhaust noise level.

Gas-tight exhaust joints are available and should be used. The muffler, if outside the engine enclosure, should be of the double-walled type to minimize the noise entering the passenger compartment.

Rohr Flxible bus retrofit noise reduction study[8] resulted in the development of such a resonator/muffler system in cooperation with Donaldson Co. for which the estimated contribution was only 65 dBA. This system may be used as a guideline for a future 70 dBA exhaust system.

Cooling System

Noise levels of 73 dBA were reported by GMC and Rohr for their quieted buses with optimized shrouds and thermostatic clutches. The rectangular shrouds should be replaced by contoured shrouds with as low a clearance as practical. The fan coverage should be optimized after the new shroud is installed. The fan to radiator distance may also have to be changed to ensure optimum air flow distribution across the radiator.

An experimental fan with a U-shaped circular ring attached to the blade tips has been tried by H. L. Blatchford Co.[23] and GMC for the RTS-2. This fan is designed to prevent tip recirculation without unusually small tip clearances. However, this is an experimental design and to date no apparent advantage from the noise viewpoint has been demonstrated.

Intake, Chassis, and Accessories

No modifications will be required.

80 dBA Exterior and Interior (Rear) Study Levels

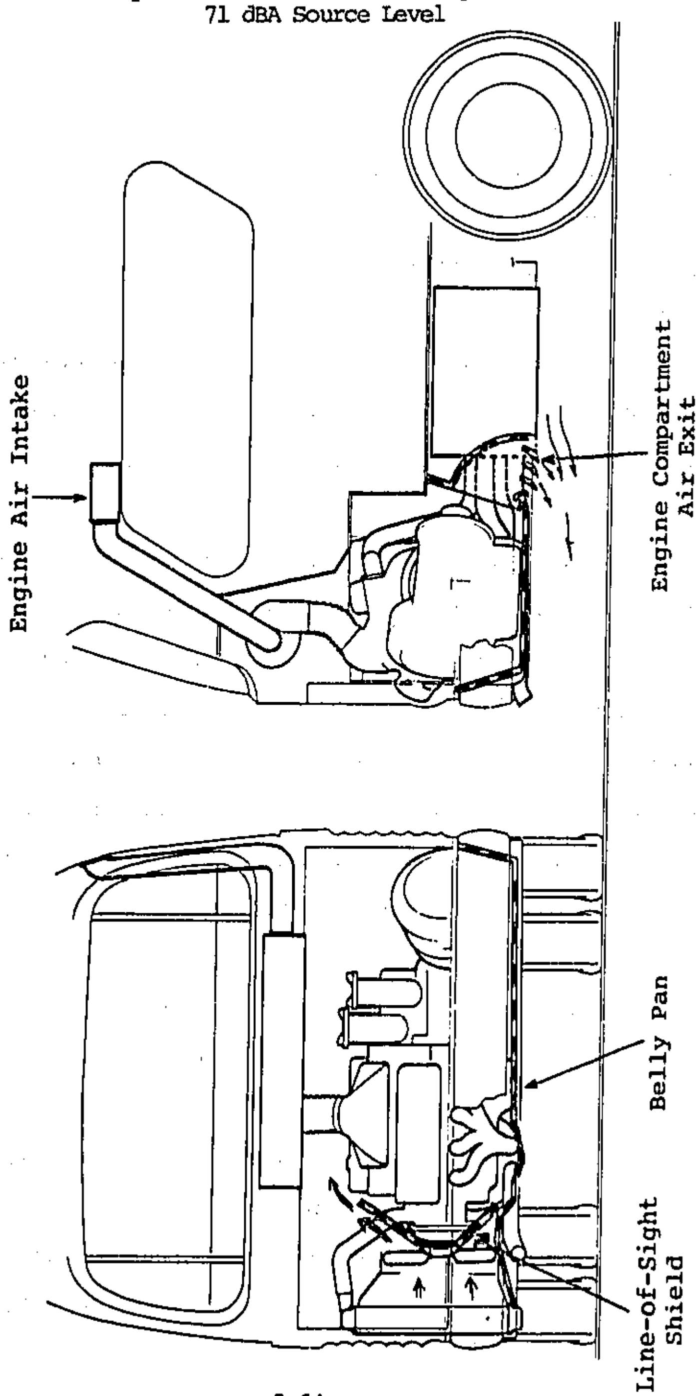
Engine

To reach engine contributed levels of 71 dBA, complete engine belly pans and line-of-sight shielding between engine and radiator opening will be required. The layout for this arrangement is shown in Figure 5-10.

It is important to provide an adequate outlet area for engine compartment ventilation and cooling air. Such an outlet can be provided forward of the engine compartment between the floor and engine support rails. The outlet opening should be designed to minimize the radiated sound energy. This may be done by lining the inside of this duct with two inches of glass fiber or open-cell foam and providing louvers at the exit to minimize line-of-sight between the interior and the pavement. The drive-shaft opening will need careful design to minimize sound escape. It is not admissible to allow any other opening in the belly pans, because that would render the belly pans ineffective. Refrigerant and other fluid lines should be routed through holes sealed with asphalt or rubber grommets.

The design of the outlet ahead of the belly pan, as shown in Figure 5-10, is critical. Proper aerodynamic shaping of the exit and the louvers may be able to provide some suction when the bus is in motion. The redesign of the cooling system will be a major undertaking.

Figure 5-10
Engine Noise Reduction Package for
71 dBA Source Level



The belly pans may be provided in two or three removable sections for maintenance. Belly pans are currently available as optional items. Suitable warning labels will be necessary to caution maintenance personnel against discarding the belly pans.

The line-of-sight shield between engine and cooling fan can be aerodynamically shaped to minimize restrictions. The shield should be carefully matched with the cooling system to maximize the air flow through the radiator. International Harvester Company used such shields to lower the pressure head against which the fan must operate, allowing lower fan speeds[14] and lower fan noise levels.

Space limitations and added heat buildup in the engine compartment for turbocharged engines will require auxiliary engine compartment ventilation systems.

Exhaust System

The same two options as for the previous study level are applicable.

Cooling System

With the sealed engine belly pans, the cooling air will experience some restriction, thereby affecting the cooling ability of the system. This increased restriction has to be overcome by increasing the pressure rise across the fan without decreasing the volumetric air flow rate. Alternatively, the radiator and fan area may be increased to permit adequate cooling at the reduced air flow velocity, again impacting the bus capacity. Since the latter approach requires increased engine compartment space, the modification of fan design to produce greater pressure rise across the fan appears more attractive.

Intake, Chassis, and Accessories

No modification will be required from the previous level.

77 dBA Exterior and 80 dBA Interior (Rear) Levels

Engine

The engine noise abatement methods for the previous level will be sufficient. Turbocharged engines will be required.

Exhaust System

The achievement of 65 dBA exhaust source levels on production model buses will be a major undertaking, although these levels have been demonstrated on the Flxible quieted bus and the Freightliner quiet truck.

The exhaust system for the previous study level, with some added volume can be used,

The Freightliner quiet truck employed a manifold muffler along with dual current production Donaldson mufflers and stack silencers. The engine was a turbocharged Cummins NTC-350, which is an in-line six cylinder engine. The experimental exhaust manifold muffler had a volume 4-1/2 times the volume of the standard manifold. For the V-form engines used in transit buses, two manifold mufflers would be required.

A turbocharged engine with large resonators as close to the manifolds as possible, followed by the exhaust pipe and muffler wrapped with asbestos or mineral wool to provide acoustic as well as thermal insulation will be needed.

Cooling System

To achieve fan noise levels of 68 dBA with the engine compartment belly pan and line-of-sight shield in position, extremely low fan tip to contoured shroud clearances and some increase in radiator frontal area will be required.

The incorporation of an engine-mounted contoured or venturi shroud with 1/4-inch tip clearance can be expected to allow fan top speed reductions of approximately 6 percent, and noise reductions of 3 to 6 dBA. The mounting of such a shroud was explained for gasoline engine school buses. The engine compartment area will probably need to be increased slightly to accommodate a 10 percent larger radiator to assure the achievement of 68 dBA noise levels in the case of high horsepower turbocharged engines for air-conditioned buses operating on highways. The increased radiator area will allow a further reduction in fan top speed by 20 percent, resulting in an average noise reduction of 8 dBA.

Because of the lack of ram air and side-facing fan position in transit bus applications, the achievement of 68 dBA will be somewhat more difficult than the achievement of 68 dBA levels for heavy duty diesel truck applications. Increased engine compartment sizes suggested for the previous level may become mandatory now.

Intake, Chassis and Accessories

Chassis and accessory noise will need to be lowered by about 2 dBA by changes in basic body design such as acrylic panels bonded to the skin. Improved accessory and engine isolation will be required.

75 dBA Exterior and 78 dBA Interior (Rear) Study Levels

Engine

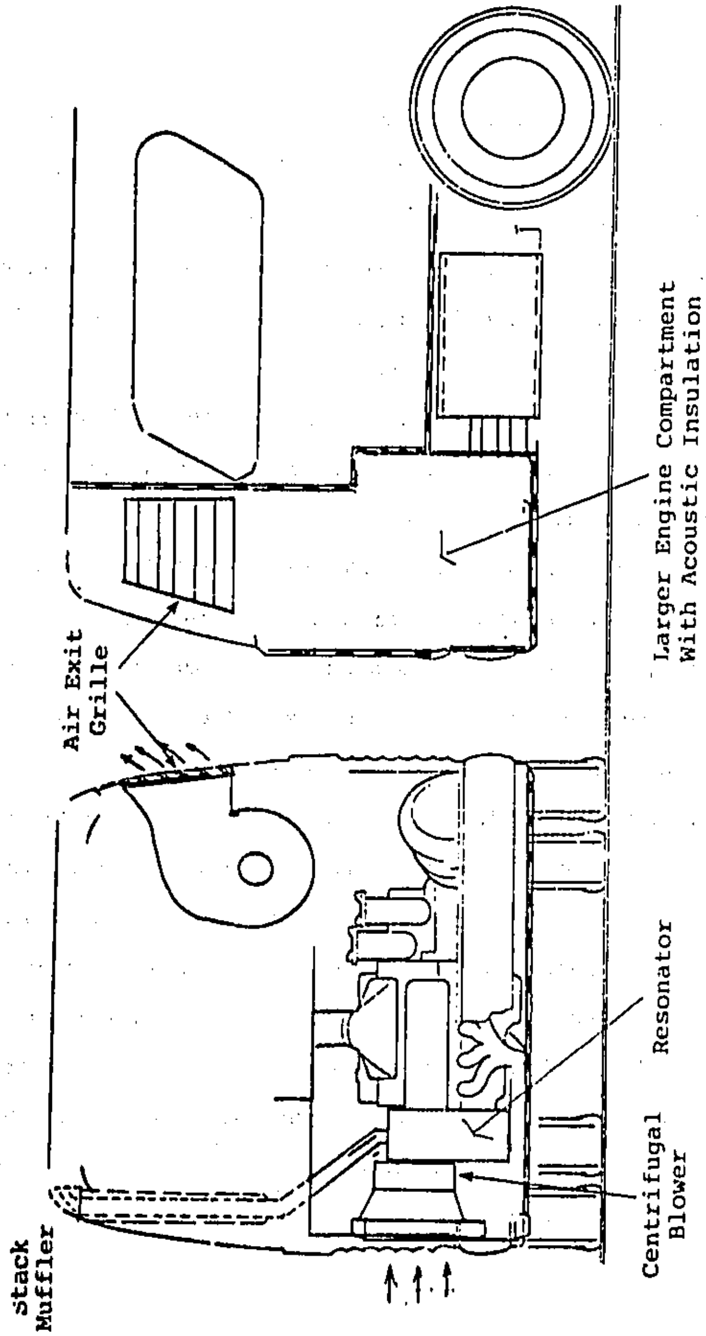
Engine contributed levels of 65 dBA will require the engine to be further enclosed and isolated from the bus framework. Two types of enclosures are possible. Neither type of enclosure has been demonstrated on a bus meeting the performance specifications of U.S. urban transit buses.

In the first, the enclosure covers the cooling fan as well as the engine. Openings for cooling air inlet and exit greatly reduce the effectiveness of the enclosure. On the other hand, the enclosure provides some shielding to fan noise. The cooling system generally has to be adjusted to prevent overheating.

A flow-through type of enclosure may be incorporated. The square radiator can be replaced by a rectangular radiator or twice the frontal area. Two centrifugal blowers in the suction mode would draw air in. Centrifugal blowers allow better isolation of engine noise. The radiator and blowers will be enclosed in a duct. The seal between bus body sidewall and radiator is particularly important.

The air from the engine compartment should be allowed to exit through an acoustically treated opening on the curbside, at a height above normal pedestrian head level. The flow-through concept is sketched in Figure 5-11.

Figure 5-11
Flow Through Engine Compartment
Concept for Achieving 65 dBA
Engine Noise Level



It is estimated that the bulkhead will have to be moved forward approximately one foot, resulting in loss of passenger capacity. However, the space above the engine need not be as large and probably the wall can be shaped to provide some interior space. Another possibility is that the floor can be inclined to provide more underfloor space in the rear of the bus.

Such an enclosure will result in source levels of 65 dBA if the future diesel engines are at least 4 dBA quieter than current engines without any treatment.

The second type of enclosure places the cooling fan outside the enclosure. This allows greater reduction of engine noise. The radiator and fan will generally require relocation because of the restriction presented by the engine enclosure. This type of enclosure is used on production buses in Europe, such as the Scania CR111M.

In the Scania buses, the engine compartment is completely sealed on all sides and is provided with a fan for ventilating of the engine compartment. The air intake for ventilation is located on the roof of the bus. The single radiator on the left side is replaced by two radiators, one on each side of the bus located ahead of the closed engine compartment. Cooling air is drawn in by individual electrically operated fans at each radiator. The cooling system of the CR111M is designed for an air-to-boil temperature of 85-90 ^{o}F. This would not be acceptable for most climates in the United States.

Air conditioning is not offered on the Scania bus, even as an option. Exclusion of air conditioning reduces horsepower requirement and engine cooling requirement significantly. Almost all transit coaches in this country are air conditioned and noise reduction, at the expense of eliminating air conditioning, would not be acceptable in our climate.

Further details of the Scania bus are given in Appendix A.

Exhaust System

Treatment remains the same as for the previous level, with the addition of water-cooled manifolds.

Cooling System

Cooling system design will have to be coupled with the achievement of 65 dBA for all the major noise producing components of the bus. The limiting factors at this stage will be the chassis and tire noises. The engine will be either completely encapsulated, or a flow-through enclosure provided with opening on both sides of the engine compartment.

(1) Totally Encapsulated Engine. - In this case, two radiators will be remotely placed, forward of the engine enclosure, with hydraulically or electrically driven thermostatically controlled fans or blowers. This technique is currently used in the Swedish Scania CR111M bus and its limitations have been discussed earlier. New innovations to improve the volumetric air flow rates without increasing fan speeds will be required. These may include air scoops or larger radiators. Another possibility would be to relocate the

radiators on the roof of the bus to reduce sideline noise, though this may result in excessive noise levels at second story apartment levels.

The noise of the auxiliary fan to ventilate the engine compartment has to be considered separately.

(2) Flow-Through Engine Enclosure - The principals of such flow-through enclosures have been studied earlier for quiet trucks. If the engine compartment area is increased to accommodate the flow, and blowers substituted in place of fans, 65 dBA cooling system noise levels appear achievable. By flowing the cooling air through the enclosure, any heat radiated from the engine and transmission is carried away.[14] With proper placement of acoustical material, much of the sound is absorbed before it escapes from the inlet or outlet. Multi-speed thermostatic speed controls will be required to maintain optimized operation.

The substitution of the axial flow fan by multiple centrifugal blowers may be beneficial in minimizinng sound and distributing the flow evenly over a rectangular radiator. MCI buses have been using a dual radiator and centrifugal fan system for engine cooling for the past twenty years.

For transit bus application, the long rectangular radiator may be located on the left side of the engine compartment with the larger side parallel to the ground. Two blowers in parallel would draw the air in, which would be directed over the engine casing. The engine compartment ventilation will be aided by another blower directing the air out on the curbside through louvers located sufficiently high as to direct air flow above by-stander head level. The design of the louvers will be important to prevent leakage of engine noise to the outside. Such a system is shown conceptually in Figure 5-11.

This type of enclosure has not been demonstrated for transit bus application. Current evaluation of feasibility is based on experience with the IH quiet truck and on the assumption that engine compartment temperatures can be maintained by providing unrestricted cooling air flow rates.

Intake, Chassis and Accessories

The comments for the previous level are applicable.

(7) Intercity Buses

In view of the many similarities in construction and source levels between urban transit and intercity buses, the progression of component and overall noise reduction will be the same as that for urban transit buses. However, due to the different mechanical layouts of intercity buses, some details of noise reduction packages, will vary from one design to another. These differences are analyzed during the discussion of the various noise abatement study levels. The component and overall noise levels are shown in Table 5-7.

Table 5-7

Component Noise Level Matrix for
Diesel Powered Integral Intercity Buses

	J366b Sound Level, dBA				
Bus Exterior Study Level (Not to exceed level)	86	83	80	77	75
Bus Exterior Design Level	83.5	80.5	77.5	75.0	72.5
Engine and Transmission	79	75	71	71	65
Exhaust System	79	75	70	65	65
Cooling Fan	77	76	73	68	65
Intake	65	65	65	65	65
Chassis	70	70	70	68	68
Interior Level (Rear)	84	83	80	80	78

The three major manufacturers of intercity buses used in the United States offer buses that look very similar from the outside with roughly the same performance and ride qualities.

Power Train Arrangements

The General Motors Corporation (GMC) intercity bus is identical in many respects to their urban transit bus. The transverse rear engine drives a 60^{o} Vee-drive transmission. Motor Coach Industries (MCI) which furnishes buses to Greyhound Lines, uses a T-drive arrangement, which offers maximum utilization of truck components but results in a long rear overhang and higher drive axle weight. Thus a third axle is needed aft of the drive axle. The Eagle International design* circumvents this problem by means of a drop back axle drive which allows the drive axle to be under the transmission giving a larger wheelbase than the conventional T-drive arrangement. Continental Trailways uses Eagle and Bus & Car Co. buses. These three power train arrangements are shown in Figure 5-12.

The accepted power source is the Detroit Diesel 8V-71 engine. Four-speed manual as well as automatic transmissions are available.

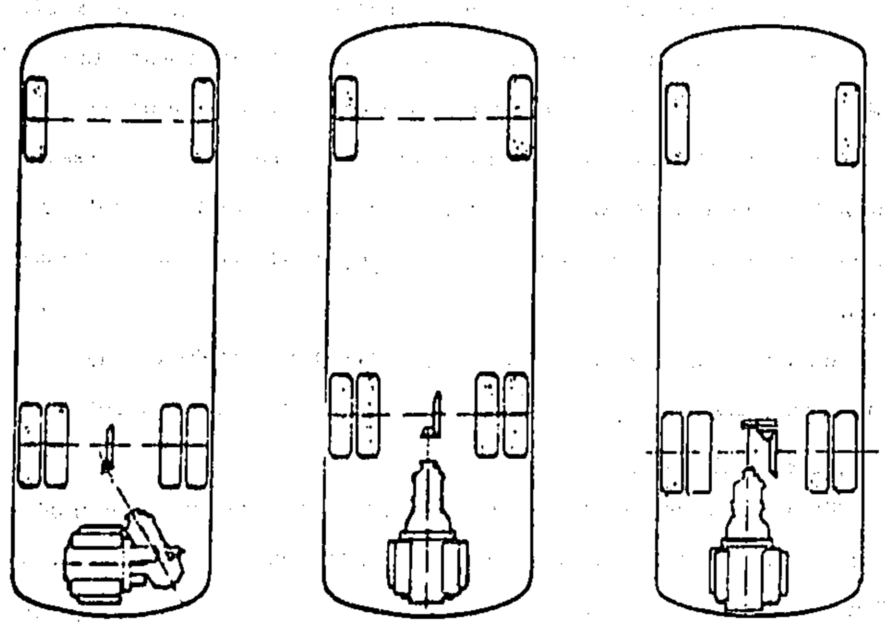
Engine Cooling Systems

The GMC bus uses an axial flow fan driven directly by the engine crankshaft. The radiator is located in the left rear as in the case of transit buses.

MCI buses use centrifugal fans located in ducts above the engine. There are two radiators with shutters, one on each side of the bus, and two fans drawing air in through the radiator and discharging it over the engine. The fans are driven from a gear-box located between them and driven by a belt from the engine crankshaft. The

*Original design by Bus & Car Co., Belgium.

Figure 5-12
Drive Train Arrangements
for Intercity Buses



60° V Drive

T Drive
(Standard)

T Drive With
Drop-Back Gear

duct between the fan housing and the radiator is sealed off from the engine compartment to maximize flow through the radiator. The engine air cleaner intake is located in the left side radiator opening. The relative locations of the system components are shown in Figure 5-13.

Eagle buses also utilize a longitudinal engine arrangement. A standard 8-bladed 28-inch diameter axial flow fan located on the left side of the bus is used for engine cooling. The fan is driven off a 90^{o} gearbox located in the rear center of the engine compartment. A 6-bladed fan, located on the right side of the engine compartment, provides air flow through the air conditioning system condenser. There is no thermostatic clutch arrangement for the fans. The layout is shown in Figure 5-14.

Exhaust Systems

The exhaust system arrangement for the GMC intercity bus is similar to GMC's transit bus. MCI uses an elliptical horizontal muffler with a short tail-pipe located in the left rear corner. The two exhaust pipes are connected together with a Wye before entering the muffler, as seen in Figure 5-13.

Eagle uses a dual horizontal exhaust system with Donaldson MTM-08-5080 mufflers. These are standard truck-type mufflers. There are two tail pipes located symmetrically in the rear, as seen in Figure 5-14.

Figure 5-13
Layout for MCI Engine
Compartment

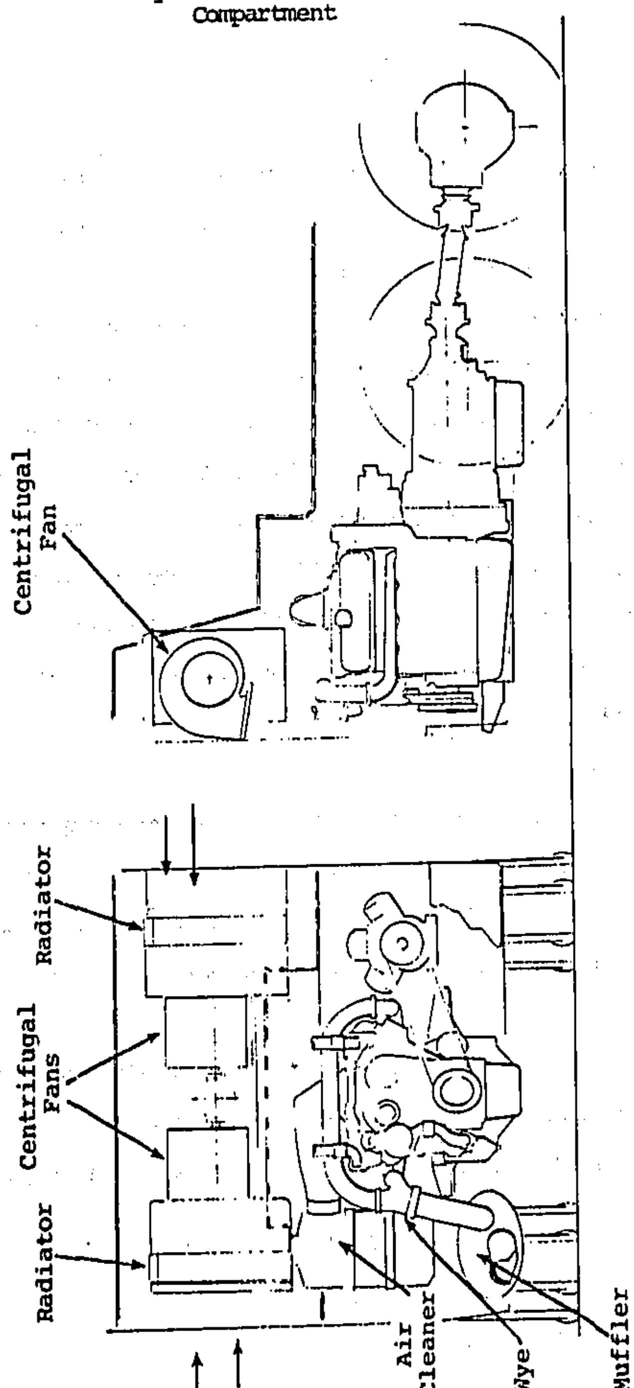
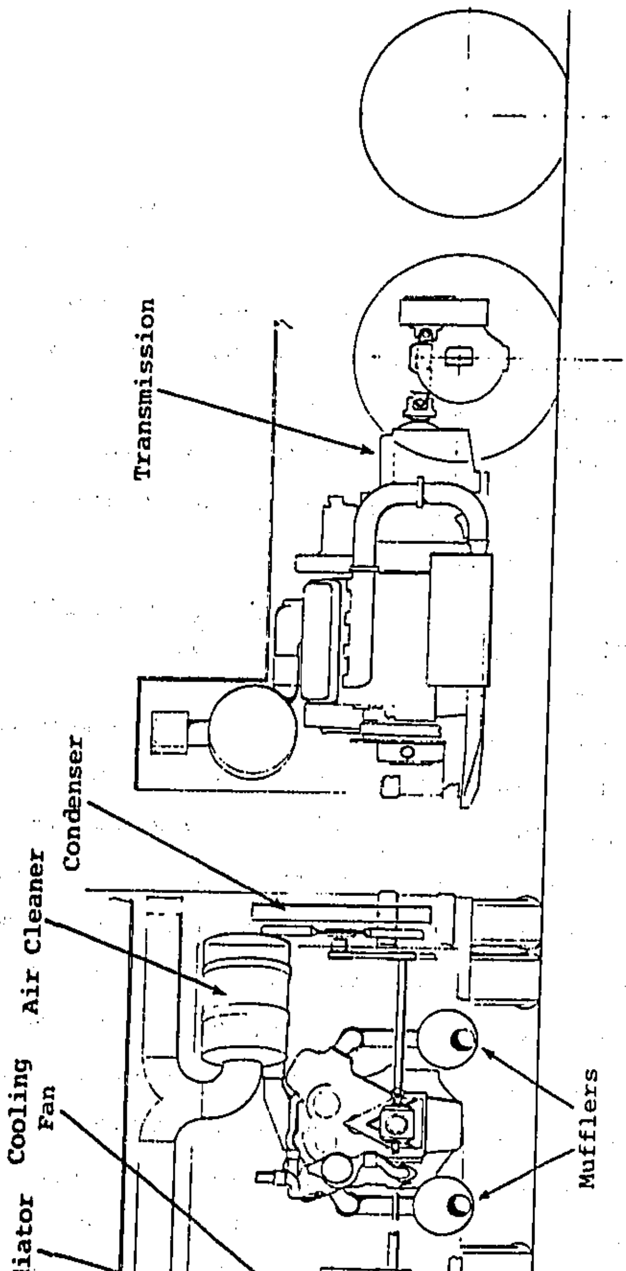


Figure 5-14
Layout of Eagle (Bus & Car)
Engine Compartment



Noise Control Packages

The noise control study levels and technologies will be similar to those for transit buses except in certain cases for MCI coaches. Moreover, in the case of intercity buses, turbocharging of the engine appears more justifiable than was the case with transit buses because of longer sustained high-speed maximum power operation periods. The joint DOT-EPA "Study of Potential for Motor Vehicle Fuel Economy Improvement"[24] has shown that the following fuel economy improvements may be obtained by engine improvements in integral intercity buses.

	Fuel Economy Improvement
Turbocharge Diesel	0-8%
Derate Horsepower	2-5%
Derate rpm	7-10%

All of the improvements are expected to lower engine noise levels.

To attain the engine source levels of under 71 dBA, Eagle buses will need an additional shield between the engine and air-conditioner condenser opening on the curbside. Since MCI buses use centrifugal fans instead of axial flow fans, engine and fan noise will not escape to the same extent as the transit buses through the radiator opening.

For the 65 dBA engine source level, the enclosure for MCI buses will need an outlet near the axle. The enclosure will cover the entire transmission casing. Additional suction fans may be needed at the enclosure exit to minimize restriction to air flow through the radiators.

Exhaust noise reduction packages will be identical to the transit bus exhaust noise packages. Differences in the exhaust systems of GMC, MCI, and Eagle buses were described earlier. Since all use the Detroit Diesel 8V-71 engine, the treatments will be similar. A dual system, already used by Eagle, will probably offer the most advantages. The tail pipes will need to be rerouted to exit at the roof line for all cases except the 79 dBA level.

The packages for cooling system noise abatement will be identical to transit buses except for MCI buses.

Centrifugal fans which MCI buses already utilize, are inherently quieter for the same mass flow delivered. Also, the ducts are amenable to acoustic treatment to minimize the noise escaping through the radiator opening. The air flow velocity is higher, and hence flow noise may become audible if other sources are quieted.

Intercity bus radiators are larger than transit bus radiators because of continous engine operation at high power factors, and heavier bus loads due to baggage. However, the percentage changes in radiator and fan sizes to achieve equivalent noise reductions for intercity and transit buses will be similar.

For interior noise abatement, MCI has experimented with treatments with no conclusive result. Eagle uses "Sorba-glass" which is a quilted material with lead sheet between layers of glass fiber and aluminum foil. In addition, the use of undercoating compounds to damp bulkhead panels near the engine has been found to be effective.

Road noise is a problem for highway operations. To this end, the baggage compartment under the passenger compartment offers a partial barrier to tire noise transmitted to the interior.

Air conditioning system noise, and especially evaporator noise, may require attention.

For the achievement of 80 dBA interior rear section noise levels, redesign of engine mounts and a careful analysis of the vibration transmission paths from the engine to body panels and floor boards will be required. If resonant vibrations are present in the panels, damping treatment will be beneficial. Otherwise, sound radiation to interior can be minimized by covering the interior surfaces with a limp heavy acoustic material such as lead/vinyl sheeting. This will impose a weight penalty which may be critical if legal restrictions on axle loading exist. The floor boards may need sandwich construction with an isolating layer of soft rubber between two boards.

Another approach to interior noise reduction would be to isolate the rear section body panels from the main integral body framework. This would mean a major redesign of the entire structure if these panels were initially designed as load-bearing members.

The addition of sound absorbing linings in the interior, such as pile carpeting and acoustic (and thermal) insulation on the roof, will minimize reverberation and ensure low front seat noise levels.

The 78 dBA interior noise level at the rear seat for the 75 dBA exterior noise level bus will be attained since the engine will be more carefully isolated and completely encapsulated.

DEGRADATION OF NOISE CONTROL TECHNOLOGY

The noise abatement methods described in Section 5 are based on existing noise control techniques for the lowering of noise emitted by currently designed buses. Many of these methods have been demonstrated on prototype trucks and transit buses, while some of the technology discussed (fan clutches, improved slower turning fans) has been incorporated into production model vehicles. The durability of these noise control technologies are of particular interest to the EPA. If individual noise control components are not durable, total vehicle noise emission characteristics may degrade (increase in measured vehicle sound level) early after introduction into service. Such an increase in noise level could significantly reduce the benefits expected as a result of noise emission standards applicable at time of vehicle manufacture. Thus, the Agency has considered in its technology assessment studies of acoustical degradation potential of the total vehicle and its noise control components. The following is a general discussion of EPA's findings on acoustical degradation as it applies to bus noise control technology.

(1) Engine Noise Control Degradation

Engine-mounted shields have been thoroughly tested by several diesel engine manufacturers, such as Cummins Engine, General Motors, Detroit Diesel Allison, and Catepillar. Degradation normally only occurs if the panels are worked loose by vibration or if the acoustical materials become saturated with oil.

Based on the above experience, engine side shields on conventional school buses, which have been integrated into the engine cowl, can reduce the accessibility of the engine to servicing. As a result; during servicing, care should be taken to avoid damage to the panels from mechanic's tools, oil contamination and excessive vibration which may loosen the shields themselves or the panels upon which they are attached.

The use of belly pans on various types of heavy vehicles has been unpopular with maintenance personnel because the pans can collect oil, reduce engine accessibility from under the vehicle, and are easily damaged by road hazards. However, rapid detachment systems have been developed which have improved accessability for maintenance.

The removal of belly pans, when they have been designed specifically for constant use on a vehicle, can cause certain vehicle systems not to operate efficiently. For example, a cooling system designed for efficient operation with belly pans in place may suffer if the pan is permanently removed, since the air flow route through the engine compartment will be changed. Increased air flow rates through the radiator, brought about by the permanent removal of the pan, may not be advisable, especially for diesel engines which are used in colder climates without radiator shutters.

Degradation of noise levels from vehicles with totally encapsuated engine compartments is unlikely if the shielding around the engine is properly assembled.

(2) Exhaust Noise Control Degradation

If manufactured with comparable materials, the improved types of mufflers, discussed in this section, should not deteriorate faster than those mufflers being presently produced.

(3) Cooling System Noise Degradation

Fans clutches and on/off fan devices are somewhat complicated devices which can malfunction due to mechanical failure or failure of the heat sensing elements. Any malfunction which causes the fan to be on when not needed will result in higher average fan noise levels across a vehicle's work cycle.

In conclusion, degradation appears to be a potential problem only in the case of engine noise abatement measures. However, with proper component design and maintenance procedures which incorporate checks on critical noise abatement devices, degradation if any, should be kept to a minimum. In support of this contention, the maxmium change in the noise levels of four International Harvester (DOT) Quiet Trucks during an average mileage of 157,000 miles was 2 dBA, with the final level of all the trucks within 1 dBA of the initial level.[21] This fact implies that with the technology applied to these vehicles there were no significant noise level changes in the noise emissions from the various components during that mileage period.

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SECTION 6

POTENTIAL BENEFITS OF BUS NOISE REGULATION SCHEDULES ON THE ENVIRONMENT

6.0 INTRODUCTION

Pursuant to the Noise Control Act of 1972, the Environmental Protection Agency (EPA) has proposed noise emission regulations on newly manufactured buses (EE). The proposed regulations specify levels not to be exceeded as measured according to a modified SAE J366b test procedure, and are intended to control all contributing components of bus noise. In the analysis of this section, predictions of the potential health and welfare benefits for a range of possible regulatory schedules of new bus noise emissions are presented.

Because of inherent differences in individual responses to noise, the wide range of traffic situations and environments encountered, and the complexity of the associated noise fields, it is not possible to examine all traffic situations precisely. Hence, in this predictive analysis, certain stated assumptions have been made to approximate typical or average situations. The approach taken to determine the benefits associated with the noise regulation is, therefore, statistical in that an effort is made to determine the order of magnitude of the population that may be affected for each regulatory option. Some uncertainties with respect to individual cases or situations may remain.

6.1 HEALTH AND WELFARE BENEFITS OF BUS NOISE REGULATION

6.1.1 Measures of Benefits to Public Health and Welfare

The phrase "public health and welfare," as used here, includes personal comfort and well-being as well as the absence of clinical symptoms such as hearing damage. People are exposed to bus noise in a variety of situations. Some examples are:

1. Inside a home or office
2. Around the home (outside)
3. As a pedestrian
4. As a bus operator
5. As a bus passenger

Reducing exterior noise emitted by buses should produce the following benefits:

1. Reduction in average traffic noise levels and associated cumulative long-term impact upon the exposed population.
2. Fewer activities disrupted by individual (single-event) passby noise.

Furthermore, the reduction of noise levels inside buses should result in reduced annoyance in terms of less interference with speech communication, and reduced potential hearing damage risk to bus operators and passengers in combination with non-bus noise exposures.

Predictions of vehicle noise levels under various regulatory schedules are presented in terms of the noise levels associated with typical vehicle passbys. These noise levels are weighted according to traffic populations or mixes before averaging to determine traffic noise levels. Reductions in average traffic noise levels from current conditions (i.e., with no noise emission regulations) are presented for 15 regulatory options on new buses both with and without noise emission regulations on other traffic noise sources. Projections of the population impacted as well as the relative reductions in impact from current conditions are determined from reductions in average traffic noise levels.

The average noise level for traffic does not adequately describe the annoyance produced by a single bus passby for all situations since annoyance frequently depends on the activity and location of the individual. In addition, the average noise level tends to average out the disruptive and annoying peak noise level produced by a single bus passby. As an additional measure of benefits, therefore, the undesirable effects of intruding bus passby noise levels are evaluated in terms of sleep disturbance, sleep awakening and speech interference.

6.1.2 Regulatory Schedules

This analysis predicts the impact of the reduction of bus noise based upon the exterior and interior regulatory schedules shown in Tables 6-1 and 6-2. For predictions of health and welfare benefits with concurrent reductions in future emissions from new automobiles and motorcycles, an effective date for the regulations of January 1979 is assumed. For predictions of benefits concurrent with the regulation of new medium and heavy duty trucks, effective dates of January 1978 for the limit of 83 dBA, and January 1980 for the limit of 80 dBA are used. It should be noted that regulatory schedule 15 for both exterior and interior bus noise were examined in order to determine the maximum benefits achievable with the virtual elimination of bus noise. Both schedule 15's are not under consideration as a noise limit for newly manufactured buses.

Table 6-1

Exterior Regulatory Schedule	Regulatory Schedules Considered in the Health and Welfare Analysis of Exterior Bus Noise					
	Not To Exceed Regulatory Level for All Bus Types Unless Noted, (dBA)					
	Calendar Year					
	1979	1981	1983	1984	1985	1986
1	-	-	-	-	-	-
2	83	-	-	-	-	-
3	-	83	-	-	-	-
4	-	80	-	-	-	-
5	-	-	80	-	-	-
6	83	80	-	-	-	-
7	83	-	80	-	-	-
8	83	80	-	78	-	-
9	83	-	80	-	78	-
10	83	80	-	-	77	-
11	83	-	80	-	77	-
12	83	80	-	-	-	75
13	83	-	80	-	-	75(1)
14	83	80	-	78	-	75
15	55	55	55	55	55	55

(1) Gasoline Powered School buses 73 dBA

Table 6-2

Interior Regulatory Schedule	Regulatory Schedules Considered in the Health and Welfare Analysis of Interior Bus Noise Not To Exceed Regulatory Level for All Bus Types Unless Noted, (dBA) Calendar Year					
	1979	1981	1983	1984	1985	1986
1	-	-	-	-	-	-
2	86	-	-	-	-	-
3	84	-	-	-	-	-
4	-	83	-	-	-	-
5	86	83	-	-	-	-
6	86	83	80	-	-	-
7	86	83	-	80	-	-
8	84	-	80	-	-	-
9	86	-	84	-	80	-
10	86	-	83	-	80	-
11	86	-	80	-	-	78
12	86	83	-	80	-	78
13	84	-	80	- (1)	-	78 (1)
14	86	83	-	80	-	78
15	55	55	55	55	55	55

(1) Gasoline Powered School buses 75 dBA

6.1.3 Outline of the Health and Welfare Analysis

The predictions of the reduction of the population impacted within various land use categories due to the reduction of average traffic noise levels by regulating buses are contained in Part 6.2. In Part 6.3, predictions of relative potential changes in sleep disturbances, sleep awakenings and speech interferences, due to single bus passbys are estimated for different land uses for each of the regulatory schedules under consideration. Related reductions in interior noise levels and the resulting potential reduction in hearing damage risk and speech interference to bus operators and passengers are presented and discussed in Part 6.4.

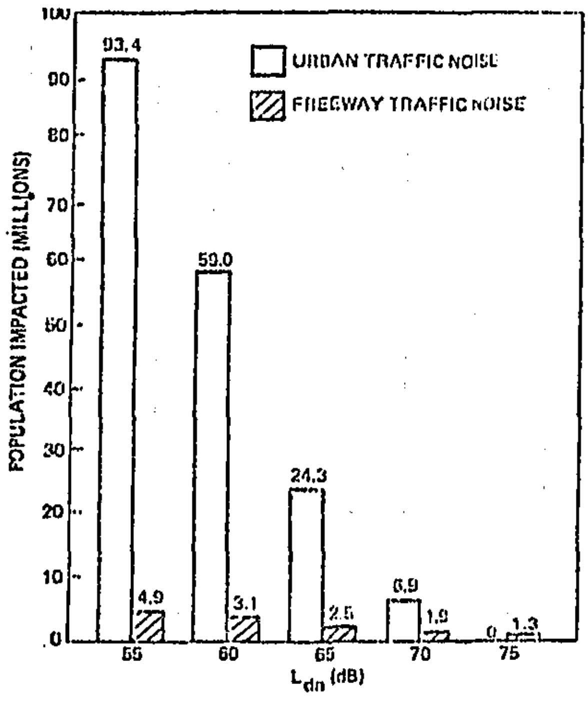

Figure 6-1. Estimated Number of People in Residential Areas Currently Subjected to Traffic Noise Above L_{dn} =55 dB.

6.2 REDUCTIONS IN THE IMPACT FROM TRAFFIC NOISE

Projections of reductions in average traffic passby noise levels are presented for scenarios of both urban street traffic, where the average vehicle speed is assumed to be 30 mph, and highway traffic, where the average vehicle speed is assumed to be 55 mph. Note that the benefits accrued from the regulatory schedules considered for new buses will be less for highway traffic than for urban street traffic for the following reasons:

- The number of people exposed to highway traffic noise is less than the number of people exposed to urban street traffic noise.
- The reductions in traffic noise levels resulting from the regulations on new buses will be less in freeway traffic than in urban street traffic.

As depicted in Figure 6-1, the number of people currently exposed to outdoor noise levels that are greater than L_{dn} = 55 dB dominated by urban street traffic noise is significantly higher than the number exposed to highway and freeway traffic noise (93.4 million as opposed to 4.9 million). Thus, reducing urban street traffic noise will benefit significantly more people than will similar reductions in highway traffic noise.

The bus regulation schedules considered in this analysis are based on bus noise emission levels measured in accordance with a modified SAE J366b test procedure. In the test procedure, bus noise emissions are measured under maximum acceleration conditions with the bus traveling at a speed less than 35 mph. Because, in general, engine-related noise emissions increase with engine speed and load, and noise generated by tires increases with vehicle speed, the test procedure is designed so that maximum engine-related noise emissions are the dominant noise sources. The noise generated by tires under the proposed test conditions is not expected to be significant.

At freeway speeds, bus tires contribute significantly to overall bus passby noise levels. Therefore, the reduction of engine-related noise brought about by bus noise regulation will be partially masked by tire noise in freeway traffic. Because vehicle speeds are lower in urban street traffic, tire noise contributes less to overall noise emissions in urban areas. Thus, reductions in overall bus noise levels by lowering engine-related noise emissions will be less affected by tire noise in urban street areas.

6.2.1 Description of Traffic Noise Impact

In examining the reduction of traffic noise by regulating buses, three steps must be followed (Figure 6-2). First, the average noise level produced by each type of vehicle is determined. This level is the average of the levels produced in each operational mode - acceleration, deceleration, cruise, and idle which are weighted according to the proportional time spent in each mode. In effect, it is an energy average of the passby levels produced by all vehicles of a given type during a typical operating cycle. From the point of view of the observer, it is an average of the passby levels that would be measured at random points along the vehicle's route of travel.

The average passby levels for each vehicle are combined in the next step to form the average traffic noise level. This level is

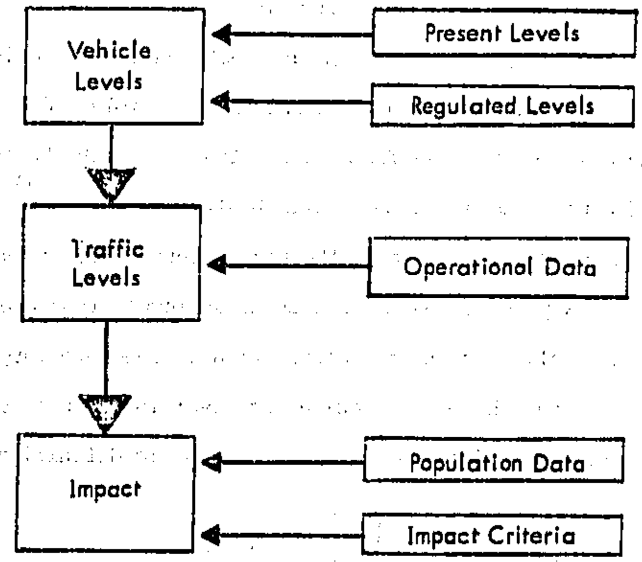

Figure 6-2. Information Flow Involved in the Calculation of the Impact of Bus Noise in Traffic

computed by weighting the average passby level produced by each type of vehicle by its relative frequency in typical traffic mixes. Composite passby levels are determined for operation on both streets and freeways based on the different passby levels and proportions of vehicles involved in each case.

The final step in determining traffic noise impact of which buses are a component, utilizes a measure that condenses the information contained in the noise environment into a simple indicator of quantity and quality of noise which correlates well with the overall long-term effects of noise on the public health and welfare.[34] This measure was adopted as a result of the Noise Control Act of 1972, which required that EPA present information on noise levels that are "requisite to protect the public health and welfare with an adequate margin of safety". EPA has chosen the equivalent level in decibels L_{eq} as its general measure for environmental noise;[8] its basic definition is:

$$L_{eq} = 10 \log_{10} \left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{P^2(t)}{P_0^2} \, dt \right) \tag{1}$$

where $(t_2 - t_1)$ is the interval of time over which the levels are evaluated, $P(t)$ is the time-varying magnitude of the sound pressure, and P_0 is a reference pressure standardized at 20 micropascals.

When expressed in terms of A-weighted sound level, L_A, the equivalent A-weighted sound level, L_{eq}, is defined as:

$$L_{eq} = 10 \log_{10} \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10^{[L_A(t)/10]} \, dt \tag{2}$$

In describing the impact of noise on people, a measure called the day-night average sound level (L_{dn}) is used. This is a 24-hour measure with a weighting applied to nighttime noise levels to account for the increased sensitivity of people to intruding noise associated with the decrease in background noise levels at night. The L_{dn} is defined as the equivalent noise level during a 24-hour period, with a 10 dB weighting applied to the equivalent noise level during the nighttime hours of 10 p.m. to 7 a.m. This may be expressed by the following equation:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \left[15 \left(10^{(L_d/10)} \right) + 9 \left(10^{(L_n+10)/10} \right) \right] \quad (3)$$

where L_d is the "daytime" equivalent level obtained between 7 a.m. and 10 p.m., and L_n is the "nighttime" equivalent level obtained between 10 p.m. and 7 a.m.

In order to assess the impact of traffic noise, a relation between the changes in traffic noise and the responses of the people exposed to the noise is needed. The responses may vary depending upon previous exposure, age, socio-economic status, political cohesiveness, and other social variables. In the aggregate, however, for residential locations, the average response of groups of people is related to cumulative noise exposure as expressed in a measure such as L_{dn}. For example, the different forms of response to noise such as hearing damage, speech or other activity interference, and annoyance were related to L_{eq} or L_{dn} in the EPA Levels Document.[8] For the purposes of this part of the study, criteria based on L_{dn} presented in the

EPA Levels Document are used. Furthermore, it is assumed that if the outdoor level meets $L_{dn} \leq 55$ dB, which is identified in the EPA Levels Document as requisite to protect the public health and welfare, no adverse impact in terms of general annoyance and community response exists.

The community reaction data presented in Appendix D of the EPA Levels Document[8] show that the expected reaction to an identifiable source of intruding noise changes from "none" to "vigorous" when the day-night average sound level increases from 5 dB below the level existing without the presence of the intruding noise to 19.5 dB above the level before intrusion. For this reason, a level which is 20 dB above L_{dn} = 55 dB is considered to result in a maximum impact on the people exposed. Such a change in level would increase the percentage of the population which is highly annoyed to 40 percent of the total exposed population.[8] Furthermore, the data in the Levels Document suggest that for environmental noise levels which are intermediate between 0 and 20 dB above L_{dn} = 55 dB the impact varies linearly, that is, a 5 dB excess (L_{dn} = 60 dB) constitutes a 25 percent impact, and a 10 dB (L_{dn} = 65 dB) constitutes a 50 percent impact.

For convenience of calculation, percentages of impact may be expressed as fractional impact (FI). An FI of 1.0 represents an impact of 100 percent, in accordance with the following formula:

$$FI = \begin{cases} 0.5(L-55) & \text{for } L \geq 55 \\ 0 & \text{for } L \leq 55 \end{cases} \quad (4)$$

where L is the observed or measured L_{dn} for the environmental noise. Note that FI can exceed unity for exposures greater than $L_{dn} = 75$.

The impact of traffic noise may be described in terms of extensiveness (the number of people impacted) and intensiveness (the severity of impact). The fractional impact method accounts for both the extent and severity of impact.

The Equivalent Noise Impact (ENI) associated with a given level of traffic noise (L_{dn}^{i}) may be assessed by multiplying the number of people exposed to that level of traffic noise by the fractional impact associated with this level as follows:

$$ENI^{i} = (FI_{i})\, P_{i} \qquad (5)$$

where ENI^{i} is the magnitude of the impact on the population exposed to traffic noise L_{dn}^{i} and is numerically equal to the number of people who would all have a fractional impact equal to unity (100 percent impacted). FI_{i} is the fractional impact associated with an equivalent traffic noise level of L_{dn}^{i} and P_{i} is the population exposed to that level of traffic noise. To illustrate this concept, if there are 1,000 people living in an area where the noise level exceeds the criterion level by 5 dB (and thus are considered to be 25 percent impacted, FI = 0.25), the environmental noise impact for this group is the same as the impact on 250 people who are 100 percent impacted, FI = 1.0 (1000 x 0.25 = 250 x 1.0).

When assessing the total impact associated with traffic noise, the observed levels of noise decrease as the distance between the source and receiver increases. The magnitude of the total impact may be computed by determining the partial impact at each level and summing over each of the levels. The total impact is given in terms of the equivalent number of people impacted by the following formula:

$$ENI = \sum_i P_i \cdot FI_i \qquad (6)$$

where FI_i is the fractional impact associated with L_{dn}^i and P_i is the population associated with L_{dn}^i. In this analysis, the mid-level of each 5 dB sector of levels above L_{dn} = 55 dB is used for L_{dn}^i in computing ENI.

The change in impact associated with regulations on the noise emissions from traffic vehicles may be assessed by comparing the magnitude of the impacts with and without regulations. One useful measure is the percent reduction in impact (Δ), which is calculated from the following expression:

$$\Delta = 100\,\frac{ENI(before) - ENI(after)}{ENI(before)} \qquad (7)$$

The population figures (P_i) in Eq (5) for urban street traffic are based on a survey in which the total population exposed to outdoor noise of L_{dn} above 55 dB was estimated from measurements taken at 100 sites throughout the United States.[12] The sites were selected far enough from freeway traffic and airports so that these sources of noise were not significant contributors to the measured outdoor noise levels. Thus, urban street traffic was a dominant source of noise for each of the survey sites. The results from this study are given in Table 6-3.

Using the data contained in Table 6-3, an ENI for existing traffic conditions (without noise regulation of medium and heavy trucks) of 34.6 million is calculated as shown in Table 6-4.

Table 6-3

Distribution of Urban Population at or Greater Than a Specified L_{dn} [12]

L_{dn}	Cumulative Number of People (Millions)	L_{dn}	Cumulative Number of People (Millions)
34	134.09	59	66.738
35	133.94	60	58.997
36	133.76	61	51.234
37	133.46	62	43.668
38	132.99	63	36.542
39	132.34	64	30.061
40	131.46	65	24.320
41	130.37	66	19.352
42	129.04	67	15.200
43	127.53	68	11.791
44	125.87	69	9.046
45	124.09	70	6.853
46	122.19	71	5.155
47	120.15	72	3.826
48	117.98	73	2.776
49	115.64	74	1.963
50	113.01	75	1.347
51	110.12	76	0.889
52	106.80	77	0.559
53	102.98	78	.332
54	98.544	79	.187
55	93.427	80	.093
56	87.665	81	.039
57	81.237	82	.012
58	74.222	83	.002
		84	.0

Table 6-4

Calculation of Equivalent Number of People Impacted By Urban Street Traffic Noise[9]

$L_{dn}i$	Population Exposed to $L_{dn}i$ or Higher P_ci (millions)	Population Exposed to Levels Between $L_{dn}i$ and $L_{dn}i+1$ $P_i = P^{i+1} - P_ci$ (millions)	Fractional Impact to Midlevel FI_i	Equivalent Number of People Impacted FI_iP_i
55	93.4	34.4	0.125	4.3
60	59.0	34.7	0.375	13.0
65	24.3	17.5	0.625	10.9
70	6.9	5.5	0.875	4.9
75	1.3	1.2	1.125	1.4
80	0.1	0.1	1.375	0.1
			Total ENI = 34.6	

The ENI values associated with reductions in the average urban street traffic noise levels are predicted by shifting (reducing) the values of L_{dn} in Table 6-3 by the traffic noise reduction of interest and performing computations similar to those shown in Table 6-4. In following this procedure for estimating ENI, it is assumed that: (1) reductions in urban street traffic noise levels produce equal reductions in the L_{dn} for the outdoor noise, and (2) the population in urban areas will remain constant until the year 2000. The latter assumption is made for convenience only. It does not affect the relative effectiveness of the study regulation schedules. If population increases are somewhat homogeneous within urban land use areas, only the absolute number of people impacted will be different from the estimates. Furthermore, the actual numbers can be approximated by multiplying the ENI estimated for a given year by the fractional increase of population expected to occur in that year.

While the exact value of present or future ENI's may not be known precisely, the relative reduction of the ENI due to noise regulations--of primary interest here--are known with much greater accuracy than the absolute value of the ENI since the changes in the theoretical components of ENI can be well defined. For instance, it may not be possible to determine whether the present estimated ENI due to urban street traffic noise, an absolute value, is actually 0.1 million too high. However, it is possible to determine, for example, that the regulation of diesel-powered school buses will not reduce the ENI by more than 0.1 million (see Part 6.2.3 below). Extensive investigation of such small changes may seem innocuous if it is not kept in mind that, although buses represent only a small part of traffic in the United States, their impacts may be considerable when measured by metrics other than ENI. Thus, the changes found to occur in ENI may help indicate what equivalent changes would occur in impact measures which are not used in this analysis but whose absolute values may reflect more accurately the effects of bus noise on people.

As discussed above, the concept of fractional impact, expressed in units of ENI, is most useful for describing relative changes in impact from a specified baseline for the purpose of comparing benefits of alternative regulatory schedules. In order to assess the absolute impact or benefits correspnding to any regulatory schedule, information on the distribution of population as a function of noise environment is required. This information is included in this section and in Appendix F in the form of graphs showing the number of people exposed to different levels of traffic and/or bus noise. The anticipated absolute impact of noise upon those individuals exposed to any given noise level may be traced by referring to the various noise effects criteria presented in the Levels Document[8] as well as in this analysis (see Figures 6-16, 6-17, 6-18 and 6-19).

6.2.2 Urban Street and Highway Traffic Noise

Two steps are employed to predict average noise levels from both urban street and highway traffic. First, an energy average is taken of the noise emissions from several passbys of each type of noise source. Next, the average traffic noise level is then computed by energy averaging the derived passby levels for each vehicular source, after appropriate weighting for the proportion of each type of vehicle in the traffic flow.

6.2.3 Vehicle Noise Levels in Urban Street and Highway Traffic

The following noise sources are considered in modeling urban street and highway traffic noise:

- o Automobile and motorcycle noise emissions that are unregulated and regulated (assumed).
- o Medium and heavy truck noise emissions that are unregulated and regulated.

For a sample of instantaneous noise levels observed at equally spaced time intervals that has a normal (Gaussian) distribution, the energy-average of the noise levels over time (see equation 1) is given by:[58]

$$L_{eq} = L_{50} + 0.115\,\sigma_T^{\,2} \qquad (8)$$

where L_{50} is the median noise level and σ_T is the standard deviation. It is assumed that the distribution of roadside passby noise levels for each type of vehicle is approximated by a normal (Gaussian) distribution and that there is a steady stream of closely spaced passbys. This assumption permits calculation of the energy-average of the passby noise levels from median passby noise levels in a manner similar to the computation of L_{eq} in Equation 8; that is

$$L_a = L_{50} + 0.115\,\sigma^2 \qquad (9)$$

where L_a is the energy-average of the passby levels, L_{50} is the median level and σ is the standard deviation of vehicle passby noise levels. As Equation 9 demonstrates, vehicle passby noise depends on both median level and the variability of these levels. The average passby noise levels assumed to be produced by trucks, automobiles and motorcycles are shown in Table 6-5 along with the references from which they were derived.

Table 6-5

Passby Noise Levels for Non Bus Vehicles

Type of Vehicle	Urban Street dBA			Highway dBA		
	L_{50}	σ	L_a	L_{50}	σ	L_a
Medium and Heavy Trucks[9]						
(a) Unregulated	85.0	3.7	86.6	85.5	3.5	86.9
(b) EPA New Truck Regulations	74.6	2.0	75.1	81.7	2.0	82.2
Automobiles[9]						
(a) Unregulated	65.0	3.7	66.6	75.0	3.5	76.4
(b) Assumed Regulation	61.0	2.0	61.5	71.0	2.0	71.5
Motorcycles[11]						
(a) Unregulated	76.0	2.9	77.0	80.6	2.8	81.5
(b) Assumed Regulation	72.0	2.9	73.0	76.5	2.8	77.5

6.2.4 Bus Noise Levels

6.2.4.1 Levels for Unregulated Buses

Bus passby noise levels are presented in Table 6-6. Bus interior noise levels as measured near the driver and the rear seat are presented in Tables 6-7 and 6-8.

Most of the bus noise research conducted to date has dealt with only one bus type; transit buses. Thus, measurements have been made under many operational conditions--acceleration, deceleration, cruise, passby, etc. These measurements, when combined with the estimated percent of time spent in each mode (Table 6-9), allow the computation of an energy average noise level over a typical drive cycle. Where similar data was found to be unavailable for particular operational modes of school and intercity buses, levels were estimated as follows: The arithmetic difference between the acceleration level and each other operational mode level was computed for transit buses. This difference was then applied to the acceleration levels of the other bus types to derive their remaining operational levels. The method was used in both the exterior and interior cases. The measurement procedure used for obtaining most of the available acceleration test level data is similar to one developed by the Society of Automotive Engineers (SAE). The EPA proposed measurement procedures for interior and exterior bus noise emissions are described in Section 8.

6.2.4.2 Levels for Regulated Buses

Vehicles which initially do not meet regulatory limits may be modified in a variety of ways in order to do so. It is expected that in order to comply with a given regulation, manufacturers will design new vehicles to produce noise levels about 2.5 to 3 dB lower than the

Table 6-6

Exterior Bus Noise Levels By Operational Mode and Bus Type
(Data from Reference 15 Unless Noted)

Bus Type	50 Foot Maximum Passby Levels, dB				Energy Average Passby Level, dB*	
	Acceleration	Deceleration & Cruise: 30 mph	Deceleration & Cruise: 55 mph	Idle	Street	Highway
Transit						
Range	76-83	70-72	78	66		
Mean	80	72	78	66	74.5	75.3
School (avg.)**						
Range	74-92[15,43]	(72-78)***	(78-85)	66[46]		
Mean	80	(72)	(78)	66	74.5	75.3
Intercity						
Range	81-86	73-77[42,54]	79-80[42,54]	66[47]		
Mean	84	75	80	66	77.5	80.1

*Based on time spent in each mode given in Table 6-9.
**Derived from vehicle population data on gasoline and diesel school buses provided in Reference 14. For complete breakdown, see Appendix F, (Table F-1).
***Data in parentheses extrapolated from transit bus data.

Table 6-7

Interior Bus Noise Levels Near the Driver By Operational Mode and Bus Type
(Data from Reference 15 unless Noted)

Bus Type	Interior Noise Levels Near Driver, dB				Energy Average Passby Level, dB*	
		Deceleration & Cruise				
	Acceleration	30 mph	55 mph	Idle	Street	Highway
Transit						
Range	78-79	74	76-78	60[16]		
Mean	79	74	78	60	75.2	75.8
School (avg.)**						
Range	80-95	80[46]	(79-84)***	(65)-70[46]		
Mean	85	80	(84)	(66)	77.8	83.8
Intercity						
Range	70-78	69-75[16,42,54]	73-75[42,54]	60[47]		
Mean	74	72	74	60	71.8	73.8

*Based on time spent in each mode given in Table 6-9.
**Derived from vehicle population data on gasoline and diesel school buses provided in Reference 14. For complete breakdown, see Appendix F, (Table F-2).
***Data in parentheses extrapolated from transit bus data.

Table 6-8

Interior Bus Noise Levels Near the Driver By Operational Mode and Bus Type
(Data from Reference 15 unless Noted)

	Interior Noise Levels Near Driver, dB				Energy Average Passby Level, dB*	
		Deceleration & Cruise				
Bus Type	Acceleration	30 mph	55 mph	Idle	Street	Highway
Transit						
Range	80-90	81-84[17]	83-85[17]	69[16]		
Mean	84	83	84	69	81.6	81.8
School (avg.)**						
Range	77-84[43]	75[46](80)***	(76)-83[28]	65-78[46,43]		
Mean	81	(80)	(81)	74	77.5	80.8
Intercity						
Range	70-84	69-78[17,42,54]	73-78	64-72[17]		
Mean	79[42,54]	73[42,54]	75	68	74.1	75.2

*Based on time spent in each mode given in Table 6-9.
**Derived from vehicle population data on gasoline and diesel school buses provided in Reference 14. For complete breakdown, see Appendix F, (Table F-3).
***Data in parentheses extrapolated from transit bus data.

Table 6-9
Percentage of Time Spent in Each Operational Mode By Buses on Streets and Highways

(Data from Reference 15 Unless Noted)

Bus Type	Operational Mode			
	Acceleration	Deceleration	Cruise	Idle
Transit				
Street	20	20	26	34
Highway	5	5	85	5
School				
Street	9	9	21	61
Highway	5	5	85	5
Intercity				
Street*	13	17	56	14
Highway	5	5	85	5

*Data based on typical urban street cycle for automobiles, Reference 33.

regulatory limit (see Section 5, Bus Noise Reduction Technology). This design level may be assumed to be the mean of what is actually a distribution of noise levels for the redesigned buses. Since it is expected that nearly all redesigned buses will comply with the regulation, the upper tail of the distribution is assumed to terminate at the regulatory limit. Thus all new production vehicles not initially complying with a regulation are assumed to be redistributed in a normal distribution with a width of 5 dB centered 2.5 dB below the regulatory limit (see Figure 6-3).

By changing the distribution of new vehicle noise levels with the implementation of noise regulations, the fleet-average acceleration test level is reduced over time as more and more old unregulated vehicles are replaced by new regulated ones. Furthermore, regulating the noise emissions from new vehicles lowers the median and average noise levels as well as the variability of the noise levels within each vehicle class. This is true because all the vehicles within each class are subject to the same regulatory level, which tends to decrease the spread in noise levels across all classes (see Figure 6-3).

For simplicity, the reduction of acceleration test levels can be assumed to result in equal reductions in the noise levels produced by buses under actual accelerating conditions. Actual reductions may be somewhat smaller, but since data is not available to estimate how much smaller, the reductions are assumed to be equal. The actual reduction in noise levels produced under deceleration and cruise conditions can be estimated, however, from measured data. Figure 6-4 demonstrates the relationship between acceleration test levels and 30 mph cruise levels that buses are expected to produce under regulatory conditions. Since

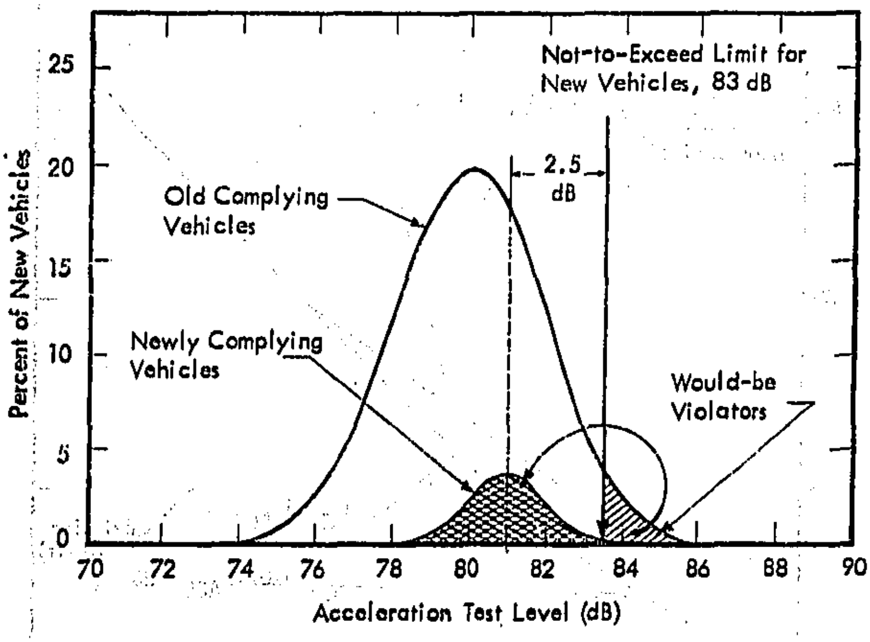

Figure 6-3. Illustrative Example of Redistribution of New Vehicles Previously Exceeding Regulatory Limit

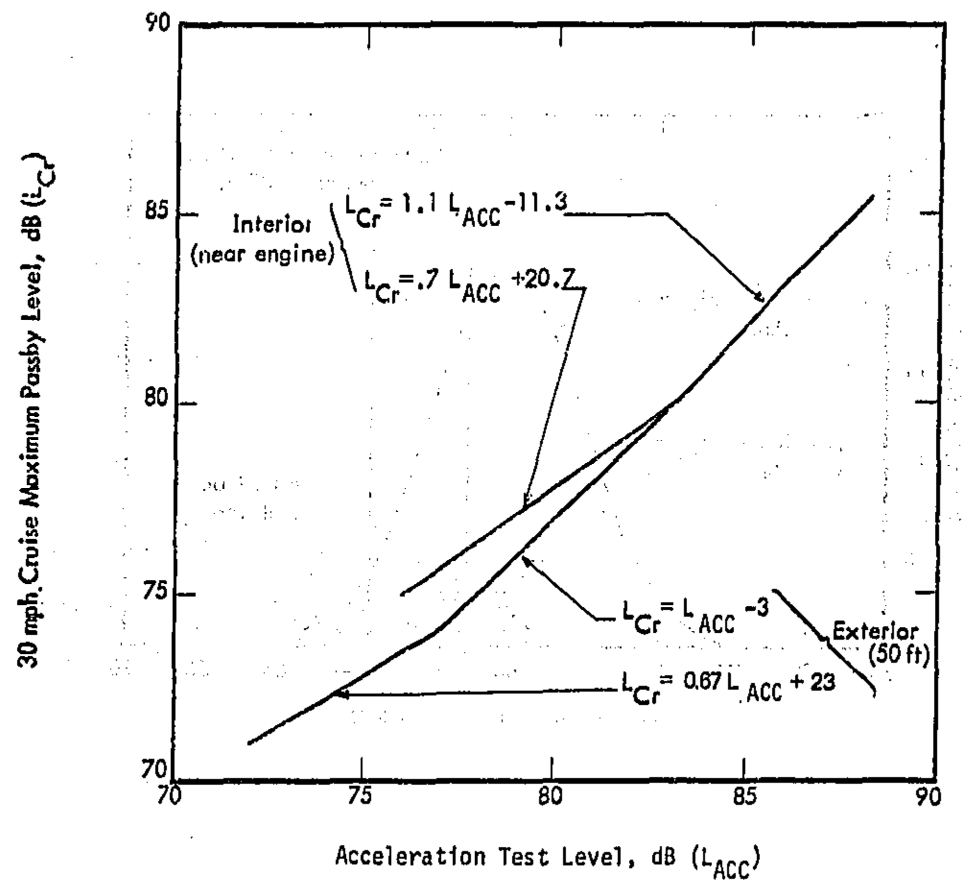

Figure 6-4. Average Relationship Between 30 mph Cruise Maximum Passby Level and Acceleration Test Level for Interior and Exterior Measurements of All Types of Buses

variations from this curve for different types of buses are extremely small, the average curve is plotted and used for all bus types. Figure 6-4 is also used to find the reduction in deceleration levels. Noise levels produced under idling conditions are not expected to be affected by regulation of acceleration noise.

The reduction of cruise levels at high speed (55 mph) is less than what can be obtained at low speed due to the fact that tire noise creates a lower limit on the cruise-by noise level. This lower limit is the "coast-by" or chassis noise level--the noise level measured when the bus coasts by the measuring point with its engine off. This level has been measured for twelve newly manufactured intercity buses at an average of 75 dB at 50 feet.[42, 54] Assuming the same level is valid for transit buses, the reduction of cruise levels at high speed can be estimated by applying the same reduction to the engine component of the high speed levels as was presented in Figure 6-4 for low speed noise, and adding the result to the tire noise floor. The result is shown in Figure 6-5.

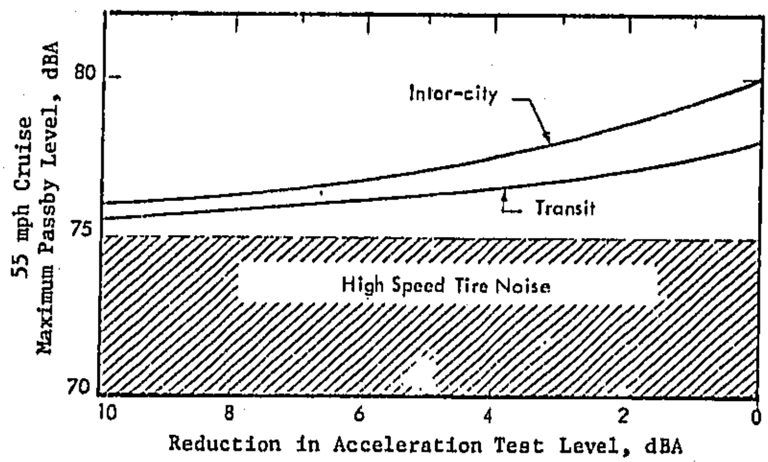

Figure 6-5. Relationship Between 55 mph Cruise Maximum Passby Level and Reduction in Acceleration Test Level Measured at 50 Feet for Transit and Intercity Buses

6.2.5 Traffic Noise Levels

Traffic noise levels at observer locations obviously depend on the traffic settings and geometry. People living downtown may find that a nearby high-rise completely blocks noise generated by a thoroughfare located on the opposite side. On the other hand, buildings may enhance the reverberation of traffic noise such that the resulting levels are higher than what would occur in a rural setting devoid of barriers. In addition to propagation factors, different traffic may have different mixes of vehicles in the traffic flow, different average speeds, etc., each giving rise to different average traffic noise levels and, thus, to different degrees of impact. To simplify the variety of cases in the following analysis, the impact of traffic noise, and the contribution of buses to that impact, is examined within four land use areas: high density urban; low density urban; suburban; and rural; as well as the total urban case which is the summation of the high density urban, low density urban, and suburban land use areas. In the urban and suburban land use areas, the assessment is further divided into street and highway settings. In rural areas, only highway and other main-road traffic are considered for bus noise impact. Transit buses are assumed to operate in the urban and suburban areas only, intercity buses and school buses are assumed to operate in all four land use areas.

The estimated average mix of trucks, automobiles, motorcycles, and buses within urban and rural traffic settings is shown in Table 6-10. The estimates are primarily based on the number of vehicle miles traveled by each bus type[1] and by other vehicles.[19] By using these traffic mixes to weight the contribution of passby levels for each traffic vehicle within

Table 6-10

Estimated Mix of Trucks, Autos, Motorcycles and Buses
in Urban and Rural Areas

Vehicle	Percentage of Total Traffic							
	URBAN						RURAL	
	High Density	Low Density	Sub.	High Density	Low Density	Sub.	Main Rd.	Local Rd.
Truck[50]	7.5	7.5	7.5	10.0	10.0	10.0	25.0[1]	25.0[1]
Automobile[1]*	90.4	90.6	90.3	88.9	88.92	89.0	73.6	72.8
Motorcycles[19]	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.5
Bus**								
Transit	0.5	0.3	0.2	0.1	0.04	-	-	-
School-gas	0.1	0.1	0.5	-	-	-	0.2	0.7
-diesel	-	-	-	-	-	-	-	-
Intercity	-	-	-	-	0.04	-	0.2	-
TOTAL	100.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*Difference between 100% and sum of percent of other vehicles.
**Derived in Appendix F, Table F-4.

the traffic stream (Table 6-5), an average traffic passby level was computed for each land use area. Noise emission limits on new buses tend to reduce these average traffic levels. Consequently, changes in urban street traffic noise levels lead to changes in the distribution of people exposed to day-night average sound levels (L_{dn}). As depicted in Figures 6-6 through 6-9, however, the change in the number of people exposed to various L_{dn} levels is minor for the regulatory schedules considered. Figure 6-6 shows the shift expected in the year 2000 between the "no regulation" case (regulation schedule number 1) and an ideally protective regulation case (regulation schedule number 15) in high density urban areas. Figure 6-7 shows similar but slightly smaller changes in low density urban areas, and Figure 6-8 displays even smaller changes in suburban areas. Figure 6-9 presents the sum of these changes for all land use areas.

If noise regulations are applied to non-bus vehicles such as trucks, there will already be an initial reduction in traffic noise, depending on the severity of the regulation, the date of its implementation, and the turnover rate for the vehicle population involved. In Appendix F, data (Tables F-5 through F-7) is presented which were used to calculate average traffic passby levels for the following three baseline cases:

(1) Regulation of new trucks, automobiles, and motorcycles

(2) Regulation of new trucks only

(3) No regulation of non-bus vehicles

The reductions of urban street traffic noise estimated by this method for each land use area are shown in Tables 6-11 through 6-13 for the

FIGURE 6-6.

HIGH DENSITY URBAN POPULATION VS OUTDOOR TRAFFIC NOISE LEVEL IN 2000 WITH REGULATION OF TRUCKS AUTOS AND MOTORCYCLES

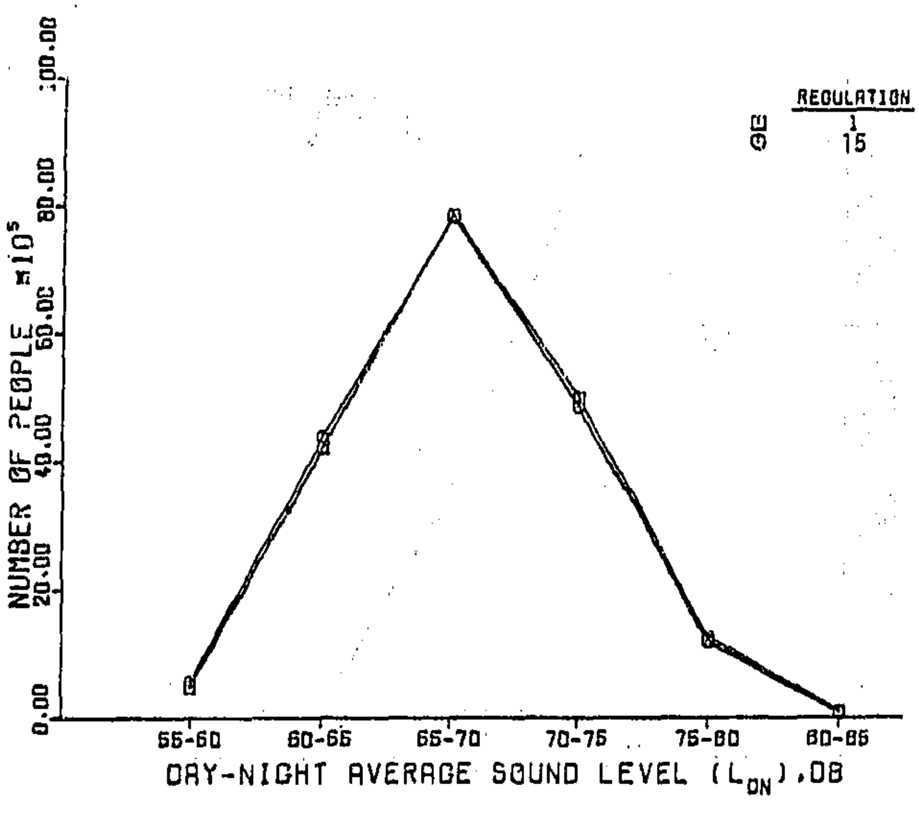

FIGURE 6-7

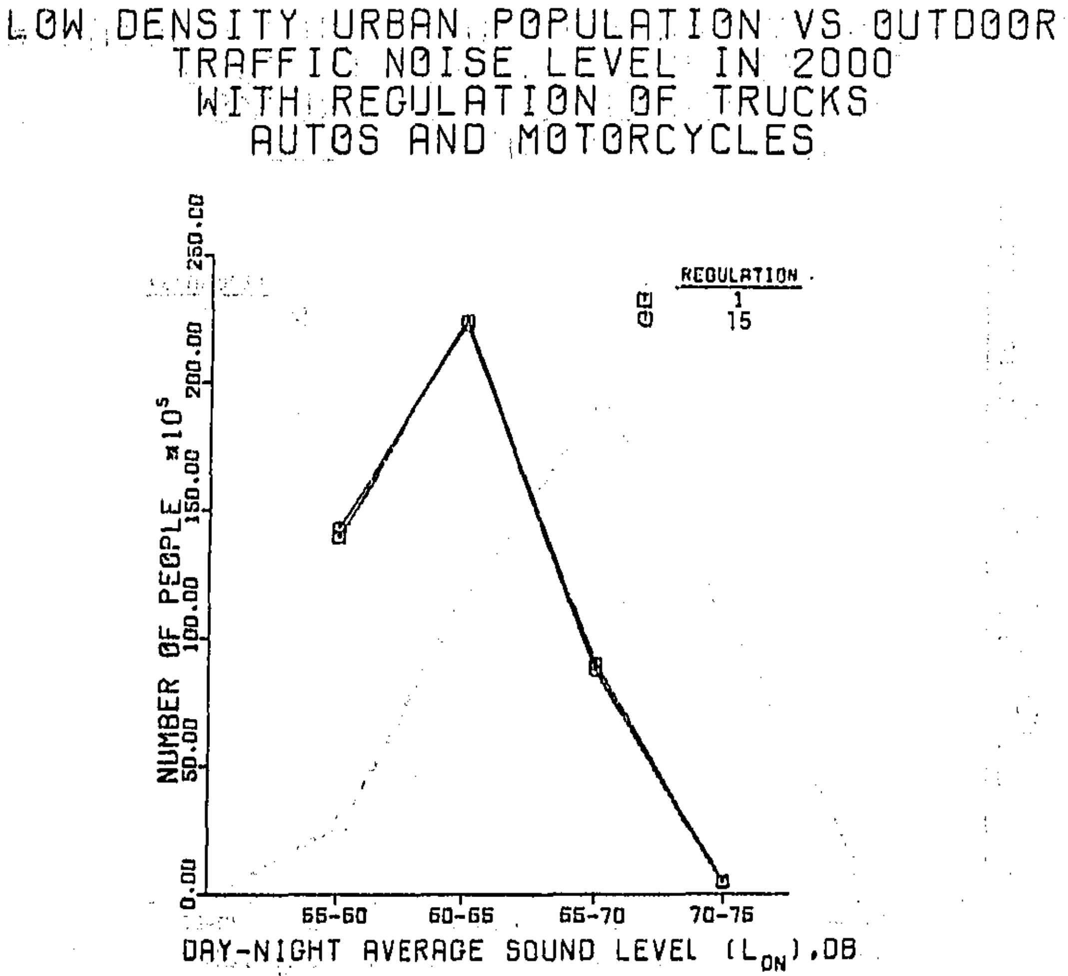
LOW DENSITY URBAN POPULATION VS OUTDOOR
TRAFFIC NOISE LEVEL IN 2000
WITH REGULATION OF TRUCKS
AUTOS AND MOTORCYCLES
REGULATION
1
15
NUMBER OF PEOPLE x10^5
0.00
50.00
100.00
150.00
200.00
250.00
55-60
60-65
65-70
70-75
DAY-NIGHT AVERAGE SOUND LEVEL (LDN),DB

FIGURE 6-8

SUBURBAN POPULATION VS OUTDOOR
TRAFFIC NOISE LEVEL IN 2000
WITH REGULATION OF TRUCKS
AUTOS AND MOTORCYCLES

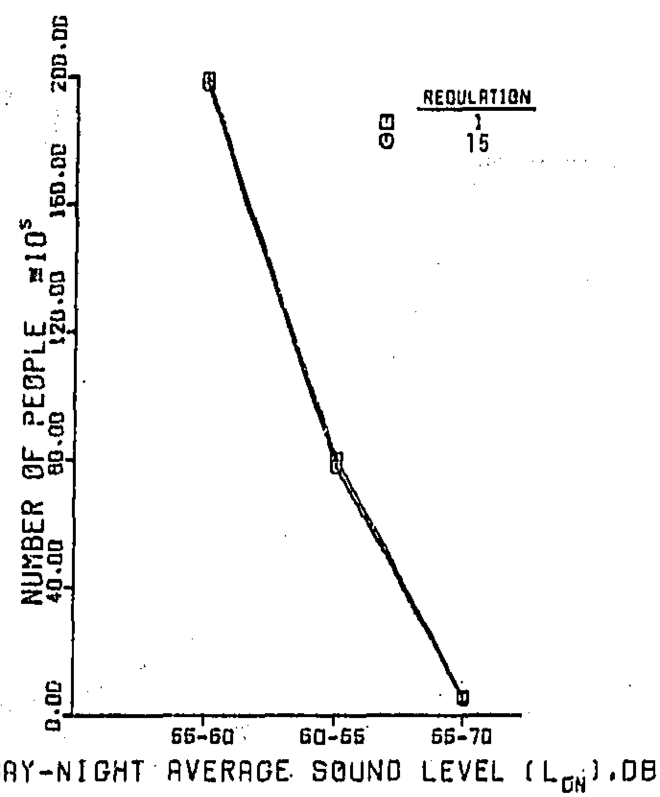

FIGURE 6-9

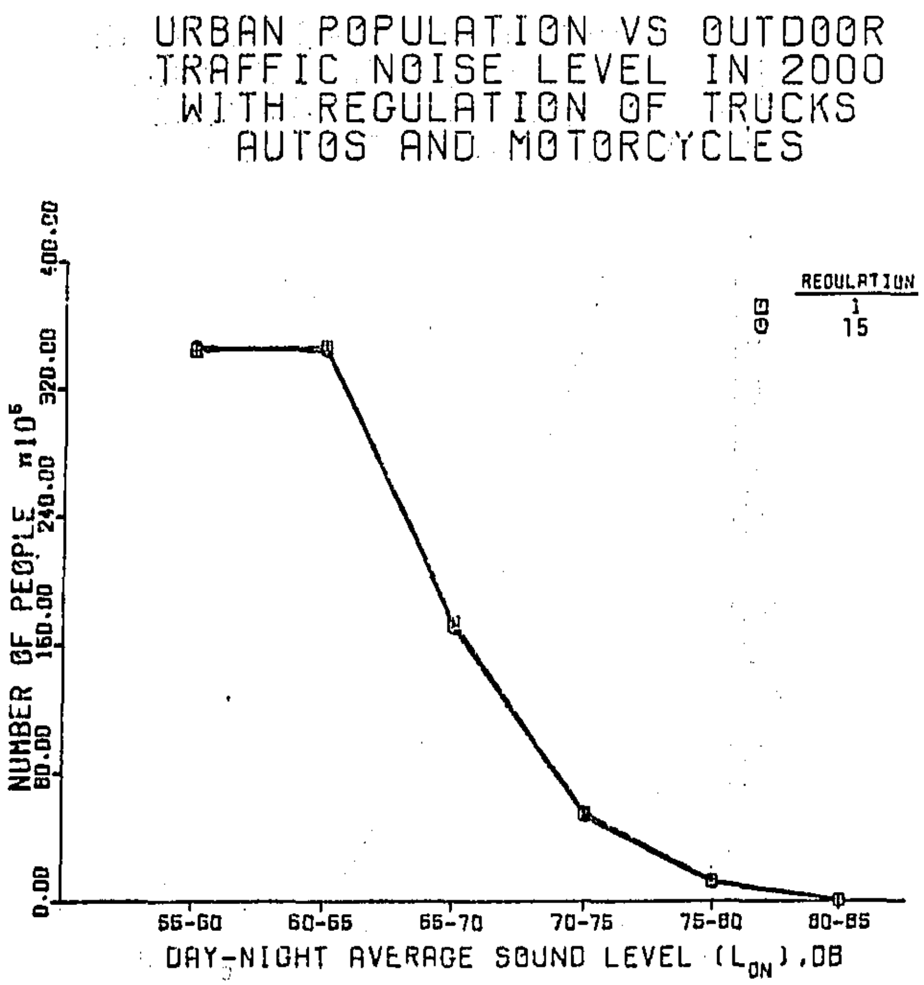
URBAN POPULATION VS OUTDOOR TRAFFIC NOISE LEVEL IN 2000 WITH REGULATION OF TRUCKS AUTOS AND MOTORCYCLES
NUMBER OF PEOPLE x10^6
0.00
80.00
160.00
240.00
320.00
400.00
REGULATION
1
15
55-60
60-65
65-70
70-75
75-80
80-85
DAY-NIGHT AVERAGE SOUND LEVEL (LDN),DB

Table 6-11

Reduction of Urban Street Traffic Noise in High Density Urban Areas with Regulation of New Trucks, Autos, and Motorcycles								
	Reduction of Average Traffic Passby Noise Level (dB at 50 ft)							
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.25	1.18	2.32	3.36	4.50	5.12	5.48	5.71
2	.25	1.18	2.32	3.36	4.50	5.13	5.49	5.72
3	.25	1.18	2.32	3.36	4.50	5.13	5.49	5.72
4	.25	1.19	2.32	3.37	4.53	5.15	5.52	5.76
5	.25	1.18	2.32	3.36	4.51	5.15	5.52	5.75
6	.25	1.19	2.32	3.37	4.52	5.15	5.52	5.76
7	.25	1.18	2.32	3.37	4.52	5.15	5.51	5.75
8	.25	1.19	2.32	3.37	4.55	5.16	5.44	5.78
9	.25	1.18	2.32	3.37	4.52	5.16	5.53	5.77
10	.25	1.19	2.32	3.37	4.53	5.16	5.54	5.78
11	.25	1.18	2.32	3.37	4.52	5.63	5.54	5.78
12	.25	1.19	2.32	3.37	4.53	5.17	5.55	5.74
13	.25	1.18	2.32	3.37	4.52	5.16	5.54	5.79
14	.25	1.19	2.32	3.37	4.55	5.17	5.55	5.80
15	.30	1.24	2.39	3.45	4.62	5.26	5.63	5.87

Table 6-12

Reduction of Urban Street Traffic Noise in Low Density Urban Areas with Regulation of New Trucks, Autos, and Motorcycles								
	Reduction of Average Traffic Passby Noise Level (dB at 50 ft)							
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.26	1.19	2.32	3.38	4.53	5.16	5.52	5.76
2	.26	1.19	2.35	3.38	4.54	5.16	5.53	5.76
3	.26	1.19	2.35	3.38	4.53	5.16	5.53	5.76
4	.26	1.19	2.34	3.39	4.55	5.18	5.55	5.79
5	.26	1.19	2.33	3.39	4.54	5.18	5.55	5.79
6	.26	1.20	2.34	3.39	4.55	5.18	5.55	5.79
7	.26	1.19	2.34	3.39	4.54	5.18	5.55	5.79
8	.26	1.20	2.34	3.39	4.55	5.19	5.56	5.80
9	.26	1.19	2.34	3.39	4.55	5.18	5.56	5.80
10	.26	1.20	2.34	3.39	4.55	5.19	5.56	5.80
11	.26	1.19	2.30	3.39	4.55	5.19	5.56	5.80
12	.26	1.20	2.34	3.39	4.55	5.19	5.57	5.81
13	.26	1.19	2.34	3.39	4.55	5.19	5.56	5.81
14	.26	1.29	2.34	3.39	4.55	5.19	5.56	5.81
15	.29	1.25	2.38	3.44	4.61	5.25	5.62	5.80

Table 6-13

Reduction of Urban Street Traffic Noise in Suburban Areas with Regulation of New Trucks, Autos, and Motorcycles								
	Reduction of Average Traffic Passby Noise Level (dB at 50 ft)							
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.25	1.18	2.32	3.36	4.51	5.13	5.49	5.72
2	.25	1.18	2.32	3.36	4.51	5.13	5.49	5.73
3	.25	1.18	2.32	3.36	4.51	5.13	5.49	5.73
4	.25	1.18	2.32	3.37	4.52	5.15	5.52	5.76
5	.25	1.18	2.32	3.37	4.52	5.15	5.52	5.76
6	.25	1.18	2.32	3.37	4.52	5.15	5.52	5.76
7	.25	1.18	2.32	3.37	4.52	5.15	5.52	5.76
8	.25	1.18	2.32	3.37	4.53	5.16	5.53	5.77
9	.25	1.18	2.32	3.37	4.52	5.16	5.53	5.77
10	.25	1.18	2.32	3.57	4.52	5.16	5.54	5.78
11	.25	1.18	2.32	3.37	4.52	5.16	5.54	5.78
12	.25	1.18	2.32	3.37	4.53	5.17	5.54	5.79
13	.25	1.18	2.32	3.37	4.52	5.16	5.54	5.79
14	.25	1.18	2.32	3.37	4.53	5.17	5.55	5.79
15	.29	1.23	2.38	3.44	4.61	5.25	5.62	6.86

first baseline case. Reductions in urban street traffic noise relative to the other baselines are presented in Appendix F (Table F-7). Reductions in urban street traffic noise relative to the other two baselines are presented in Appendix F (Tables F-8 through F-13).

From these tables, it should be noted that:

(1) Reducing bus noise emissions has little effect on overall traffic noise for either urban highways or urban streets.

(2) The most stringent regulation schedule considered in the analysis--a reduction of bus noise to an ideally protective level of 55 dB at 50 feet (regulation schedule 15)--results in a statistical change in the average traffic passby level of less than 0.16 dB in the baseline case most favorable for observation of measurable differences due to bus regulation, i.e., baseline (1).

6.2.6 Reduction of Traffic Noise Impact

The equivalent noise impact in each land use area is calculated for each regulation schedule and study year by (1) applying the traffic noise reduction for the land use to the present distribution of people living in all urban areas with L_{dn} greater than 55 dB (Table 6-3), (2) calculating the new total ENI, and then (3) taking the same percent of the ENI as the percent of population contained in the given land use. The results obtained by this method are presented in Tables 6-14 through 6-16 for the first baseline case. Summary tables show the total ENI due to urban street traffic for all urban land uses (Table 6-17) and the percent reduction of this total ENI (Table 6-18) for each regulation schedule and study year--for baseline (1). Results for baselines (2) and (3) are given in Appendix F (Tables F-14 through F-23).

Table 6-14

Equivalent Number of People Impacted By Urban Traffic Noise in High Density Urban Areas with Regulation of New Trucks, Autos, and Motorcycles								
	Equivalent Number of People Impacted (Millions) Per Day							
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	2.92	2.61	2.27	1.97	1.64	1.46	1.36	1.30
2	2.92	2.61	2.27	1.97	1.64	1.46	1.36	1.30
3	2.92	2.61	2.27	1.97	1.64	1.46	1.36	1.30
4	2.92	2.61	2.27	1.96	1.63	1.46	1.35	1.29
5	2.92	2.61	2.27	1.96	1.64	1.46	1.35	1.29
6	2.92	2.61	2.27	1.96	1.63	1.46	1.35	1.29
7	2.92	2.61	2.27	1.96	1.63	1.46	1.35	1.29
8	2.92	2.61	2.27	1.96	1.63	1.45	1.35	1.28
9	2.92	2.61	2.27	1.96	1.63	1.45	1.35	1.28
10	2.92	2.61	2.27	1.96	1.63	1.45	1.35	1.28
11	2.92	2.61	2.27	1.96	1.63	1.45	1.35	1.28
12	2.92	2.61	2.27	1.96	1.63	1.45	1.34	1.28
13	2.92	2.61	2.27	1.96	1.63	1.45	1.35	1.28
14	2.92	2.61	2.27	1.96	1.63	1.45	1.34	1.28
15	2.90	2.60	2.25	1.94	1.61	1.43	1.32	1.25

Table 6-15

Equivalent Number of People Impacted By Urban Traffic Noise in Low Density Urban Areas with Regulation of New Trucks, Autos, and Motorcycles								
Equivalent Number of People Impacted (Millions) Per Day								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	8.34	7.47	6.49	5.61	4.67	4.16	3.87	3.68
2	8.34	7.47	6.48	5.61	4.66	4.16	3.86	3.68
3	8.34	7.47	6.48	5.61	4.66	4.16	3.87	3.68
4	8.34	7.47	6.48	5.60	4.66	4.14	3.85	3.66
5	8.34	7.47	6.48	5.60	4.66	4.15	3.85	3.66
6	8.34	7.47	6.48	5.60	4.65	4.14	3.85	3.66
7	8.34	7.47	6.48	5.60	4.66	4.15	3.85	3.66
8	8.34	7.47	6.48	5.60	4.65	4.14	3.84	3.65
9	8.34	7.47	6.48	5.60	4.65	4.14	3.84	3.65
10	8.34	7.47	6.48	5.60	4.65	4.14	3.84	3.64
11	8.34	7.47	6.48	5.60	4.65	4.14	3.84	3.64
12	8.34	7.47	6.48	5.60	4.65	4.14	3.83	3.64
13	8.34	7.47	6.48	5.60	4.65	4.14	3.84	3.64
14	8.34	7.47	6.48	5.60	4.65	4.13	3.83	3.64
15	8.31	7.44	6.45	5.56	4.60	4.09	3.79	3.60

Table 6-16

Equivalent Number of People Impacted By Urban Traffic Noise in Suburban Areas with Regulation of New Trucks, Autos, and Motorcycles								
Equivalent Number of People Impacted (Millions) Per Day								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	22.26	19.96	17.33	15.00	12.50	11.16	10.39	9.90
2	22.26	19.96	17.33	15.00	12.49	11.15	10.38	9.88
3	22.26	19.96	17.33	15.00	12.49	11.15	10.38	9.88
4	22.26	19.96	17.32	14.98	12.47	11.11	10.32	9.82
5	22.26	19.96	17.33	14.99	12.47	11.11	10.33	9.82
6	22.26	19.95	17.32	14.98	12.45	11.08	10.29	9.78
7	22.26	19.96	17.32	14.97	12.45	11.09	10.29	9.78
8	22.26	19.95	17.32	14.98	12.45	11.08	10.29	9.77
9	22.26	19.96	17.32	14.97	12.45	11.09	10.29	9.78
10	22.26	19.95	17.32	14.98	12.45	11.08	10.28	9.77
11	22.26	19.96	17.32	14.98	12.46	11.09	10.29	9.77
12	22.26	19.95	17.32	14.98	12.45	11.08	10.27	9.75
13	22.26	19.96	17.32	14.99	12.46	11.09	10.28	9.76
14	22.26	19.95	17.32	14.97	12.45	11.07	10.27	9.74
15	22.16	19.84	17.19	14.82	12.27	10.09	10.11	9.60

Table 6-17

Equivalent Number of People Impacted By Urban Traffic Noise in All Urban Areas with Regulation of New Trucks, Autos, and Motorcycles*								
Equivalent Number of People Impacted (Millions) Per Day								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	33.51	30.05	26.09	22.58	18.81	16.79	15.63	14.88
2	33.51	30.94	26.08	22.57	18.79	16.77	15.60	14.85
3	33.51	30.05	26.09	22.57	18.80	16.77	15.60	14.85
4	33.51	30.04	26.07	22.55	18.76	16.71	15.52	14.76
5	33.51	30.05	26.08	22.56	18.77	16.72	15.53	14.77
6	33.51	30.04	26.07	22.54	18.75	16.71	15.52	14.76
7	33.51	30.04	26.08	22.55	18.76	16.72	15.53	14.77
8	33.51	30.04	26.07	22.54	18.74	16.68	15.48	14.71
9	33.51	30.04	26.08	22.55	18.75	16.69	15.49	14.72
10	33.51	30.04	26.07	22.54	18.74	16.67	15.47	14.69
11	33.51	30.04	26.08	22.55	18.75	16.68	15.48	14.70
12	33.51	30.04	26.07	22.54	18.74	16.66	15.45	14.67
13	33.51	30.04	26.08	22.55	18.75	16.68	15.46	14.67
14	33.51	30.04	26.07	22.54	18.73	16.66	15.44	14.66
15	33.37	29.88	25.88	22.32	18.48	16.41	15.22	14.45

*The ENI Baseline for traffic noise from Table 6-4 is 34.6 million.

Table 6-18

Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	3.14	13.16	24.60	34.74	45.63	51.48	54.83	56.99
2	3.14	13.17	24.61	34.77	45.68	51.54	54.90	57.07
3	3.14	13.16	24.61	34.76	45.67	51.54	54.90	57.07
4	3.14	13.17	24.65	34.84	45.79	51.71	55.13	57.34
5	3.14	13.16	24.61	34.80	45.76	51.68	55.11	57.32
6	3.14	13.18	24.65	34.84	45.80	51.71	55.13	57.34
7	3.14	13.17	24.63	34.82	45.77	51.68	55.11	57.32
8	3.14	13.18	24.65	34.86	45.85	51.80	55.26	57.49
9	3.14	13.17	24.63	34.83	45.80	51.76	55.23	57.46
10	3.14	13.18	24.65	34.86	45.85	51.81	55.29	57.53
11	3.14	13.17	24.63	34.83	45.82	51.78	55.27	57.52
12	3.14	13.18	24.65	34.84	45.85	51.83	55.34	57.61
13	3.14	13.17	24.63	34.82	45.82	51.80	55.31	57.59
14	3.14	13.18	24.65	34.86	45.87	51.86	55.36	57.63
15	3.55	13.64	25.19	35.48	46.58	52.57	56.00	58.24

Percent Reduction in Total Equivalent Number of People Impacted By Urban Traffic Noise With Regulation of New Trucks, Autos, and Motorcycles

Equivalent Number of People Impacted (Millions) Per Day

Upon inspection of Tables 6-17 and 6-18, it is clear that little relative change in the impact of overall traffic noise is obtained through the regulation of bus noise. In the most severe case (regulatory schedule 15), the equivalent of slightly less than half a million people would be benefited by the implementation of bus noise regulation in the year 2000--less than 2 percent of the present total ENI. Yet bus noise is perceived by many as a major concern in comparison with noise from other vehicles.[21] To investigate the cause of these concerns, a more direct approach is discussed in Part 6.3 for evaluating the impact attributable to bus noise in isolated passby situations.

6.3 REDUCTION OF INDIVIDUAL PASSBY NOISE IMPACT

Up to this point, the analysis of bus noise impact has been concerned with the contribution that buses make to day-night average traffic levels (L_{dn}). The impact contributions which are calculated in this way are not wholly representative of the input attributable to bus noise, for the calculations are relatively independent of the actual operating conditions of the buses. For example, they do not reflect the fact that almost the entire amount of hourly acoustical energy contributed by buses in an area may be generated in only 10 seconds of noise during a single acceleration near a bus stop. Yet this intrusive, short, intense event may be the most annoying noise-related situation faced over the entire day by a large number of pedestrians, residents, or people waiting near the bus stop.[2, 21]

On some occasions bus noise will be completely masked out by other noises, making the conclusions reached by using L_{dn} essentially correct. At other times or situations, one can expect that other noise sources will not mask the noise of a passing bus, and thus the bus will cause a finite impact. The actual impact from buses is certainly due to a combination of various levels of bus noise and other environmental noise.

Annoyance is difficult to describe. It may pass rapidly and the cause remain unnoticed. Or it may add to other agents causing stress and lead to physiological problems.[20] As measured from people's responses in questionnaires, however, there is no doubt that annoyance to bus noise does exist. In fact, in a recent survey of people's annoyance to motor vehicles, it was found that, on the average, buses are perceived as the loudest and the most intensely annoying of any of the motor vehicle noises."[21]

A loud vehicle passby may also interrupt people's activities, such as conversation or sleeping. The interruptions may again lead to annoyance, but in themselves they may represent a degradation of health and welfare. For instance, in a recent study of the annoyance caused by different levels of simulated aircraft noise for people seated indoors watching television, annoyance was seen to be mediated at least in part by speech interference.[35] Not only is the TV program, or other person speaking, more difficult to hear during the time in which a noisy vehicle is passing by, but it has been observed that the distraction which may occur from the conversation in which the person is engaged may contribute in itself to annoyance.[35] The speaker may behaviorally attempt to cope with the noise intrusion either by increasing his or her vocal effort, or in more severe cases, by ceasing to speak altogether. Such behavioral reactions may be quite indicative of general annoyance and disturbance with the intrusive noise event. Similarly, the reaction to a noise intrusion during sleep may be in many cases a change in sleep stage (from a "deeper" to a "lighter" stage) or, if the intrusive noise is intense or long enough, an actual awakening may result. In either case, repeated disturbance of people's activities may be expected to adversely affect their well-being. The covariance of verbalized annoyance with the interference of activities has been amply demonstrated in several investigations.[8, 23, 56, 57]

For these reasons it seems appropriate for the analysis of passby impacts to examine the two activities of speech communication and sleep in some detail, both in order to determine the direct effect bus noise may have on them, as well as to aid in an estimation of the total annoyance attributable to bus noise. These single event passby noise intrusions become particularly important in light of other regulations and efforts to reduce the noise from other motor vehicles and urban noise sources, i.e., without a reduction in noise emissions for buses, the bus may very well stand out as one of the most, if not the most, intrusive noise source.

6.3.1 Sleep Disturbance

The sleep periods of humans are typically classified into five stages. In Stages I and II, sleep is light and the sleeper is easily awakened. Stages III and IV are states of deep sleep where a person is not as easily awakened by a given noise, but the sleep may shift to a lighter stage. An additional stage is termed rapid eye movement (REM) and corresponds to the dream state. When exposed to an intrusive noise, a sleeper may (1) show response by a brief change in brainwave pattern, without shifting sleep stages; (2) shift to a lighter sleep stage; or (3) awaken. The greatest known impact occurs due to awakening, but there are also indications that disruption of the sleep cycle can cause (irritability, etc.) even though the sleeper may not awaken.[34]

Two recent studies[36, 37] have summarized and analyzed sleep disturbance data. These studies showed a linear relationship between frequency of response (disturbance and awakening) and noise level, and demonstrated that the duration of the noise stimulus was a critical parameter in predicting response. The studies also showed that the frequency of sleep disruption is predicted by noise exposure better than is arousal or behavioral awakening. An important fact is that sleep disturbance is defined as any physiological change which occurs as a result of a stimulus. The person undergoing such disturbance may be completely unaware of being afflicted; however, the disturbance may adversely affect total sleep quality. This effect on overall sleep quality may lead to, in certain situations, behavioral or physiological consequences.[34]

To determine the magnitude of sleep disturbance caused by buses, some consideration must be made of the hours of bus operation. Only two types of buses generally operate at night--transit buses and intercity buses. School buses may be operating in the early morning hours in some locales, but probably not much before 7:00 a.m. Transit buses, too, have limited nighttime operation. For five major bus lines in Los Angeles, for example, only 1/6 of the scheduled runs occur at night, i.e., before 7:00 a.m. and after 10:00 p.m. (this ratio of daytime to nighttime operation is not atypical throughout the nation). Although some fraction of the population sleeps during the daytime, it is assumed for the purposes of this analysis that sleep only occurs during the nighttime hours. Therefore, the fraction of the total vehicle miles traveled by transit buses which are likely to disturb sleep is assumed to be 1/6 of the total.

Official estimates of the portion of inter-city bus mileage traveled at night are not available; however, some approximations may be made. If there were no change between night and day operations, 37.5 percent (9/24) would occur at night and 62.5 percent (15/24) in the day. For people taking short trips (a few hours long) on inter-city buses it is assumed that somewhat less bus travel per hour actually occurs during nighttime hours than during the day. A brief investigation of several cross-country, inter-city bus schedules indicates that only a slightly greater daytime biasing of the travel time is warranted for long trips (37.1 percent night versus 62.9 percent day).[49] In this analysis, a 35/65 percent split between intercity bus nighttime and daytime operations is used.

To find impact on sleep and the reduction in sleep disturbance achievable with bus noise emission regulations, the following method is utilized:

Step 1. Average passby levels at 50 feet are computed for both bus types (transit and inter-city buses). These data are presented in Table 6-6.

Step 2. The distances from a typical bus passby at which these levels are decreased in steps of 5 dB are calculated (Figure 6-10). These distances are assumed to begin from the center of the roadway since, on most roads, buses travel both directions in equal frequency.

Step 3. The number of people living in each 5 dB band from the 50-foot passby level is calculated by multiplying the population density of each land use in which the buses operate by the

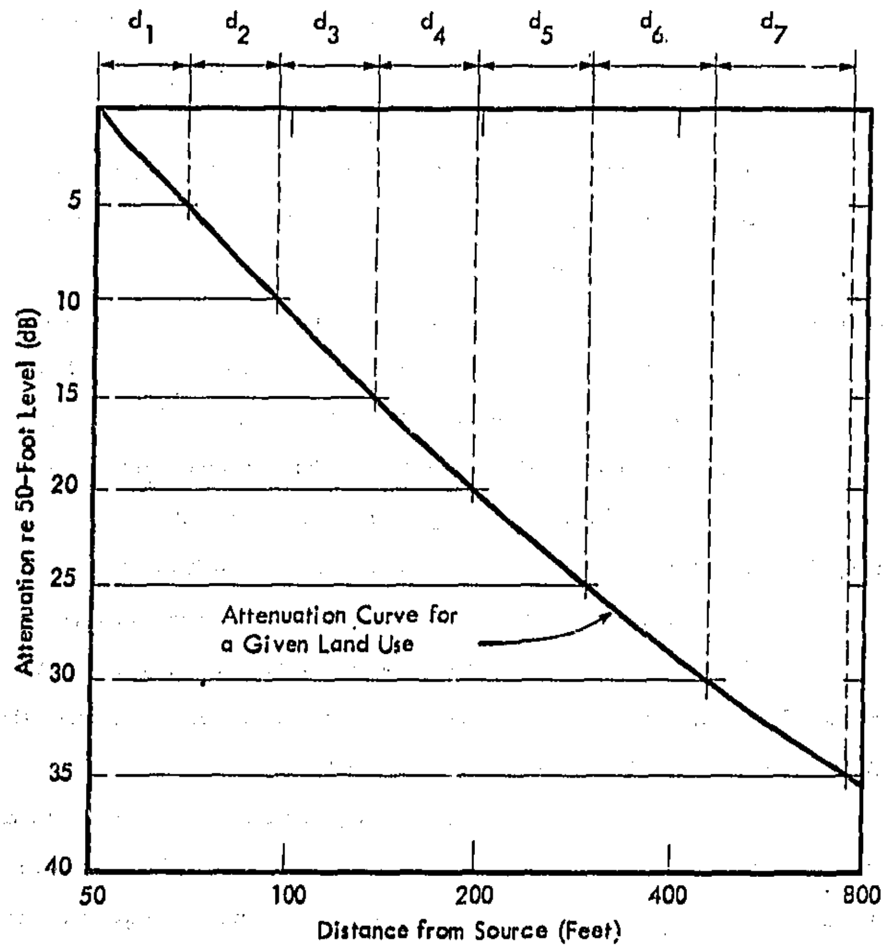

Figure 6-10. Illustrative Example of Calculation of Distances Between Steps of 5 dB Attenuation from the 50-Foot Average Bus Passby Noise Level

width of the 5 dB bands (calculated in Step 2) and then by the number of miles traveled within the given land use by buses. Depending on the land use, the first 40 to 90 feet on each side of the center line is assumed to be part of the roadway and adjoining sidewalk, and thus it is assumed to contain no people.

Step 4. The average sleep impact is calculated in each of the 5 dB bands. The impact, expressed as a fraction, is found from a curve relating sleep impact to passby noise level (Figure 6-16 and Figure 6-17). This procedure is analogus to the fractional impact method presented in Part 6.2.

Step 5. The relative total impact is computed in each band by multiplying the number of people living in each band (from Step 3) by the associated fractional impact (from Step 4).

We shall now discuss in detail the steps outlined above, starting with Step 2, since Step 1 has been previously defined.

Step 2 - For the purpose of analyzing bus passby noise in this section, each of the four land uses discussed in Part 6.2 is assumed to have a simplified mix of high-rise, low-rise, and open-space areas (Table 6-19)[51] which correspond to different propagation laws. The computation of the distance between each 5 dB band of attenuation from the bus roadway involves determining the noise attenuation characteristics typical of each area. In urban high-rise areas the building density may be so great that the noise from a point source, such as a bus, located in the middle of an intersection, decays in the lateral direction as if the vehicle were a line source: the acoustical waves have little chance

Table 6-19

Assumed Mix of Building Types and Land Uses Impacted by Buses

Land Use	Percent of Different Types of Building Development Corresponding to Different Propagation Laws*		
	High-Rise	Low-Rise	Open Space
High Density Urban	100	0	0
Low Density Urban	50	50	0
Suburban	0	100	0
Rural	0	0	100

*See Figures 6-12 through 6-14

to dissipate in the direction parallel to the bus's line of travel (Figure 6-11). In low-rise areas, the noise travels more radially and the attenuation is correspondingly greater. In addition to these two forms of laterally directed geometric spreading, building, ground, and air absorption also contribute to attenuation. A recent review of the literature on urban sound propagation produced the attenuation values for traffic line sources shown in Figure 6-12.[22] Applying the same excess attenuation values to point source spreading losses yields the curves of Figure 6-13. As a simplification, all low-rise areas are assumed to have point source attenuation characteristics and all high-rise areas are assumed to have line source characteristics.

The attenuation of noise in rural areas also involves many factors (Figure 6-14). The low density of buildings in rural areas allows the neglection of building reflection and absorption, so that the distance computations are straightforward.

The build-up of reverberation in the longitudinal direction (along the path of travel of the bus) must also be considered as a factor in the propagation of passby noise in high-rise areas. Figure 6-15 shows the apparent amplification of noise level due to reveberant buildup on narrow streets completely, or nearly completely, bounded by buildings.[38] The amplification of the noise level will occur when buses are traveling along streets bounded by buildings less than 78 feet apart. In a survey of twenty metropolitan areas,[39, 40] it was found that distances between building fronts vary widely within each city. In Boston, for example, some building fronts are 50 feet apart, while others are 120 feet apart. Although there are thoroughfares in Eastern and Mid-western

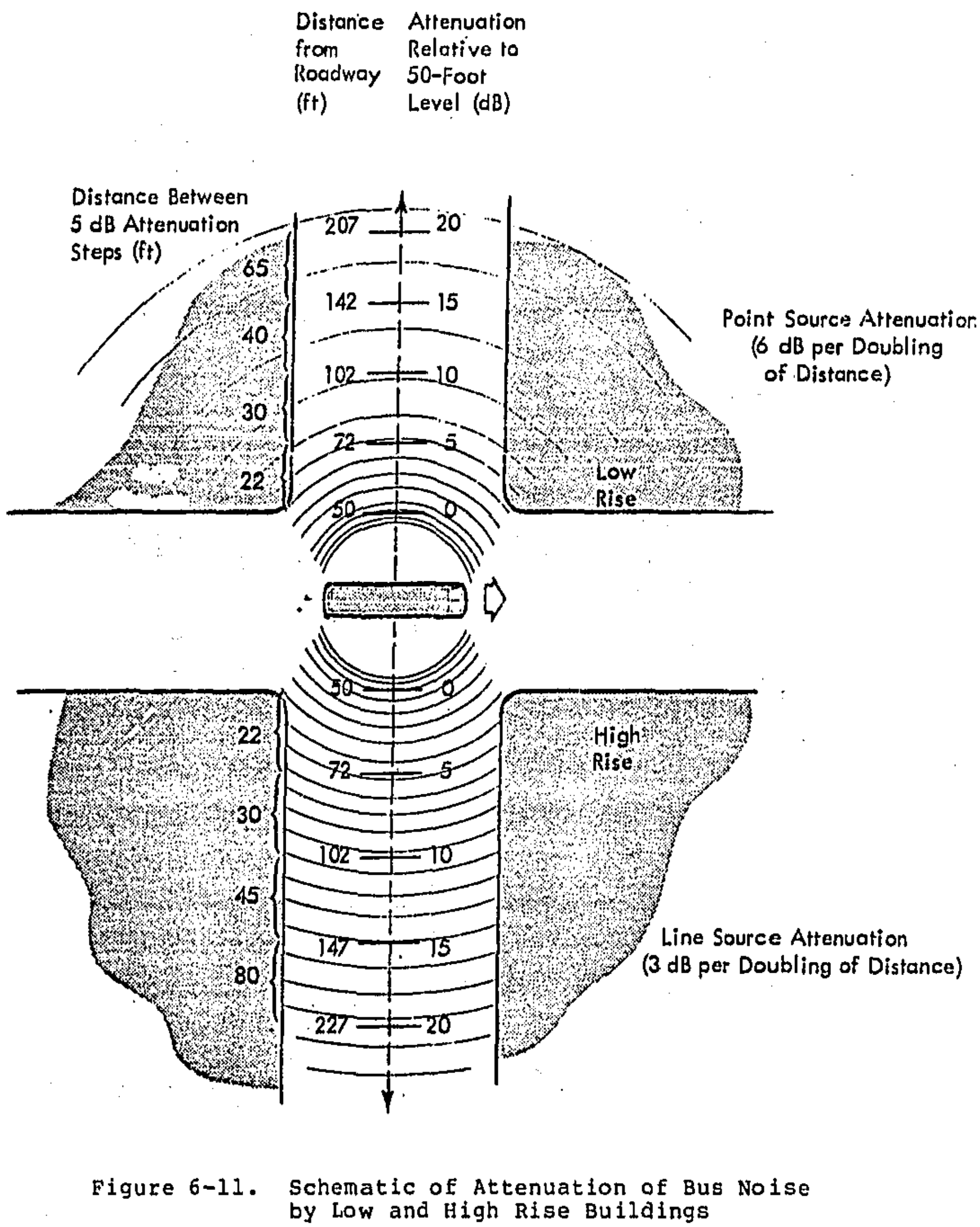

Figure 6-11. Schematic of Attenuation of Bus Noise by Low and High Rise Buildings

Note: Not drawn to scale.

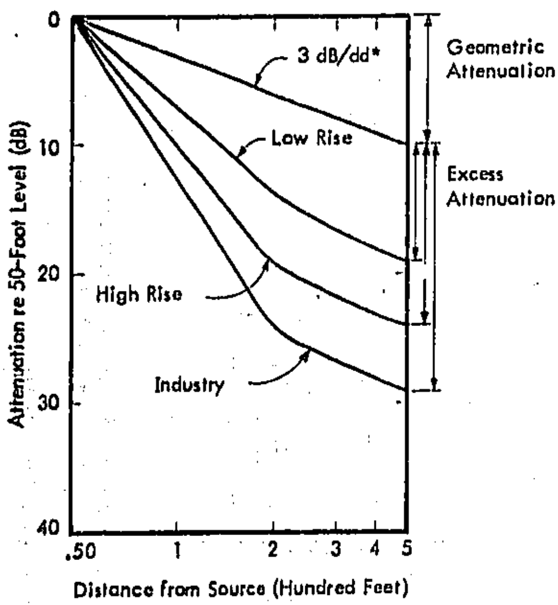

Figure 6-12 Attenuation of Traffic Line Sources, by Urban Land Use[22]

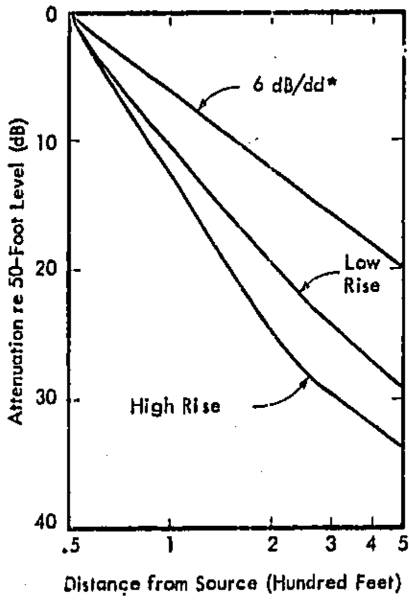

Figure 6-13 Predicted Attenuation of Point Sources, by Urban Land Use

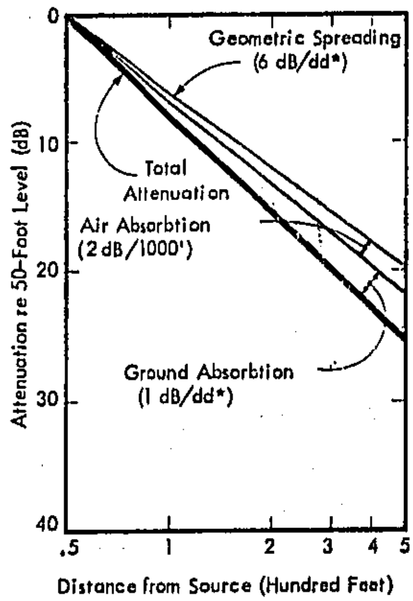

Figure 6-14 Attenuation of Point Source Noise Levels Over Open Terrain[30]

* Doubling of distance.

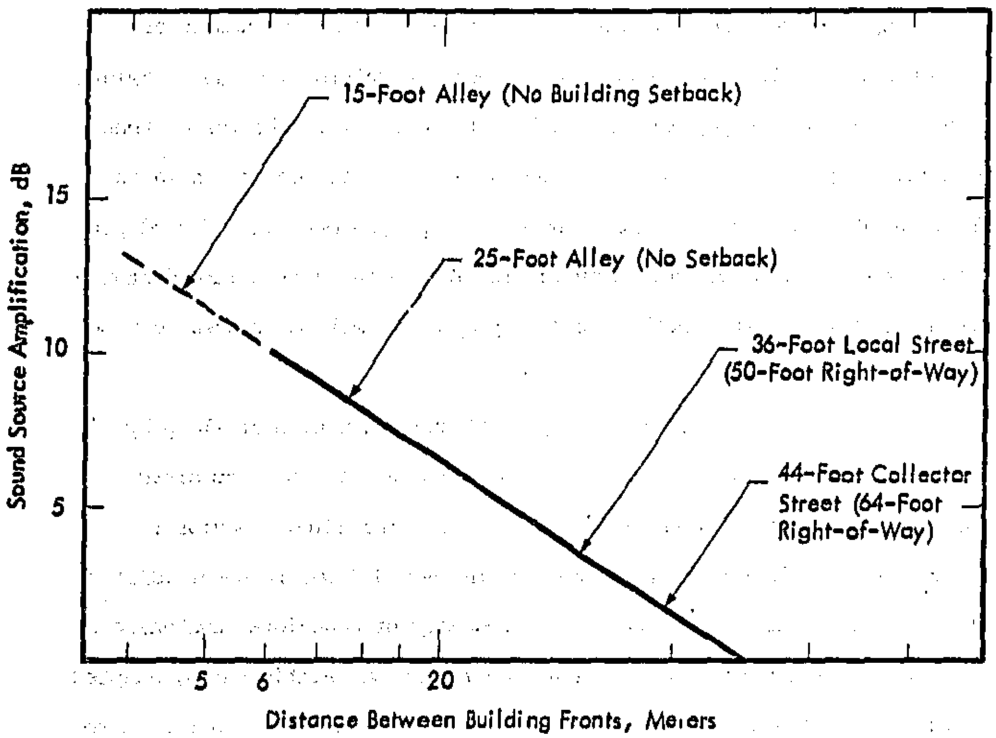

Figure 6-15. Noise Amplification Factors for Bus Operation on Narrow Streets[38]

cities with building fronts less than 78 feet apart, it is estimated that these do not constitute the vast majority of public bus routes. Western cities, as a rule, have constructed streets with building fronts farther apart than Eastern and Mid-western cities. Thus, reverberant amplification along bus routes was excluded from the analysis used in this study.

Step 3 - Once the 5 dB band distances are known, the number of people living within each band can be found by multiplying the bandwidth area by the average population density of the locale. The three urban densities and one rural density which have been selected are shown in Table 6-20. The densities are converted to people per mile of road per foot from the roadway. Thus, by multiplying by the appropriate distance from the roadway, the total number of people per mile of roadway can be found.

Step 4 - The fractional impact of the disruption of sleep by noise is given in Figure 6-16 where the frequency of no sleep disturbance (as measured by changes in sleep state, including behavioral awakening) is plotted as a function of the Sound Exposure Level (SEL) of the intruding noise. Likewise, the frequency of behavioral awakening as a function of SEL is shown in Figure 6-17. These relationships, adapted from Figures 1 and 2 of reference 36, consist of data derived from a review of most of the recent experimental sleep data as related to noise exposure. The curves, which indicate the approximate degree of impact (percent disruption or awakening) as a function of noise level, have been modified somewhat from those contained in References 36.* (Note that

*Personal Communication, J. S. Lukas, July 1976

Table 6-20

Population Densities for Selected Areas of Bus Operation

Land Use Area	Urban			Rural
	High Density	Low Density	Suburban	
Type of Housing[51]	Dense and Very Dense Urban Apartments	Urban Row Apartments and Suburban Duplexes	Suburban Single Family Detached	Single Family Detached
Percent of the 1970 U.S. Urban Population[51]	8.7	24.9	66.4	-
Average Population per Square Mile[24]	20,877	8,473	2,286	20
Population per Mile of Road per Foot from Roadway (Both Sides)	7.908	3.209	.866	.0076

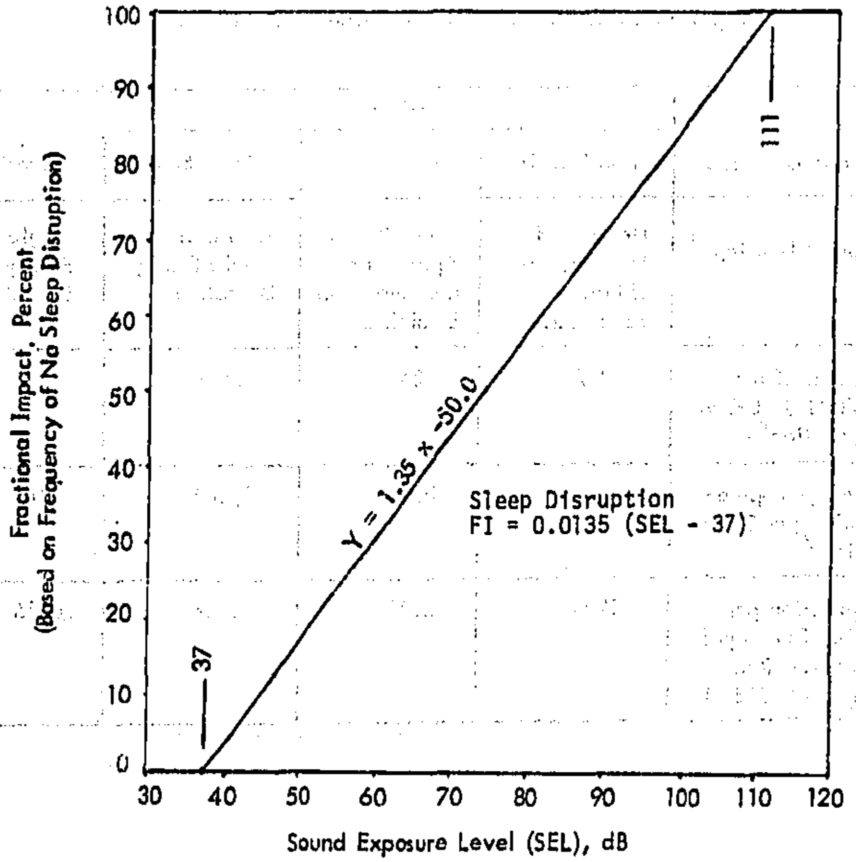

Figure 6-16. Fractional Impact of Sleet Distruption as a Function of Sound Exposure Level[36] (Regressions of Sleep Distruption on SEL, revised)

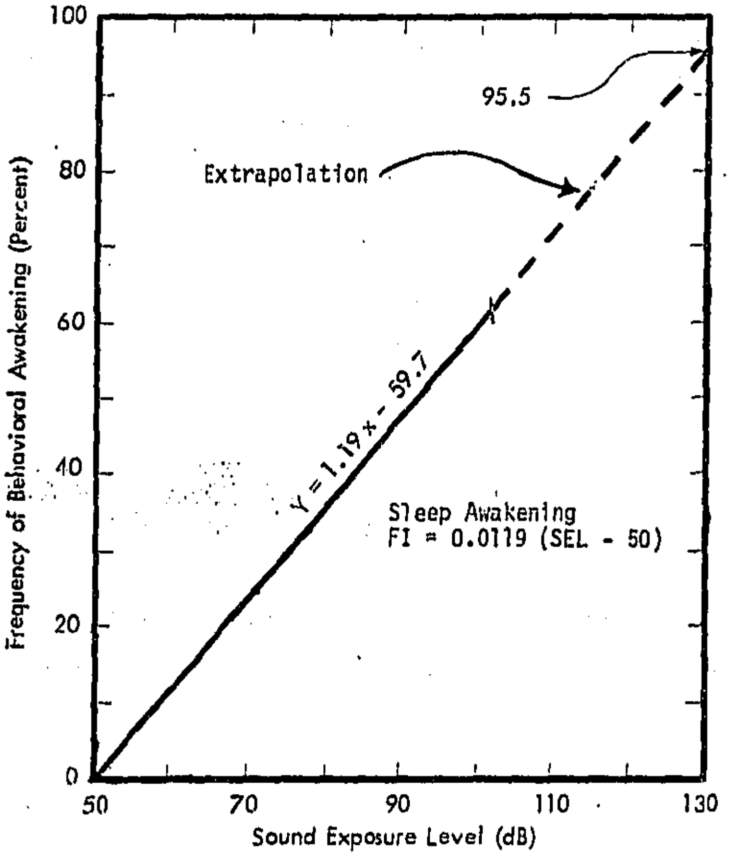

Figure 6-17 Frequency of Arousal or Awakening From Sleep in College or Middle-Aged Men and Women as a Function of Sound Exposure Level (regressions of percent awakened on SEL, revised)[36]

in Figure 6-17, the relationship beyond SEL = 95 dB is an extrapolation of data. However, indoor SEL's from bus passbys rarely exceed SEL = 70 dB.) Furthermore, the noise data contained within these studies were measured in terms of "effective perceived noise level" with a reference duration of .5 second ($EPNL_{.5\ sec}$). $EPNL_{.5\ sec}$ is converted to SEL by the following approximate relationship:

$$SEL = EPNL_{.5\ sec} - 16\ dB \qquad (10)$$

The SEL is defined as:

$$SEL = \log_{10} \int_0^t \frac{P(t)2}{P_o^2}\, dt \qquad (11)$$

where

t is the duration of the noise

P(t) is the A-weighted sound pressure

and

P_o is the reference pressure (20 micropascals).

For triangular time histories such as vehicular passbys, an approximation is

$$SEL = L_{max} + 10 \log_{10} t/2 \qquad (12)$$

where

L_{max} is the maximum A-weighted sound level

and

t is the duration in seconds measured between the "10 dB down" points where the sound level is equal to L_{max} -10.

Based on the urban and rural attenuation curves (Figures 6-12 through 6-14), an observer located 50 feet from the roadway would find t = 8 seconds for an average bus speed of 15 mph.[5] In rural bus operation on main roads where the average speed is likely to be twice this value but the excess attenuation is less, it is found that t = 6 seconds. These durations are increased to 17 and 14 seconds, respectively, at distance of 100 feet from the road. The difference between the longer and shorter durations shifts the SEL by 3 to 4 dB which changes the fractional impact of sleep disruption by only 4 to 5 percent. It was therefore decided to use an average value of 10 seconds as the passby duration for all buses in the analysis. Selecting this duration simplifies equation (12) to:

$$SEL = L_{max} + 7.0 \qquad (13)$$

Using the average passby levels given in Table 6-6 for L_{max}, the SEL's were found for each bus type. To determine the resulting SEL inside the home the following transmission losses were applied to the propagated noise levels, depending on land use.

1. A noise level reduction of 20 dB was used for high and low density urban areas to represent the case in which, (because of the type of building construction) windows of half of the homes are open and half of the homes are closed.[6]

2. A noise level reduction of 15 dB was used for suburban and rural areas to represent the case in which the windows of all homes are open.[6]

Step 5 - The equivalent noise impact (ENI) for sleep disturbance was derived for each of the regulatory schedules and study years under investigation. The FI equations for sleep disturbance and sleep awakening are included in Figures 6-16 and 6-17. Table 6-21 presents the total sleep disturbance ENI per night as a function of regulatory schedule summed over all land use areas for various years. Table 6-22 shows the percent reduction in potential sleep disturbances brought about by each regulation schedule with reference to the no regulation case.

Table 6-23 shows the total potential sleep awakening ENI occurring per night as a function of regulatory schedule for all land uses. Table 6-24 shows the percent reduction in potential sleep awakenings brought about by each regulation schedule with reference to the no regulation case.

In order to more fully explain the contents of Tables 6-23 and 6-24 an example follows. In Table 6-23, by consulting the year 2000 column, it is found that for regulation schedules 3 and 12 the sleep awakening ENI due to buses are reduced to 27.88 million and 15.52 million per night respectively. Therefore, the relative difference in ENI between the two schedules in the year 2000 is 12.36 million per night. (Regulatory noise levels and dates of implementation for all schedules are shown in Table 6-1.) Table 6-24 indicates the percent reduction from the baseline level, 30.38 million (regulation schedule 1, 1979 shown in Table 6-23). Thus, the 27.88 million ENI value for regulatory schedule 3 from Table 6-23 translates into a 8.23 per cent reduction while the 15.52 million ENI value for regulation schedule 12 translates into a 48.91 per cent reduction from the baseline, a difference of 40.68 per cent between the two schedules. The above procedure can be used to assess the relative differences among any group of regulatory schedules for any of the years shown in the tables. Furthermore, the tables presented throughout this analysis (Section 6) follow the

Table 6-21

Sleep Disturbance ENI Due to Bus Passbys in All Land Use Areas

Sleep Disturbance ENI (Millions Per Night)*

Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0
2	245.13	241.92	239.21	237.09	235.18	233.07	228.49	227.19
3	247.00	245.13	241.92	239.21	237.09	234.38	231.43	229.72
4	247.00	241.83	232.49	224.57	217.77	209.32	199.95	187.42
5	247.00	247.00	241.33	232.49	224.57	214.16	203.38	196.45
6	245.13	238.47	229.76	222.08	215.66	208.01	199.17	187.38
7	245.13	241.92	235.74	227.46	220.83	212.34	202.76	196.39
8	245.13	238.47	229.76	217.80	207.37	194.78	172.65	162.20
9	245.13	241.92	235.40	225.28	214.90	201.11	186.52	174.46
10	245.13	238.47	229.76	218.28	207.12	192.03	165.80	152.43
11	245.13	241.92	235.74	224.49	212.72	197.07	178.75	164.42
12	245.13	238.47	229.76	222.08	207.37	188.86	156.69	140.32
13	245.13	241.92	235.74	227.46	213.08	194.10	169.66	151.49
14	245.13	238.47	229.65	217.80	203.51	185.82	154.39	138.89
15	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99

*Values include potential for multiple disturbances per night for individuals near bus routes

Table 6-22

Percent Reduction in Sleep Disturbance ENI Due to Bus Passbys								
Percent Reduction in Sleep Disturbance ENI								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.76	2.06	3.15	4.01	4.79	5.64	7.49	8.02
3	0.00	0.76	2.06	3.15	4.11	5.11	6.30	7.00
4	0.00	2.09	5.88	9.08	11.84	15.26	19.05	24.12
5	0.00	0.00	2.09	5.88	9.08	13.08	17.66	20.46
6	0.76	3.45	6.98	10.09	12.69	15.79	19.36	24.14
7	0.76	2.06	4.56	7.91	10.60	14.03	17.91	19.64
8	0.76	3.45	6.98	11.82	16.05	21.14	30.10	34.33
9	0.76	2.06	4.56	8.79	13.00	18.58	24.49	29.37
10	0.76	3.45	6.98	11.22	16.15	22.26	32.87	38.29
11	0.76	2.06	4.56	9.12	13.88	20.21	27.63	33.43
12	0.76	3.45	6.98	10.09	16.05	23.54	36.57	43.19
13	0.76	2.06	4.56	7.91	13.73	21.42	31.31	38.67
14	0.76	3.45	6.98	11.82	17.61	24.77	37.50	43.77
15	97.17	97.17	97.17	97.17	97.17	97.17	97.17	97.17

Table 6-23

Sleep Awakening ENI Due to Bus Passbys in All Land Use Areas								
Sleep Awakening ENI (Millions per Night)								
Exterior Regulation Schedule	Calandar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	30.38	30.38	30.38	30.38	30.38	30.38	30.38	30.38
2	30.11	29.65	29.25	28.95	28.67	28.37	27.76	27.54
3	30.36	30.11	29.65	29.25	28.95	28.55	28.13	27.88
4	30.38	29.48	27.89	26.57	25.47	24.11	22.63	21.20
5	30.38	30.38	29.48	27.89	26.57	24.97	23.16	22.19
6	30.11	29.00	27.50	26.21	25.17	23.95	22.53	21.19
7	30.11	29.65	28.60	27.18	26.07	24.67	23.08	22.17
8	30.11	29.00	27.50	25.45	23.75	21.99	19.38	18.19
9	30.11	29.65	28.60	27.18	26.07	24.67	23.08	22.43
10	30.11	29.00	27.50	25.72	23.70	21.64	18.62	17.11
11	30.11	29.65	28.60	26.63	24.64	22.29	20.02	18.37
12	30.11	29.00	27.50	26.21	23.75	21.23	17.57	15.52
13	30.11	29.65	28.60	27.18	24.70	21.91	19.00	16.80
14	30.11	29.00	27.50	25.45	23.11	20.84	17.30	15.34
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-24

Percent Reduction in Sleep Awakening ENI Due to Bus Passbys								
Percent Reduction in Sleep Awakening ENI								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.91	2.42	3.72	4.71	5.64	6.63	8.63	9.37
3	0.00	0.91	2.42	3.72	4.71	6.02	7.41	8.23
4	0.00	2.96	8.21	12.55	16.19	20.63	25.52	30.24
5	0.00	0.00	2.96	8.21	12.55	17.81	23.78	26.95
6	0.91	4.57	9.48	13.72	17.16	21.22	25.85	30.26
7	0.91	2.42	5.86	10.55	14.21	18.81	24.04	27.02
8	0.91	4.57	9.48	16.23	21.85	27.62	36.23	40.12
9	0.91	2.42	5.86	11.88	17.66	25.00	31.19	35.73
10	0.91	4.57	9.48	15.36	21.98	28.78	38.72	43.70
11	0.91	2.42	5.86	12.36	18.90	26.64	34.09	39.53
12	0.91	4.57	9.48	13.72	21.85	30.12	42.18	48.91
13	0.91	2.42	5.86	10.55	18.70	27.90	37.48	44.72
14	0.91	4.57	9.48	16.23	23.95	31.40	43.06	49.53
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

same general pattern as Tables 6-23 and 6-24 for all exterior bus noise ENI calculations and all interior bus noise ENI calculations. The only major difference is that in the case of interior bus noise ENI, Table 6-2 should be consulted for the interior bus noise regulatory levels and their respective implementation dates.

The potential equivalent number of sleep disturbances and sleep awakenings categorized by bus type (transit, intercity) and land use are presented in Appendix F (Tables F-24 through F-35).

The data presented in this section and in Appendix F concerning reductions in potential sleep disturbances and sleep awakenings are measures of people times events. One person impacted (e.g., awakened) 10 times is equivalent to 10 people being impacted one time each.

It should also be noted that the individual bus passby noise impact analysis examines the effects of reducing bus noise alone, and hence does not take into account the presence of other noise sources in the environment. It is obvious that other environmental noise sources create background noise over which in many situations bus noise will not intrude. The benefits presented in this analysis represent the benefits accrued during those times when the bus noise clearly intrudes over an ambient level. The absolute sleep disturbance and sleep awakening impact attributable to buses is dependent, of course, on the background level assumed. However, the per cent reduction of ENI (Tables 6-22 and 6-24) is representative of the relative reduction of bus noise impact over <u>any</u> given ambient level. For a more precise description of the absolute number of people impacted by nighttime bus noise, computer plots are presented in Appendix F (Figures F-1 through F-8) showing, for each of the study years, the number of people exposed to various bands of noise measured in terms of the SEL inside their homes for each regulatory schedule.

Additional analyses are underway to examine the absolute impact of individual bus passbys assuming various background noise levels.

6.3.2 Speech Interference

Unlike the disruption of sleep, the interference of speech, i.e., conversation, occurs when people are both indoors and outdoors. For the purposes of this analysis, it was assumed that virtually all conversation takes place during the daytime hours; thus, only "daytime" (7 a.m. to 10 p.m.) bus operations were considered to contribute to speech disruptions, whereas only "nighttime" operations were considered to contribute to the disruption of sleep. This assumption pertains to all types of buses in the speech impact analysis.

People can have their conversation disrupted by externally propagating bus noise in at least three major settings during the day: as pedestrians on the street, as residents inside their homes, or as residents who are involved in leisurely activity just outside their homes. Three different approaches are required to assess the impact of these three different situations. Each approach will be examined separately. In the discussions that follow, "inside the home" and "outside the home" should be taken to mean, respectively, "inside any building" and "outside any building but not along a street."

6.3.2.1 Pedestrian Speech Interference

Approximately 149 million people live in urban areas of the United States according to the 1970 census.[24] Extensive information on pedestrian travel is not available to estimate the portion of the urban population which experiences bus noise as a pedestrian. However, for the purposes of this discussion, a rough estimate of one-half mile of travel per person per day may be assumed. A large fraction of the population is probably too old or too young to walk even a tenth of this value per day. Yet many healthy urbanites of young or middle age may walk as much as a mile or more each day. Bus stops are typically spaced 1/2 mile apart.[45] The average distance from a person's house stationed along a bus route to the nearest bus stop is then about 1/8 mile. An average bus passenger thus walks a total of 1/2 mile each day going to and from the bus stop at which the passenger alights. For people who do not ride buses, a 1/2 mile per day average walk would be equivalent to driving to work in a car and walking two blocks (1/8 mile each) to and from a restaurant for lunch. This walk may be assumed to take place along main streets, and therefore these people are also exposed to bus noise.

Table 6-25 gives the step-by-step rationale for the derivation of the number of pedestrians exposed to bus noise used in this analysis.

From the point of view of the pedestrian, two average maximum passby levels are considered to occur for each bus type: (1) the level measured when the bus is passing by on the same side of the street as the pedestrian (10 to 15 feet away), and (2) the level measured when the bus passes by on the opposite side (60 to 75 feet away). The exposure level occurring in the first case can be estimated from data on transit bus levels at 3 feet.[52] Under the acceleration mode a maximum passby level of 97 dB is reported. This level represents approximately a 4 dB increase per halving of distance from the average acceleration level

Table 6-25

Derivation of the Number of Equivalent Pedestrian-Impacts Due to the Disruption of Speech by Bus Passby Noise

	Transit	School	Inter-City	Derivation
1. Daytime Vehicle Miles Traveled on Urban Streets (Millions per Year, 1973)	1450	478	25	Reference 1
2. Vehicle Miles Per Day Per Street Mile	8.28	2.73	.14	(1) ÷ (480,000 St. Miles) ÷ (365 Days)
3. Pedestrian Miles Traveled Per Day on Urban Streets		40,000,000		(80 Million Workers)* x (1/2 Mile/Day Walk Per Worker)
4. Pedestrian/Street Mile		1.85		(3) ÷ (480,000 St. Miles) ÷ (3 mph Pedestrian Velocity ÷ (15 Hours/Day
5. Pedestrian-Impact Events Per Street Mile Per Day	15.3	5.05	.26	(2) x (4)
6. Average Fractional Speech Impact	.68	.52	.81	From Table 6-26
7. Equivalent Impacts (millions per day)	5.0	1.3	.1	(5) x (6) x (480,000 St. Miles)

*Employed non-agricultural civilians in 1973.[24]

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at 50 feet of about 81 dB. Assuming the same attenuation figure can be applied to the noise levels produced under other operational modes as well, the average maximum passby levels can be computed for buses on either side of the street. The estimated values are given in Table 6-26.

The criteria for outdoor speech interference is shown in Figure 6-18 as a function of the level of an interfering noise. (Note that the appropriate noise metric for the criteria is an L_{eq} occurring for the duration of the passby, rather than the SEL of the event.) The ENI speech for pedestrians is obtained by finding the fractional impact produced by the average passby level of each bus type (Table 6-26) and multiplying by the number of pedestrians impacted (Table 6-25). Reductions of bus levels measured at 50 feet were assumed to yield equal reductions in levels measured at the distances from the bus at which pedestrians are exposed. The effect of various regulations on the predicted equivalent number of pedestrians impacted by bus noise interfering with speech is given in Table 6-27. The percent reduction in ENI is given in Table 6-28.

6.3.2.2 Residential Speech Interference

The interference of conversation between people located in or near their homes involves both indoor and outdoor situations. For the outdoor case, the same criteria used in the pedestrian impact analysis was again utilized. In this case, however, disruptions only occur beyond 40-90 feet from the bus, depending on land use, and they are measured out to the point where the bus passby level is equal to the background level. In this assessment, an outdoor cutoff background level of 55 dB, and an indoor cutoff level of 45 dB are used. Although

Table 6-26

Average Maximum Passby Levels to Which Pedestrians Are Exposed and Fractional Speech Impact, by Bus Type and Location of Passby			
Location of Passby	Bus Type		
	Transit	School	Inter-City
	Average Maximum Passby Level (dBA)		
Bus on Same Side of Street as Pedestrian	81.6	80.4*	85.5
Bus on Opposite Side of Street	74.0	71.3*	77.0
	Fractional Speech Impact**		
Bus on Same Side of Street	1.0	.94	1.0
Bus on Opposite Side of Street	.35	.10	.62
Arithmetic Average	.68	.52	.81

*Levels weighted 97 percent gas-powered, 3 percent diesel-powered school buses.[14]

**From Figure 6-18. Six dB is added to the x-axis legend to account for a halving of the speaker-listener distance to 1 meter.

Table 6-27

Speech Interference ENI Due to Bus Passbys for Pedestrians								
Speech Interference ENI (Millions Per Day)								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
2	2.42	2.40	2.37	2.36	2.34	2.33	2.31	2.30
3	2.44	2.42	2.40	2.37	2.36	2.34	2.32	2.31
4	2.44	2.38	2.28	2.20	2.13	2.03	1.93	1.85
5	2.44	2.44	2.33	2.28	2.20	2.09	1.97	1.89
6	2.42	2.35	2.26	2.18	2.11	2.03	1.92	1.84
7	2.42	2.40	2.33	2.24	2.17	2.08	1.97	1.90
8	2.42	2.35	2.26	2.12	2.00	1.85	1.66	1.54
9	2.42	2.40	2.33	2.22	2.10	1.93	1.73	1.60
10	2.42	2.36	2.26	2.14	2.00	1.82	1.58	1.42
11	2.42	2.40	2.33	2.21	2.07	1.88	1.64	1.48
12	2.42	2.36	2.26	2.18	2.00	1.77	1.46	1.24
13	2.42	2.40	2.33	2.24	2.07	1.84	1.53	1.30
14	2.42	2.35	2.26	2.12	1.95	1.73	1.41	1.20
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-28

Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.62	1.64	2.53	3.16	3.76	4.38	5.25	5.74
3	0.00	0.62	1.64	2.53	3.16	4.00	4.88	5.38
4	0.00	2.26	6.37	9.87	12.78	16.51	20.77	23.87
5	0.00	0.00	2.26	6.37	9.82	14.13	19.17	22.48
6	0.62	3.38	7.22	10.63	13.52	16.80	21.31	24.59
7	0.62	1.65	4.26	7.93	10.86	14.66	19.13	22.04
8	0.62	3.38	7.22	12.86	17.82	23.95	31.94	36.97
9	0.62	1.65	4.26	9.07	13.96	20.61	28.86	34.33
10	0.58	3.29	7.15	12.06	17.93	25.41	35.30	41.58
11	0.62	1.65	4.26	9.48	15.10	22.77	32.72	39.39
12	0.62	3.38	7.22	10.63	17.82	27.16	40.12	48.96
13	0.62	1.65	4.26	7.93	14.91	24.36	37.07	46.52
14	0.62	3.38	7.22	12.86	20.01	29.19	41.98	50.82
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Percent Reduction in Speech Interference ENI Due to Bus Passbys for Pedestrians

Percent Reduction in Equivalent Number of Speech Interferences

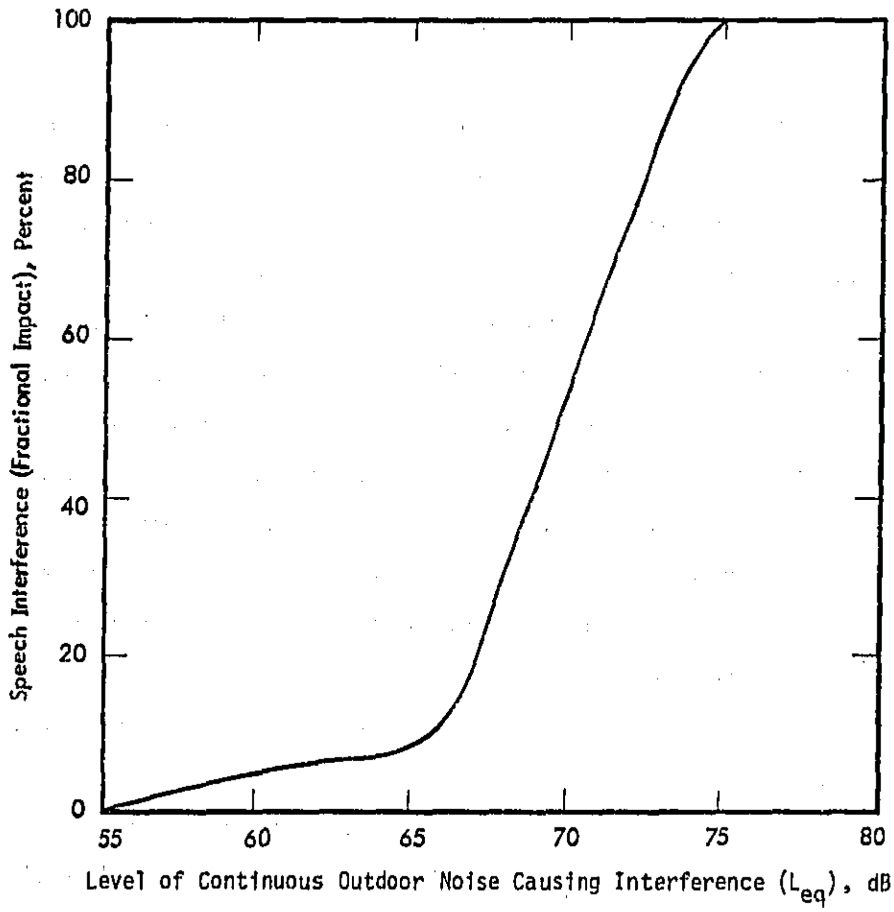

Figure 6-18. Fractional Impact Criteria of Outdoor Speech Interference[8] (Normal Voice at 2 Meters)

average urban ambient noise (L_{dn}) tends to be about 5 dB greater than the assumed outdoor background level, a concerted effort to reduce motor vehicle noise in the future would make the 55 dB level a more appropriate figure to use for this analysis.

Propagation loss is computed for each land use category in the same manner as was discussed in Part 6.3.1. First, the distances from the road at which the passby noise levels fall off in 5 dB steps are computed. Then the number of "people" per mile living within each band is derived. Finally, the relative impact is fractionally calculated using the criteria shown in Figure 6-18. This number is multiplied by the number of bus miles traveled during the time in which people are estimated to be outdoors each day (.4 hours, i.e., 2.7 percent of the day)[33] to give the total ENI due to outdoor speech interference.

The potential ENI for outdoor speech interferences per day is given in Table 6-29 for the 15 regulatory schedules. The reductions in ENI obtained with these regulations are tabulated in Table 6-30. It should be noted that "people outdoors" does not include pedestrians, or people engaged in other forms of transportation during the day. Rather it is intended to include those time-periods in which people are relaxing outdoors - either outside a home, business, or cultural institution.

Indoor speech interference is assumed to occur when bus noise propagates through walls of residences or buildings and remains above a typical indoor background level of 45 dB. The criteria of impact for indoor speech interference is given in Figure 6-19. The curve is based on the reduction of sentence intelligibility relative to the intelligibility

Table 6-29

Speech Interference ENI Due to Bus Passbys for People Outdoors								
Speech Interferences ENI (Millions Per Day)								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11
2	13.00	12.82	12.66	12.55	12.44	12.31	12.14	12.05
3	13.11	13.00	12.82	12.66	12.55	12.39	12.22	12.13
4	13.11	12.71	11.98	10.15	9.53	9.02	8.56	8.13
5	13.11	13.11	12.71	11.98	10.15	9.27	8.73	8.39
6	13.00	12.51	11.83	9.97	9.39	8.97	8.52	8.10
7	13.00	12.82	12.36	11.70	9.92	9.21	8.70	8.37
8	13.00	12.51	11.83	9.52	8.88	8.25	7.26	6.74
9	13.00	12.82	12.36	10.30	9.29	8.59	7.76	7.10
10	13.00	12.51	11.83	9.68	8.87	8.09	6.91	6.24
11	13.00	12.82	12.36	10.22	9.17	8.37	7.31	6.58
12	13.00	12.51	11.83	9.97	8.88	7.92	6.42	5.49
13	13.00	12.82	12.36	11.70	9.19	8.21	6.85	5.84
14	13.00	12.51	11.83	9.52	8.67	7.74	6.28	5.39
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-30

Percent Reduction Speech Interference ENI Due to Bus Passbys for People Outdoors								
Percent Reduction in Speech Interference ENI								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.85	2.21	3.39	4.27	5.11	6.09	7.42	8.08
3	0.00	0.85	2.21	3.39	4.27	5.45	6.78	7.49
4	0.00	3.05	8.57	22.57	27.26	31.22	34.69	37.95
5	0.00	0.00	3.05	8.57	22.57	29.25	33.39	36.03
6	0.85	4.54	9.74	23.94	28.33	31.56	34.97	38.22
7	0.85	2.21	5.72	10.74	24.31	29.76	33.64	36.16
8	0.85	4.54	9.74	27.39	32.22	37.09	44.64	48.60
9	0.85	2.21	5.72	21.42	29.09	34.45	40.76	45.80
10	0.85	4.54	9.74	26.17	32.31	38.24	47.29	52.40
11	0.85	2.21	5.72	22.06	30.01	36.14	44.23	49.83
12	0.85	4.54	9.74	23.94	32.22	39.59	50.99	58.11
13	0.85	2.21	5.72	10.74	29.86	37.38	47.76	55.42
14	0.85	4.54	9.74	27.39	33.83	40.92	52.06	58.89
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

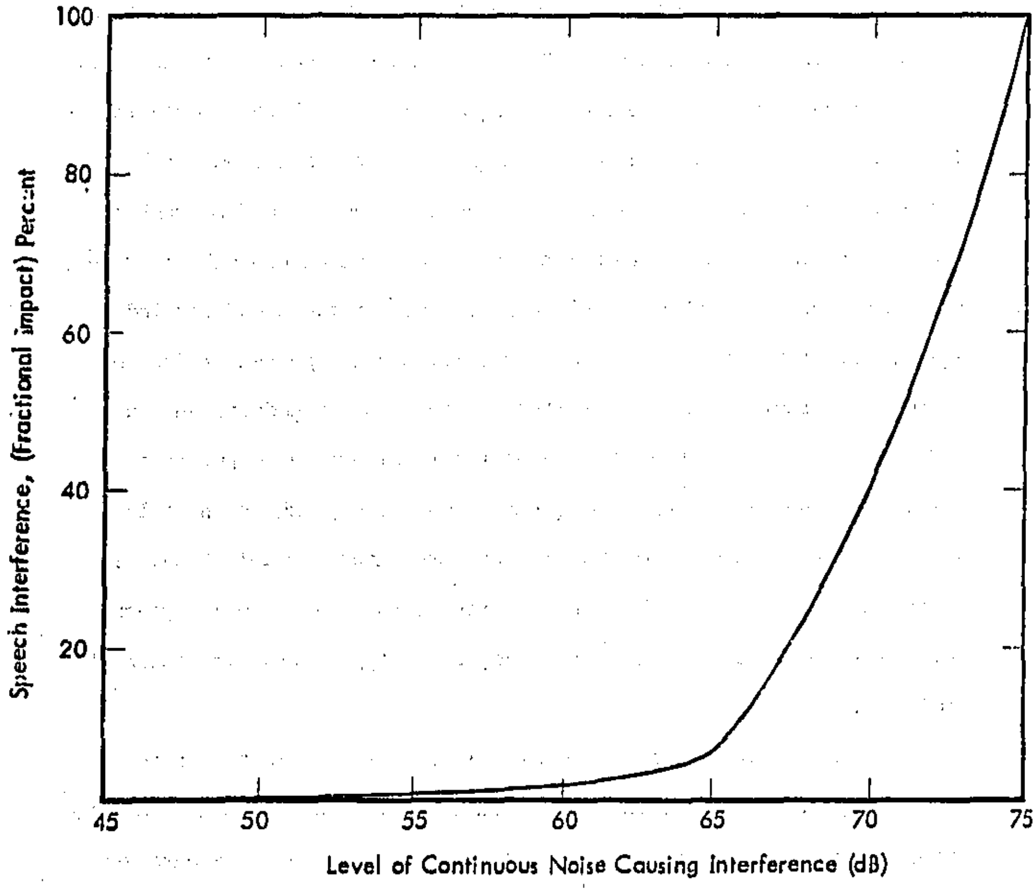

Figure 6-19. Fractional Impact of Indoor Speech Interference[8] (Relaxed Conversation at Greater Than 1 Meter Separation, 45 dB Background in the Absence of Interfering Noise.)

which would occur at 45 dB. If people are conversing indoors during the time a bus is passing by, the probability of a disruption in communication is given by Figure 6-19. Before the fractional impact is computed, the same reductions in the passby levels due to transmission through walls which were used in Part 6.3.1 must be taken into account. During times when buses are not passing by, no bus-related speech interference occurs. It is estimated that people spend an average of 13 daytime hours inside each day, i.e., they spend about 86.7 percent of the day inside.[33] Taking this fraction of the daytime bus vehicle-miles, we can compute the indoor speech impact. The estimated ENI for indoor speech interference is given in Table 6-31, and the percent reduction is given in Table 6-32. Adding these impacts to the pedestrian and outdoor impacts described above gives the total estimated potential ENI due to the interference of speech by bus passbys shown in Table 6-33. The associated percent reductions are shown in Table 6-34. In Appendix F, Tables F-36 through F-38 present the reduction in speech interference ENI categorized by the major bus types (transit, intercity and school).

The actual levels to which people are exposed in the areas of speech impact described above are of interest for analyzing the daytime effects of bus passby noise. Appendix F contains figures (Figure F-9 through F-16) which show the average maximum passby levels to which the daytime population of pedestrians, people indoors, and people located outdoors are exposed. Each graph is a plot of the distribution of population by exposure level for a given year. Again, the differences become more noticeable as the years progress.

Table 6-31

Speech Interference ENI Due to Bus Passbys for People Indoors								
Speech Interference ENI (Millions Per Day)								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
7	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
9	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
10	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
12	0.81	0.01	0.01	0.01	0.01	0.01	0.00	0.00
13	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
14	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-32

Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2.39	6.44	11.27	15.49	19.14	23.76	40.00	49.56
3	0.00	2.39	6.94	11.27	15.49	20.79	35.48	41.74
4	0.00	3.43	10.12	17.32	24.13	33.17	50.39	80.07
5	0.00	0.00	3.43	10.12	17.32	27.30	45.05	76.05
6	2.39	7.97	15.23	22.06	28.51	36.96	51.90	80.55
7	2.39	6.94	12.70	19.77	26.34	38.14	50.98	78.74
8	2.39	7.97	15.23	23.26	30.89	41.36	80.45	82.82
9	2.39	6.94	12.70	20.31	28.07	38.90	78.80	80.89
10	2.39	7.97	15.23	22.87	30.94	42.38	81.02	83.51
11	2.39	6.94	12.70	20.53	28.72	40.29	80.75	82.07
12	2.39	7.97	15.23	22.06	30.89	43.50	81.85	84.58
13	2.39	6.94	12.70	19.77	28.62	41.36	82.60	84.10
14	2.39	7.97	15.23	23.26	31.97	49.95	81.48	84.70
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Percent Reduction in Speech Interference ENI Due to Bus Passbys for People Indoors

Percent Reduction in Speech Interference ENI

Table 6-33

Speech Interference ENI Due to Bus Passbys for Pedestrians, People Indoors, and People Outdoors								
Speech Interference ENI (Millions Per Day)								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	15.55	15.55	15.55	15.55	15.55	15.55	15.55	15.55
2	15.43	15.22	15.05	14.92	14.79	14.65	14.45	14.35
3	15.55	15.43	15.22	15.05	14.92	14.74	14.54	14.44
4	15.55	15.10	14.28	12.36	11.67	11.06	10.50	9.99
5	15.55	15.55	15.10	14.28	12.36	11.37	10.71	10.28
6	15.43	14.88	14.10	12.16	11.51	11.00	10.45	9.96
7	15.43	15.22	14.70	13.95	12.10	11.29	10.70	10.27
8	15.43	14.88	14.10	11.65	10.89	10.10	8.92	8.27
9	15.43	15.22	14.70	12.52	11.40	10.53	9.50	8.71
10	15.43	14.88	14.10	11.83	10.88	9.92	8.49	7.66
11	15.43	15.22	14.70	12.43	11.25	10.26	8.95	8.06
12	15.43	14.88	14.10	12.16	10.89	9.70	7.88	6.74
13	15.43	15.27	14.70	13.45	11.27	10.06	8.39	7.15
14	15.43	14.88	14.10	11.65	10.63	9.47	7.70	6.59
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-34

Percent Reduction in Speech Interference ENI Due to Bus Passbys for Pedestrians, People Indoors, and People Outdoors								
Percent Reduction in Speech Interference ENI								
Exterior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.82	2.13	3.20	4.10	4.91	5.84	7.10	7.74
3	0.00	0.82	2.13	3.26	4.10	5.23	6.50	7.17
4	0.00	2.93	8.22	20.57	24.99	28.92	32.35	35.77
5	0.00	0.00	2.93	8.22	20.57	26.88	31.17	33.92
6	0.82	4.36	9.35	21.85	26.00	29.26	32.81	35.95
7	0.82	2.13	5.49	10.30	22.20	27.40	31.20	33.95
8	0.82	4.36	9.35	25.11	29.97	35.04	42.67	46.80
9	0.82	2.13	5.49	19.49	26.72	32.29	38.89	44.00
10	0.82	4.36	9.35	23.96	30.06	36.23	45.43	50.73
11	0.82	2.13	5.49	20.09	27.68	34.04	42.43	48.20
12	0.82	4.36	9.35	21.85	29.97	37.64	49.31	56.70
13	0.82	2.13	5.49	10.30	27.52	36.34	46.08	54.02
14	0.82	4.36	9.35	25.11	31.66	39.09	50.50	57.65
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

6.4 REDUCTION OF INTERIOR NOISE IMPACT

Interior bus noise affects primarily two population groups; bus operators and bus passengers. Transit and inter-city bus operators tend to spend more time each day driving their buses than school bus operators since school transportation is usually only required during the opening and closing hours of school. Typical passenger exposure times are also different for each bus type. Inter-city passengers tend to take infrequent but long trips, whereas short but recurrent trips are characteristic of transit and school bus passengers. Two kinds of impact may be associated with interior bus noise: the impact on hearing for bus operators and passengers, and the disturbance of conversation of bus passengers. These impacts are discussed in the following section along with the reductions which are obtainable with the interior regulation schedules (Table 6-2).

6.4.1 Hearing Loss Reduction

Average exposure levels measured in the driver's position and in the rear of the bus have been given in Tables 6-7 and 6-8. Since these levels are averages, an accurate description of the effects of interior bus noise must include an assessment of those buses which are much noisier than these levels may suggest. Based on data from EPA studies, interior noise levels have a standard deviation of about 2 dB for buses of the same bus type.[15] If the distribution is normal, buses producing an average interior noise level of L are distributed about L as follows:[18]

Level (dB)	L - 4	L - 2	L	L + 2	L + 4
Percent (%)	6.6	24.2	38.4	24.2	6.6

Although it is possible that some bus operators and passengers are exposed to a variety of bus levels and therefore receive the <u>average</u> noise exposure for a given type of bus over a long period of time, in many cases passengers and operators may receive higher-than-average or lower-than-average exposures. This would be the case if a school system were to purchase only one type of bus for its operations, for instance, or if bus operators were assigned particular buses for long periods of time.

The distribution of people about an average interior bus noise level may be estimated in this way for both front and rear seat locations. Lacking information to the contrary, it may be assumed that half of the population riding buses of a given type (transit, school, etc.) receive front seat exposure levels and half receive rear seat exposures, i.e., half ride in the rear of the bus and half ride in the front. In the case where the engine is located in the middle of the bus and middle seats receive the loudest exposure levels, as occurs with mid-engine diesel-powered school buses, the distribution of people by exposure level will again be broken down into two equal groups - those receiving an average middle seat exposure level and those receiving an average of the front and rear seat exposure levels.

The reduction in the acceleration test interior noise levels measured near the engine due to the regulation of interior noise is calculated in much the same manner as the exterior noise situation, using the HINCSAM program.[33] These reductions are again assumed to yield equal reductions in the acceleration levels measured under actual operating conditions. The reduction of deceleration and cruise levels are taken from Figure 6-3. Interior noise levels produced in the idling mode are again expected to remain constant and unaffected by the regulation. With these assumptions, the calculations of the new average interior noise levels are made for each regulation and study year for the front and rear seat locations.

The total number of operators and passengers riding each type of bus is given in Table 6-35. To find the equivalent noise impact on hearing (ENIH) applicable to each population group the following fractionalization equation is used:[13]

$$FIH = 0.025\ (L_{eq(24)} - 70)^2 \qquad (14)$$

where

FIH is the representative Noise Induced Permanent Hearing Threshold Shift (NIPTS) expected over a 40-year exposure period averaged over the .5, 1, 2, and 4 kilo hertz frequency bands

and

$L_{eq(24)}$ is the equivalent continuous sound level experienced by the bus operator or passenger over typical 24-hour periods.

To estimate the $L_{eq(24)}$ of the bus-riding population it is necessary to ascertain the exposure levels received while off the bus. While some data has been collected in this regard for workers in manufacturing industries, very little data is available which would enable an accurate prediction of the average daily exposures experienced by the great majority of the population. In order to proceed with the estimate of $L_{eq(24)}$ therefore, three non-bus exposures have been chosen in order to

Table 6-35

Statistics of Bus Operators and Passengers
Estimated for Each Bus Type

Bus Type	Drivers (thousands)	Passengers (miles/day)
Transit	80 (1)	8.3 (4)
School - Gas	290 (2)	23.0 (5)
School - Diesel	10 (2)	.7 (5)
Inter-city	24 (3)	1.1 (6)

(1) $\frac{(1.545 \times 10^{9} \text{ vehicle miles/yr})}{(15 \text{ miles/hr})} \times ((6 \text{ work hours/day}) \times (225 \text{ work days/yr}))$

(2) Assuming approximately one driver per bus. Gas/Diesel breakdown from Ref. 14.

(3) Estimate based on extrapolation from Class I carrier data in Ref. 27.

(4) Assuming 2 trips per day. Total from Ref. 28.

(5) Ref. 28. Gas/Diesel breakdown from Ref. 14.

(6) Ref. 27.

cover the possible range of values which may occur: 60 dB, 70 dB, and 80 dB. The $L_{eq}(24)$ is then calculated using the following formula:

$$L_{eq(24)} = 10 \log \frac{t_b}{24} 10^{L_b/10} + \frac{24-t_b}{24} 10^{L_n/10} \qquad (15)$$

where

t_b is the time spend on the bus per day

$24-t_b$ is the time spent off the bus per day

L_b is the average level of interior bus noise

L_n is the level of non-bus exposure

Exposure times for operators and passengers are derived in Table 6-36 for each bus type.

Once $L_{eq}(24)$ is calculated for a given interior noise level and FIH is thereby defined, the estimated ENIH is found by the formula:[13]

$$ENIH = \sum FIH \cdot P$$

where

P is the population exposed

The impact of bus noise on potential hearing loss is estimated for each regulation schedule and assumed non-bus exposure level. Table 6-37 shows the ENIH for bus <u>operators</u> assuming they are exposed to an energy-average level of 60 dB during the time they are not driving buses. Table 6-38 shows the percent reduction from the baseline case (regulatory schedule 1) that each regulation would accomplish. Note that for regulation 15, interior bus noise is set to an arbitrary health and welfare level of 55 dB. Table 6-39 shows the ENIH for operators which would occur if their non-bus driving exposure were 70 dB, and Table 6-40 shows

Table 6-36

Duration of Daily Noise Exposure Experienced by Operators and Passengers, by Bus Type						
Exposure Per Day (Hours)						
Operator			Passenger			
T	S	I	T	S	I	Basis For Estimate
2	2	4	2	2	4	Reference 2
8	8	8	-	-	-	Assuming a full work day
-	1-2	-	-	1-2	-	Derived below(1)
-	-	-	-	-	1-2	Derived below(2)
-	-	5-6	-	-	-	Derived below(3)
6	2	6	2	2	2	Assumed for this report

Key
T Transit S School I Inter-City

(1) $\frac{\text{(2 bil bus miles/yr} \div \text{(15 - 30 mph)}}{\text{330,000 buses)} \times \text{(180 school days/yr)}}$

= 1 - 2 hours/operator or passenger/day

(2) $\frac{\text{(25.6 billion revenue passenger miles/yr)} \div \text{(30 - 50 mph)}}{\text{(0.4 billion revenue passengers/yr)}}$

= 1 - 2 hours/passenger/day

(3) $\frac{\text{(1.2 billion bus miles/yr)} \div \text{(40 mph)}}{\text{(24,000 operators)} \times \text{(225 work days/yr)}}$

= 5 - 6 hours/operator/day

Table 6-37

Hearing Loss ENI Caused By Noise Inside Buses Assuming a Non-Bus Exposure of 60 dB - Bus Operators								
Hearing Loss ENI (Thousands)								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	11.66	11.66	11.66	11.66	11.66	11.66	11.66	11.66
2	11.25	10.54	10.04	9.73	9.45	9.18	8.84	8.70
3	10.47	8.65	7.26	6.32	5.65	4.99	4.32	4.02
4	11.66	9.96	7.31	5.59	4.48	3.56	2.77	2.38
5	11.25	9.29	6.93	5.33	4.34	3.49	2.75	2.36
6	11.25	9.29	5.79	3.31	1.98	0.87	0.84	0.21
7	11.25	9.29	6.92	3.82	2.31	1.04	0.87	0.22
8	10.47	8.65	5.75	3.29	1.98	0.87	0.84	0.21
9	11.25	10.54	9.38	6.23	3.50	1.63	0.80	0.22
10	11.25	10.54	8.83	5.58	3.21	1.48	0.86	0.22
11	11.25	9.29	5.79	3.31	1.63	0.40	0.11	0.08
12	11.25	9.29	6.93	3.85	1.93	0.51	0.11	0.08
13	10.47	8.65	5.75	3.29	1.63	0.40	0.11	0.08
14	11.25	9.29	6.93	3.75	1.93	0.51	0.11	0.08
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-38

Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3.57	9.62	13.92	16.58	18.97	21.29	29.20	25.37
3	10.21	25.84	37.73	45.80	51.55	57.20	62.95	65.53
4	0.00	14.60	37.29	52.05	61.57	69.47	76.22	79.55
5	3.57	20.38	40.58	54.26	62.79	70.11	76.44	79.75
6	3.57	20.38	50.31	71.59	32.99	92.53	92.80	98.18
7	3.57	20.38	40.68	67.26	80.19	91.10	92.54	98.10
8	10.21	25.84	50.72	71.76	83.00	92.53	92.80	98.18
9	3.57	9.62	19.55	46.61	69.96	86.02	93.14	98.15
10	3.57	9.62	24.31	52.13	72.51	87.27	92.62	98.15
11	3.57	20.38	50.31	71.59	86.03	96.61	99.06	99.30
12	3.57	20.38	40.58	67.00	83.43	95.64	99.04	99.29
13	10.21	25.84	50.72	71.76	86.04	96.61	99.06	99.30
14	3.57	20.38	40.58	67.81	83.43	95.64	99.04	99.29
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Percent Reduction in Hearing Loss ENI Due to Noise Inside Buses for Average Non-Bus Exposure of 60 dB - Bus Operators

Percent Reduction in Hearing Loss ENI

Table 6-39

Hearing Loss ENI Caused by Noise Inside Buses Assuming a Non-Bus Exposure of 70 dB - Bus Operators								
Hearing Loss ENI (Thousands)								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	56.76	56.76	56.76	56.76	56.76	56.76	56.76	56.76
2	55.94	54.54	53.41	52.62	51.88	51.13	50.19	49.71
3	54.37	50.38	47.05	44.46	42.46	40.20	37.59	36.19
4	56.76	53.32	47.40	42.80	39.11	35.05	30.62	28.16
5	55.94	51.89	46.40	41.90	38.46	34.59	30.37	28.02
6	55.94	51.89	43.62	34.92	28.27	21.09	14.17	10.54
7	55.94	51.89	46.38	36.90	29.83	22.12	14.68	10.84
8	54.37	50.38	43.36	34.70	28.09	20.99	14.06	10.52
9	55.94	54.54	51.94	44.59	35.60	25.99	16.65	11.84
10	55.94	54.51	50.81	42.87	34.31	25.11	16.20	11.61
11	55.94	51.89	43.62	34.92	26.52	17.77	9.71	5.95
12	55.94	51.89	46.40	37.03	28.11	18.77	10.17	6.15
13	54.39	50.38	43.36	34.70	26.16	17.68	9.67	5.91
14	55.94	51.89	46.40	35.99	26.82	17.35	8.77	4.90
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-40

Percent Reduction in Hearing Loss ENI Due to Noise Inside Buses for Average Non-Bus Exposure of 70 dB - Bus Operators								
Percent Reduction in Hearing Loss ENI								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.44	3.91	5.89	7.28	8.59	9.92	11.56	12.41
3	4.20	11.24	17.09	21.66	25.18	29.18	33.77	36.24
4	0.00	6.05	16.47	24.59	31.08	38.25	46.05	50.39
5	1.44	8.58	18.26	26.17	32.24	39.06	40.49	50.63
6	1.44	8.58	23.14	38.47	50.19	62.84	75.03	81.43
7	1.44	8.58	18.31	34.98	47.45	61.03	74.15	80.90
8	4.20	11.24	23.61	38.86	50.51	63.02	75.23	81.47
9	1.44	3.91	8.48	21.43	37.28	54.22	70.66	79.14
10	1.44	3.91	10.48	24.47	39.55	55.77	71.46	79.54
11	1.44	8.58	23.14	38.47	53.28	68.69	82.90	89.51
12	1.44	8.58	18.26	34.76	50.48	66.93	82.09	89.16
13	4.20	11.24	23.61	38.86	53.59	68.86	82.97	89.59
14	1.44	8.58	18.26	36.63	52.75	69.44	84.55	91.37
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

the resulting percent reduction. Tables 6-41 and 6-42 show the comparable ENIH and percent reduction respectively, for an operator non-bus exposure of 80 dB. Tables 6-43 through 6-48 show the ENIH and percent reduction for the same three non-bus exposure levels for bus passengers. Appendix F (Table F-39) contains a percentage breakdown of the contribution to hearing loss impacts for each major bus type considered in the analysis.

The distribution of bus operators by interior bus exposure level (level experienced independent of the time of exposure) is presented in Appendix F (figures F-17 though F-34). From these figures it is clear that in the year 1979 there is very little difference between the regulations except for the ideally protective level (55 dBA) regulation number 15, which is assumed to be implemented and complied with immediately by all buses. As the years progress, however, a shift is noticeable from the higher to the lower noise bands. Appendix F also contains figures (Figures F-25 thgough F-32) showing the distribution of bus passengers by interior bus exposure level which display the noise band shift again becoming more noticeable as the years progress.

6.4.2 Speech Interference Reduction

Interior bus noise has a second impact on people which must be considered - the interference with speech. The implications of speech interference for passengers are perhaps not too great. A conversation may be interrupted for a few seconds as the bus accelerates, for instance, or a few words may be missed. On the other hand, the interruption of speech between passengers and the driver during an emergency situation may have critical implications. A school bus driver should be able to hear a child in need, for example, regardless of the loud commotion that usually occurs on school buses.

Table 6-41

Hearing Loss ENI Caused by Noise Inside Buses Assuming a Non-Bus Exposure of 80 dB - Bus Operators								
Hearing Loss ENI (Thousands)								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	1414.66	1414.66	1414.66	1414.66	1414.66	1414.66	1414.66	1414.66
2	1413.98	1412.79	1411.83	1411.15	1410.49	1409.82	1408.97	1408.52
3	1412.59	1409.07	1406.06	1403.66	1401.77	1399.59	1397.00	1395.57
4	1414.66	1411.65	1406.34	1402.04	1398.48	1394.42	1389.77	1387.06
5	1413.98	1410.43	1405.44	1401.20	1397.86	1393.95	1389.49	1386.90
6	1413.98	1410.43	1402.81	1394.22	1387.13	1378.69	1369.26	1363.43
7	1413.98	1410.43	1405.41	1396.27	1396.27	1379.98	1370.01	1363.94
8	1412.59	1409.07	1402.56	1394.00	1386.93	1378.57	1369.10	1363.40
9	1413.98	1412.79	1410.52	1403.76	1394.94	1384.57	1372.86	1365.62
10	1413.98	1412.79	1409.49	1402.12	1393.61	1384.55	1372.22	1365.25
11	1413.98	1410.43	1402.81	1394.22	1385.14	1374.38	1362.06	1354.51
12	1413.98	1410.43	1405.44	1396.38	1386.95	1375.72	1362.88	1354.98
13	1412.59	1409.07	1402.56	1394.00	1384.95	1374.26	1362.00	1354.42
14	1413.98	1410.43	1405.44	1395.33	1385.56	1373.93	1360.60	1352.34
15	1315.56	1315.5	1315.56	1315.56	1315.56	1315.56	1315.56	1315.56

Table 6-42

Percent Reduction in Hearing Loss ENI Due to Noise Inside Buses for Average Non-Bus Exposure of 80 dB - Bus Operators								
Percent Reduction in Hearing Loss ENI								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.05	0.13	0.20	0.25	0.29	0.34	0.40	0.43
3	0.15	0.39	0.61	0.78	0.91	1.07	1.25	1.35
4	0.00	0.21	0.59	0.89	1.14	1.43	1.76	1.95
5	0.05	0.30	0.65	0.95	1.19	1.46	1.78	1.96
6	0.05	0.30	0.84	1.44	1.95	2.54	3.21	3.62
7	0.05	0.30	0.65	1.30	1.82	2.45	3.16	3.59
8	0.15	0.39	0.85	1.46	1.96	2.55	3.22	3.62
9	0.05	0.13	0.29	0.77	1.39	2.13	2.95	3.47
10	0.05	0.13	0.37	0.89	1.49	2.20	3.00	3.49
11	0.05	0.30	0.84	1.44	2.09	2.85	3.72	4.25
12	0.05	0.30	0.65	1.29	1.96	2.75	3.66	4.22
13	0.15	0.39	0.85	1.46	2.10	2.86	3.72	4.26
14	0.05	0.30	0.65	1.37	2.06	2.88	3.82	4.41
15	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01

Table 6-43

Hearing Loss ENI Caused by Noise Inside Buses Assuming a Non-Bus Exposure of 60 dB - Bus Passengers								
Hearing Loss ENI (Thousands)								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	523.89	523.89	523.89	523.89	523.89	523.89	523.89	523.89
2	510.42	487.89	472.09	462.45	453.94	445.73	435.60	431.56
3	488.42	432.74	389.14	358.37	335.39	311.62	285.15	271.97
4	523.89	473.78	391.67	333.41	290.92	249.00	209.55	190.30
5	510.42	451.78	378.56	324.02	285.21	245.38	208.25	189.17
6	510.42	451.78	340.65	236.65	172.59	112.24	57.36	32.95
7	510.42	451.78	378.56	261.34	187.46	122.12	61.53	34.85
8	488.42	432.74	339.09	235.94	172.48	112.24	56.85	32.95
9	510.42	487.89	453.09	355.43	246.13	154.88	77.23	41.27
10	510.42	487.89	436.94	333.03	231.91	146.69	73.53	39.75
11	510.42	451.78	340.65	236.65	156.27	83.03	26.97	11.33
12	510.42	451.78	378.56	262.21	171.55	91.90	29.49	12.22
13	488.42	432.74	339.09	235.94	156.22	83.03	26.97	11.20
14	510.42	451.78	378.56	258.94	172.31	91.90	29.49	12.22
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-44

Percent Reduction in Hearing Loss Due to Noise Inside Buses for Average Non-Bus Exposure 60 dB - Bus Passengers								
Percent Reduction Hearing Loss ENI								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2.57	6.87	9.89	11.73	13.35	14.92	16.85	17.62
3	6.77	17.40	25.72	31.59	35.98	40.52	45.57	48.09
4	0.00	9.56	25.24	36.36	44.47	52.47	60.00	63.68
5	2.57	13.76	27.74	38.15	45.56	53.16	60.25	63.89
6	2.57	13.76	34.98	54.83	67.06	78.58	89.05	93.71
7	2.57	13.76	27.74	50.12	64.22	76.69	88.26	93.35
8	6.77	17.40	35.27	54.96	67.08	78.58	89.15	93.71
9	2.57	6.87	13.51	32.16	53.02	70.44	85.26	92.12
10	2.57	6.87	16.60	36.43	55.73	71.90	85.97	92.41
11	2.57	13.76	34.98	54.83	70.17	84.15	94.85	97.84
12	2.57	13.76	27.74	49.95	67.25	82.46	94.37	97.67
13	6.77	17.40	35.27	54.96	70.18	84.15	94.85	97.86
14	2.57	13.76	27.74	50.57	67.28	82.46	94.37	97.67
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 6-45

Hearing Loss ENI Caused by Noise Inside Buses Assuming a Non-Bus Exposure of 70 dB - Bus Passengers								
Hearing Loss ENI (Thousands)								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	3309.03	3309.03	3309.03	3309.03	3309.03	3309.03	3309.03	3309.03
2	3261.77	3182.70	3118.59	3072.44	3029.93	2986.69	2935.44	2906.55
3	3188.57	2983.13	2814.80	2681.37	2578.88	2460.43	2327.10	2254.27
4	3309.03	3140.38	2849.08	2619.82	2435.11	2227.57	2001.55	1873.21
5	3261.77	3058.62	2790.12	2568.12	2396.06	2201.33	1986.41	1866.15
6	3261.77	3058.62	2669.19	2257.19	1931.16	1563.45	1183.29	967.64
7	3261.77	3058.62	2789.76	2342.90	1998.89	1612.78	1209.88	984.33
8	3188.57	2983.13	2651.26	2242.23	1918.57	1555.98	1176.21	966.16
9	3261.77	3182.70	3046.72	2702.99	2281.45	1811.12	1321.24	1046.06
10	3261.77	3182.70	2996.44	2623.77	2220.09	1765.01	1296.26	1032.33
11	3261.77	3058.62	2669.19	2257.19	1852.13	1432.33	940.06	690.27
12	3261.77	3058.62	2790.12	2350.95	1927.62	1454.34	968.24	704.67
13	3188.57	2983.13	2651.26	2242.23	1839.99	1395.48	937.08	687.17
14	3261.77	3058.62	2790.12	2280.13	1839.65	1354.08	862.95	602.28
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-46

Percent Reduction in Hearing Loss ENI Due to Noise Inside Buses for Average Non-Bus Exposure of 70 dB - Bus Passengers								
Percent Reduction in Hearing Loss ENI								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.43	3.82	5.76	7.15	8.43	9.74	11.29	12.16
3	3.64	9.85	14.94	18.97	22.07	25.65	29.67	31.88
4	0.00	5.10	13.90	20.83	26.41	32.68	39.51	43.39
5	1.43	7.57	15.68	22.39	27.59	33.48	39.97	43.60
6	1.43	7.57	19.34	31.79	41.64	52.75	64.24	70.76
7	1.43	7.57	15.69	29.20	39.59	51.26	63.44	70.25
8	3.64	9.85	19.88	32.24	42.02	52.98	64.45	70.80
9	1.43	3.82	7.93	18.31	31.05	45.27	60.07	68.39
10	1.43	3.82	9.45	20.71	32.91	46.60	60.83	68.80
11	1.43	7.57	19.34	31.79	44.03	57.62	71.59	79.14
12	1.43	7.57	15.68	28.95	41.75	56.05	70.74	78.70
13	3.64	9.85	19.88	32.24	44.39	57.83	71.68	79.23
14	1.43	7.57	15.68	31.09	44.41	49.08	73.92	81.80
15	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 6-47

Interior Regulatory Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	81786.20	81764.70	81764.70	81764.70	81764.70	81764.70	81764.70	81764.70
2	81748.92	81686.18	81634.14	81596.05	81560.29	81523.18	81478.38	81451.93
3	81689.70	81521.61	81381.37	81267.43	81178.40	81072.69	80951.12	80882.41
4	81786.20	81650.54	81411.14	81217.11	81056.57	80870.07	80659.07	80533.76
5	81748.92	81584.72	81361.94	81172.20	81021.12	80845.30	80643.39	80526.29
6	81748.92	81584.72	81261.38	80905.29	80609.12	80254.70	79855.74	79607.71
7	81748.92	81584.72	81361.41	80979.19	80670.69	80302.13	79883.65	79626.34
8	81689.70	81521.61	81244.91	80890.64	80595.99	80246.18	79847.29	79605.54
9	81748.92	81686.18	81574.64	81289.02	80925.43	80494.46	80003.51	79698.95
10	81748.92	81686.18	81533.74	81222.08	80871.04	80452.54	79997.11	79683.11
11	81748.92	81584.72	81261.39	80905.29	80536.24	80094.37	79585.07	79269.40
12	81748.92	81584.72	81361.94	80986.39	80605.58	80148.21	79617.82	79428.15
13	81689.70	81521.61	81244.91	80890.64	80523.42	80086.24	79580.81	79264.92
14	81748.92	81584.92	81361.94	80916.80	80511.92	80025.80	79462.38	79107.10
15	77307.69	77307.69	77307.69	77307.69	77307.69	77307.69	77307.69	77307.69

Hearing Loss ENI Caused by Noise Inside Buses Assuming a Non-Bus Exposure of 80 dB - Bus Passengers

Hearing Loss ENI (Thousands)

Table 6-48

Percent Reduction in Hearing Loss ENI Due to Noise Inside Buses for Average Non-Bus Exposure of 80 dB - Bus Passengers								
Percent Reduction in Hearing Loss ENI								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.05	0.12	0.19	0.23	0.28	0.32	0.38	0.41
3	0.12	0.32	0.49	0.63	0.74	0.87	1.02	1.11
4	0.00	0.17	0.46	0.70	0.89	1.12	1.38	1.53
5	0.05	0.25	0.52	0.75	0.94	1.15	1.40	1.54
6	0.05	0.25	0.64	1.08	1.44	1.87	2.36	2.66
7	0.05	0.25	0.52	0.99	1.36	1.81	2.33	2.64
8	0.12	0.32	0.66	1.09	1.46	1.88	2.37	2.67
9	0.05	0.12	0.26	0.61	1.05	1.58	2.18	2.55
10	0.05	0.12	0.31	0.69	1.12	1.63	2.21	2.57
11	0.05	0.25	0.64	1.08	1.53	2.07	2.69	3.08
12	0.05	0.25	0.52	0.98	1.44	2.00	2.65	3.05
13	0.12	0.32	0.66	1.09	1.54	2.08	2.70	3.08
14	0.05	0.25	0.52	1.06	1.56	2.15	2.84	3.28
15	5.48	5.48	5.48	5.48	5.48	5.48	5.48	5.48

It has been suggested that the masking of speech between passengers not conversing with one another is a benefit of bus noise. Passengers are often reluctant to have their conversation overheard by others, and in cases where the bus level is quite low, they may compensate by lowering their voices unnaturally or by not talking at all due to the lack of privacy. This argument may be somewhat valid, however, it cannot take precedence over a program to reduce the impact of interior bus noise on hearing.

EPA has identified 72 dB as the intruding noise level at which a conversation at .5 meters with normal voice projection is considered to be satisfactorily intelligible (95% sentence intelligibiity) in steady state noise.[8] It has been suggested that 0.5 meters is a typical speaker-to-listener distance for bus passenger.[2] Thus, the outdoor speech interference curve shown in Figure 6-18 was adjusted to 0.5 meters for bus passengers by adding 6 dB per halving of distance,[8] or a total of 12 dB, to the abscissa. The outdoor speech intelligibility criteria was then used to assess the ENI for speech inside buses.

It was decided that outdoor speech criteria were better than indoor speech criteria for estimating the impact of speech disturbance inside buses because the background level assumed for the estimation of outdoor speech disturbance is closer to the background level actually experienced by bus riders and operators. A typical outdoor day-night equivalent sound level in urban areas is 60 dB,[7] which is the background level assumed in the outdoor speech disruption criteria and is considered comparable to actual background levels inside buses. The indoor criteria, however, uses 45 dB as a background level. In addition to reasoning on the basis of background levels, it is also felt that outdoor criteria should be applied to the case of bus passengers and operators because the setting inside buses is not the typically relaxed environment one experiences indoors.

Utilizing the values for the average interior front and rear noise levels described in Part 6.4.1, the speech fractionalization method described above, and the passenger population data of Table 6-35, the equivalent number of people disturbed by interior noise as measured by the potential disruption of speech can be estimated by the following formula:

$$ENI_{speech} = FI_{i\ speech} \times P$$

where

$FI_{i\ speech}$ is shown by Figure 6-18 (as adjusted by the above discussion) for each interior level and P_i is the population exposed per day.

Table 6-49 shows the potential equivalent number of people estimated for ENI_{speech} for each of the sample interior regulatory schedules and study years. Table 6-50 shows the percent reduction which can be accomplished with each regulation schedule.

Appendix F contains information (Table F-39) regarding the ENI contributions by bus type to all interior ENI (hearing loss effects and speech interference effects) discussed in this part.

Table 6-49

Speech Interference ENI Due to the Noise Inside Buses								
Speech Interference ENI (Thousands Per Day)								
Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	4970.06	4970.06	4970.06	4970.06	4970.06	4970.06	4970.06	4970.06
2	4841.50	4841.50	4840.07	4840.07	4759.05	4759.05	4753.82	4731.73
3	4841.50	4841.50	4840.07	4759.05	4659.76	4569.96	4547.86	4539.57
4	4970.06	4841.50	4841.50	4825.36	4575.18	4569.96	4547.86	4539.57
5	4841.50	4841.50	4840.07	4659.76	4575.18	4569.96	4547.86	4539.57
6	4841.50	4841.50	4825.36	4575.18	4569.02	3435.10	2859.03	2848.27
7	4841.50	4841.50	4840.07	4575.18	4569.96	3413.01	2859.03	2848.27
8	4841.50	4841.50	4825.36	4575.18	4569.02	3425.10	2859.03	2848.27
9	4841.50	4841.50	4840.07	4759.05	4515.18	4533.66	3047.17	2848.27
10	4841.50	4841.50	4840.07	4744.34	4575.18	4533.66	3047.17	2848.27
11	4841.50	4841.50	4825.36	4575.18	4538.89	3055.47	2846.93	2193.67
12	4841.50	4841.50	4840.07	4575.18	4569.02	3055.47	2846.93	2193.67
13	4841.50	4841.50	4825.36	4575.18	4533.66	3055.47	2846.13	2188.44
14	4841.50	4841.50	4840.07	4575.18	4569.02	3055.47	2671.43	2109.09
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6-50

Interior Regulation Schedule	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2.59	2.59	2.62	2.62	4.25	4.25	4.35	4.80
3	2.59	2.59	2.62	4.25	6.24	8.05	8.49	8.66
4	0.00	2.59	2.59	2.91	7.95	8.05	8.49	8.66
5	2.59	2.59	2.62	6.24	7.95	8.05	8.49	8.66
6	2.59	2.59	2.91	7.95	8.07	30.88	42.47	42.69
7	2.59	2.59	2.62	7.95	8.05	31.33	42.47	42.69
8	2.59	2.59	2.91	7.95	8.07	30.88	38.69	42.69
9	2.59	2.59	2.62	4.25	7.95	8.78	38.69	42.69
10	2.59	2.59	2.62	4.54	7.95	8.78	42.72	42.69
11	2.59	2.59	2.91	7.95	8.68	38.52	42.72	55.86
12	2.59	2.59	2.62	7.95	8.07	38.52	42.72	55.86
13	2.59	2.59	2.91	7.95	8.78	38.52	42.72	55.97
14	2.59	2.59	2.62	7.95	8.07	38.52	46.25	57.56
15	100.00	100.00	100.00	100.00	100.00	100.00	10.008	100.00

Percent Reduction in Speech Interference ENI Due to the Noise Inside Buses

Percent Reduction in Speech Interference ENI

6.5.0 SUMMARY

The impacts from bus noise presented in Parts 6.2, 6.3, and 6.4 are based primarily on a single equation:

$$ENI = FI \times P$$

where

ENI is the equivalent noise impact

FI is the fractional impact produced by the noise

and

P is the population impacted

This basic equation finds many forms as the investigated area of impact changes from traffic noise to single passbys to interior noise. Table 6-51 summarizes the forms used in the preceding sections. Five areas of impact are distinguished:

a. Annoyance from urban street traffic

b. Sleep disturbance from bus passbys

c. Speech disturbance from bus passbys

d. Hearing loss from interior bus noise

e. Speech disturbance from interior bus noise

The first three impact areas concern exterior bus noise, while the last two areas concern interior bus noise.

Table 6-51

Summary Equations Describing Calculation of Bus Noise Impacts

Basic Equation: Equivalent Noise Impact = Fractional Impact x Population

a. $$ENI_{traffic} = \sum_{i=55\ dB}^{L_{dn}\ max} \left(FI^{i}_{annoyance} \times Pop_i \right)$$

where

$$FI_{annoyance} = \begin{cases} 0 & L_{dn} \le 55dB \\ .05(L_{dn} - 55) & L_{dn} > 55\ dB \end{cases}$$

b. $$ENI_{\substack{sleep \\ disturbance \\ (awakening)}} = \sum_{\substack{i=37\ dB \\ (50)}}^{SEL\ max} \left(FI^{i}_{\substack{sleep \\ disturbance \\ (awakening)}} \times \text{Pop Density} \times \text{Bus Miles} \times \text{Distance from Road}_i \right)$$

where

$$FI_{sleep\ disturbance} = (1.35\ SEL - 50.0) \times .01$$

$$FI_{sleep\ awakening} = (1.19\ SEL - 59.7) \times .01$$

c. $$ENI_{\substack{speech \\ disturbance \\ outdoors \\ (indoors)}} = \sum_{\substack{i=55\ dB \\ (45)}}^{L_{eq}} \left(FI^{i}_{\substack{speech \\ outdoors \\ (indoors)}} \times \text{Pop Density} \times \text{Bus Miles} \times \text{Distance from Road}_i \right)$$

where $L_{eq} = L_{max} - 10 \log 2.3 (L_{max} - L_b)/10$

L_{max} is the maximum level of a triangular time history passby

L_b is the background level

FI_{speech} is defined in reference 8.

Table 6-51 (Continued)

Summary Equations Describing Calculation of Bus Noise Impacts

d. $$ENI_{hearing} = \sum_{i=70\text{ dB}}^{L_{eq(24)}^{max}} \left(FI_{hearing}^{i} \times Pop_i \right)$$

where $$FI_{hearing} = .05\ (L_{eq(24)} - 70)^2$$

e. $$ENI_{\substack{speech\\disturbance\\for\ passengers}} = \sum_{i=55}^{L_{max}} \left(FI_{\substack{speech\\outdoors}}^{i} \times Pop_i \right)$$

where

FI_{speech} is defined in reference 8.

Section 6

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SECTION 7

ECONOMIC IMPACT OF BUS NOISE CONTROL

I. OVERVIEW OF ECONOMIC IMPACT ANALYSIS

The purpose of this overview is to outline EPA's approach to the economic impact analysis of bus noise regulation. Figure 7-1 describes the conceptual format of the analysis in terms of a flow diagram, and the discussion that follows is essentially an elaboration of that diagram.

ECONOMIC IMPACT ANALYSIS METHODOLOGY

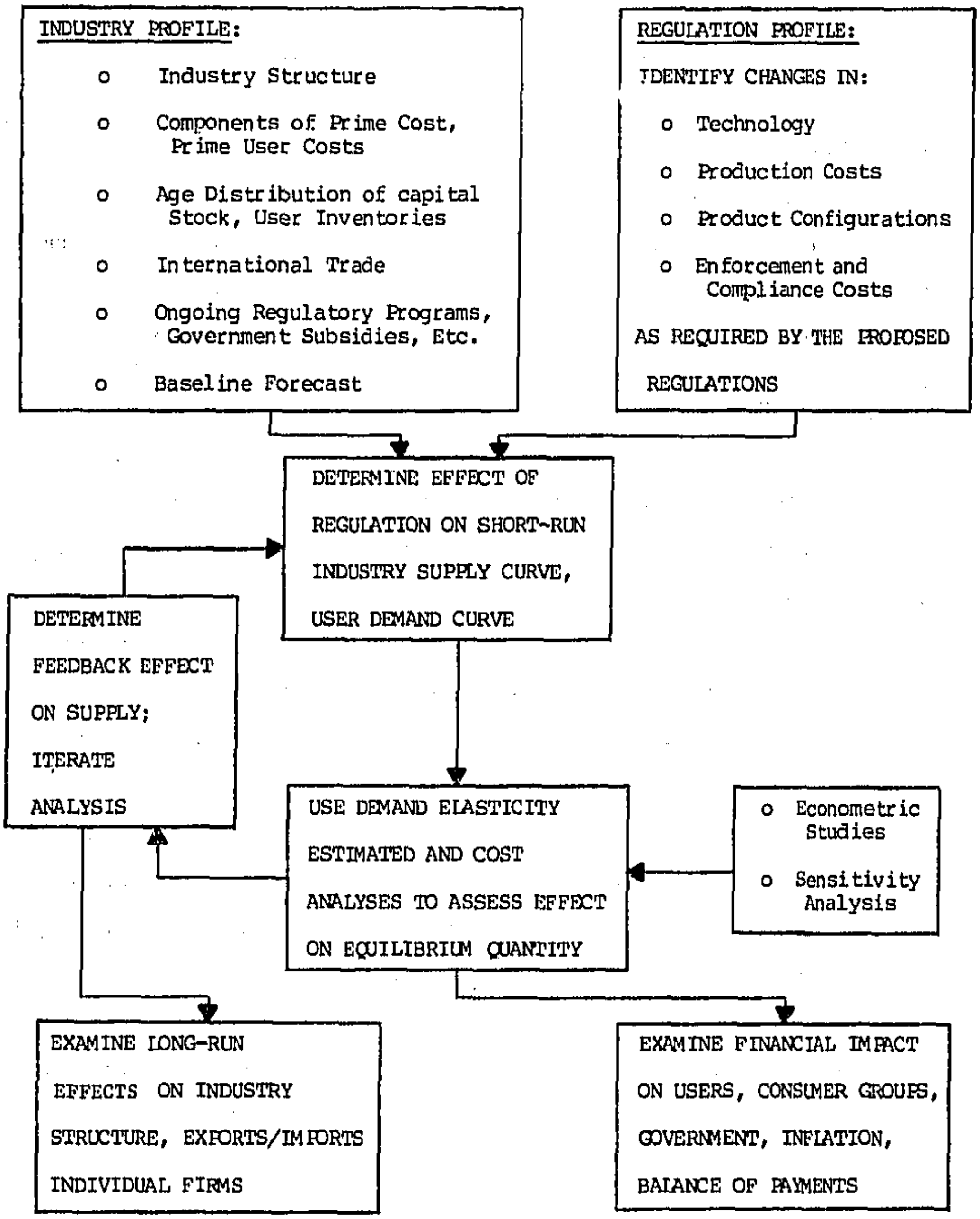
This part describes the basic supply/demand model underlying the analysis. For each of the major areas of bus noise abatement -- intercity buses, urban transit buses, and school buses -- two separate but highly related markets are under analysis:

1. The market for fully equipped, finished buses, viewed as durable capital goods input to producing transportation services.
2. The market for bus transportation, from the view point of final consumers of bus services.

It should be noted that the market for school bus services in a consumer sense differs from the market for other bus transportation in that it is dictated more by the need to transport pupils and associated policy and legal considerations than by individual consumer choice.

Bus transit firms, whether intercity carriers, urban transit authorities, or public school districts, act as intermediaries, operating in both of these markets.

FIGURE 7-1. ECONOMIC IMPACT ANALYSIS OF NOISE REGULATION



The demand for buses as a capital good is a "derived" demand for a factor input, that is, derived from the demand for final consumption of bus services by eventual end users. A large portion of the economic analysis is devoted to describing the relationship between facts that can be ascertained about final demand and the conditions under which that final demand translates into a demand for buses as capital inputs.

The mix of regulatory and managerial incentives observed in the various bus transportation markets implies a variety of potential responses to the proposed regulations. A separation of the parallel analyses of the three major categories (transit, intercity, and school buses) is maintained throughout the Economic Impact Analysis.

SUPPLY AND DEMAND AT THE CONSUMER LEVEL

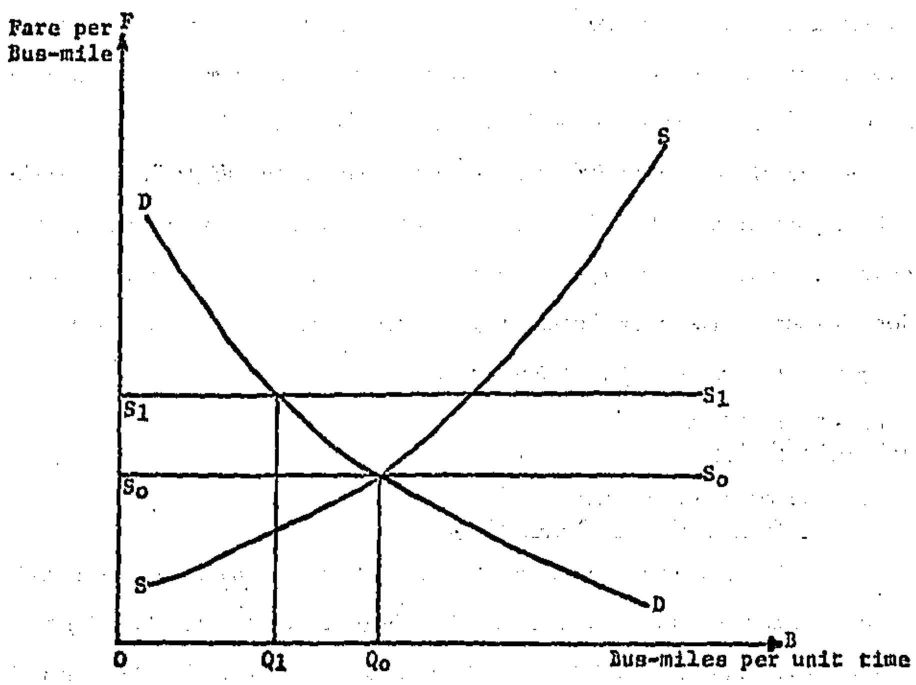
(a) Urban and Intercity Transportation Services

Figure 7-2 portrays a standard supply and demand model for urban and intercity transportation services at the consumer level. Ideally, both the supply and demand schedules could be estimated econometrically, and the analysis conducted in precise, empirical terms. Realistically, however, we know very little about either the supply or the demand curve, particularly the former, and it is necessary to proceed in terms of heuristic arguments combined with sensitivity tests of specific parametric assumptions.

The supply and demand curves of Figure 7-2 apply to the relevant market or submarket in which the transit firm operates. For example, the relevant market for an urban transit system is the appropriate urbanized area, while the market for intercity bus carriers is nationwide.

FIGURE 7-2

SUPPLY AND DEMAND AT THE CONSUMER LEVEL



Consider the effect of a rise in the cost of transportation equipment. Assume, to begin with, that the increased cost of equipment results in an increase in the marginal cost of operating a bus transit firm, hence of the supply curve facing bus passengers. The assumption can be verified subsequently in an analysis of transit firms.

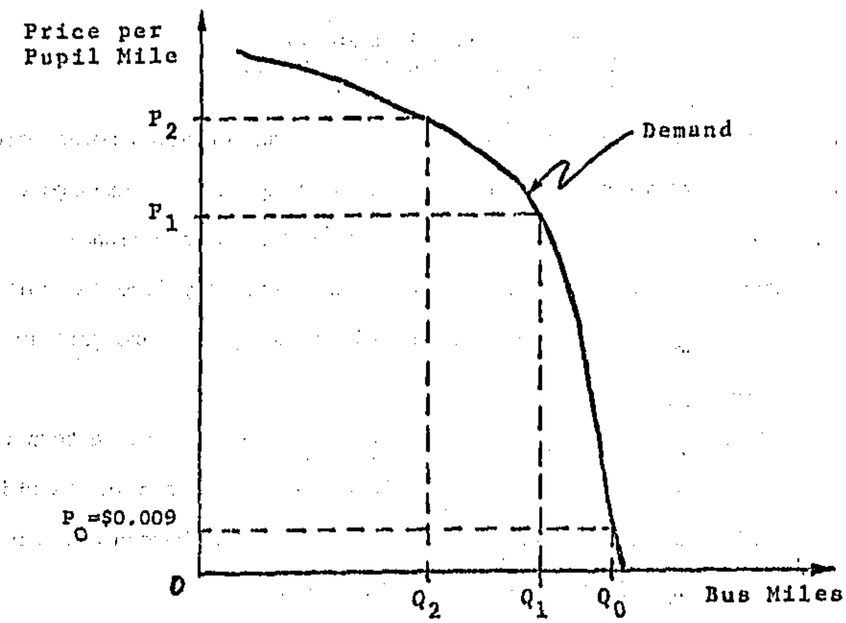
Since the exact shape of the curve SS is not known in advance, a horizontal supply curve S_oS_o is taken as a first approximation. This shape is consistent with a long-run supply of an industry that does not experience economies or diseconomies of scale (Reference 1) in its bus operations, so the initial analysis also has implications for long-term economic impacts.

(b) School Bus
<u>Transportation Services</u>

The demand for school transportation services are viewed as being significantly different from that of urban and intercity transportation services. Figure 7-3 is an approximation of the demand for school bus transportation.

FIGURE 7-3

TOTAL MARKET DEMAND FOR
SCHOOL BUS TRANSPORTATION



Present conditions are approximated by the price/quantity relationship of $Q_o \times P_o$ where P_o = \$0.009 represents an approximation[1] of the present taxpayer burden per pupil mile for school bus transportation (calculated in terms of numbers of students transported at public expense).

Price P_1 represents one of several alternative price levels per pupil mile where other forms of transportation become visible alternatives to school bus transportation. Depending upon individual circumstances, prices around level P_1 can be viewed as the operating costs associated with the following transportation alternatives:

-- price of riding transit buses to and from school

-- car pool costs on a per pupil basis

-- cost of automobile transport (if car pools are not a viable alternative)

As the price per pupil mile for school bus transportation moves between P_o and P_1 very few parents would be rational if they chose to transport their children on a personal basis due to the following conditions:

1. Pupil transportation is viewed as an essentially free commodity due to the tax burden being shared by nearly all taxpayers in an area.

2. If large numbers of publicly transported pupils chose alternative forms of transportation, the public costs would remain essentially unchanged in the short term with an additional burden being borne by the individual transporting families.

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1 For 1973-74, 267,704 school buses transported 21,347,039 pupils at an average cost of \$0.72 per bus mile. (National Center for Education Statistics, Statistics of State School Systems, 1973-74, Table 41)

If the individuals were the only interested parties, the demand curve between P_o and P_1 would be perfectly inelastic such that no reduction in school bus usage would be realized from price/cost increases. However, state and local transportation coordinators and legislators feasibly have options available to them such as changing policy to the extent that volume of service offered as a free commodity would be reduced. Such policy considerations might be in the following areas:

- -- reduction in the quantity and/or length of field trips
- -- elimination of free transportation to sporting events
- -- changing physical conditions which presently preclude walking at present (such as installing sidewalks and traffic lights where necessary for safe walking)

Nevertheless, the section of the demand curve between P_o and P_1 is viewed as being essentially inelastic.

As prices move above level P_1, the likelihood of eliminating school transportation services becomes much more viable, and we would view the curve as being essentially elastic where it might be more attractive to eliminate school transportation services entirely, with school districts possibly offering payments to differentially impacted families.

INCREMENTAL
COST ANALYSIS

An estimate of the effect of the proposed noise regulations on the supply curve SS (see Figure 7-2) can be formed by examining the expense statement of a typical transit firm (or of U. S. transit firms in the aggregate). From economic theory, we know that the supply curve of an industry is the horizontal sum of individual firm supply curves, and individual firm supply curves are the "marginal" or "incremental" cost schedules for operating transit fleets.

The transit firm's expense statement e is a sum of contributing expense accounts, including labor (L), maintenance (M), fuel (F), capital expense (X), stations (S), and other expenses (O):

$$\text{Expense} = L + M + F + X + S + O.$$

Imposition of noise control technology, as a first approximation, affects only a subset of these expenses. (For the costs of bus noise technology, refer to Appendix C.) Since only incremental impact is relevant to movements in the supply curve, consideration of many expense categories can be eliminated.

Specifically, we determine (from Appendix C) the incremental effect on E of imposition of regulatory level R:

$$dE/dR = dM/dR + dF/dR + dX/dR.$$

The derivatives with respect to other expense categories vanish, since as a first approximation the technology has no effect on these items.

Note, however, that the full response to the regulation may change all expense categories as different forms of bus and fleet management technology are applied. The "first-round" approximation is an approach that provides an upper bound to the predicted economic cost impact.

Analysis of incremental capital cost dX/dR deserves special attention. If the firm's capital stock of buses is K dollars, then the relevant annual carrying cost is $X - (r + i)\ K$ dollars, where r is the rate of depreciation per year and i is the rate of interest. Incremental capital cost therefore is:

$$dX/dR = (r + i)\ dK/dR,$$

where dK/dR represents the additional cost of noise reduction equipment installed on a newly-equipped bus.

(a) Effect on Quantity Demanded

A rise in the supply curve to S_1 S_1 (see Figure 7-2) implies a reduction in equilibrium quantity from Q_o to Q_1. The econometric formula for estimating this relationship is given by the fare elasticity of transit demand, E_{BF}:

$$E_{BF} = \frac{\text{\% Change in Quantity Demanded (B)}}{\text{\% Change in Fare (F)}}$$

Appendix D reviews estimates of the fare elasticity of demand for the urban bus transit market and the intercity bus transportation market; adequate data for a similar estimate of the school bus market is unavailable, due to difficulties associated with defining the concept of a "fare" in that market.

It is important to bear in mind certain cross-effects vis-a-vis other modes of transportation. Empirical work in this area suggests that such "cross elasticities" are indeed present to some extent, hence that a differential rise in the price of bus services as compared with fares (or user costs, in the case of private automobiles) of competing modes will have a non-negligible impact on demand for the mode in question. A relevant consideration in this regard is the possibility that simultaneous promulgation of noise regulations on all modes of transit may have similar effects on fares in all markets. To the extent that this phenomenon is true, the effect of cross elasticities of demand is diminished.

(b) Equilibrium
Quantity Impact

As a first approximation, the reduction of output to Q_1 translates into a reduced long-run demand for bus capital as input to providing bus services by the ratio $(1 - Q_1 Q_O)$. To examine this impact further, we consider the market for finished buses. In doing so, it is hoped that some knowledge may be gained concerning the shape of the supply curve SS.

Analysis of the market for finished buses draws on the industry profile section (Section 3). The aspects of the analysis can be distinguished as one which is long-run and somewhat theoretical, and the other as which is short-run and descriptive.

LONG RUN
ANALYSIS

The long-run analysis considers the effect of a long-run reduction in output of buses by the ratio $1 - Q_1/Q_O$, superimposed on the natural long-term growth rate of the industry. Inasmuch as reduction in bus service is predicted by movements along the demand curves in Figures 7-2 and 7-3, reduction in long-run bus output will be forthcoming. (This assumption is supported by an observed constant share of bus capital costs in the expense accounts of bus fleet operators.)

The bus industry profile (Section 3) provides information concerning the size distribution and profitability of bus manufacturers, the history and growth of the industry, trade-in buses with foreign countries, life-cycle characteristics of buses, and technical data concerning the manufacture and design technology of buses. This information is examined to assess the likelihood that reduced output levels result in a lower marginal cost of newly produced buses (hence that the supply curve SS in Figure 7-2 is upward-sloping) and whether there are marginal firms in the industry, including importers, who would be forced to cease operations due to the potential reduction in equilibrium output. Note that this latter consideration properly belongs to the normative phase of the overall impact analysis.

If so indicated, a rising supply schedule for bus production would imply a rising supply curve SS in Figure 7-2, and a revision in the quantitative estimate of the impact Q_1/Q_o. An interative procedure (Figure 7-1) then leads to a determination of the long-run equilibrium.

SHORT-RUN ANALYSIS

Although the long-run analysis is a reliable indicator on which to base the overall study, some relevant short-run elements are worth considering, particularly in regard to assessing the possible costs of disruptions following the initial promulgation of the regulations.

One such effect is the so-called "pre-buying" phenomenon wherein bus fleet operators invest heavily in pre-regulation bus capital to avoid the higher costs associated with the post-regulation equipment. In contrast to the effect on buyers of buses, the disruptive impact on manufacturers of buses is reduced by providing adequate lead times for the development and introduction of noise abatement technology. A precise statement as to the relative magnitude of these phenomenon is difficult to produce, but the potential existence merits attention.

A second short-run phenomenon is the determination of the degree to which higher equipment costs are passed through to eventual consumers and end-users by the manufacturers and the bus fleet firms. Since most bus fleets (except tourism, some charters, and private, non-revenue fleets) operate in a regulated or public ownership setting, immediate pass-through of operating cost increases may not occur, particularly in the short-run. Factors working against immediate operating cost pass-through include:

— government funding of bus capital expenditures

-- political decision-making processes of regulatory bodies

-- regulations relating to routes and service requirements

-- direct subsidies to mass transit systems

— costs of record-keeping and financial control

Since all of these factors serve to reduce or forestall the pass-through of long-run incremental cost increases, the long-run analysis serves as an "upper-bound" on the overall impact estimates.

SENSITIVITY ANALYSIS

In complex numerical computations, the term "sensitivity analysis" refers to tests concerning estimated values of certain key parameters by varying their magnitude and by performing the calculations under the changed assumptions to detect the significance of errors on the final results.

Such sensitivity tests are performed in two ways on the economic analysis below. First, the estimate of technology costs (Appendix C) are determined as a range of potential values and EPA's independent estimate. The three values (high, low, and the EPA independent estimate) are carried through the economic and financial impact analyses. Since the high estimate generally corresponds to the highest estimate provided by industry sources, the calculations for this level also have implications for assessing the "worst case" conditions envisioned by respondent industry firms.

A second use of sensitivity analysis is in examining the effect of certain heuristic assumptions about demand elasticities, public funding levels, and product costs. These tests are made routinely in the development of the overall analysis.

FINANCIAL IMPACT ANALYSIS

The positive economic analysis of what occurs after the regulations are promulgated has implications for financial impacts on various special interest groups. Since these normative aspects of the regulations may affect the decision-maker's decisions, pertinent information is supplied.

Specific areas covered are the effects on exports and imports, impacts on marginal producers, differential impacts on municipalities and consumer groups, costs to government in the form of increased subsidies to transit firms, inflationary impacts, and possible balance of payments repercussions.

The industry profile section (Section 3) presents projections for industry output during the period 1976-90. The projections are combined with the various technology cost estimates (Appendix C) and the assumptions about the current capital stock of buses to produce a simulation of the financial cost impact of the proposed regulations. The simulation permits the assessment of alternative regulatory actions on the basis of an annualized resource cost to the economy as a whole.

Because the intent of these projections is to obtain estimates of the total resource cost, and not to predict economic behavior, incremental capital cost is handled somewhat differently here than in the above economic analysis. Here the objective is to measure the incremental capital cost actually expended in the aggregate, as opposed to the effect of a change in marginal capital costs on pricing decisions of bus fleet operators.

Actual incremental capital expenditures in any given year are estimated by multiplying the sum of depreciation and interest (r + i) times the value of the stock of additional outstanding equipment, net of reserves for depreciation, that has been committed for the purpose of noise abatement. If, for example, Δk_t additional equipment is installed in year t for noise abatement, then the capital cost related to that investment in year t + s is given by:

$$(r + i)\ (1 - r)^s \quad \Delta k_t,$$

where the term $(1 - r)^s$ reflects depreciation at annual rate r for s years.

Alternatively, if straight line depreciation is employed, this cost is estimated by:

$$k_t/n \ + i\ (1 - s/n)^s \quad \Delta k_t,$$

where n is the depreciable life of the equipment installed.

II. ECONOMIC IMPACT OF NOISE REGULATIONS ON USERS AND MANUFACTURERS

INTRODUCTION

This part of the analysis deals with the economic impact of the promulgation of noise abatement regulations on bus manufacturers, industry suppliers, end-users and other affected groups as have been identified. The industry has been divided into three separate product groups -- intercity, transit, and school buses -- due to the following considerations.

1. The products are dissimilar with respect to their end-use characteristics.

2. Operating entities in each category are structured and regulated differently.

The three economic impact assessments appear in the following order:

A. Economic Impact of Noise Regulations on Intercity Motor Bus Carriers and manufacturers

B. Economic Impact of Noise Regulations on Urban Transit Motor Bus Carriers and Manufacturers

C. Economic Impact of Noise Regulations on School Bus Carriers and Manufacturers

A. ECONOMIC IMPACT OF NOISE REGULATIONS ON INTERCITY MOTOR BUS CARRIERS AND MANUFACTURERS

Appendix C indicates three major effects of bus noise reduction technology:

- o Additional noise-abatement equipment installed on newly-produced buses
- o Increased maintenance costs for new buses
- o Reduced fuel efficiency of new buses

Since the primary impact of these costs is on bus users -- fleet operators, intercity cariers, and, ultimately, consumers -- the analysis below concentrates attention initially on the user end of the industry. Induced impacts on manufacturers and financing authorities is studied subsequently.

ANALYSIS OF
USER COSTS

By way of introduction, Table 7-A-1 summarizes operating expense accounts of the Class 1 intercity motor bus carrier[2] during the years 1939-75. An important result from economic theory (reference 2) states that as the demand for an intermediate product (like buses) is less sensitive (elastic) to changes in its own price, the smaller is the share of that intermediate product in the composition of the final product demanded (bus transportation). The reason is that for a given elasticity of demand for the final product, bus transportation, the smaller the share of the intermediate input, buses, the smaller will be the percentage impact of a change in bus prices on the total cost and price of the final product. A relatively small change in the price of the final product, transportation, implies a relatively small effect on quantity demanded of both the final product and the intermediate good.

2
Class designations are formed using annual revenue dollars.
Class 1 carriers have revenues of $1,000,000 ore more.
Class 2 carriers have revenues of $300,000 or more but less than $1,000,000.
Class 3 carriers have revenues less than $300,000.

TABLE 7-A-1
OPERATING EXPENSE (CENTS PER BUS MILE),
CLASS I MOTOR BUS CARRIERS, 1939-75

Expense Category	1939	1950	1960	1970	1973	1974p	1975p
Total	19.90	32.77	48.08	67.50	86.82	97.05	105.33
Operation and Maintenance - Total	14.72	26.53	39.59	57.52	74.09	83.29	91.38
Equipment Maintenance and Garage	3.44	6.67	8.01	10.33	12.27	13.31	14.58
Transportation	5.93	10 98	17.33	23.97	30.67	35.54	38.88
Station	1.85	3.69	6.49	11.62	15.01	16.63	17.69
Traffic, Solicitation, and Advertising	0.94	1.13	1.72	2.22	2.86	3.21	3.83
Insurance and Safety	1.06	1.45	1.99	2.41	3.49	4.04	4.20
Administrative and General	1.49	2.62	4.08	7.43	9.79	10.56	12.19
Depreciation and Amortization	2.06	2.82	3.47	3.52	3.82	4.38	4.54
Operating taxes and Licenses	2.40	2.98	4.31	5.19	6.93	7.18	7.55
Operating Rents, Net	0.72	0.43	0.71	1.28	1.98	2.20	1.86

Source: National Association of Motor Bus Operators, One-half Century of Service to America, Tables 3 and 4. p: preliminary.

Using this theorem, Table 7-A-1 lends insight into the probable results of the economic impact analysis. Bus capital, the major component of the "Depreciation and Amortization" account in the ICC reporting format, represents a small fraction of total operating expenses, say five percent of less. Hence, a given regulation-induced change in the price of new buses has only a small effect on the "derived" demand for new buses, and the ability of the bus manufacturing industry to pass through the additional equipment costs without severely reducing their sales is thereby enhanced.

Expenses for fuel and maintenance, are relatively important components of the operating expense accounts, but here the potential for adverse economic economic impacts on the suppliers of these inputs — the petroleum industry and the supply of skilled mechanic labor, respectively — is negligible due to the overwhelming size of these markets relative to the bus service industry.

COST ESTIMATES
FROM APPENDIX C

Table 7-A-2 summarizes the pertinent estimates of technology cost from Appendix C. Expense estimates are in terms of 1976 dollars. It should be noted that the various proposed technology levels are cost independent of one another.

The estimates in Table 7-A-2 are "incremental" expenses, that is, additional expenses over and above the costs in 1976 of purchasing and operating a typical bus that has no noise abatement equipment installed. Incremental fuel costs are computed on the basis of midpoint mileage estimates, as described in the footnote to the table.

TABLE 7-A-2

INCREMENTAL EQUIPMENT AND OPERATING EXPENSES ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED INTEGRAL INTERCITY BUSES

TECHNOLOGY LEVEL	EXTERIOR dBA	INTERIOR dBA	EQUIPMENT COST PER BUS High	Low	EPA Estimate	FUEL COST PER BUS-YEAR[a]	MAINTENANCE PER BUS-YEAR
1	86	84	$ 205	$ 0	$ 50	$ 0	$ 0
2	83	83	505	0	195	0	70
3	80	80	1,395	350	875	790	305
4	77	80	2,090	650	1,670	1,805	520
5	75	78	4,090	750	3,270	4,060	830

Source: Appendix C

Note: [a] Fuel cost per bus-year is estimated by multiplying incremental gallons per mile (Appendix C) times 42.2 cents per gallon times 250,000 vehicle miles per bus-year. (National Association of Bus Owners, One-half Century of Service to America (1976)), Tables 2 and 4 indicate that the average Class I intercity carrier operated 86,000 miles in 1975. From industry sources, however, EPA has determined that intercity buses are driven very intensively during the initial two years of operation. Thus, 250,000 miles per year estimate is used for purposes of the economic impact analysis.

For Technology Level 5, an additional consideration not reflected in Table 7-A-2 is the fact that noise abatement equipment required to attain the 75 dBA exterior level and the 78 dBA interior level also entails a reduction in seating capacity by two seats (four passengers) from the standard 43-seat bus. Reduced seating capacity clearly imposes costs on the intercity carrier, but the magnitude of these costs is difficult to assess. The average passenger load on intercity trips is 20 passengers, or less than half-full, so a large proportion of current service would be unaffected by the loss of these seats, except to the extent that increased crowding of remaining capacity adversely affects customer demand.

Industry sources[3] have indicated to EPA that the price differential for similarly-equipped 41 and 49 passenger-rated buses is $12,000 in 1976. The implied differential for estimating the cost of losing two seats (four passengers) is $6,000. No measurable difference is indicated in the operating and maintenance costs between the two buses.

The only adjustment called for in Table 7-A-2 is the addition of $6,000 to the equipment cost for Technology Level 5. This adjustment is included in all subsequent calculations of the economic impact analysis.

The $6,000 estimate is substantiated by some evidence collected in 1973 by Greyhound Lines, Inc., in connection with their discussion at that time to make the 43-seat bus standard equipment in preference to the 38-seat bus. Greyhound's study involved a survey of departure loads for twelve different U.S. locations. For a sample of 2,179 scheduled bus departures, 45, or 2.07

[3] Housman Bus Sales; Chicago, Illinois (a major distributor)

percent, had passenger loads of 39 to 43 passengers. Since Greyhound has a legal obligation to provide service for all paying customers, the implication is that a reduction in bus seating capacity from 43 to 38 seats would raise total operating costs by roughly two percent.

In the analysis set forth below, an increase of $6,000 in equipment costs implies a maximum 1.40 percent increase (see Table 7-A-8) in total operating costs. After adjusting this estimate to reflect five lost seats instead of four, the agreement with Greyhound's measure is apparent, particularly in light of the fact that the $6,000 estimate reflects full adjustment of schedules to fleet capacity whereas Greyhound's test held schedules constant.

ESTIMATES OF INCREMENTAL CAPITAL COSTS

The formula for estimating incremental capital costs is

$$dX/dR = (r + i)\ dK/dR,$$

where dX/dR is the incremental capital cost associated with regulatory level R, dK/dR is the dollar value of noise abatement equipment installed on new buses, r is the rate of depreciation, and i is the rate of interest. A major difficulty arises in providing accurate estimates of the rate of depreciation r.

Three alternatives for estimating r are discussed: estimates based on observations of prices of used equipment, life cycle estimates, and analysis of carriers' accounting statements. Each of these methods encounters difficulties which are examined in turn.

(a) Estimates Based on Observed
Used Equipment Prices

The major difficulty in this case is the lack of meaningful data on which to base estimates. For time periods of ten years or more, the difference in quality and design of used buses versus newly produced buses makes price comparisons highly difficult. The used market itself is not well organized, thus pure quotations are not easily obtained or necessarily representative.

One major dealer did provide EPA with a pair of prices of standard intercity buses for the years 1976 and 1964. The price for the 1964 bus includes expenses incurred by the dealer for equipment overhaul and refurbishing (as much as $10,000 per bus), so the extent to which the price reflects true "depreciation" is not certain:

1976 new intercity bus	$85,000 - $95,000
1964 good condition used intercity bus	$31,000 - $32,000

The implied rate of depreciation over the 12-year period is estimated as follows:

$$1 - (31{,}500/90{,}000)^{1/12} = 8.4\%$$

(b) Estimates Based on
Life Cycle Assumptions

Tables 7-A-3 and 7-A-4 demonstrate that the total U.S. population of intercity buses has remained relatively constant during the past two decades, and that new bus production has amounted to five-to-ten percent of total stocks. The difference between the two tables in the ratio of new bus production to total stocks is explained by the fact that Table 7-A-4 records only Class I bus inventories, whereas Table 7-A-3 gives estimates of Class I, II and III inventories.

TABLE 7-A-3

INTERCITY BUS FLEET VEHICLE
INVENTORY AND PRODUCTION
1970-75

Calendar Year	Bus Inventory[a]	Bus Shipments	Shipments as Percent of Existing Stock
1970	22,000	1,064	4.84%
1971	21,900	977	4.46
1972	21,400	1,353	6.32
1973	20,800	1,276	6.13
1974	20,600	1,350	6.55
1975p	20,500	------	----

Source: National Association of Motor Bus Owners (NAMBO).

Note: [a] Bus inventory refers to estimated inventories of all operating companies, including Class I, Class II and Class III Carriers, from NAMBO, One-half Century of Service to America, Table 1. p: preliminary.

TABLE 7-A-4

SELECTED BALANCE SHEET AND OPERATING STATISTICS, CLASS I INTERCITY MOTOR BUS CARRIERS, 1941-73

Calendar Year	Total Revenue Passenger Equipment (millions)	Net Revenue Passenger Equipment[a] (millions)	Depreciation of Revenue Equipment (millions)	Equipment Acquired During Year (Buses)	Equipment Owned At Year-End (Buses)
1941	$ 75.0	$ 42.4	$ 12.1	1,358	7,891
1950	214.2	88.7	24.4	697	13,200
1955	264.7	112.1	25.0	1,344	11,547
1960	319.8	119.4	27.6	1,639	11,093
1961	332.1	127.8	26.7	1,057	11,036
1962	402.2	178.5	32.6	1,329	13,873
1963	408.3	184.3	32.0	1,102	13,608
1964	428.0	205.1	37.7	1,543	14,274
1965	376.0	171.8	34.8	1,084	11,295
1966	394.7	186.1	37.4	1,376	11,749
1967	424.1	199.0	38.9	1,411	12,307
1968	450.0	194.3	40.7	1,205	12,257
1969	415.9	250.2	34.3	743	10,063
1970	418.7	256.6	32.8	1,042	10,158
1971	439.5	255.9	32.9	893	9,900
1972	454.0	249.5	31.3	972	9,711
1973	464.2	226.3	34.9	1,000	9,300

Source: Interstate Commerce Commission, Transport Statistics in the United States (annual).

Note: [a] Net of Reserves for Depreciation. Coverage varies from year to year according to ICC definition of Class I carriers.

A large portion of the supply of buses to Class II and Class III fleet operators is in the form of second-hand, used buses from Class I operators, and only a small part of this supply is in the form of newly-produced buses. Hence, the total supply of new buses, around 1,200 per year, more properly represents replacement service to the entire population of carriers and not just to Class I Carriers.

On the assumption that the age distribution and technology of buses is roughly uniform over time, these numbers indicate a lower bound on the rate of depreciation of five percent per year.

(c) Estimates Based on <u>Carriers' Financial Statements</u>

An upper bound on the rate of depreciation may be obtained by examining the pertinent accounting statements from ICC Class I annual complications. These statistics are provided in Table 7-A-4 for the period 1941 through 1973.

ICC accounting rules permit a variety of depreciation formulas for reporting purposes, including depreciation by number of miles driven, but the industry norm is eight-year, straight-line depreciation. The ICC Class I motor bus statistics are dominated by the major carriers (Greyhound, Continental Trailways, Bluebird, etc.) and the numbers in Table 7-A-4 undoubtedly reflect this method of accounting in large part.

The eight-year figure is well below the true economic life of intercity buses: actual service life is at least fifteen and potentially thirty years or more. But due to the significantly greater intensity with which new intercity buses are driven during the initial two years of operation (250,000 miles per year as compared with an average annual mileage of 86,000 miles per year for all Class I intercity buses), the official depreciation life of eight years represents a compromise between straight-line method and true economic loss-of-value.

The question remains as to whether to use the "total equipment" or "net equipment" accounts as the basis for estimating the rate of annual depreciation. Use of the "total" depreciation (Column 2 of Table 7-A-4) results in an understatement of depreciation, since it includes equipment still owned but older than eight years and therefore no longer depreciated. Net equipment, on the other hand, results in an overstatement of depreciation because the eight-years straight-line formula results in an understatement of the total capital stock.

Note, however, that estimates of the rate of depreciation based on these accounting summaries are not biased due to price inflation: both the numerator (stated depreciation) and the denominator (total or net assets) are increased each year by equally inflated increments.

Using the net equipment definition of depreciable assets, an upper bound for the annual rate of depreciation r is estimated from the years 1964 through 1973 as 16.65% per year.

(d) Summary of Rate of Depreciation Estimates

Intercity buses have potentially long service lives, and the concept of a "rate of depreciation" is not necessarily well-defined or applicable. Depreciation is itself an economic variable, subject to variation according to the maintenance and route decisions of the fleet operator.

Historically, however, the size of the total U.S. fleet and production of new equipment have maintained relatively constant levels through the past two decades. On the assumption that this record is representative of the type of depreciation that buses do in fact experience, EPA estimates an annual rate of depreciation of five to fifteen percent, with a best midrange estimate of ten percent per annum.

ESTIMATES OF INCREMENTAL PRIME COST

The technology cost estimates from Table 7-A-2 for incremental equipment, fuel, and maintenance costs can be combined into single estimates of incremental cost per vehicle mile. This is accomplished by converting equipment cost increments from Table 7-A-2 into per annum capital costs (depreciation plus interest), and then by dividing the sum of annual capital, fuel, and maintenance cost by 250,000 miles per year.

The relatively high figure of 250,000 vehicle miles per year is used rather than the average 86,000 miles per year, because the purpose of the analysis is to estimate the effect of marginal prime cost. The results of using the alternative 86,000 miles per year figure are indicated below in Table 7-A-8.

Tables 7-A-5 and 7-A-6 provide results of the calculation for assumptions of 5% and 15% annual rate of depreciation. It is clear that the calculated numbers are relatively insensitive to both the assumption about the annual rate of depreciation and the incremental capital cost from Table 7-A-2. In the following analysis, only the midrange estimate of these numbers (i.e., 10% depreciation and EPA's independent estimate of incremental capital costs) is considered.

TABLE 7-A-5

INCREMENTAL PRIME COST PER BUS-MILE OF SERVICE ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED INTEGRAL INTERCITY BUSES

Technology Level	Exterior dBA	Interior dBA	Incremental Cost--Cents per Vehicle-Mile[a] High	Low	EPA Estimate
1	86	84	0.012	0.000	0.003
2	83	83	0.058	0.028	0.040
3	80	80	0.522	0.459	0.491
4	77	80	1.055	0.969	1.030
5	75	78	2.561[b]	2.361[b]	2.512[b]

Source: Table 7-A-2. Interest and depreciation are calculated as 15% of incremental capital cost (5% depreciation from Table 7-A-3 plus 10% interest). Estimates reflect an assumption of 250,000-vehicle-miles per bus year. (See Source note to Table 7-A-2.)

Note: [a] 1976 dollars.

[b] Includes adjustment for seat loss.

TABLE 7-A-6

INCREMENTAL PRIME COST PER BUS-MILE OF SERVICE
DIESEL POWERED INTEGRAL INTERCITY BUSES
ASSUMING 15 PERCENT RATE OF
DEPRECIATION IN EQUIPMENT

Technology Level	Exterior dBA	Interior dBA	Incremental Cost--Cents per Vehicle-Mile[a] High	Low	EPA Estimate
1	86	84	0.021	0.000	0.005
2	83	83	0.079	0.028	0.048
3	80	80	0.578	0.473	0.526
4	77	80	1.139	0.995	1.097
5	75	78	2.965[b]	2.631[b]	2.883[b]

Source: Same as Table 7-A-5 but with interest and depreciation computed as 25% of incremental captial cost (i.e., 15% depreciation plus 10% interest).

Note: [a] 1976 dollars.

[b] Includes adjustment for seat loss.

IMPACT ON QUANTITY OF
BUS SERVICE DEMANDED

On the assumption that increments to prime cost are passed through fully, to consumers, results of the sort provided in Tables 7-A-5 and 7-A-6 can be combined with average revenue statistics to estimate the potential increase in average fare per mile that results from the various levels of noise abatement technology.

Statistics on average revenues per vehicle mile are provided in Table 7-A-7. Comparison of these numbers with expenses per revenue mile, Table 7-A-1, indicates that profit margins in this regulated industry are moderate and relatively constant over time. The average fare in 1976 dollars can be estimated by applying the percentage increase in the Consumer Price Index (transportation)[2] for 1975 to June 1976:

(165.9/150.6) X 93.20 = 102.67c per vehicle mile.

Midrange calculations for the estimated percentage increase in average fares are given in Table 7-A-8. These numbers are multiplied by the demand elasticity estimate of -0.5 from Appendix D to compute the expected change in quantity of service demanded.

IMPACT ON EQUILIBRIUM
BUS PRODUCTION

The foregoing analysis, and Table 7-A-8, indicates that for all technology levels proposed, the impact on equilibrium bus service demanded is quite small, and in most cases virtually imperceptible. Since it is unlikely that the technology of bus fleet management permits substantial substitution

2 Survey of Current Business, July 1976; page S-8.

TABLE 7-A-7

OPERATING REVENUE PER PASSENGER AND PER VEHICLE MILE, 1939-75, U.S. CLASS I INTERCITY BUS OPERATIONS

Calendar Year	Passenger Revenue (millions)	Operating Revenue per Passenger	Operating Revenue per Vehicle Mile
1939	$113.9	$ 0.83	22.35¢
1950	321.4	0.97	34.32
1960	354.8	2.12	48.68
1965	453.2	2.73	55.36
1968	463.7	3.18	60.93
1969	483.2	3.55	65.25
1970	510.9	3.81	68.84
1971	540.1	4.19	74.32
1972	540.3	4.25	76.45
1973	562.4	4.73	79.91
1974p	643.3	5.27	89.09
1975p	638.2	5.45	93.20

Source: National Association of Motor Bus Owners, One-Half Century of Service to America, Tables 3 and 4: Regular route inter-city service. p: preliminary.

TABLE 7-A-8

ESTIMATED PERCENTAGE INCREASE IN AVERAGE FARE PER MILE, AND EFFECT ON QUANTITY DEMANDED, ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED INTEGRAL INTERCITY BUSES

			ASSUMPTION A		ASSUMPTION B	
Technology Level	Exterior dBA	Interior dBA	Fare Increase	Change in Demand	Fare Increase	Change in Demand
1	86	84	0.004%	-0.002%	0.011%	-0.006%
2	83	83	0.042	-0.021	0.123	-0.062
3	80	80	0.495	-0.247	0.851	-0.426
4	77	80	1.036	-0.518	1.670	-0.835
5	75	78	2.627[a]	-1.314[a]	4.622[a]	-2.311[a]

Source: Tables 7-A-2 and 7-A-7. Operating revenues per mile in 1976 dollars are estimated at 102.67¢ per revenue mile.

Note: Calculations assume 10 percent per annum depreciation, 10 percent per annum rate of interest and EPA estimates of costs. Calculations under Assumption A assume 250,000 vehicle miles per bus-year, whereas calculations under Assumption B assume 86,000 vehicle miles per bus-year.

[a] Includes adjustment for lost seats.

between buses and other inputs in the production of bus service, it is probable that reduced patronage of one or two percent resulting from noise abatement technology will translate into an equivalent reduction in long-run demand for new buses.[5]

To buttress this argument further, note in Table 7-A-2 that the noise abatement technology in Levels 3 through 5 simultaneously affects maintenance and fuel costs each to a greater extent than interest and depreciation expense on incremental equipment.

Fluctuations in annual bus output of one or two percent are well below the normal variation experienced from year to year by the bus industry as a whole (Table 7-A-3). Any attempt to refine the analysis further along the lines of an aggregate demand model would prove fruitless. The remainder of Subsection 7-A addresses secondary financial impacts and the baseline projections.

FINANCIAL IMPACTS
ON USERS

The proposed regulations may have adverse economic impacts not recorded above in the "long-run" analysis if they cause short-run financial disruptions or have adverse distributional effects. Consider first the impact on the consumer and fleet operators.

[5] Passengers per bus (average load) have remained remarkably constant on intercity bus service. 1950: 18.2 passengers per bus; 1960: 18.0; 1965: 19.2; 1970: 19.1; 1975: 19.3. (Source: NAMBO, One-half Century of Service to America.)

Since motor bus intercity travel is typically somewhat slower and less convenient than travel by alternative modes (especially air and auto), a larger portion of intercity bus patronage is from lower income groups than for other modes. Increases in the costs of intercity bus transportation will, therefore, affect lower income groups more adversely than others. The magnitude of this distributional effect is likely to be quite small, however. An increase in fare revenues by 4.62 percent (Table 7-A-8) and a resulting predicted loss in demand of 2.31 would increase the total revenue of all U.S. carriers by about $25.7 million (in 1976).

Fleet operators would be disadvantaged by the noise abatement technology if the increased equipment costs could not be met without incurring substantial additional financing. The relatively small share of equipment replacement costs (Table 7-A-1) in total operating expenditures makes this an unlikely possibility, however. Moreover, the increased responsiveness of regulatory bodies to permitting cost-justified fare increases will help firms to maintain satisfactory profit margins.

FINANCIAL IMPACTS ON PRODUCERS, INCLUDING EXPORTERS AND IMPORTERS

As indicated in the above economic analysis, the long-run impact on equilibrium industry output is likely to be small in percentage terms, so that given the current growth rate of industry output no actual reductions in output are projected from one year to the next as a result of reduced demand for bus services. There remains, however, the possibility of adverse impact on specific supplies if their product or technology differs significantly from the industry norm.

For U.S. producers of intercity buses, Figure 3-16 (Section 3) indicates that the market is dominated by three large producers: Motor Coach Industries (Greyhound), General Motors, and Eagle International, who together account for virtually 100 percent of U.S. production. The production of these busmakers is highly standardized (Figure 3-6), and no differential impact on producers is envisaged.

U.S. International trade in intercity buses involves two major foreign countries: Canada and Belgium. Canadian production, trade, and regulation of buses are so completely integrated with U.S. production (under the Automotive Pact Trade Agreement) that virtually no differential impacts vis-a-vis Canadian imports is expected. Imports of buses from Belgium, which have amounted to approximately 62 percent of annual U.S. production during 1970-75, are almost exclusively production of a subsidiary of Eagle International; currency devaluation by the U.S. has led Eagle to shift its manufacturing facilities back to the United States, and beginning in 1976 this "import" source is largely eliminated.

ANNUALIZED COSTS FOR
INTERCITY BUS NOISE ABATEMENT

Annualized cost calculations projected to the year 2000 for 15 regulatory schedules are presented in Appendix E. Input variables for intercity buses are listed in Table 7-A-9.

TABLE 7-A-9

DATA INPUT AND PARAMETER VALUES
FOR ANNUALIZED COST CALCULATIONS
DIESEL POWERED INTEGRAL INTERCITY BUSES

Variable Description	Source or Value
Baseline Production Rate	Figure 3-23
Projected Production Rate	Figure 3-23
Incremental Operating Cost	Table 7-A-2
Incremental Maintenance Cost	Table 7-A-2
Incremental Equipment Cost	Table 7-A-2[a]
Depreciable Life (years)	15
Price Elasticity of Demand	-0.50
Rate of Discount	0.10

Note: [a]Incremental equipment costs in Table 7-A-2 for Technology Level 6 are increased by $6,000 to reflect seat loss.

B. ECONOMIC IMPACT OF NOISE REGULATIONS ON URBAN TRANSIT MOTOR BUS CARRIERS AND MANUFACTURERS

Appendix C indicates three major effects of bus noise reduction technology, as applied to the standard diesel powered integral urban transit bus:

- o Additional noise-abatement equipment installed on newly-equipped buses
- o Increased maintenance costs for new buses
- o Reduced fuel efficiency of new buses

The primary impact of these costs is on bus users -- fleet operators, transit authorities, and consumers. The analysis below concentrates attention initially on the user end of the industry. Subsequently, induced impacts on manufacturers and financing authorities are studied.

ANALYSIS OF USER COSTS

Tables 7-B-1 and 7-B-2 summarize operating expense accounts of a sample of urban bus transit systems which are also members of the American Public Transit Association. The tables demonstrate that bus capital, the major component of the "Depreciation and Amortization" account, represents a small fraction of total operating expense, about seven percent or less.

An important result from economic theory (reference 2) states that the demand for an intermediate product (like buses) is less sensitive (elastic) to changes in its own price, the smaller is the share of that intermediate product in the composition of the final product demanded (bus transportation). The reason is that for a given elasticity of demand for the final product,

TABLE 7-B-1

PERCENTAGE DISTRIBUTION OF EXPENSES BY EXPENSE CATEGORY, APTA BUS TRANSIT SYSTEM RESPONDENTS, 1960 AND 1969

Expense Category	Percent of Total	
	1960	1969
Total Operating Expenses	100.00	100.00
Operation and Maintenance - Total	85.56	86.72
Equipment Maintenance and Garage	19.26	16.37
Transportation	49.42	52.68
Station	0.60	1.04
Traffic, Solicitation, and Advertising	0.90	1.29
Insurance and Safety	5.31	4.41
Administrative and General	10.07	10.93
Depreciation and Amortization	6.06	6.98
Operating Taxes and Licenses	7.92	5.81
Operating Rents, Net	0.46	0.46

Note: Numbers are compiles from American Transit Association, Transit Operating Report, 1960 and 1969, as aggregates of respondent-firm data. The sample contains 107 firms in 1960 and 76 firms in 1969.

Source: John D. Wells, et. al., Economic Characteristics of the Public Transportation Industry, Table 3.5 Washington, D.C.: U.S. Government Printing Office, 1972.

TABLE 7-B-2

EXPENSES PER BUS-MILE BY EXPENSE CATEGORY,
AGGREGATE FOR 48 BUS TRANSIT SYSTEMS,
AND PERCENTAGE DISTRIBUTION, 1974

EXPENSE CATEGORY	CENTS PER BUS-MILE	PERCENT OF TOTAL
Total Operating Expenses	116.65	100.00
Operation and Maintenance -- Total	106.18	91.02
Equipment Maintenance and Garage	20.68	17.73
Transportation	63.31	54.27
Station	0.25	0.21
Traffic, Solicitation, and Advertising	1.93	1.65
Insurance and Safety	4.65	3.99
Administrative and General	15.36	13.17
Depreciation and Amortization	5.27	4.52
Depreciation of Revenue Equipment	4.60	3.94
Operating Taxes and Licenses	5.20	4.46

Source: American Public Transit Association, Transit Operating Report for Calendar/Fiscal Year 1974, Section D. The sample consists of all APTA respondent systems in locations where buses are the sole public transit mode and for which either ICC or APTA format of accounts are provided.

transportation, the smaller the share of the intermediate input, buses, the smaller will be the percentage impact of a change in bus prices on the total cost and price of the final product. A relatively small change in the price of the final product, transportation, implies a relatively small effect on quantity demanded of both the final product and the intermediate good.

Using this theorem, Tables 7-B-1 and 7-B-2 lend insight into the probable results of the economic impact analysis. Since bus capital has a small share in total factor cost, a given regulation-induced change in the price of new buses has only a small effect on the "derived" demand for new buses. The ability of the bus manufacturing industry to pass through the additional equipment costs without severely reducing sales is thereby enhanced.

Expenses for fuel and maintenance are relatively important components of the operating expense accounts, but here the potential for adverse economic impacts on the suppliers of these inputs -- the petroleum industry and the supply of skilled mechanic labor, respectively, -- is negligible due to the overwhelming size of these markets relative to the bus service industry.

COST ESTIMATES
FROM APPENDIX C

Table 7-B-3 summarizes the pertinent estimates of technology cost from Appendix C. Expense estimates are in terms of 1976 dollars. It should be noted that the various proposed technology levels are cost independent of one another.

TABLE 7-B-3

INCREMENTAL EQUIPMENT AND OPERATING EXPENSES ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES

			EQUIPMENT COST PER BUS				
TECHNOLOGY LEVEL	EXTERIOR dBA	INTERIOR dBA	High	Low	EPA Estimate	FUEL COST PER BUS-YEAR[a]	MAINTENANCE PER BUS-YEAR
1	86	84	$ 205	$ 0	$ 50	$ 0	$ 0
2	83	83	505	0	195	0	70
3	81	83	1,683	0	380	0	140
4	80	80	2,900	350	875	145	305
5	77	80	4,200	650	1,670	300	520
6	75	78	5,500	950	3,270	890	830

Source: Appendix C

Note: [a] Fuel cost per bus-year is estimated by multiplying incremental gallons per mile (Appendix C) times 42.2 cents per gallon times 30,000 vehicle miles per bus-year. (American Public Transit Association, Transit Fact Book '75-'76 pp. 23-24.)

The estimates in Table 7-B-3 are "incremental" expenses, that is, additional expenses over and above the costs in 1976 of purchasing and operating a typical bus that has no noise abatement equipment installed. Incremental fuel costs are computed on the basis of midpoint mileage estimates, as described in the footnote to the table.

For Technology Level 6, an additional consideration not reflected in Table 7-B-3 is the fact that noise abatement equipment required to attain the 75 dBA exterior level and the 78 dBA interior level also entails a reduction in seating capacity by two seats (four passengers) from the standard 45 or 53 passenger bus. Reduced seating capacity clearly imposes costs on the transit firm, but the magnitude of these costs is difficult to assess in the absence of accurate information on capacity utilization of existing buses.

An indirect estimate of the cost of reduced seating capacity is available by comparing the costs of constructing and operating buses of different sizes. Currently, two sizes of urban transit buses are produced, with passenger ratings and specification as follows:

Passenger Rating	Standard Wheelbase (Inches)	Length (Feet)	Weight (1,000 lbs.)	Engine Make and Model
45	225	35	17.6 - 22.7	Det D 6V-71N
				- or -
53	285	40	19.3 - 23.8	Det D 8V-71N

Industry sources have indicated to EPA that the two bus types are priced in 1976 as follows:

35 foot	$58,000 - $68,000
40 foot	$64,000 - $75,000

A comparison of midpoint price estimates indicates a price differential of $6,500 for eight passengers, hence an implied differential of $3,250 for four passengers.

Bus industry sources have also indicated to EPA that there is no measurable difference in operating and maintenance costs between the two buses. Hence, the only adjustment called for in Table 7-B-3 is the addition of $3,250 to the equipment cost for Technology Level 6. <u>This alteration is included in all subsequent calculations of the economic impact analysis.</u>

ESTIMATES OF INCREMENTAL CAPITAL COSTS

The formula for estimating incremental capital costs is:

$$dX/dR = (r + i)\ dK/dR,$$

where dX/dR is the incremental capital (equipment) cost associated with regulatory level R, dK/dR is the dollar value of noise abatement equipment installed on new buses, r is the rate of depreciation, and i is the rate of interest. A major difficulty arises in providing accurate estimates of the rate of depreciation r.

In the absence of satisfactory price information on used urban transit buses, two alternatives for estimating r are discussed: (1) estimates based on life cycle assumptions, and (2) analysis of fleet operators' accounting statements. Both of these methods encounter difficulties, which are examined in turn.

(a) Estimates Based on Life-Cycle Assumptions

Table 7-B-4 demonstrates that the total U.S. population of transit buses has remained virtually constant at roughly 50,000 units during the

TABLE 7-B-4

URBAN BUS TRANSIT VEHICLE INVENTORY AND PRODUCTION, 1940-75

Calender Year	Motor Bus Inventory	New Passenger Buses Delivered	Deliveries as Percent of Existing Stock
1940	35,000	3,984	11.38%
1945	49,670	4,441	8.94
1950	56,820	2,668	4.70
1955	52,400	2,098	4.00
1960	49,600	2,806	5.66
1961	49,000	2,415	4.93
1962	48,800	2,000	4.10
1963	49,400	3,200	6.48
1964	49,200	2,500	5.08
1965	49,600	3,000	6.05
1966	50,130	3,100	6.18
1967	50,180	2,500	4.98
1968	50,000	2,228	4.46
1969	49,600	2,230	4.50
1970	49,700	1,442	2.90
1971	49,150	2,514	5.11
1972	49,075	2,904	5.92
1973	48,286	3,200	6.63
1974	48,700	4,818	9.89
1975p	50,811	5,261	10.35

Source: American Public Transit Association, Transit Fact Book '75-'76, Tables 12 and 14. p: preliminary.

post World War II period. New production has averaged roughly six percent of total inventories during this period.

On the assumption that the age distribution and technology of buses is roughly uniform over time, these numbers indicate a lower bound on the rate of depreciation of six percent per year. Some caution should be exercised, however, in accepting this figure as an unbiased estimate of depreciation, because of the likely possibility that inventory figures represent an increasing proportion of relatively inactive buses. Such buses serve as capital reserves to meet contingencies and periods of peak demand. The accretion of such reserves during the post-war period implies a downward bias in the above estimate of the actual annual rate of depreciation.

A comparable estimate of the rate of depreciation based on life cycle data was recently undertaken using fleet inventory characteristics collected by the American Public Transit Association (Reference 3). Using survivor curve techniques applied to the age distribution of current bus fleet inventories, the study concluded that transit buses have an average life of 19 years, implying a depreciation rate of roughly six percent per annum. As with the above estimate, however, the 19-year age may be biased (upwards) due to the existence of significant stocks of old, low-use buses.

(b) Estimates Based on Fleet Operators' Financial Statements

An upper bound on the rate of depreciation may be obtained by examining the pertinent accounting statements from ICC annual compilations for Class I carriers engaged primarily in local or suburban service. Since the coverage is limited to the large carriers, and hence to the larger urban areas, the rate of depreciation is probably somewhat higher than that experienced on a nationwide basis.

ICC accounting rules permit a variety of depreciation formulas for reporting purposes, but the industry norm (and the rule of the Internal Revenue Service) is eight year, straight-line depreciation. Eight years is well below the true economic life of urban transit buses; actual service life can extend to fifteen or twenty years or longer. Table 7-B-5 records the pertinent statistics from the ICC Annual Statistics. A question remains as to whether to use the "total equipment" or "net equipment" accounts as the basis for estimating the rate of annual depreciation. Use of the "total" definition (Column 2 in Table 7-B-5) results in an understatement or depreciation, since it includes equipment still owned but older than eight years and therefore no longer depreciated. Net equipment (Column 3 in Table 7-B-5), on the other hand, overstates depreciation because the eight-year formula understates the total capital stock.

Note, however, that estimates of the rate of depreciation based on these accounting summaries are <u>not</u> biased due to price inflation; both the numerator (stated depreciation) and the denominator (total or net assets) are increased each year by equally inflated increments.

Using the net equipment definition of depreciable assets, an upper bound on the annual rate of depreciation r is estimated for the years 1960-73 as 14.3% per annum.

TABLE 7-B-5

SELECTED BALANCE SHEET AND OPERATING STATISTICS, CLASS I MOTOR BUS CARRIERS ENGAGED IN LOCAL OR SUBURBAN SERVICE, 1941-73

Calendar Year	Total Revenue Passenger Equipment (millions)	Net Revenue Passenger Equipment[a] (millions)	Depreciation of Revenue Equipment (millions)	Equipment Acquired During Year (Buses)	Equipment Owned At Year-End (Buses)
1941	$ 23.6	$ 9.1	$ 2.34	355	3,167
1950	259.7	25.7	5.26	247	5,146
1955	292.3	31.2	7.05	510	6,547
1960	390.9	37.3	6.08	578	5,928
1961	100.1	40.7	6.83	424	5,755
1962	43.8	17.8	3.38	414	3,311
1963	47.3	16.5	3.29	281	3,135
1964	55.3	21.0	3.55	439	3,357
1965	139.0	81.6	9.99	709	6,603
1966	141.2	87.6	10.46	622	6,953
1967	149.7	60.1	11.05	533	7,342
1968	152.2	97.2	11.09	635	7,344
1969	131.0	84.6	8.52	331	4,912
1970	132.0	88.5	8.24	213	4,837
1971	117.1	79.5	6.59	150	4,054
1972	134.6	89.1	7.44	127	4,518
1973	92.0	22.0	4.71	79	3,001

Source: Interstate Commerce Commission, Transport Statistics in the United States (annual).

Note: [a] Net of Reserves for Depreciation. Coverage varies from year to year according to ICC definition of Class I carriers.

(c) Summary of Rate of
Depreciation Estimates

Urban transit buses have potentially long service lives, and the concept of a single "rate" of depreciation is not obviously well-defined or applicable. Depreciation is itself an economic variable, subject to variation according to the maintenance and route decisions of the fleet operator.

Historically, however, the size of the total U.S. fleet and production of new urban transit buses have maintained relatively constant levels over the past three decades. On the assumption that this record is representative of the type of depreciation that buses do, in fact, experience, EPA estimates an annual rate of depreciation of six to fourteen percent, with a best mid-range estimate of ten percent per annum.

ESTIMATES OF INCREMENTAL
PRIME COST

The technology cost estimates from Table 7-B-3 for incremental equipment, fuel, and maintenance cost can be combined into single estimates of incremental cost per vehicle mile. This is accomplished by converting equipment cost increments from Table 7-B-3 into per annum capital costs (depreciation plus interest), and then by dividing the sum of annual capital, fuel, and maintenance cost by 30,000 vehicle miles per year.[6]

Table 7-B-6 provides results of the calculations for the assumption of a 10% annual rate of depreciation. The calculated numbers are relatively insensitive to the assumption about incremental capital cost from Table 7-B-3 (i.e., low versus medium versus high).

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6 American Public Transit Association, Transit Fact Book '75-'76, pp. 23-24.

TABLE 7-B-6

INCREMENTAL PRIME COST PER BUS-MILE OF SERVICE ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES

Technology Level	Exterior dBA	Interior dBA	Incremental Cost--Cents per Vehicle-Mile[a] High	Low	EPA Estimate
1	86	84	0.137	0.000	0.033
2	83	83	0.570	0.233	0.363
3	81	83	1.589	0.467	0.720
4	80	80	3.433	1.733	2.083
5	77	80	5.533	3.167	3.847
6	75	78	11.567[b]	8.533[b]	10.080[b]

Source: Tables 7-B-3 and 7-B-4. Interest and depreciation are calculated as 20% of incremental capital cost (10% depreciation plus 10% interest). Estimates reflect an assumption of 30,000 vehicle-miles per bus-year (American Public Transit Association, Transit Fact Book '75-'76, pp. 23-24).

[a] 1976 dollars.

[b] Includes adjustment for seat loss.

EFFECT OF UMTA SUBSIDIES
FOR EQUIPMENT PURCHASES

Qualified urban transit authorities receive a subsidy of up to 80% of the cost of new equipment purchases from the Urban Mass Transit Administration (UMTA). Since the urban transit firm has no incentive to pass on costs borne by the Federal Government to its customers, the effect of UMTA subsidies is to reduce the effective capital cost by 80%. Table 7-B-7 reproduces the calculations of Table 7-B-6 on the assumption that incremental equipment costs have an annual value equal to 20% that assumed in Table 7-B-6.

The calculations also constitute a sensitivity analysis with respect to the assumption about the rate of depreciation. In effect, Table 7-B-7 assumes an annual rate of depreciation of 2.0% in place of 10% in Table 7-B-6. The difference in the resulting numbers is not substantial, and one may conclude that the economic impact analysis is relatively insensitive to the assumption about the annual rate of depreciation.

IMPACT ON QUANTITY OF
BUS SERVICE DEMANDED

On the assmption that increments to price cost are passed through to consumers, at least in part, results of the sort provided in Table 7-B-7 can be combined with average revenue statistics to estimate the potential increase in average fare per mile that results from various levels of noise abatement technology.

Statistics on average revenue per vehicle mile are provided in Table 7-B-8. The average fare in terms of 1976 dollars can be estimated by applying

TABLE 7-B-7

INCREMENTAL PRIME COST PER BUS-MILE OF SERVICE
DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES
ASSUMING 80 PERCENT FUNDING OF CAPITAL
EXPENDITURES BY THE URBAN MASS
TRANSPORTATION ADMINISTRATION

Technology Level	Exterior dBA	Interior dBA	Incremental Cost--Cents per Vehicle-Mile[a] High	Low	EPA Estimate
1	86	84	0.027	0.000	0.007
2	83	83	0.301	0.233	0.259
3	81	83	0.691	0.467	0.517
4	80	80	1.887	1.547	1.617
5	77	80	3.293	2.820	2.956
6	75	78	6.900[b]	6.293[b]	6.603[b]

Source: Same as Table 7-B-6, but with interest and depreciation computed as 4.0% of incremental capital cost (i.e., 1/5 x 20%).

Note: [a] 1976 dollars.

[b] Includes adjustment for seat loss.

TABLE 7-B-8

OPERATING REVENUE PER PASSENGER AND PER VEHICLE MILE, 1940-75, U.S. MOTOR BUS TRANSIT SYSTEMS

Calendar Year	Passenger Revenue (millions)	Operating Revenue per Passenger	Operating Revenue per Vehicle Mile
1940	$248.8	6.87¢	20.83¢
1945	590.0	7.07	34.26
1950	734.2	9.56	38.74
1955	826.3	14.41	48.32
1960	910.3	17.17	57.75
1961	897.8	18.57	58.69
1962	910.1	19.07	60.06
1963	932.2	19.62	61.20
1964	950.4	20.10	62.20
1965	971.9	20.55	63.59
1966	998.1	21.23	65.59
1967	1037.3	22.39	67.98
1968	1049.7	23.20	69.60
1969	1114.8	25.71	75.41
1970	1193.6	29.41	84.69
1971	1226.8	32.23	89.19
1972	1177.8	33.07	90.05
1973	1183.8	32.40	86.38
1974	1269.6	31.76	88.72
1975p	1310.1	32.10	85.74

Source: American Public Transit Association, Transit Fact Book '75-'76, Tables 7, 9, and 10. p: preliminary.

the percentage increase in the Consumer Price Index (transportation)[7] from 1975 to June 1976:

(165.9/150.6) X 85.74 = 94.45 per vehicle mile.

Examination of the cost/revenue ratio of U.S. urban mass transit systems (Table 7-B-9) indicates that an assumption of full cost pass-through of incremental expenses is unwarranted. Not only do urban transit systems enjoy significant subsidies in the purchase of new equipment (a relatively small proportion of total operating costs), but subsidies by federal (UMTA), state and municipal financing authorities has brought about a condition of costs in excess of revenues by a ratio approaching two-to-one in 1976.

A reasonable assumption is that such subsidization will continue at present levels. The calculations of Table 7-B-10 assume, therefore, that only one-half of regulation induced cost increments are passed on to consumers in the form of higher fares.

Percentage increase in fares as computed in Table 7-B-10 translates into estimates of the corresponding decrease in ridership demanded by applying demand elasticity estimates from Appendix D. The calculations of regulation-induced reductions in quantity demanded in Table 7-B-10 assume the relatively high elasticity of -0.5: actual percentage decreases in quantity will probably be less than those computed in the table.

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Survey of Current Business, July 1976; page S-8.

TABLE 7-B-9

TREND OF TRANSIT OPERATIONS, 1940-1975

Calendar Year	Operating Revenue (millions)	Operating Expense (millions)	Cost-Revenue Ratio
1940	$ 737.0	$ 660.7	0.896
1945	1,380.4	1,231.7	0.892
1950	1,452.1	1,385.7	0.954
1955	1,426.4	1,370.7	0.961
1960	1,407.2	1,376.5	0.978
1965	1,443.8	1,454.4	1.007
1966	1,478.5	1,515.6	1.025
1967	1,556.0	1,622.6	1.043
1968	1,562.7	1,723.8	1.103
1969	1,625.6	1,846.1	1.136
1970	1,707.4	1,995.6	1.169
1971	1,740.7	2,152.1	1.236
1972	1,728.5	2,241.6	1.297
1973	1,797.6	2,536.1	1.411
1974	1,939.7	3,239.4	1.670
1975p	2,002.4	3,705.9	1.851

Source: American Public Transit Association, Transit Fact Book '75-'76 Table 4. p: preliminary.

TABLE 7-B-10

ESTIMATED PERCENTAGE INCREASE IN AVERAGE FARE PER MILE, AND EFFECT ON QUANTITY DEMANDED, ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES

			HIGH		LOW		EPA INDEPENDENT ESTIMATE	
Technology Level	Exterior dBA	Interior dBA	Fare Increase	Change in Demand	Fare Increase	Change in Demand	Fare Increase	Change in Demand
1	86	84	0.014%	-0.007%	0.0%	0.0%	0.004%	-0.002%
2	83	83	0.159	-0.080	0.124	-0.062	0.137	-0.069
3	81	83	0.366	-0.183	0.247	-0.124	0.274	-0.137
4	80	80	0.999	-0.499	0.819	-0.409	0.856	-0.428
5	77	80	1.743	-0.872	1.493	-0.746	1.565	-0.782
6	75	78	3.653[a]	-1.826[a]	3.332[a]	-1.666[a]	3.495[a]	-1.748[a]

Source: Table 7-B-3 and 7-B-8. Operating revenues per mile in 1976 dollars are estimated at 94.45¢ .

Note: Calculations assume 10 percent per annum depreciation and 10 percent per annum rate of interest, and that 20% of the incremental capital costs are incurred by transit firms (UMTA financing the remaining 80%). Fare increase are computed on the assumption of a fifty percent cost pass-through. Calculations assume 30,000 vehicle miles per bus-year.

[a] Includes adjustment for lost seats.

IMPACT ON EQUILIBRIUM
BUS PRODUCTION

The foregoing analysis, and Table 7-B-10, indicates that for all Technology Levels proposed, the impact on equilibrium bus service demanded is quite small, and in most cases virtually imperceptible. Since it is unlikely that the technology of bus fleet management permits substantial substitution between buses and other inputs in the production of bus service, it is probable that reduced patronage of one or two percent resulting from noise abatement technology will translate into an equivalent reduction in long-run demand for new buses.[8]

To buttress this argument further, note in Table 7-B-3 that the noise abatement technology in Levels 4 through 6 simultaneously affects maintenance and fuel costs each to a greater extent than interest and depreciation expense on incremental equipment.

Fluctuations in annual bus output of one or two percent are well below the normal variation experienced from year to year by the bus industry as a whole (Table 7-B-4). The remainder of this analysis for transit buses addresses secondary financial impacts and baseline projections.

FINANCIAL IMPACT
ON USERS

The proposed regulations may have adverse economic impacts not recorded above in the "long-run" analysis if they cause short-run financial dislocations

[8] Motor bus passengers per vehicle have declined steadily since World War II, despite fluctuations in relative operating costs. 1945; 5.74 passengers per vehicle; 1950: 4.74; 1955: 4.24; 1960: 4.08; 1965: 3.80; 1970: 3.57; 1975: 3.32. (Source: APTA, Transit Fact Book '75-76, Tables 6 and 10.)

or have distributional effects. Consider first the impact on consumers and fleet operators.

Since urban transit by motor bus is typically somewhat slower and less convenient than travel by alternate modes, especially auto, a larger portion of urban bus patronage is from lower income groups than for other modes.[9] Increases in the costs of urban transit will therefore effect lower income groups more adversely than others. The magnitude of this distributional effect is likely to be quite small, however. A maximum predicted increase in fare revenues of 3.65 percent (Table 7-B-10) and a corresponding decrease in demand of 1.83 percent would increase the total revenue of U.S. bus transit systems by $35.1 million (in 1976).

Fleet operators would be disadvantaged by the noise abatement technology if the increased equipment costs could not be met without incurring substantial additional financing. The relatively small share of equipment replacement costs (Tables 7-B-1 and 7-B-2) in total operating expenses makes this an unlikely possibility, however, particularly when consideration is taken of the UMTA equipment subsidy program.

The annual survey by the American Public Transit Association of urban transit fleet inventories makes possible a statement of the likely replacement needs of various municipalities. Table 7-B-11 presents such a summary, broken down by size of city fleet. It is apparent from Table 7-B-11 that

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9 The Federal Highway Administrations's <u>Nationwide Personal Transportation Study, 1973</u>, shows that for 1969-70, ridership on bus and street car transportation is distributed as follows (by annual household income): $0-3,000: 12.7%; $3,000-3,999: 10.8%; $4,000-4,999: 9.2%; $5,000-5,999: 8.8%; $6,000-7,499: 12.3%; $7,500-9,999: 15.4%; $10,000-14,999: 16.3%; $15,000 and over: 7.9%; Not applicable: 6.6%.

larger cities do not differ significantly from smaller cities in terms of median fleet age.

Table 7-B-12 identifies major municipalities with median fleet age in excess of ten years as of June 10, 1975. Municipalities that are especially prone to replacement needs appear to be distributed evenly by geographical region and city type.

FINANCIAL IMPACTS ON PRODUCERS, INCLUDING EXPORTERS AND IMPORTERS

As indicated in the above economic analysis, the long-run impact on industry output equilibrim is likely to be small in percentage terms. Thus, given the current growth rate of industry output (in recent years), no actual reductions in output are projected from one year to the next as a result of reduced demand for bus services. There remains, however, the possibility of adverse impact on specific suppliers if their product or technology differs significantly from the industry norm.

Figure 3-17, section 3, indicates that the market is dominated by three large producers: General Motors, Flexible, and AM General, who together account for virtually 100 percent of U.S. production. The production of these bus-makers is highly standardized (Figure 3-7), in fact virtually interchangeable, and no differential impact on producers is envisaged.

Since the noise abatement technology involves mostly minor additions and modifications to existing equipment, the potential for impacting U.S. export production to non-regulated countries is minimal. The only, importer of consequence of urban transit buses is Mercedes-Benz, whose marketing activities are devoted exclusively to the airport-hotel and municipal "feeder route" markets.

TABLE 7-B-11

MEDIAN AGE OF FLEET BY FLEET SIZE,
U.S. MOTOR BUS TRANSIT SYSTEMS,
AS OF JUNE 30, 1975

Fleet Size (Buses)	Number of Cities	Mean Median Age	Standard Deviation
500 or more	17	9.82 years	4.14
100 to 499	43	8.23	4.48
50 to 99	41	9.54	7.23
3 to 49	104	8.64	6.68

Source: American Public Transit Association, Transit Passenger Vehicle Fleet Inventory as of June 30, 1975.

TABLE 7-B-12

MAJOR BUS TRANSIT SYSTEMS WITH MEDIAN FLEET AGE IN EXCESS OF TEN YEARS AS OF JUNE 30, 1975

City	Fleet Size (Buses)	Median Fleet Age (Years)
Maplewood, New Jersey	1847	12
Boston, Massachusetts	1149	13
Oakland, California	878	12
Seattle, Washington	559	20
Buffalo, New York	556	12
Milwaukee, Wisconsin	523	13
Cincinnati, Ohio	444	11
Houston, Texas	421	13
Norfolk, Virginia	285	18
Richmond, Virginia	233	14
Sacramento, California	204	13
Jacksonville, Florida	193	13
Louisville, Kentucky	179	14
Charlotte, North Carolina	132	14
Hampton, Virginia	106	19
Holyoke, Massachusetts	98	23
Dayton, Ohio	93	27
Des Moines, Iowa	90	17
Des Plaines, Illinois	88	20

Source: American Public Transit Association, Transit Passenger Vehicle Fleet Inventory as of June 30, 1975.

The Mercedes-Benz buses sold in the U.S. are small (passenger rating: 19), limited use vehicles which do not compete with the industry standard U.S. urban transit model. Annual average sales amount to 200 units, with a base price of $26,111. Sales to municipalities are primarily to service "feeder" routes, and some further penetration of this market is anticipated in future years.

Noise levels of the Mercedes bus are currently high (84 dBA) at 75% of maximum throttle at 45 mph). Mercedes-Benz has engaged in research to reduce these levels, including the development of optional equipment to reduce exterior noise to 80 dBA. Information on their ability or the cost of attaining noise levels below 80 dBA is not available at present. Some adverse impact on Mercedes-Benz imports to the U.S. market does appear possible at this point.

ANNUALIZED COSTS FOR
URBAN TRANSIT BUS NOISE ABATEMENT

Annualized cost calculations projected to the year 2000 for 15 regulatory schedules are presented in Appendix E. Input variables for urban transit buses are listed in Table 7-B-13.

TABLE 7-B-13

DATA INPUT AND PARAMETER VALUES
FOR ANNUALIZED COST CALCULATIONS
DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES

Variable Description	Source or Value
Baseline Production Rate	Figure 3-24
Projected Production Rate	Figure 3-24
Incremental Operating Cost	Table 7-B-3
Incremental Maintenance Cost	Table 7-B-3
Incremental Equipment Cost	Table 7-B-3[a]
Depreciable Life (years)	12
Price Elasticity of Demand	-0.50
Rate of Discount	0.10

[a] Note: Incremental equipment costs in Table 7-B-3 for Technology Level 6 are increased by $3,250 to reflect seat loss.

C. ECONOMIC IMPACT OF NOISE REGULATIONS ON SCHOOL BUS CARRIERS AND MANUFACTURERS

INTRODUCTION

The school bus industry is a highly complex entity consisting of several manufacturers producing an almost infinite number of variations to the basic product - a vehicle designed to transport pupils to and from schools. Almost any combination of the following characteristic variables can be specified by the school bus customer:

1. Engine Type - Gasoline or diesel of various horsepower ratings.
2. Construction - Body-on-chassis or integral.
3. Engine Placement - Forward, mid-unit, or rear.
4. Make - Chassis (3 primary manufacturers), body (6 primary manufacturers), integral (2 manufacturers).
5. Size (seating capacity) - as many as 97 passengers.
6. Options - Air conditioning, interior quality, transmissions (various speeds; standard or automatic), etc.

The production of school buses is, therefore, of a customizing nature with differing costs and prices associated with each of the variables described above.

Due to the impracticality of assessing the economics impact of noise abatement regulations on all possible variations in the product, the analysis has been limited in the following manner:

- Small buses (under 10,000 pound gross vehicle weight rating (GVWR) have been eliminated from consideration.
- Size of buses (in terms of passenger capacity) and optional equipment have been considered only with respect to their contribution to the price range of the final product.

The outgrowth of these limiting factors are the following school bus "product" types:

1. Gasoline powered conventional
2. Gasoline powered forward control
3. Parcel delivery and motor home chassis
4. Diesel powered conventional
5. Diesel powered forward control
6. Diesel powered integral mid-engine
7. Diesel powered integral rear-engine

The proposed noise abatement schedules differ by type of power unit (gas and diesel), and costs of meeting the proposed regulations differ by each of the seven product types defined above. Furthermore, consideration has been given to differential noise abatement costs associated with individual manufacturers insofar as these costs can be identified.

The primary economic areas affected by the noise abatement requisitions are shown schematically in Figure 7-C-1. Each of the following economic impact areas are given consideration in the analysis:

1. Manufacturers
2. End users
3. Suppliers

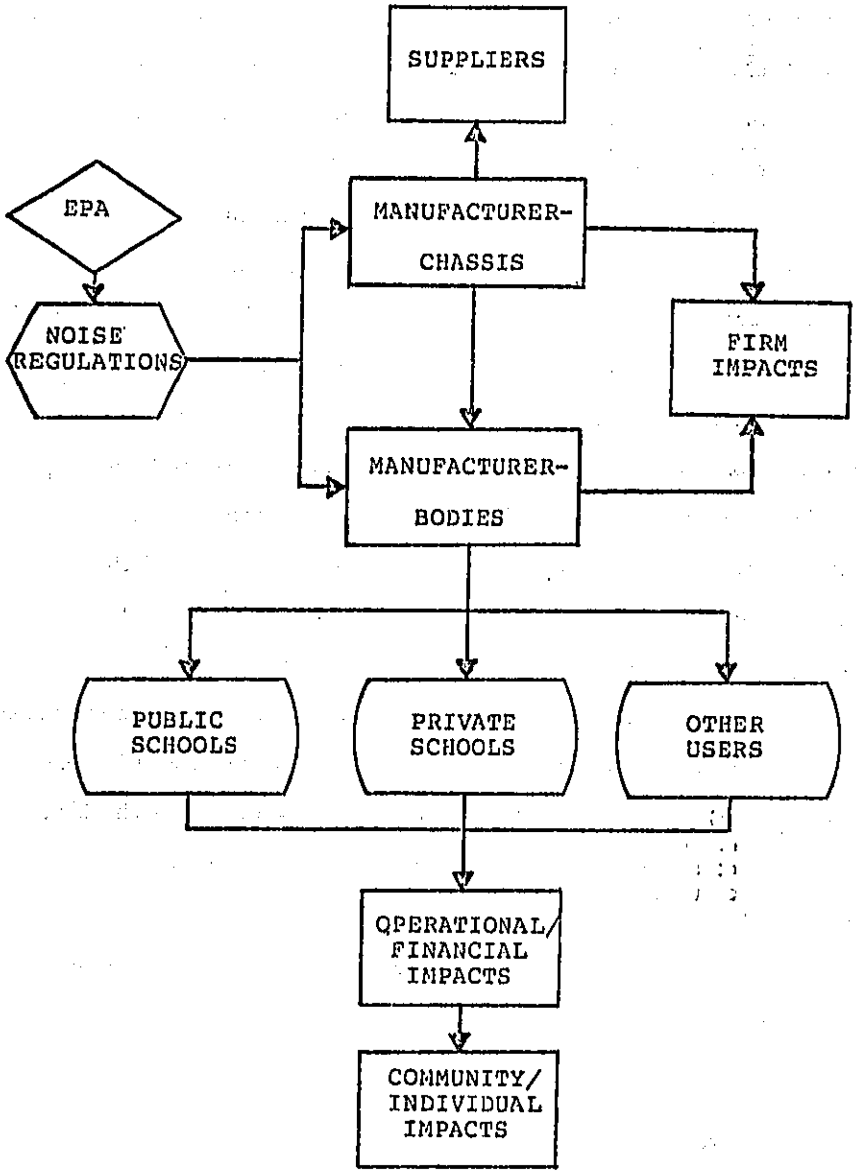
The economic impact analysis assumes a quantitative posture where possible, and the discussion is ordered in the following manner:

- -- Timing of the regulation
- -- Costs of noise abatement
- -- Industry considerations
- -- Analysis of User Costs
- -- Estimates of Incremental Capital Costs
- -- Estimates of Incremental Prime Costs
- -- Impact on Quantity of Bus Production
- -- Financial Impacts
- -- Baseline Projections

TIMING OF THE REGULATION

The point in time when regulations are to be imposed on the industry is important in several respects.

FIGURE 7-C-1
ECONOMIC IMPACT FLOW CHART-
SCHOOL BUSES



1. Technology considerations. The development of the technology associated with quieting vehicles to the noise level allowed by the requisitions can take several years of effort on the part of manufacturers. If the lead time given to the industry is sufficiently long, the opportunity exists to develop and implement less costly emission control equipment for the vehicles. Furthermore, the potential for technology advancements to be realized by all industry groups increases with time.
2. Planning horizon. The promulgation of regulatory constraints has the potential of producing disruptive effects on an industry and its market if the effective date and level of regulation are known only a short time before regulation occurs. The longer the time that industry has to gauge the effects of the regulation on its markets, the more intelligently it is able to react to those effects.

Thus, the economic impact of the various regulatory levels as recommended by EPA and presented in this analysis assumes that sufficient time will have elapsed between announcement and promulgation of the regulations such that:

1. Technology will be adequately developed when regulations are effective.
2. The planning horizon for industry adjustment to any discernable market reactions is sufficiently lengthy.

COSTS OF NOISE
ABATEMENT

After the assessment of the noise abatement technology presently available to the school bus industry was made by EPA an analysis of the costs associated with applying that technology to the various types of school buses was undertaken. EPA's estimates of those costs and discussions concerning the required manufacturing processes are included in the text and figures of Appendix C of this report.

Note that each dBA level has three costs associated therewith -- low, high, and one called the EPA independent estimate. The low and high estimates in most cases refer to cost estimates which were provided to EPA by industry representatives who responded to requests for cost information. The independent estimates were developed by EPA and consulting firms utilizing all available information. Although all three estimates are utilized in developing the economic impact analysis, it is felt that the independent estimate more adequately reflects the actual costs which can be expected to be expended in the process of meeting the regulations.

In order to analyze the costs of quieting school buses in the proper context, it is appropriate to relate the post-regulatory costs of manufacture to the present costs. Cost data of this nature in considered by most companies to be proprietary and confidential. Therefore, the post-regulatory price (assuming a full cost pass-through) related to the pre-regulatory price will serve as a best available approximation of the estimated cost increase.

(a) Present School
Bus Prices

Due to the variance in model types available to the consumer (as described in the introduction of this section), there is no one price which can be pinpointed as being representative of all school bus prices. However, Table 7-C-1 attempts to identify the range of prices a consumer could expect to pay for each type of bus.

Note in Table 7-C-1 the wide range of prices quoted within bus type category and between different categories of bus. The range within categories is primarily due to the variance in specifications required by bus purchasers rather than any discernible differences of manufacturing companies. With respect to the wide variance between prices paid for different school bus types, it should be noted that diesel powered units cost from $3,000 to $4,000 more than comparably equipped gasoline powered units. Also, the nature of construction and special characteristics of the integral units account for the large price difference, in terms of the average price, between all other bus types.

(b) Estimated Cost
Increases

The percent cost increase due to the proposed regulatory scenarios is calculated by applying the manufacturing cost increases expressed in Appendix C to the prices of respective units presented in Table 7-C-1.

IMPORTANT INDUSTRY
CONSIDERATIONS

In addition to the following industry considerations, Section 3 contains a profile of the school bus industry. Certain major points are detailed here as they are important factors to be considered for analyzing the economic impact of proposed noise emission regulations.

TABLE 7-C-1

August, 1976 Prices for
Completed School Buses, by Type of Bus

Type of Bus	Range of Prices	Average Price[1]
Gasoline Powered:		
Conventional	$11,000-18,000	$14,500
Forward Control	$26,000-30,000	$27,000
Parcel Delivery	$10,000-11,500	$11,000
Diesel Powered:		
Conventional	$17,000-25,000	$19,000
Forward Control	$28,000-30,000	$30,000
Integral Mid-engine	$37,000-90,000	$50,000
Integral Rear-engine	$37,000-75,000	$50,000

Note: [1]The average price expressed here is the price given by respondents as closely approximately the mean price paid for units of the respective type.

Source: Telephone interviews conducted between EPA consultants and manufacturers and school bus distributors.

(a) Competition Nature of the Industry

Due to the complex nature of the channels of distribution operating in the school bus market, it is important to highlight some salient points relative to industry competition.

The market for integrally constructed buses is distinctly different from that of body-on-chassis models both in terms of market interactions and marketability. The principle difference are as follows:

1. The sale of the integrally constructed bus is generally conducted by the manufacturer of the unit, whereas the body-on-chassis bus is normally sold through a distributor representing a particular body builder. The body builder, in turn, obtains the driveable chassis from the chassis manufacturers (with the chassis make and specifications being indicated in the bid document).
2. The integrally constructed unit contains physical characteristics which make it more appropriate for use in a particular region and for specific functions where the body-on-chassis type of bus is physically unsuitable or economically unjustified. Integral units appear to be particularly well-suited for use in mountainous terrain and when high speed highway driving is necessary. Also, integral units all well-suited for such special purposes as the transportation for college football teams to and from games.

Due to these important considerations, among others, body-on-chassis school buses are not thought of as being substitutes for integrally constructed buses. Rather, they are in a class more like that of intercity buses although they are neither as heavily constructed nor as costly in terms of purchase price.

As far as competition between buses other than the integrally contructed types, a high degree of competition appears to exist at least within bus categories. For example, gasoline powered conventional buses of different makes compete directly, as readily substitutable goods. Any make of bus body can be constructed on any one of the four major chasses makes, and sales are typically made on the basis of competitive bids by several producers. Domestic market share data for the four major chassis manufacturers (Table 7-C-2) shows that a great deal of brand switching does occur from year-to-year -- further a priori information indicating a high degree of competition.

At the assembly stage of manufacture, diesel and gasoline body-on-chassis school buses are highly substitutable, and the assembler can switch easily from production of one to the other. This is a significant consideration in connection with the differential lead times envisaged for attainment of the various levels of noise attenuation. Should an industry-wide noise standard be promulgated, say, one year in advance of compliance capability by diesel chassis maufacturers but not so for gasoline chassis, the assemblers could shift production entirely to gasoline chassis with minimal hardship. Advance notice of the forthcoming regulations would enable bus purchasers with strong preference for the diesel mode to advance or delay their buying.

TABLE 7-C-2

SHARES OF DOMESTIC MARKET
FOR SCHOOL BUS CHASSIS -- 1973-1975

Make	1973	1974	1975
Chevrolet	11.9%	12.8%	15.0%
GMC	8.2%	9.2%	8.2%
Ford	29.6%	35.0%	22.7%
International Harvester	50.3%	43.9%	54.1%
	100.0%	100.0%	100.0%

Source: Motor Vehicle Manufacturers Association

(b) Price
Movements

No information has been found during the course of this study to express, in a quantitative manner, the way in which manufacturers of school buses per se have reacted to increased production costs in the past. However, if the Wholesale Price Index for all buses is a representative measure of school bus price movements, we find that bus prices have lagged behind the WPI for all manufactured goods since 1973 when prices jumped from an index of 117.9 (1967 base) for 1972 to 129.2 for 1973 (Table 7-C-3). In 1975, bus prices showed an extraordinary increase from 128.6 in 1974 to 156.4 in 1975. The margin of difference has narrowed again by June of 1976, possibly due in part to cost increases associated with brake system regulations.

Irrespective of the behavior of manufacturers to other associated cost increases, industry sources indicate that cost increases caused by regulatory actions are passed through to consumers in full. Such is the expectation relative to safety regulations to be effective in early 1977 and thereafter.

(c) Differential
Impacts

Differential impact on the school bus industry are discussed in the following paragraphs in the context of differing costs, by firms manufacturing the same product type, and of differing costs associated with quieting different types of buses.

1. Differential costs, by manufacturer, for producing the same product. As discussed previously, it is felt that the regulatory levels under analysis here will cause no differential costs which will put one firm in a less favorable competitive position than may be the case at present.

TABLE 7-C-3

WHOLESALE PRICE COMPARISON -
ALL MANUFACTURERS VS. BUSES

(1967=100)

YEAR	WPI - BUSES	WPI - ALL MANUFACTURED GOODS
1967	100.0	100.0
1968	103.6	102.6
1969	106.9	106.3
1970	111.2	110.2
1971	115.0	113.8
1972	116.8	117.9
1973	117.7	129.2
1974	128.6	154.1
1975	156.4	171.1
1976	167.8	178.7

Source: U.S. Department of Labor, Bureau of Labor Statistics

2. Differential costs associated with quieting different product types. Here it is necessary to analyze the pre-and-post-regulatory prices of different product types relative to competitive product types.

It can be concluded from inspection of the price differential movements for the various regulatory levels that little change in the relative competitive positions of competing units will derive from the regulatory levels under study.

This result is of importance because it demonstrates that differential impacts on the demand for various construction categories of school buses will be minimal under the proposed regulatory level.[10] In the following analysis cross-effects on demand, as between the different categories will not be considered in detail.

For purposes of the overall microeconomic analysis, there is little loss in generality by proceeding to terms of the two principal construction categories: conventional gasoline and conventional diesel school buses. Table 7-C-4 shows that in percentage terms, this simplification sacrifices coverage only to a very limited extent.

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10 Integrally constructed mid-engine and rear-engine buses built by Crown Coach and Gillig Bros. are an exception to this statement, but as mentioned earlier, they are considered specialized products not competing directly with other school bus types.

TABLE 7-C-4

PERCENT DISTRIBUTION
OF ALL SCHOOL BUS TYPES

Type of Bus	Percent of Total Buses
Gasoline Powered:	
-Conventional	84.8%
-Forward Control	0.7%
-Parcel Delivery and Motor Home Chassis	4.4%
Subtotal Gasoline	89.9%
Diesel Powered:	
-Conventional	4.9%
-Forward Control	3.9%
-Integral Mid-Engine	1.0%
-Integral Rear-Engine	0.3%
Subtotal Diesel	11.1%
TOTAL ALL TYPES	100.0%

Source: Based on market share information from Motor Vehicle Manufactures Association, School Bus Fleet, industry interviews, and EPA estimates.

ANALYSIS OF
USER COSTS

To assess the economic impact of noise abatement technology on the overall market for school buses, an examination of user costs parallel to that in Subsections 7-A and 7-B is appropriate, despite the fact that no "fare", as such, is generally charged to riders of school buses. Instead, pupil transportation expenses are funded out of general school system revenues. Route service decisions are determined in part by local school boards and in part by requirements of state and federal law to provide adequate transportation for all pupils.

Just under half of the pupils attending schools travel to their destination by means other than school buses,[11] either on foot, by public conveyance, or in private automobiles. Since the allocation of school system revenues is in part at the discretion of local government, service decisions -- and by implication, the demand for transportation equipment -- will respond to changes in the cost of providing transportation service.

Figure 7-C-2 demonstrates that during the period 1963-74 expenditures by school systems for replacement and new vehicles was a relatively small percentage of total transportation expenditures. Since total bus inventories were also rising significantly during this period (Table 7-C-7), annual capital replacement costs were at most ten percent of total transportation expenditures.

11 In 1971-72, 46.1 percent, and in 1973-74, 51.5 percent, of average daily attendance was transported at public expense. (National Center for Educational Statistics, Statistics of State School Systems.)

Figure 7-C-2

HISTORICAL REVIEW OF EXPENDITURES BY ELEMENTARY AND SECONDARY SCHOOLS BY MAJOR ACCOUNT AND BY TRANSPORTATION RELATED ACCOUNTS

(Dollar figures in thousands)

	School Years					
	1963-1964	1965-1966	1967-1968	1969-1970	1971-1972	1973-1974
Total Expenditures(1)	$20,897	$25,600	$32,111	$40,048	$47,655	$56,518
Total Current Expenditures for Elementary and Secondary Schools	17,218	21,053	26,877	34,218	41,818	50,025
Capital Outlays	2,978	3,755	4,256	4,659	4,459	4,979
Interest on School Debt	701	792	978	1,171	1,378	1,514
Total Pupil Transportation Expenditures	723	812	1,021	1,268	1,607	1,955
Capital Outlays for Transportation Vehicles and Equipment	49	25	40	49	99	97
Current Transportation Expenditures	674	787	981	1,219	1,508	1,858
Salaries(2)	245	310	348	445	532	625
Replacement of Vehicles(2)	72	77	82	88	104	132
Supplies & Maintenance for(2) Buses and Garages	121	137	143	185	208	271
Other Transportation Expenses(2)(3)	236	263	408	501	664	830
Total Pupil Transportation Expenditures As % of Total Expenditures	3.5%	3.2%	3.2%	3.2%	3.4%	3.5%
Total Pupil Transportation Expenditures As % of Total Current Expenditures	4.2%	3.9%	3.8%	3.7%	3.8%	3.9%
Salaries as % of Total Pupil Transportation Expenditures	33.9%	38.2%	34.1%	35.1%	33.1%	32.0%
Vehicle Replacement & Capital Outlays for Vehicles and Equipment as % of Total Transportation Expenditures	16.7%	12.6%	11.9%	10.8%	12.6%	11.6%
Supplies and Maintenance as % of Total Transportation Expenditures	16.7%	16.9%	14.0%	14.6%	12.9%	13.9%
Other Expenses as % of Total Transportation Expenditures	32.6%	32.4%	40.0%	39.5%	41.3%	42.5%

Notes: (1) Excluding current expenditures for services not related to elementary and secondary education.

(2) Calculated on the basis of expense distribution of states which were consistent in their reporting methodology. The following nine states were inconsistent for most years of the analysis: Alabama, Alaska, Arizona, California, Hawaii, Iowa, Montana, Ohio, and Texas.

(3) Includes contracted services, fares for public transportation, and payments in lieu of transportation.

Sources: Digest of Educational Statistics, 1975 Edition, U.S. Department of Health, Education, and Welfare, Education Division, Table 69.

Statistics of State School Systems, various editions, U.S. Department of Health, Education, and Welfare, National Center for Education Statics, various tables.

Following the analysis of the previous subsections, the fact that bus capital is a small fraction of total factor cost in the production of bus service implies that a given regulation induced change in the price of new buses has only a small effect on the total cost of transportation and therefore, on the "derived demand" for new buses. The ability of the bus manufacturing industry to pass through the additional equipment costs without severely reducing sales is thereby enhanced.

COST ESTIMATES
FROM APPENDIX C

Tables 7-C-5 and 7-C-6 summarize the pertinent estimates of technology cost from Appendix C. Expense estimates are in terms of 1976 dollars. The various proposed technology levels are also independent of one another.

The estimates in the tables are "incremental" expenses, that is, additional expenses over and above the costs in 1976 of purchasing and operating a typical bus that has no noise abatement equipment installed. Incremental fuel costs, a negative quantity in the case of gasoline powered conventional school buses, are computed on the basis of a midpoint mileage estimate, as described in the note for Table 7-C-5.

ESTIMATES OF INCREMENTAL
CAPITAL COSTS

The formula for estimating incremental capital costs is:

$$dX/dR = (r + i)\, dK/dR,$$

TABLE 7-C-5

INCREMENTAL EQUIPMENT AND OPERATING EXPENSES ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, GASOLINE-POWERED CONVENTIONAL SCHOOL BUSES

TECHNOLOGY LEVEL	EXTERIOR dBA	INTERIOR dBA	EQUIPMENT COST PER BUS (Body and Chassis) High	Low	EPA Estimate	FUEL COST PER BUS-YEAR	MAINTENANCE PER BUS-YEAR
1	83	83	$ 275	$ 0	$ 50	$ 0	$ 20
2	80	80	950	110	150	-25	135
3	77	80	1,045	210	285	-25	160
4	75	75	1,955	405	845	-25	170
5	73	75	2,190	700	1,145	-25	450

Source: Appendix C.

Notes: [a] Appendix C indicates that the miles per gallon increase from 4.0 to 4.25, for buses which adopt the viscous fan clutch technology. Only half of production (i.e, other than International Harvester) is projected to adopt this technology, and average miles per bus-year is roughly 10,000 (U.S. Department of Health, Education, and Welfare, Statistics of State School System, 1973-74, Tables 25 and 41.)

TABLE 7-C-6

INCREMENTAL EQUIPMENT AND OPERATING EXPENSES ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL-POWERED CONVENTIONAL SCHOOL BUSES

TECHNOLOGY LEVEL	EXTERIOR dBA	INTERIOR dBA	EQUIPMENT COST PER BUS (Body and Chassis)			FUEL COST PER BUS-YEAR	MAINTENANCE PER BUS-YEAR
			High	Low	EPA Estimate		
1	83	86	$ 650	$ 165	$ 630	$ 0	$ 20
2	80	84	2,125	260	730	0	155
3	77	80	3,005	900	1,480	0	215
4	75	75	3,410	1,010	1,580	0	450

Source: Appendix C

where dX/dR is the incremental capital (equipment) cost associated with regulatory level R, dK/dR is the dollar value of noise abatement equipment installed on new buses, r is the rate of depreciation, and i is the rate of interest. A major difficulty arises in providing accurate estimates of the rate of depreciation r.

In the absence of satisfactory data summarizing fleet operators' balance sheets and annual depreciation charges, two alternatives for estimating r are discussed: (1) estimates based on life cycle assumptions; (2) estimates based on observed used equipment prices.

(a) Estimates Based on Life Cycle Assumptions

Table 7-C-7 demonstrates that the total population of school buses in the United States has grown dramatically in the last decade. Replacement requirements, as indicated in the last column of the table, have constituted a relatively modest proportion of the total population, roughly five percent per year.

This five percent figure is lower than the actual rate of depreciation experienced, however, for two reasons. First, a significant portion of the observed population of school buses consists of relatively inactive, reserve inventories that are used only occasionally during the year for emergency purposes or special events. Such buses, which have outlived their normal lives as useful working capital, do not properly belong in the denominator of the depreciation estimate. Secondly, the fact that the bus population has experienced growth means that production from previous years was smaller than in recent years, hence that the rate of obsolescence of past years is lower than the rate of depreciation of the total stock.

TABLE 7-C-7

UNITED STATES SCHOOL BUS
INVENTORY AND PRODUCTION
1968-74

Calendar Year	Bus Inventory	Bus Shipments	Shipments as Percent of Existing Stock	Net Shipments[a] as Percent of Existing Stock
1968	262,204	29,015	11.07%	6.58%
1969	273,973	28,064	10.24	4.85
1970	288,750	27,408	9.51	3.09
1971	307,285	28,358	9.23	6.26
1972	316,421	30,635	9.68	4.16
1973	333,892	30,039	9.00	2.78
1974	354,634	29,561	8.34	--

Source: Industry Sources.

Note: [a] Net shipments are defined as gross shipments less replacement requirements to keep inventory at a constant level.

A somewhat cruder estimate based on life cycle assumptions is the industry estimate of an average useful life of 9-10 years for gasoline powered conventional school buses (which comprise 85% of the total stock). (See Table 7-C-4.) The implied depreciation rate is 10-11% per year.

(b) Estimates Based on Observed Used Equipment Prices

One major dealer in used school buses provided EPA with a representative pair of prices for good condition conventional gasoline-powered school buses built in the years 1976 and 1970. Both buses are equipped with five-speed transmissions:

1976 new conventional school bus	$14,100
1970 good condition used conventional school bus	$ 5,500

The implied rate of depreciation over the 6-year period is estimated as follows:

$$1 - (5{,}500/14{,}100)^{1/6} = 14.52\%$$

(c) Summary of Rate of Depreciation Estimates

As with intercity and urban transit buses, conventional school buses have potentially long service lives depending on routes traveled, maintenance, and mileage figures. Estimates based on life cycle assumptions indicate a minimum rate of depreciation of at least six percent per annum, whereas observed market prices of old versus new buses imply a depreciation rate as high as fifteen percent. EPA's independent estimate for conventional gasoline-powered school buses is twelve percent, somewhat above the ten percent figure for transit and intercity buses. For conventional diesel powered school buses, EPA's estimate is ten percent per annum.

ESTIMATES OF INCREMENTAL PRIME COST

The technology cost estimates from Tables 7-C-5 and 7-C-6 for incremental equipment, fuel, and maintenance costs can be combined into single estimates of incremental cost per vehicle mile. This is accomplished by converting equipment cost increments into per annum capital costs (depreciation plus interest), and then by dividing the sum of annual capital, fuel, and maintenance cost by 10,000 vehicle miles per year.

Tables 7-C-8 and 7-C-9 provide results of the calculations for conventional gasoline-powered and conventional diesel-powered school buses, respectively. Sensitivity tests with respect to the assumption concerning depreciation demonstrate relatively low sensitivity, and they are not reproduced here.

IMPACT ON QUANTITY OF BUS SERVICE DEMANDED

On the premise that increments to prime cost are transmitted to taxpayers, the political decision-making process will respond to increased transportation costs by reducing service, by lengthening pupil riding times, and by increasing the number of pupils riding in each bus. Given that the decision-making process is performing optionally, the equilibrium response of ridership, equipment, and routes will be precisely the same as the response that would occur in a market environment where a fare equal to average expense including normal profit was charged to each pupil.

The correspondence of market and non-market equilibria enables us to obtain predictions concerning the effect of increments to prime cost on equilibrium school bus ridership and the demand for school buses.

TABLE 7-C-8

INCREMENTAL PRIME COST PER BUS-MILE OF SERVICE ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, GASOLINE POWERED

Technology Level	Exterior dBA	Interior dBA	Incremental Cost--Cents per Vehicle-Mile[a] High	Low	EPA Estimate
1	83	83	0.805	0.200	0.310
2	80	80	3.190	1.342	1.430
3	77	80	3.649	1.812	1.977
4	75	75	5.751	2.341	3.309
5	73	75	9.068	5.790	6.769

Source: Table 7-C-5. Interest and depreciation are calculated as 22% of incremental capital cost (12% depreciation plus 10% interest). Estimates reflect an assumption of 10,000 vehicle miles per bus year.

Note: [a] 1976 dollars.

TABLE 7-C-9

INCREMENTAL PRIME COST PER BUS-MILE OF SERVICE
ASSOCIATED WITH PROPOSED LEVELS OF NOISE
ABATEMENT TECHNOLOGY, DIESEL POWERED
CONVENTIONAL SCHOOL BUSES

Technology Level	Exterior dBA	Interior dBA	Incremental Cost--Cents per Vehicle-Mile[a] High	Low	EPA Estimate
1	83	86	1.500	0.530	1.460
2	80	84	5.800	2.070	3.010
3	77	80	8.160	3.950	5.110
4	75	75	11.320	6.520	7.660

Source: Table 7-C-5. Interest and depreciation are calculated as 20% of incremental capital cost (10% depreciation plus 10% interest). Estimates reflect an assumption of 10,000 vehicle miles per year.

Note: [a] 1976 dollars.

Statistics on average expense per vehicle mile for the United States are provided in Table 7-C-10. Average expense for 1974 may be adjusted to 1976 dollars by applying the percentage increase in the Consumer Price Index[12] (transportation) for 1974 to June 1976:

$$(165.9/137.7) \times .72 = 86.75¢ \text{ per vehicle mile}$$

Calculations for the estimated percentage increase in average expense are given in Tables 7-C-11 and 7-C-12. These numbers are multiplied by the demand elasticity estimate of -0.50 to compute the expected change in the quantity of service demanded. This elasticity is the same as that estimated in Appendix D for urban transit. It is probably high in absolute terms due to imperfections in the political process, but the fact that pupils' marginal cost of time is relatively low implies less sensitivity to service charges.

IMPACT ON QUANTITY OF BUS PRODUCTION

The foregoing analysis, and Tables 7-C-11 and 7-C-12, indicate that the impact on equilibrium bus service is relatively small, particularly compared to the three percent per annum projected growth rate of (baseline) industry production. Since it is unlikely that the technology of bus fleet management permits substantial substitution between buses and other inputs in the production of bus service, reduced ridership of three to five percent resulting from noise abatement technology translates into a similar reduction in long-run demand for new buses.

Table 7-C-13 demonstrates the fact that school buses are utilized at near capacity levels. The ability of school bus fleet managers to reduce equipment expenditures for a given level of pupil service is severely limited, and it is doubtful that substantial factor substitution will occur in response to a change in the relative price of bus capital.

TABLE 7-C-10

TRANSPORTATION EXPENDITURES PER PUPIL
AND PER BUS MILE, 1963-74,
U.S. PUBLIC SCHOOLS

School Year	Average Cost Per Pupil Transported	Average Cost per Bus Mile	Vehicle Replacement and Capital Outlays as % of Transport Expenses
1963-64	$46.53	$0.40	16.7%
1965-66	50.68	0.42	12.6
1967-68	57.27	0.50	11.9
1969-70	66.96	0.54	10.8
1971-72	77.43	0.63	12.6
1973-74	87.04	0.72	11.6

Source: Statistics of State School Systems, various editions. U.S. Department of Health, Education, and Welfare, National Center for Education Statistics, Table 41.

TABLE 7-C-11

ESTIMATED PERCENTAGE INCREASE IN AVERAGE COST PER MILE, AND EFFECT ON QUANTITY DEMANDED, ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, GASOLINE POWERED CONVENTIONAL SCHOOL BUSES

			HIGH		LOW		EPA Estimate	
Technology Level	Exterior dBA	Interior dBA	Cost Increase	Change in Demand	Cost Increase	Change in Demand	Cost Increase	Change in Demand
1	83	83	0.928%	-0.464	0.231%	-0.115%	0.357%	-0.179%
2	80	80	3.677	-1.839	1.547	-0.773	1.648	-0.824
3	77	80	4.206	-2.103	2.089	-1.044	2.279	-1.139
4	75	75	6.629	-3.315	2.699	-1.349	3.814	-1.907
5	73	75	10.453	-5.227	6.674	-3.337	7.803	-3.901

Source: Tables 7-C-8 and 7-C-10. Operating costs per bus mile in 1976 are estimated at 86.75¢ (72¢ from Table 7-C-10 times inflation factor derived from Consumer Price Transportation Index change to June 1976). The elasticity of demand is estimated as -0.50.

TABLE 7-C-12

ESTIMATED PERCENTAGE INCREASE IN AVERAGE COST PER MILE, AND EFFECT ON QUANTITY DEMANDED, ASSOCIATED WITH PROPOSED LEVELS OF NOISE ABATEMENT TECHNOLOGY, DIESEL POWERED CONVENTIONAL SCHOOL BUSES

			HIGH		LOW		EPA Estimate	
Technology Level	Exterior dBA	Interior dBA	Cost Increase	Change in Demand	Cost Increase	Change in Demand	Cost Increase	Change in Demand
1	83	86	1.729%	-0.865	0.611%	-0.305%	1.683%	-0.841%
2	80	84	6.686	-3.343	2.386	-1.193	3.470	-1.735
3	77	80	9.406	-4.703	4.553	-2.277	5.891	-2.945
4	75	75	13.049	-6.524	7.516	-3.758	8.830	-4.415

Source: Tables 7-C-9 and 7-C-10. Operating costs per mile in 1976 are estimated at 86.75¢ (72¢ from Table 7-C-10 times inflation factor derived from Consumer Price Index Transportation change to June 1976). The elasticity of demand is estimated as -0.50.

TABLE 7-C-13

AVERAGE RIDERSHIP PER SCHOOL BUS, 1963-74

School Year	Average Daily Attendance Transported/Total Number of Vehicles
1963-64	72.06
1965-66	84.09
1967-68	80.67
1969-70	76.77
1971-72	76.75
1973-74	82.07

Source: National Center for Education Statistics, Statistics of State School Systems, Table 25.

FINANCIAL IMPACT ON
SCHOOL BUS USERS

The proposed regulations may have adverse economic impacts not recorded above in the "long-run" analysis if they prompt short-run financial dislocations or have distributional effects. Consider first the impact on taxpayers and municipal and state financing authorities.

The preceding analysis (Tables 7-C-11 and 7-C-12) demonstrates that increases of no more than ten-to-twelve percent (across all school bus types) in pupil transportation expenditures are anticipated even at the most stringent level of proposed noise attenuation. This estimate can be combined with statistics on public school finance to assess the extent of financial impact.

Table 7-C-14 demonstrates the fact that total pupil transportation accounts for only a small percentage of public school system expenditures, and that this percentage increases significantly in smaller, non-metropolitan systems. For the purposes of estimation, a ten percent increase in total pupil transportation expenditures translates into a 0.24 percent increase in total pupil expenditures in central metropolitan areas as compared with a 0.57 percent increase in non-metropolitan areas.

Public school system finances are shared by local, state, and federal sources as shown in Table 7-C-15.

FINANCIAL IMPACTS ON
PRODUCERS, INCLUDING
EXPORTERS AND IMPORTERS

The above economic analysis puts an upper bound on the aggregate percentage reduction in equilibrium demand for school buses at 5.4 percent

TABLE 7-C-14

PUPIL TRANSPORTATION SERVICES EXPENDITURES BY ENROLLMENT SIZE AND METROPOLITAN STATUS, 1970-71

(Dollar Figures in Millions)

	(1) Total Current Expenditures	(2) Pupil Transportation Expenditures	(3) Pupil Transportation As % of Total Expenditures
All U.S. Public School Systems	$25,827.3	$1,376.7	3.84%
System Enrollment Size:			
5,000 and Over	$23,746.4	$ 707.9	2.98%
Less than 5,000	$12,080.9	$ 668.8	5.54%
Metropolitan Status:			
Central Metropolitan	$10,193.8	$ 249.3	2.45%
Metropolitan, Other	$15,178.3	523.7	3.45%
Non-Metropolitan	$10,455.2	603.8	5.78%

Source: Statistics of Local Public School Systems, Finance, 1970-71. U.S. Department of Health, Education and Welfare, Ofice of Education

TABLE 7-C-15

REVENUE AND NONREVENUE RECEIPTS OF LOCAL PUBLIC SCHOOL SYSTEMS BY SOURCE OF FUNDS: UNITED STATES, 1970-71

	(Millions)	(Percent)
Total Receipts	$45,511	100.0%
Revenue Receipts	$42,424	93.2%
Local	22,851	50.2
Intermediate	504	1.1
State	15,784	34.7
Federal	3,285	7.2
Nonrevenue Receipts (Bonds)	$ 3,087	6.8%

Source: National Center for Educational Statistics, Statistics of Local Public School Systems, Finance 1970-71, Table A-1.

from baseline levels, with an independent estimate of 3.9 percent at the most stringent level of noise abatement.[13]

Figure 3-25, (Section 3) indicates a growth rate in baseline production of 3.0 percent per year through the year 1990. Given proposed lead times of sufficient length for the various noise abatement levels studied, no reduction in existing manufacturing capacity will be required, and at the aggregate level no financial impacts on producers are foreseen.

Two individual cases have been identified, however, for which the estimated incremental cost impact of the noise abatement technology is substantial. These are the transit-style integral construction school buses produced in relatively small numbers by Gillig Bros. and Crown Coach Corporation in California.

EPA's attempts to assess the cost impact on these producers has been hampered by a lack of substantial information provided by the companies involved. Differentially higher costs of noise abatement do appear likely, however, and further investigation by EPA of the specific problems involved appears warranted.

An important mitigating factor, not capable of accurate estimation from an econometric viewpoint based on available data, is the fact that these buses serve a significantly different market than the conventional school bus market.

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[13] These figures are computed as a weighted average from Tables 7-C-11 (85%) and 7-C-12 (15%).

They are long-lived (20-30 years as opposed to 9-10 years), expensive ($50,000 as opposed to $14,000-$19,000), and intended primarily for long-route, intensive use typical of the west-coast region in which they are marketed. It is clear that the "cross-elasticity" of demand for these buses vis-a-vis conventional buses is substantially below infinity, but the precise elasticity is not possible to estimate from available data.

Section 3 indicates that the vast majority of school bus chassis and bodies are produced domestically and in Canada (which is virtually equivalent, given the Automotive Pact Trade Agreement). Finished school buses are generally built according to customer specifications, so that the producers already possess the necessary flexibility to treat the noise reduction package as an optional item, not included on exports to nonregulated countries.

Since school buses are not imported in significant quantities to the United States, no balance of trade or balance of payments effects are foreseen for the proposed technologies under consideration for regulation.

ANNUALIZED COSTS FOR
SCHOOL BUS NOISE ABATEMENT

Annualized cost calculations projected to the year 2000 for 15 regulatory schedules are presented in Appendix E. Input variables for school buses are listed in Table 7-C-16.

TABLE 7-C-16

DATA INPUT AND PARAMETER VALUES
FOR ANNUALIZED COST CALCULATIONS
SCHOOL BUSES

Variable Description	Source or Value
Baseline Production Rate	Figure 3-25
Projected Production Rate	Figure 3-25
Incremental Operating Cost	Appendix C
Incremental Maintenance Cost	Appendix C
Incremental Equipment Cost	Appendix C
Depreciable Life (years)	10
Price Elasticity of Demand	-0.50
Rate of Discount	0.10

GENERAL REFERENCES

SECTION 7

1. "An Econometric Model of Urban Bus Operations," Chapter IV of John D. Wells et al, Econometric Characteristics of the Urban Public Transportation Industry (Washington, D.C.: Government Printing Office, 1972).

2. Hicks, John R., The Theory of Wages. London: MacMillan, 1932.

3. Heightchew, Robert E., United States Transit Bus Demand. Highway Users Federation, Washington, D.C.: June, 1975.

4 "A Study to Determine the Economic Impact of Noise Emission Standards in the Bus Manufacturing Industry," Draft Final Report submitted by A. T. Kearney, Inc. under EPA Contract No. 68-01-3512, prepared for the Office of Noise Abatement and Control, September, 1976.

Section 8

MEASUREMENT METHODOLOGY

The choice of a procedure for measuring the noise emitted by buses was based on several considerations:

- o Existing bus noise measurement procedures
- o Bus noise characteristics
- o Work cycle of buses
- o Enforcement requirements
  - Repeatability of measurement

1. EXISTING PROCEDURES

A number of existing and proposed noise measurement procedures for buses and trucks were examined for applicability.

For a number of years U.S. industry has been using the SAE J366b measurement procedure (full throttle acceleration) for measuring the exterior sound levels for heavy trucks and buses. ISO recommendation, R362, which follows a similar procedure,[1] is the basis for noise measurement in some European countries. Table 8-1 compares the main features of these two procedures.

Table 8-1

Comparison of Existing Procedures

Procedure	Microphone		Vehicle Condition		Length of Acceleration Lane	Sound Level Reported
	Distance	Height	At Start of Acceleration	At End of Acceleration		
SAE J366b	50 ft. (15.2 m)	4 ft. (1.2 m)	66% of rated or governed engine speed	Maximum rated or governed engine speed, without exceeding 35 mph (56 km/hr)	60 to 100 ft. (18.3 to 30.5 m)	Average of two highest dBA, fast readings within 2 dB of each other
ISO R362	7 m	1.2 m	75% of rated or governed engine speed, or 50 km/hr	Not specified	20 m	All readings—dBA, fast

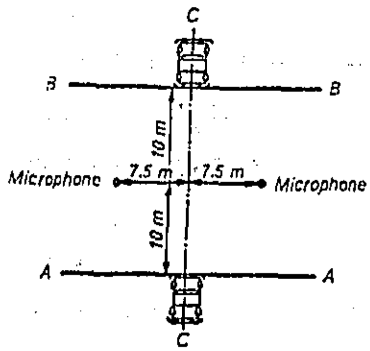
Both procedures require the use of high quality (Type I or "Precision") sound measuring equipment, background noise levels at least 10 dBA below the level produced by the test vehicle, and a flat, open space free of reflecting surfaces. The recommended test sites for performing measurements are shown in Figure 8-1.

The ISO recommendation includes a procedure for measurements with stationary vehicles, with the engine operating at governed speed, or at three-quarters of maximum rated speed if the engine is ungoverned.

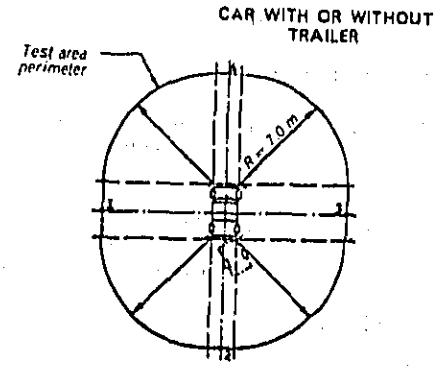
The MITRE Corporation, under contract to the U. S. DOT Urban Mass Transit Administration, has developed a standard procedure specifically directed at urban transit buses.[2] For exterior noise, two microphones are required, one at a 15.2 m (50 feet) distance and a 1.2 m (4 feet) height and another at a 10.8 m (35.4 feet) distance and 12.0 m (39.4 feet) height. The latter position corresponds to a slant distance of 15.2 m (50 feet) from the bus lane along a line 45 degrees to the road surface, and is designed to insure controlled noise levels to apartment dwellers. A recommended test site area is shown in Figure 8-2. A stationary starting point ahead of the microphone reference line is selected such that, when the vehicle is accelerated from that point with rapid application at wide open throttle, the chief vehicle noise source of the test coach shall fall within a 32.8 ft. (10 m) region on either side of the microphone reference lines when the vehicle reaches maximum

FIGURE 8-1
Recommended Test Sites for
ISO and SAE Procedures

ISO R362 Procedure



— Measuring positions for measurement with vehicles in motion



— Measuring positions for measurement with stationary vehicles

SAE J366b Procedure

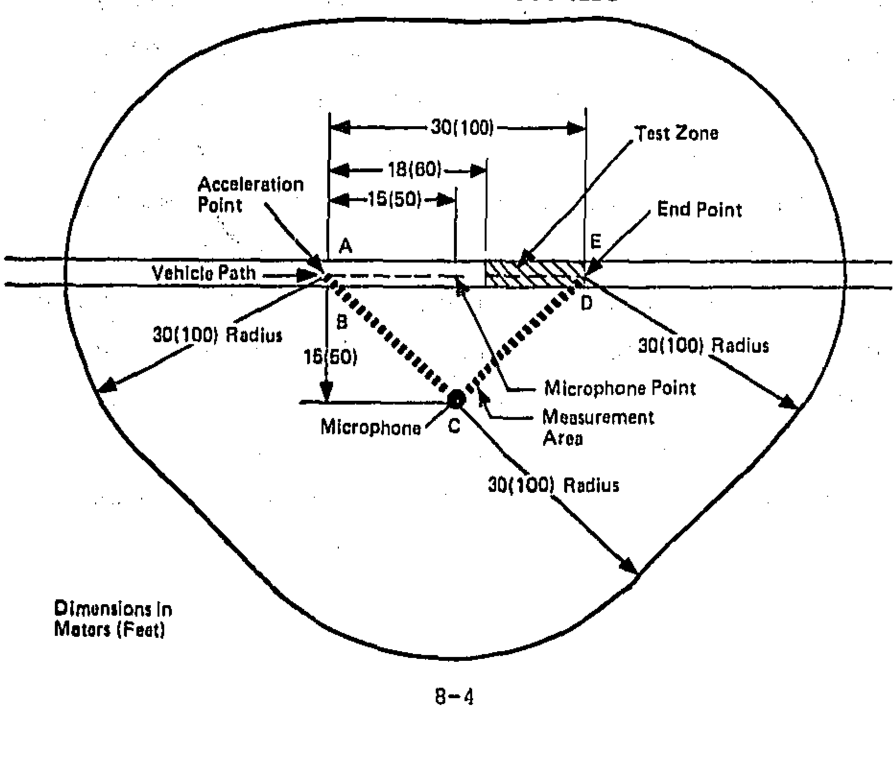
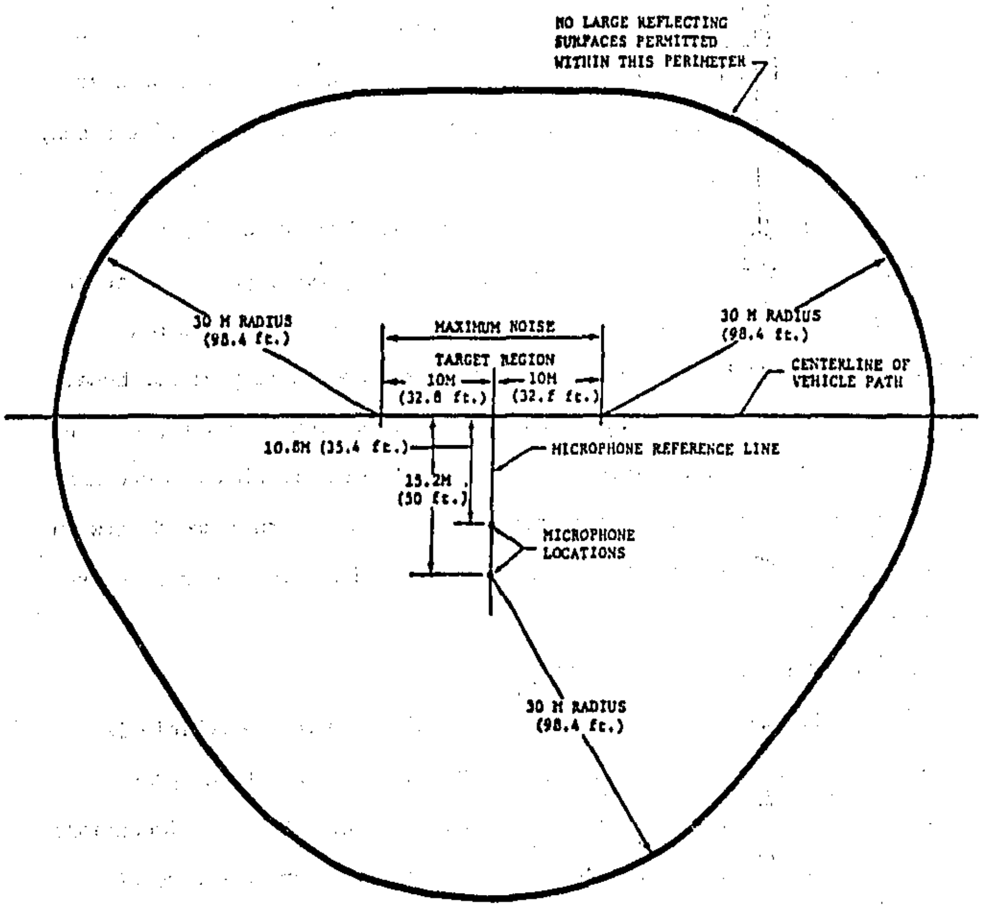


FIGURE 8-2
Minimum Acceptable Test Area for Urban Transit Buses, MITRE Recommendation[2]



governed speed for manual transmission models or shift point for automatic transmission models. Maximum vehicle speed during the test is limited to 31 mph (50 km/hr). Interior noise levels are measured at the forwardmost passenger seat, the seat nearest the center of the bus, and the rearmost seat.

The Coach Noise Subcommittee of the SAE Vehicle Sound Level Committee has also been preparing recommended procedures for exterior and interior sound levels of motor coaches which include school, transit, and intercity buses. This subcommittee feels that for buses, the "pull-away" or standing start mode of operation normally produces maximum exterior noise levels. They are also considering a shortened end zone where the bus reaches maximum rated or governed speed between tests. Test conditions have also been established for interior noise measurements.

2. BUS NOISE CHARACTERISTICS

If the noise characteristics are similar while the vehicle is stationary and moving, stationary test procedures are to be preferred because of the resultant ease of testing. Other considerations are the consistency of noise levels between tests and the ease of extrapolation of the measured level to actual noise levels experienced in the community. One of the difficulties with stationary procedures is that if the engine is ungoverned, the maximum engine speed cannot be precisely controlled. In addition, sudden acceleration of gasoline engines without load is considered damaging since excessively high engine speeds would result. The stationary procedure does offer the advantage of removing one of the unwanted sound sources, namely tires, from the overall sound measured.

Existing bus noise level data (Section 4) include stationary and acceleration noise levels. The SAE Vehicle Sound Level Committee has collected and analyzed noise data on various vehicle types using stationary and acceleration procedures. The data indicate that while each of the procedures gives repeatable measurements for a given vehicle, and about equal spread in levels between different vehicles, the correlation between the two procedures is poor. In other words, vehicles may or may not emit higher levels during acceleration tests as opposed to stationary tests. Thus, there does not appear to be a simple method to predict which of the two levels would be higher for a given vehicle. Because of this problem, most bus manufacturers have adopted the J366b procedure as the standard procedure.

Interior noise has not received much attention from bus manufacturers, except for intercity bus manufacturers. They have discovered mainly that the noisiest section of the bus is generally around the seat nearest the engine.

3. WORK CYCLES

Buses are used for a wide variety of applications under different road and traffic conditions. The proportions of operating time spent under acceleration, deceleration, cruise, and idle conditions vary accordingly. The work or duty cycles of buses are important considerations in the development of a noise measurement procedure because the measured level should be representative of one or more of the prominent modes of operation of the bus.

The school bus generally operates in a suburban environment as opposed to the urban environment of the transit bus. Metropolitan transit buses generally operate in an urban environment picking up and discharging passengers frequently along their daily runs. As a result work cycles consist mainly of accelerations and decelerations with minimum cruise time at constant speeds. The work cycle of an intercity bus is comprised mainly of cruise time at high speed with stops occurring only near bus terminal locations.

A representative work cycle for school buses was estimated from data obtained from the Radnor School District near Philadelphia, Pennsylvania.[6]

Number of Routes	25
Number of Stops	541
Total Time	1263 min.
Total Distance Covered	129 miles

Assuming an average cruise speed of 27 mph and acceleration/deceleration rate of 3.22 ft/sec/sec, the percentage of time under different conditions was obtained:

9% of time under acceleration
9% of time under deceleration
21% of time at cruise
61% of time at engine idle

A representative work cycle for urban transit buses was estimated from data furnished by the EPA Mobile Source Air Pollution Laboratory, Ann Arbor, and from the report on the California Steam Bus Project.[3] Urban drive cycles vary widely. An average work cycle for buses making seven to ten stops per mile would be as follows:

20% of time under acceleration
20% of time under deceleration
26% of time at cruise
34% of time at engine idle.

Eagle International Inc., has furnished the following data for intercity buses:

Average cruise speed of intercity buses - 60 mph

Average acceleration and deceleration rates - 1.5 to 3.0 mph/sec

Average cruise distances - 50 miles

Average number of stops and starts per year - 5,000

Typical drive cycles:	Acceleration	- 5%
	Deceleration	- 5%
	Cruise	- 85%
	Idle	- 5%

4. MEASUREMENT DISTANCE

The location of the receptors of bus noise vary widely. Pedestrians are possibly subjected to the loudest noise levels from buses because of their close proximity to the bus. GMC has reported the existance of data showing that transit buses contribute measurably to the background noise levels in downtown Detroit. They argue that urban transit bus noise should, therefore, be measured at a distance of 15 to 25 feet from the curbside of the bus.[4] Extrapolation to 50 ft. measurements from closer distances than 50 ft., however, using the standard 6 dB loss per doubling of distance would suggest levels lower than those actually existing at 50 ft. In addition, because buses can be up to 40 ft. long, measurement distances shorter than 50 ft. place the microphone in a closer proximity to the acoustic nearfield of the bus, an undesirable position for repeatable results.

5. ENFORCEMENT REQUIREMENTS

All available bus noise level data are in A-weighted decibel units. All standard and recommended test procedures also recommend that measurements be made in A-weighted decibel units. Available equipment for measurement of sound directly in these units is reliable and readily available. Since sound levels measured in these units also approximate human subjective response to noise, the A-weighted decibel unit is recommended for any test procedure.

The procedure should be such that repeatable test conditions can be easily obtained. Repeatability can be ensured by specifying engine speeds, engine rpm, and test site surface and surrounding conditions.

6. TEST MEASUREMENTS

Noise measurements from 65 school, transit and intercity buses were taken under various test procedures. Exterior as well as interior noise levels were measured during each test.

The SAE J366b Standard procedure was used for measuring exterior and interior noise for all buses with manual transmissions and for those buses with automatic transmissions which could be manually held in gear. In addition, stationary noise measurement procedures were also employed for all buses tested.

A modified J366b procedure was used in the case of buses with automatic transmission which could not be manually held in gear. The modified J366b procedure consisted of the bus accelerated under wide open throttle from a predetermined stationary position. The starting position was selected to assure that the bus reached maximum governed speed (i.e., upshift) in the end zone defined by the SAE J366b procedure.

A full throttle pull-away procedure was also examined for all bus types with microphones in line with the front and rear bumpers of the bus. This test is not suitable for vehicles with manual transmissions because of the non-repeatablity of the bus pull-aways.

It should be noted that all interior bus noise measurements were taken with all bus windows and doors closed and all interior fan accessories (including air conditioner fans and/or heating fans) operating. Windscreens were utilized during all the interior measurements to assure that no variation in sound level due to the movement of air throughout the bus would occur. In addition, in order to assure that the interior microphone did not receive acoustic standing wave sound propagation from any bus wall (i.e., the ceiling), the microphone was tilted towards the front of the bus at a 20-30 degree angle from the vertical for all interior bus measurements made.

SCHOOL BUSES

The principal noise sources on conventional school buses, the cooling fan, the engine, and the exhaust outlet, are separated by the length of the bus. Thus, two microphones, separated by the length of the bus, were used simultaneously on one side of the bus as shown in Figure 8-3.

Two stationary test procedures were examined for school buses. The IMI (Idle-Max. Governed Speed-Idle) procedure requires the engine throttle to be opened at a rapid rate from idling condition to its maximum governed speed and then closed to return it to idle speed. The maximum governed speed test requires the maximum governed speed to be maintained for approximately ten seconds. This test is not recommended for ungoverned engines as engine damage might result.

Measured noise levels for 29 new and in-use conventional gasoline school buses under the stationary, pull-away and acceleration procedures may be found in Section 4, Tables 4-1 and 4-2. Maximum interior noise levels were obtained during the J366b procedure at the seat (driver) nearest the engine.

Since microphones were used to record maximum noise exterior levels with the front and the rear of the school bus as reference points, the tests revealed which of the two ends of each bus was noisier. Figure 8-4 shows that on the average, the front of the bus is louder by 3 decibels on the curbside. Both ends of the bus are about equally loud on the streetside.

FIGURE 8-3
Bidirectional Test Site for
School Bus Noise Measurement

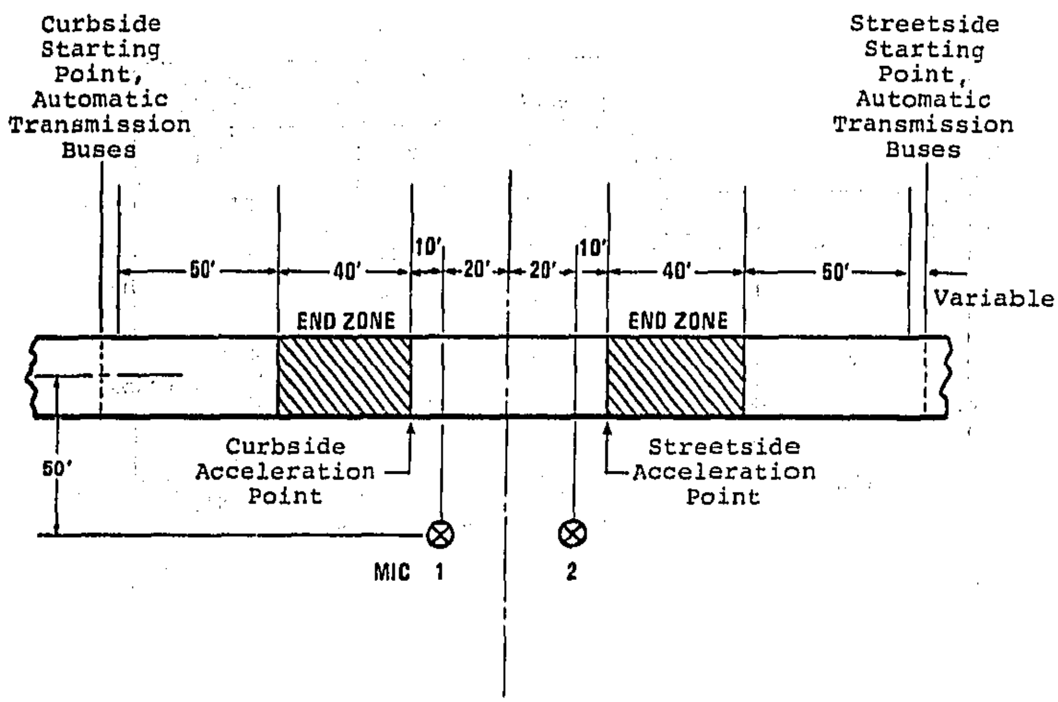
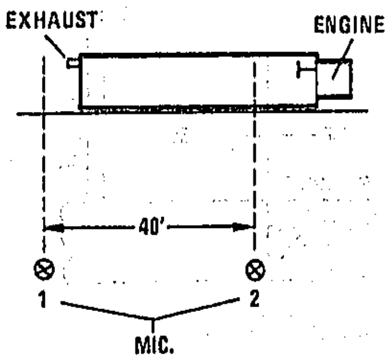


FIGURE 8-4
Differences in Sound Levels of Conventional School Buses with the front and rear used for reference



TEST NO.	L(2) - L(1) CURBSIDE	L(2) - L(1) DRIVERSIDE
1	2 dB	0.75 dB
2	3	0.25
3	3.25	-1.25
4	3.67	0
5	3.5	-0.25
6	3.0	-0.33
10	3.0	-1.0
AVERAGE	3.06 dB	-0.167 dB

TRANSIT BUSES

Exterior and interior noise levels for 24 diesel powered transit buses are summarized in Table 4-10 (Section 4). During the testing, difficulty was encountered in maintaining uniformity of procedure when performing maximum acceleration (modified J366b) and pull-away testing. In the case of the maximum acceleration procedure the buses would not always shift at the same point in the end zone. In the case of the pull-away procedure, although the buses were accelerated at wide-open throttle the run-up of the engines to the maximum governed rpm was not always consistent. Most of the variation in the bus operations was felt to be due to the age of the buses tested.

It is interesting to note that in correcting for the variability in the bus operation, it was found that it was easier to correct for the variation in the shift point location by changing the starting point location than for the variation in the engine run-up.

INTERCITY BUSES

Tables 4-19 and 4-21 (Section 4) display summaries of exterior and interior noise level data measured from 12 newly manufactured intercity buses. Data was recorded using a modified J366b sound measurement procedure (both acceleration and deceleration modes were tested), a pull-away procedure (for automatic transmission vehicles) and a stationary IMI procedure. Interior noise level data was taken using all procedures.

7. SUMMARY

Exterior Procedures

The standard SAE J366b procedure was found acceptable for school buses and intercity buses with standard transmissions and automatic transmissions that can be manually locked in gear to prevent upshifting above desired gears.

For transit buses with automatic transmissions which cannot be manually locked in gear, the modified J366b procedure was found acceptable for exterior sound measurement testing.

Interior Procedure

The selection of an interior measurement procedure is closely linked to the selection of an exterior procedure. This leaves the location of the microphone as the most salient question. To this end, it has been found that in all EPA bus noise measurements, as displayed in Section 4, the noisiest location in the bus is the seat location nearest the main body of the engine. Thus, it may be concluded that measurements at this seat location (nearest the main body of the engine) characterize the loud extreme of the noise environment inside a bus.

8. RECOMMENDED TEST PROCEDURE FOR MEASUREMENT OF EXTERIOR SOUND LEVELS

(a) Instrumentation. The following instrumentation shall be used, where applicable.

(1) A sound level system which meets the Type 1 requirements of ANSI SI.4-1971, Specification for Sound Level Meters or a sound level system with a magnetic tape recorder and/or a graphic level recorder or indicating meter, may be used providing the system meets the Type I performance requirements of ANSI SI.4-1971, Specification for Sound Level Meters.

(2) A sound level calibrator. The calibrator shall produce a sound pressure level, at the microphone diaphragm that is known to within an accuracy of ± 0.5 dB. The calibrator shall be checked annually to verify that its output has not changed.

(3) An engine-speed tachometer which is accurate within ±2 percent of meter reading.

(4) An anemometer or other device for measurement of ambient wind speed accurate within ±10 percent at 19.3 km/hr (12 mph).

(5) A thermometer for measurement of ambient temperature accurate within ±1°C.

(6) A barometer for measurement of ambient pressure accurate within ±1 percent.

(7) A windowscreen must be employed with the microphone during all sound measurements. The windscreen shall not affect the A-weighted sound levels from the vehicle in excess of ± 0.5 dB.

(b) (1) The test site shall be such that the bus radiates sound into a free field over a reflecting plane. This condition may be considered fulfilled if the test site consists of an open space free of large reflecting surfaces, such as parked vehicles, signboards, buildings or hillsides, located within 30.4 meters (100 feet) of either the vehicle path or the microphone.

(2) The microphone shall be located 15.2 ± 0.1 meter (50 feet ± 4 inches) from the centerline of vehicle travel and 1.2 ± 0.1 meters (4 feet ± 4 inches) above the ground plane. The microphone point is defined as the point of intersection of the vehicle path and the normal to the vehicle path drawn from the microphone.

The microphone shall be oriented with respect to the source in a fixed position so as to minimize the deviation from the flattest frequency response characteristic over the frequency range 100 Hz to 10 kHz for an accelerating vehicle traversing through the end zone.

(3) For vehicles with manual transmissions or with automatic transmissions which can manually be held in gear, an acceleration point shall be established on the vehicle path 15.2 meters (50 feet) before the microphone point.

(4) For vehicles with automatic transmissions, which cannot be manually held in gear, a starting point shall be established as described in paragraph (c)(2).

(5) An end point shall be established on the vehicle path 30.5 meters (100 feet) from the acceleration point and 15.2 meters (50 feet) from the microphone point.

(6) The end zone is the last 12.2 meters (40 feet) of vehicle path prior to the end.

(7) The measurement area shall be the triangular-paved (concrete or sealed asphalt) area formed by the acceleration point, the end point, and the microphone location.

(8) The reference point on the vehicle, used to indicate when the vehicle is at any of the points on the vehicle path,shall be the front of the vehicle except as follows:

- o If the engine is front-mounted and the horizontal distance from the front of the vehicle to the exhaust outlet is more than 5.1 meters (200 inches), tests shall be run using both the front and rear of the vehicle as reference points. The two measurements may be made simultaneously by placing two microphones, the distance of the vehicle apart, as shown in Figure 8-3.

- o If the engine is located rearward to the center of the chassis or at the approximate center (± 1.5 meters ± 5 feet) of the chasis, the rear of the vehicle shall be used as the reference point.

(9) The plane containing the vehicle path and the microphone location (plane ABCDE in Figure 8-1) shall be flat within ± .05 meters (+2 inches)

(10) Measurements shall not be made when the road surface or the measurement area is wet, covered with snow, or during precipitation.

(11) Bystanders have an appreciable influence on sound level meter readings when they are in the vicinity of the vehicle or microphone; therefore, not more than one person, other than the observer reading the meter, shall be within

15.2 meters (50 feet) of the vehicle path or measuring instrument and the person shall be directly behind the observer reading the meter, on a line through the microphone and observer. To minimize the effect of the observer and the container of the sound level meter electronics on the measurements, cable should be used between the microphone and the sound level meter. No observer shall be located within 1 meter (3.3 feet) in any direction of the microphone location.

(12) The maximum A-weighted fast response sound level observed at the test site immediately before and after the test shall be at least 10 dB below the regulated level.

(13) The road surface within the test site upon which the vehicle travels, and, at a minimum, the measurement area (BCD in Figure 8-1) shall be smooth concrete or smooth scaled asphalt, free of extraneous material such as gravel.

(14) Vehicles with diesel engines shall be tested using Number 1D or Number 2D diesel fuel possessing a cetane rating from 42 to 50 inclusive.

(15) Vehicles with gasoline engines shall use the grade of gasoline recommended by the manufacturer for use by the purchaser.

(16) Vehicles equipped with thermostatically controlled radiator fans (fan clutches) will be tested with the fan engaged in a "lock up" mode such that the fan drive hub and the fan are turning at the same speed or as near the

same speed as is possible within the design limits of the particular fan clutch design.

(c) Procedure

(1) Buses equipped with manual (standard) transmissions or buses with automatic transmissions which can be manually held in gear (governed or ungoverned engines.). Full throttle acceleration and closed throttle deceleration tests shall to be used. A beginning engine speed and proper gear ratio must be determined for use during measurements.

- o Select the highest rear axle and/or transmission gear ("highest gear" is used in the usual sense; it is synonymous to the lowest numerical ratio) and an initial vehicle speed such that at wide-open throttle the vehicle will accelerate from the acceleration point:

  - Starting at no more than two-thirds (66 percent) of maximum rated engine speed, if the vehicle is not equipped with an engine governor, or of governed engine speed, if the vehicle is equipped with an engine governor.

  - Reaching maximum rated or governed engine speed within the end zone.

  - Without exceeding 35 mph (56 k/h) before reaching the end point.

- o Should maximum rated or governed rpm be attained before reaching the end zone, decrease the approach rpm in 100 rpm increments until maximum rpm is attained within the end zone.

- Should maximum rated or governed rpm be attained before reaching the end zone, decrease the approach rpm in 100 rpm increments until maximum rpm is attained within the end zone.
- Should maximum rated or governed rpm not be attained until beyond the end zone, select the next lower gear until maximum rated or governed rpm is attained within the end zone.
- Should the lowest gear still result in reaching maximum rated or governed rpm beyond the permissible end zone, unload the vehicle and/or increase the approach rpm in 100 rpm increments until the maximum rated or governed rpm is reached within the end zone.
- For the acceleration test, approach the acceleration point using the engine speed and gear ratio selected in paragraph (c)(1) of this procedure and at the acceleration point rapidly establish wide-open throttle. The vehicle reference shall be as indicated in paragraph (b)(8) of the recommended exterior noise measurement procedure. Acceleration shall continue until the entire vehicle has vacated the end zone.
- Buses equipped with governed engines must be held at wide open throttle until the entire vehicle is out of the end zone. Buses equipped with ungoverned engines must not be allowed to drop more than 100

rpm below maximum rated engine speed until the vehicle is out of the end zone.

- Wheel slip which affects maximum sound level must be avoided.
- If the vehicle being tested is equipped with an engine brake, it must also be tested as follows: Approach the microphone point at maximum rated or governed engine speed in the gear selected for the acceleration test. When the vehicle reference point reaches the microphone point, close the throttle and immediately apply the engine brake fully and allow the vehicle to decelerate to one-half of maximum rated or of governed engine speed. The vehicle reference shall be as indicated in paragraph (b)(8) of the recommended exterior measurement procedure. The engine brake must be full on during this test.

(2) Buses equipped with automatic transmissions which cannot be manually held in any gear. Full throttle acceleration tests are to be employed.

- Select the highest rear axle and/or transmission gear (highest gear is used in the usual sense; it is synonymous to the lowest numerical ratio) to accelerate the bus under wide open throttle from a stationary position.

- A starting point along the test path at which the vehicle shall begin the acceleration test shall be determined by the following procedure:

  - The vehicle's reference point shall be placed at the midpoint (± 0.3 meters, ± 1 foot) of the end zone with the front end of the vehicle facing back along the test path in the opposite direction of travel that is used for the sound measurement tests.

  - The vehicle shall then be accelerated as rapidly as possible to establish a wide open throttle, until the first transmission shift point is reached.

  - The location along the test path at which the front end of the vehicle is passing when the first transmission shift point occurs shall be the designated starting point.

  - The vehicle's direction of travel shall then be reversed for sound testing.

- For the acceleration test, accelerate the vehicle from a standing position with the front of the vehicle at the selected stationary starting point, obtained by using the procedure outline above, as rapidly as possible to establish a wide open throttle. The acceleration shall continue until the entire vehicle has vacated the end zone.

- Wheel slip which affects maximum sound level must be avoided.

- If the vehicle being tested is equipped with an engine brake, it must also be tested as follows: Approach the microphone point at maximum rated or governed engine speed, in the gear utilized during the acceleration test. When the vehicle's reference point reaches the microphone point, close the throttle, immediately apply the engine brake fully and allow the vehicle to decelerate to one-half of governed engine speed. The vehicle reference shall be as indicated in paragraph (b)(8) of the recommended exterior measurement procedure. The engine brake must be full on during the test.

(3) Measurements.

- o The meter shall be set for "fast response" and the A-weighted network.
- o The sound meter shall be observed during the period while the vehicle is accelerating. The applicable reading shall be the highest sound level obtained for the run. The test is to be rerun if unrelated peaks should occur due to extraneous ambient noises.
- o Sound level measurements shall be taken on both sides of the vehicle. The sound level associated with a side shall be the average of the first two pass-by measurements for that side, if they are within 2 dBA of each other. Average of measurements on each side shall be computed separately. If the first two measurements for a given side differs by more than 2 dBA, two additional measurements shall be made on each side, and the average of the two highest measurements on each side, within 2 dBA of each other, shall be

taken as the measured vehicle sound level for that side. The reported measured vehicle sound level shall be the higher of the two averages.

(d) General Requirements

(1) Measurements shall be made only when wind velocity is below 19.3 km/hr (12 mph).

(2) Proper usage of all test instrumentation is essential to obtain valid measurements. Operating manuals or other literature furnished by the instrument manufacturer shall be referred to for both recommended operation of the instrument and precautions to be observed. Specific items to be adequately considered are:

- The effects of ambient weather conditons on the performance of the instruments (for example, temperature, humidity, and barometric pressure).
- Proper signal levels, terminated impedances, and cable lengths on multi-instrument measurement systems.
- Proper acoustical calibration procedure, to include the influence of extension cables, etc. Field calibration shall be made immediately before and after each test sequence. Internal calibration means is acceptable for field use, provided that external calibration is accomplished immediately before or after field use.

(3) A complete calibration of the instrumentation and external acoustical calibrator over the entire frequency range of interest shall be performed at least annually and as frequently as necessary during the

yearly period to insure compliance with the standards cited in American National Standard S1.4-1971 "Specifications for Sound Level Meters" for a Type 1 instrument over the frequency range 100 Hz - 10,000 Hz.

- o If calibration devices are utilized which are not independent of ambient pressure (e.g., a pistonphone) corrections must be made for barometric or altimetric changes according to the recommendation of the instrument manufacturer.

(4) The vehicle shall be brought to its normal operating temperature prior to commencement of testing. During testing appropriate caution shall be taken to maintain the engine at temperatures within the normal operating range.

8. RECOMMENDED PROCEDURE FOR MEASUREMENT OF INTERIOR SOUND LEVELS

Interior sound levels shall be measured using the same vehicle operation and measuring equipment as described in the Recommended Procedure for Measurement of Exterior Sound Levels.

(a) Instrumentation. The following instrumentation shall be used, where applicable.

(1) A sound level system which meets the Type I requirements of ANSI SI.4-1971, Specifications for Sound Level Meters.

(2) A windscreen must be employed along with the microphone during all measurements. The windscreen shall not affect the A-weighted sound levels from the bus in excess of ± 0.5 dB.

(3) A sound calibrator. The calibrator shall produce a sound pressure level, at the microphone diaphragm, that is

known to within an accuracy of ± 0.5 dB. The calibrator shall be checked annually to verify that its output has not changed.

(4) An engine speed tachometer which is accurate to within ± 2 percent of the meter reading.

(5) A thermometer for measurement of ambient temperature accurate within ± 1°C.

(6) A barometer for measurement of ambient pressure accurate within ±1 percent.

(b) Microphone placement.

- The microphone shall be located next to the seat location closest to the main body of the engine at a height of 1.25 meters (4.1 ft.) from the bus floor. In addition, the microphone shall be placed at least 0.5 meters (1.6 ft.) from the nearest vehicle wall.
- For front engine buses the microphone shall be placed next to the vehicle operator's seat, at a height of 1.25 meters (4.1 ft.) from the floor and at least 0.5 meters (1.6 ft) from the nearest vehicle wall.
- The microphone shall be tilted towards the front of the vehicle at an angle of 20° - 30° from the vertical.
- The test site shall be such that the bus radiates sound in a free field over a reflecting plane. This condition may be considered fulfilled if the test site consists of an open space free from reflecting surfaces, such as parked vehicles, signboards, buildings or hillsides, located within 30.4 meters (100 ft) of the vehicle.

(c) Vehicle operation.

- o The vehicle shall be operated in the same manner as stated in the recommended exterior noise measurement procedure. The same axle ratios, gear ratios, along with the same procedure as modified by transmission type shall be utilized.
- o All windows and doors shall be closed on the vehicle and all interior fan accessories (including air conditioning fans and/or heating fans) turned on.

(d) Measurements.

- o The meter shall be set for "fast response" and the A-weighted network.
- o The meter shall be observed during the period while the vehicle is accelerating. The applicable reading shall be the highest sound level obtained for the run. The observer is cautioned to rerun the test if unrelated peaks should occur due to extraneous ambient noises.
- o The average of the two highest levels within 2 dB of each other shall be reported as the interior level of the bus.

(e) General requirements.

(1) Bystanders have an appreciable influence on sound level meter readings when they are in the vicinity of the microphone; therefore, not more than one person, other than the observer reading the meter and the driver shall be in the vehicle at the time of measurement.

(2) The maximum A-weighted fast response sound level observed in the test vehicle immediately before and after the test shall be at least 10 dB below the regulatory level.

(3) Proper usage of all test instrumentation is essential to obtain valid measurements. Operating manuals or other literature furnished by the instrument manufacturer shall be referred to for both recommended operation of the instrument and precautions to be observed. Specific items to be adequately considered are:

- o The effects of ambient weather conditions on the performance of the instruments (for example, temperature, humidity, and barometric pressure).
- o Proper signal levels, terminating impedances, and cable lengths on multi-instrument measurement systems.
- o Proper acoustical calibration procedure, to include the influence of extension cables, etc. Field calibration shall be made immediately before and after each test sequence. Internal calibration means is acceptable for field use, provided that external calbration is accomplished immediately before or after field use.

(4) o A complete calibration of the instrumentation and external acoustical calibrator over the entire frequency range of interest shall be performed at least annually and as frequently as necessary during the yearly period to insure compliance with the standards cited in American National Standard S1.4-1971 "Specifications for Sound Level Meters" for a Type 1 instrument over the frequency range 100-Hz - 10,000 Hz.

- o If calibration devices are utilized which are not independent of ambient pressure (e.g., a pistonphone) corrections must be made for barometric or altimetric changes according to the recommendation of the instrument manufacturer.

(5) The vehicle shall be brought to a temperature within its normal operating range prior to the commencement of testing. During appropriate caution shall be taken to maintain the engine temperature within the normal operating range.

REFERENCES

SECTION 8

1. ISO Recommendation R362-1967 (E), "Measurement of Noise Emitted by Vehicles," February, 1964.

2. Swetnam, G. W. and Murray, W.S., "Proposed Standard Noise Measurement Procedure for Diesel Transit Buses," Report No. UMTA-VA-06-0028-75-1, Prepared by MITRE Corp., for U. S. Dept. of Transportation, Washington, D.C., July 1975.

3. "California Steam Bus Project Final Report," Prepared by The Assembly Office of Research , Sacramento, Calif., January 1973.

4. "A Status Report of an Environmental Noise Study of Transit Buses," by the Environmental Activities Staff (Vehicular Noise Control), General Motors Corp., December 1975.

5. Oswald, L. J. and Hickling, R., "An Overhead Microphone Facility for Recording Vertically-Radiated Vehicle Noise," Research Publication GMR-1944, GM Research Laboratories, November 1975.

6. "An Assessment of the Technology for Bus Noise Abatement," Draft Final Report submitted by Booz-Allen Applied Research, under EPA Contract No. 68-01-3509, prepared for the Office of Noise Abatement and Control, June 22, 1976.

Section 9

ENFORCEMENT

A. GENERAL. The EPA enforcement strategy will place a major share of the responsibility on the manufacturers for pre-sale testing to determine the compliance of buses with the regulation. This approach, besides relieving EPA of an administrative burden benefits the manufacturers by leaving their personnel in control of many aspects of the compliance program and imposing only a minimum burden on their business. Therefore, monitoring by EPA personnel of the tests and manufacturers' actions taken in compliance with the regulation is advisable to insure that the Administrator is provided with the accurate test data necessary to determine whether the vehicles distributed in commerce by manufacturers are in compliance with the regulation. Accordingly, the proposed regulation provides that EPA enforcement officers may be present to observe any testing required by the regulation. In addition, enforcement officers under previously promulgated regulations [40 CFR Part 205 Subpart A] are empowered to inspect records and facilities in order to assure that manufacturers are carrying out their responsibilities properly.

The enforcement strategy in the proposed regulation, applicable to both exterior and interior standards consists of three parts: (1) Production Verification (PV), (2) Selective Enforcement Auditing (SEA), and (3) In-Use Compliance Provisions.

The manufacturer who assembles the completed bus, as in the case of intercity and transit buses, is responsible for satisfying the PV, SEA and in-use requirements of the regulation for both the interior and exterior standards. In the case of vehicles which are assembled by two manufacturers, such as many Type I school buses, the chassis manufacturer must comply with the PV, SEA and in-use provisions of this regulation with respect to the vehicle exterior noise emission standard. The body assembler/mounter of such a bus which is assembled by two manufacturers is responsible for compliance with the provisions with respect to the vehicle interior standard. In addition, the body assembler is prohibited from causing the vehicle exterior noise emissions to exceed the standard and is subject to SEA provisions of the regulation for the exterior standard.

B. Production Verification. Production verification is testing by a manufacturer of selected early production models of a configuration intended for sale, to verify a manufacturer has the requisite noise control technology in hand to comply with the standard at the time of sale and during the Acoustical Assurance Period (AAP), and is capable of applying the technology to the manufacturing process. The first production models of a configuration tested must not exceed the level of the standard minus that configuration's expected sound level degradation (Sound Level Degradation Factor, SLDF) before any models in that configuration may be distributed in commerce. Any testing shall be done in accordance with the proposed test procedures.

Production verification does not involve any formal EPA approval or issuance of certificates subsequent to manufacturer testing, nor is any extensive testing required of EPA. The proposed regulation would require that prior to distribution in commerce of any model of a configuration, as defined within the regulation, the configuration must undergo production verification. All testing is performed by the manufacturer. However, the Administrator reserves the right to be present to monitor any test (including simultaneous testing with his equipment) or to require that a manufacturer supply him with vehicles for testing at EPA's Noise Enforcement Facility in in Sandusky, Ohio, or at any other site the Administrator may find appropriate.

The production unit selected for testing is a vehicle configuration. A vehicle configuration is defined on the basis of various parameters including the exhaust system, the air induction system, the cooling fan type, horsepower, and, where applicable, certain interior design characteristics, and any additional parameters that a manufacturer may select.

A manufacturer shall verify production vehicles prior to sale by one of two methods. The first method will involve testing any early production vehicle intended for sale of each configuration.

A vehicle configuration is considered to be production verified after the manufacturer has shown, based on the application of the sound measurement tests, that a configuration does not exceed a sound level defined by the new product standard minus that configuration's expected sound level degradation during its defined acoustical assurance period.

The second method allows a manufacturer, in lieu of testing vehicles of every configuration, to group configurations into categories. A category will be defined by basic parameters such as engine and fuel type, engine manufacturers, engine displacement, engine configuration, manufacturers, engine displacement, engine configuration, engine location, and bus body style. Again, the manufacturer may designate additional categories based on additional parameters of its choice. Within a category, the configuration estimated by the manufacturer to be emitting the greatest A-weighted sound pressure level at the end of the Acoustical Assurance Period is determined either by testing or good engineering judgment. The manufacturer can then satisfy the production verification requirements for all configurations within that category by demonstrating that that configuration complies with the applicable standards. This can eliminate the need for a substantial amount of testing. However, it must be emphasized that the loudest configuration at the end of the acoustical assurance period must be clearly identified.

The proposed regulation also provides that the Administrator may test vehicles at a manufacturer's test facility using either his own equipment or the manufacturer's equipment. This will provide the Administrator an opportunity to determine that the manufacturer's test facility and equipment are technically qualified for conducting the required tests. If it is determined that the equipment and/or facilities are not technically qualified, he may disqualify them from further use for bus testing. Procedures that are available to the manufacturer subsequent to disqualification are delineated in the proposed regulation.

A production verification report must be filed by the manufacturer performing the required production verification test before any vehicles of the configuration represented are distributed in commerce.

A vehicle configuration is considered to be production verified when the manufacturer has shown, based on the application of the noise measurement test, that a configuration does not exceed a level defined by the standard minus the SLDF, and a timely report indicating such compliance has been mailed to EPA.

If a manufacturer is unable to test due to weather conditions, the production verification of a configuration is automatically waived by the Administrator for a period of up to 45 consecutive days without the manufacturer's request provided that he tests on the first day that he is able. This procedure will minimize disruptions to manufacturing facilities. The manufacturer may request an additional extension of up to 45 days if it is demonstrated that weather or other uncontrollable conditions prohibited testing during the first 45 days. However, to avoid any penalties under the proposed regulation, the manufacturer must test for purposes of production verification on the first day that he is able.

If a manufacturer plans to add a new configuration to his product line or change or deviate from an existing configuration with respect to any of the parameters which define a configuration, the manufacturer must verify the new configuration either by testing a vehicle and submitting data or by filing a report which demonstrates verification on the basis of previously submitted data.

Production verification is an annual requirement. However, the Administrator, upon request by a manufacturer, may permit the use of data from previous production verification reports for specific vehicle configurations and/or categories. The considerations that are cited in the proposed regulation as being relevant to the Administrator's decision are illustrative and not exclusive. The manufacturer can submit all data and information that he believes will enable the Administrator to make a proper decision. It must be again emphasized that the manufacturer must request the use of previous data. If he fails to do so, then he must production verify all categories and configurations for each subsequent year.

The manufacturer need not verify configurations at any particular point in a year. The only requirement is that he verify a configuration prior to distribution in commerce. The inherent flexibility in the scheme of categorization in many instances will allow a manufacturer to either verify a configuration that he may not produce until late in a year based on representation or else wait until actual production of that configuration to verify it.

If a manufacturer fails to properly verify and a configuration is found to be in non-conformity with the regulations, the Administrator may issue an order requiring the manufacturer to cease the distribution in commerce of vehicles of that configuration. The Administrator will provide the manufacturer the opportunity for a hearing prior to the issuance of such an order.

Production verification performed on the early production models provides EPA with confidence that production models will conform to the standards and limits the possibility that non-conforming products will be distributed in commerce. Because the possibility still exists that subsequent models may not conform, selective enforcement audit testing of assembly line vehicles is made a part of this enforcement strategy in order to determine whether production vehicles continue to comply with the standards.

C. Selective Enforcement Auditing. Selective Enforcement Auditing (SEA) is the term used in the proposed regulation to describe the testing of a statistical sample of production vehicles from a specified vehicle category or configuration selected from a particular assembly plant in order to determine whether production vehicles comply with the noise emission standards including the in use standard and to provide the basis for further action in the case of non-compliance.

Testing is initiated by a test request which will be issued to the manufacturer by the Assistant Administrator for Enforcement or his authorized representative. A test request will address itself to either a category or a configuration. The test request will require the manufacturer to test a sample of vehicles of the specified category or configuration produced at a specified plant. An alternative category or configuration may be designated in the test request in the event vehicles of the first category or configuration are not available.

Upon receipt of the test request the manufacturer will select the sample as specified in the test request in one of the following ways:

(1) Random selection from the first batch of vehicles of the specified category or configuration by sequentially numbering all vehicles in the batch and using a table of random numbers to select the proper number of vehicles or;

(2) Selection by the manufacturer using his own random selection plan, if it is approved by the Administrator; or

(3) Consecutive selection from the batch, if the test request does not specify random selection; or

(4) Selection of vehicles from the batch in a manner specified by the EPA Enforcement Officer.

Generally, a batch will be defined as the number of vehicles produced during a time period specified in the test request. A batch defined in this manner will allow the Administrator to select batch sizes small enough to keep the number of vehicles to be tested at a minimum and still enable EPA to eventually draw statistically valid conclusions about the noise emission performance of all vehicles of the category or configuration which is the subject of the test request.

One important factor that will influence the decisions of the Administrator not to issue a test request to a manufacturer is the evidence that a manufacturer has to demonstrate that his vehicles comply to the applicable standard. If a manufacturer can provide evidence that his vehicles are meeting the noise emission standards based on testing results, the issuance of a test request may not be necessary.

The Selective Enforcement Audit plan is designed to determine the acceptability of a batch of items for which one or more inspection criteria have been established. As applied to vehicle noise emissions, the items being inspected are buses and the inspection criterion is the noise emission standard, taking into consideration the sound level degradation estimated to occur during the acoustical assurance period (See Part G., <u>In Use Compliance</u> of this section).

Once the sample of a batch has been selected, each item is tested to determine whether it meets the prescribed criterion; this is generally referred to as inspection by attributes. The basic criteria for acceptance or rejection of a batch is the number of sample vehicles whose parameters meet specification rather than the average value of some parameter.

The particular type of inspection plan which has been adopted for SEA of buses is known as sequential batch sampling. Sequential batch sampling differs from single sampling in that small test samples are drawn from sequential batches rather than one large sample being drawn from a single batch.

This sampling offers the advantage of keeping the number of vehicles tested to a minimum when the majority of products are meeting the standards.

The sampling plans are arranged according to the size of the batch from which a sample is to be drawn. Each plan specifies the sample size and acceptance and rejection number for the established acceptance quality level (AQL). As applied to bus noise emissions, this AQL is the maximum percentage of failing vehicles that for purposes of sampling inspection can be considered satisfactory. A vehicle is considered a failure if it exceeds the noise emission standard minus its SLDF. An AQL of 10% was chosen to take into account some test variability. The number of failing vehicles in a sample is compared to the acceptance and rejection numbers for the appropriate sampling plan. If the number of failing vehicles in the sample is greater than or equal to the rejection number, then there is a high probability that the percentage of non-complying vehicles in the batch is greater than the AQL and the batch fails. On the other hand, if the number of failures is less than or equal to the acceptance number, then there is insufficient evidence to conclude that the percentage of non-complying vehicles in the batch is greater than the AQL, and the batch is accepted.

Since the sampling strategy involves a sequential batch sampling plan, in some instances the number of failures in a test sample may not allow acceptance or rejection of a batch so that continued testing may be required until a decision can be made to either accept or reject a batch.

Regardless of whether a batch is accepted or rejected, failed vehicles would have to be repaired and/or adjusted and pass a retest before they can be distributed in commerce.

The proposed regulation establish two types of inspection criteria. These are normal inspection and 100% testing. Normal inspection is used until a decision can be made as to whether a batch sequence is accepted or rejected. When a batch sequence is tested and accepted in response to a test request, the manufacturer will not be required at that time to do any further testing pursuant to that test request. When a batch sequence is tested and rejected, the Administrator may then require 100 per cent testing of the vehicles of that category or configuration produced at that plant. The Administrator will notify the manufacturer of the intent to require 100 per cent testing. The manufacturer can request a hearing on the issue of non-compliance of the rejected category or configuration.

The proposed regulation also discusses the situation where batches consist of four or less vehicles. The proposed regulation requires that each vehicle in that batch be tested and comply with the noise emission standards. This will allow testing to take place within a more reasonable period of time when a test request is issued for particular categories or configurations which are not produced in a sufficiently high volume for the normal SEA scheme to be applicable.

Since the number of vehicles tested in response to a test order may vary considerably, a fixed time limit cannot be placed on completing all testing. The proposed approach is to establish the time limit on a test time per vehicle basis, taking transportation requirements, if any, into consideration. The manufacturer would be allowed a reasonable amount of time for transport of vehicles to a test facility if one were not available at the assembly plant.

The Administrator estimates that the manufacturers can test a minimum of five (5) vehicles per day. However, manufacturers are requested to present any data or information that may affect a revision of this estimate.

D. Administrative Orders. Section 11(d)(1) of the Noise Control Act of 1972 provides that:

"Whenever any person is in violation of section 10(a) of this Act, the Administrator may issue an order specifying such relief as he determines is necessary to protect the public health and welfare."

Clearly, this provision of the Act is intended to grant to the Administrator discretionary authority to issue administrative orders to supplement the criminal penalties of section 11(a). If vehicles which were not designed, built, and equipped so as to comply with the noise emission standard, including the in-use requirement, at the time of sale to the ultimate purchaser were distributed in commerce, such act would be a violation of section 10(a) and remedy of such non-compliance would be appropriate. Remedy of the affected vehicles shall be carried out pursuant to an administrative order.

The proposed regulation provides for the issuance of such orders in the following circumstances: (1) recall for the failure of a vehicle or group of vehicles to comply with the applicable noise emission standard, (2) cease to distribute vehicles not properly production verified, and (3) cease to distribute vehicles for failure to test.

In addition, the proposed regulation provides for cease to distribute orders for substantial infractions of the regulation requiring entry to manufacturers' facilities and reasonable assistance. These provisions do not limit the Administrator's authority to issue orders, but give notice of cases where such orders would in his judgment be appropriate. In all such cases, notice and opportunity for a hearing will be given.

E. Compliance Labeling. The proposed regulation requires that buses subject to it shall be labeled to provide notice that the product complies with the exterior and/or interior noise emission standards. The label shall contain a notice of tampering prohibitions.

F. Applicability of Previously Promulgated Regulations. Manufacturers who will be subject to the proposed regulation must also comply with the the general provisions of 40 CFR Part 205 Subpart A. These include the provisions for inspection and monitoring by EPA enforcement officers of manufacturers' actions taken in compliance with the proposed regulation and for granting exemptions from the proposed regulation for testing, pre-verification vehicles, national security reasons, and export vehicles.

G. In-Use Compliance. The manufacturer is required to design, build, and equip vehicles subject to the regulation so that the degradation of emitted noise levels is minimized provided that they are properly maintained, used, and repaired.

In-use compliance provisions are included in the proposed regulation to insure that this obligation is satisfied.

EPA does not specify what testing or analysis a manufacturer must conduct to determine that his vehicles will meet the standard during the Acoustical Assurance Period (AAP) of the regulation. However, the proposed regulation requires the manufacturer to make such determination and maintain records of the test data and other information upon which the determination was based. This determination may be based on information such as tests of critical noise producing or abatement components, rates of noise control deterioration, engineering judgements based on previous experience, and physical durability characteristics of the product.

An SLDF is the degradation (sound level increase in A-weighted decibels) which the manufacturer expects will occur on a configuration during the period of the one year in-use standard. The manufactuer must determine an SLDF for each of his vehicle configurations.

To ensure that the vehicles will meet the noise standard throughout the acoustical assurance period, they must emit a sound level at the time of sale less than or equal to the standard minus the SLDF. A vehicle is in compliance only if its measured dBA level, is less than or equal to the applicable standard minus the SLDF. Production verification and selective enforcement audit testing both embody this principle.

All vehicles must emit a sound level that is less than or equal to the standard at the time of sale, so a negative SLDF cannot be used. A vehicle that becomes quieter during Acoustical Assurance Period must still meet the standard on the day of sale; an SLDF of 0 must be used for that configuration.

As stated above, the Agency is not requiring durability testing as a matter of course, however, should it be necessary, section 13(a) of the Noise Control Act authorizes EPA to require the manufacturer to run such tests on selected vehicles.

These provisions also include a requirement that the manufacturer provide a warranty to purchasers [required by section 6(d)], assist the Administrator in fully defining those acts which constitute tampering [under section 10(a) (2)(A)], and provide retail purchasers with instructions specifying the maintenance, use, and repair required to minimize degradation during the life of the bus, and with a log book to record maintenance and repairs performed.

In the case of a bus which is assembled by two manufacturers such as the Type I School Bus, the manufacturer who assembles the chassis must satisfy these requirements with respect to the exterior standard. The manufacturer who then assembles the body must satisfy these requirements as they relate to the interior noise emissions standard.

Section 6(d)(1) of the Act requires the manufacturer to warrant to the ultimate and subsequent purchasers that the buses subject to the proposed regulation are designed, built, and equipped to conform at the time of sale with the applicable Federal noise emission standards. The proposed regulation requires that the manufacturer furnish this time-of-sale warranty to the ultimate purchaser in a prescribed written form. The proposed regulation also provides for EPA review of the written warranty and related information furnished to purchasers, dealers, zone representatives, etc., in order that the Agency can determine whether the manufacturer's warranty policy is consistent with the intent of the Act.

The tampering regulations require the manufacturer furnish the Agency a list of those acts which in the manufacturer's estimation might be done to a vehicle and result in that vehicle emitting sound levels above the standards. The Administrator will respond to the manufacturer's list within 30 days by developing a list of specific tampering acts that the manufacturer must include in the owner's manual for each product. It is stressed that the Administrator's list is not all inclusive; any act of tampering is unlawful and subject to Federal penalty.

The provisions dealing with instructions for proper operation, use, and repair are intended to assure that purchasers know exactly what is required to minimize any degradation of the vehicle's emitted noise level during use. The instructions are necessary to minimize degradation and also must be reasonable in the burden placed on the purchaser. A record or log book must be provided to the ultimate purchaser to assist purchasers in demonstrating proper maintenance should a record be necessary at any time during the life of the vehicle. The instructions may not contain language which tends to give manufacturers or their dealers an unfair competitive advantage over the after-market manufacturers. Finally, the proposed regulation provides for Agency review of the instructions and related language.

SECTION 10

EXISTING NOISE REGULATIONS APPLICABLE
TO BUSES

A. INTRODUCTION

Federal noise regulations applied to any particular product are developed primarily on the basis of the assessment of available technology together with associated economic and health and welfare impacts as required by Section 6 of the Noise Control Act of 1972. In most cases, actions by the EPA in proposing and finalizing new product noise regulations will not be the first cases of regulatory action, but will have been preceded by various state and local regulations. These state and local regulations refer, in some cases, to the noise emissions of the product at the time of sale, and in others cases to the control of noise produced during the product's operation. It may be expected that the scope and stringency of state and local noise standards will differ from place to place in a way that is dependent on the degree of annoyance, local citizen pressures and the amount of work put into the development of the regulation. The results of these regulations will also probably differ considerably based on the degree of enforcement and compliance.

B. REVIEW OF EXISTING NOISE ORDINANCES

The increased interest in noise brought about in recent years by the wider understanding of its potential effects on people has resulted in the development of a large number of state and local noise ordinances. Many of these ordinances can be classified as "nuisance" laws that make it unlawful to conduct certain acts that would disturb the peace of "a reasonable person of normal sensitivity." However, there are an increasing number of state laws and local ordinances that refer quantitatively to specific noise sources in the community.

The first motor vehicle noise regulations were introduced in the State of California in 1967, which established noise standards for different types of vehicles, including trucks and buses with a Gross Vehicle Weight Rating (GVWR) in excess of 10,000 lbs. The regulations were applicable both to the sale of new vehicles and the operation of vehicles on the highway. Since 1967, a number of other states and cities have introduced such regulations, many of them identical to regulations applicable to trucks and buses operated by interstate motor carriers. Again, the lower limit on the GVWR was 10,000 lbs.

In each of the many regulations applicable to medium and heavy vehicles described above, there is no distinction in noise standards between the various classes. Thus the category of vehicles having a GVWR in excess of 10,000 lbs. includes not only trucks but inter-city buses, transit buses and school buses. In other words, buses are combined with trucks in every case. There are therefore no separate noise regulations for buses in the United States. A summary of state and local noise standards applicable to buses and trucks is given in Reference 10-1. Since the publication of this referenced document, many of these regulations have been preempted in part by the issuance of federal regulations for new medium and heavy trucks and for new and in-service interstate motor carriers, the latter also including in-service inter-city buses. However, there has been no federal preemption of newly manufactured inter-city, transit, or school buses, so these standards remain as stated in Reference 10-1.

The situation concerning the nonspecificity of buses in noise regulations is similar in the vehicle noise regulations of many other countries. A distinction between buses and trucks is made in Australia, Sweden, and the United Kingdom, as well as by ECE (Geneva) and EEC (Brussels), but in each case the noise standards are identical. It appears that only one country, Portugal, has a different set of noise standards for new buses and trucks. A summary of the foreign noise standards applicable to buses is given in Table 10-1.

C. ANALYSIS OF EXISTING REGULATIONS

In view of the fairly uniform approach taken towards the regulation of medium and heavy vehicles, it is interesting to determine the reasons for not separating buses from trucks. A review of the decision criteria for noise regulations adopted at the state and local level reveals the following information:

- Many considered that buses and trucks exhibit very similar noise characteristics. It is true that the two vehicles use the same type of engines--whether diesel or gasoline--and some of the same auxiliary components, but the conclusion that their noise emissions are the same must be taken advisedly because of the lack of available data.
- Whereas there was a considerable amount of data on the noise characteristics of heavy trucks, the same was not

Table 10-1

Summary of Noise Standards*
Applicable to Buses in Foreign Countries

Country	Type of Regulation and Effective Date	Applicability	Max. Noise Level (dBA)
Australia Sweden	• New vehicles manuf'd after 1975	• > 3.5 Mg w/engine < 200 HP	89
W. Germany Yugoslavia		• > 3.5 Mg w/engine < 200 HP	92
Belgium	• New vehicles manuf'd after 1968	• diesel engine > 200 HP DIN	92
	• Operation		2 dB greater than above
Canada	• New vehicles manuf'd after 1970	• Heavy Duty Vehicles	88
Czechoslovakia	• New vehicles manuf'd after 1969	• > 3.5 Mg	88
		• > 220 BHP engine power	89
	• Operation		2 dB greater than above
Denmark	• New vehicles	• > 3.5 Mg	89
		• > 200 HP DIN	92
	• Operation		3 dB greater than above
ECE (Geneva)	• New vehicles	• > 3.5 Mg > 9 Seats	89
		• > 200 HP DIN > 9 Seats	91
EEC (Brussels)	• New vehicles	As for ECE	

*Measured according to ISO R362 at 25 feet.

Table 10-1 (cont.)

Country	Type of Regulation and Effective Date	Applicability	Max. Noise Level (dBA)
Finland	• New vehicles	• > 200 DIN HP	92
France	• New vehicles	• Public Service Vehicles	90
	• Operation		2 dB greater than above
Italy	• New vehicles manuf'd after 1968	• > 1500 cc	93
Luxembourg Netherlands	• New vehicles manuf'd after 1973	• > 3.5 Mg	88
		• > 200 HP DIN	92
	• Operation		2 dB greater than above
Portugal	• New vehicles	• < 5 Mg	86
		• > 5 Mg	88
Great Britain	• New vehicles	• > 12 passengers, excluding driver	89
	• Operation		92

true of buses. Hence, the two vehicles were combined into one category in the absence of reasons to do otherwise.

- o Some states not having the resources to perform their own background studies have incorporated the results of testing done in other states.
- o As an aid to enforcement, it was considered unwise to have a large number of vehicle categories with different noise standards.
- o At the state level, the enforcement activities are often restricted to highways outside of the cities. In these areas, buses were not considered to pose significant problems.
- o There are indications that some agencies did not consider buses at all, but were mainly concerned with heavy trucks.

In no case has there been reported any impetus to treat buses separately from heavy trucks. Furthermore, many State and local officials have indicated they do not now believe that such a separation is required, although some indicate that a special case might be made for transit buses.

REFERENCES

SECTION 10

1. U.S. Environmental Protection Agency, "Noise Source Regulation in State and Local Noise Ordinances," Report No. 550/9-75-020, February 1975.

2. Society of Automotive Engineers, "Exterior Sound Level for Heavy Trucks and Buses," SAE Standard J366b.

3. "Interstate Motor Carrier Noise Emission Standards," Federal Register, Vol. 38, No. 144, July 27, 1973.

4. "Interstate Motor Carrier Noise Emission Standards--Final Regulations on Compliance," Federal Register, Vol. 40, No. 178, September 12, 1975.

5. "Existing Noise Regulations Applicable to Buses," Draft Final Report submitted by Wyle Laboratories under EPA Contract No. 68-01-3516, prepared for the Office of Noise Abatement and Control, June 24, 1976.

APPENDIX A

FOREIGN TECHNOLOGY BUSES

Two European bus manufacturers currently produce urban transit buses that claim to be considerably quieter than any available in the United States.

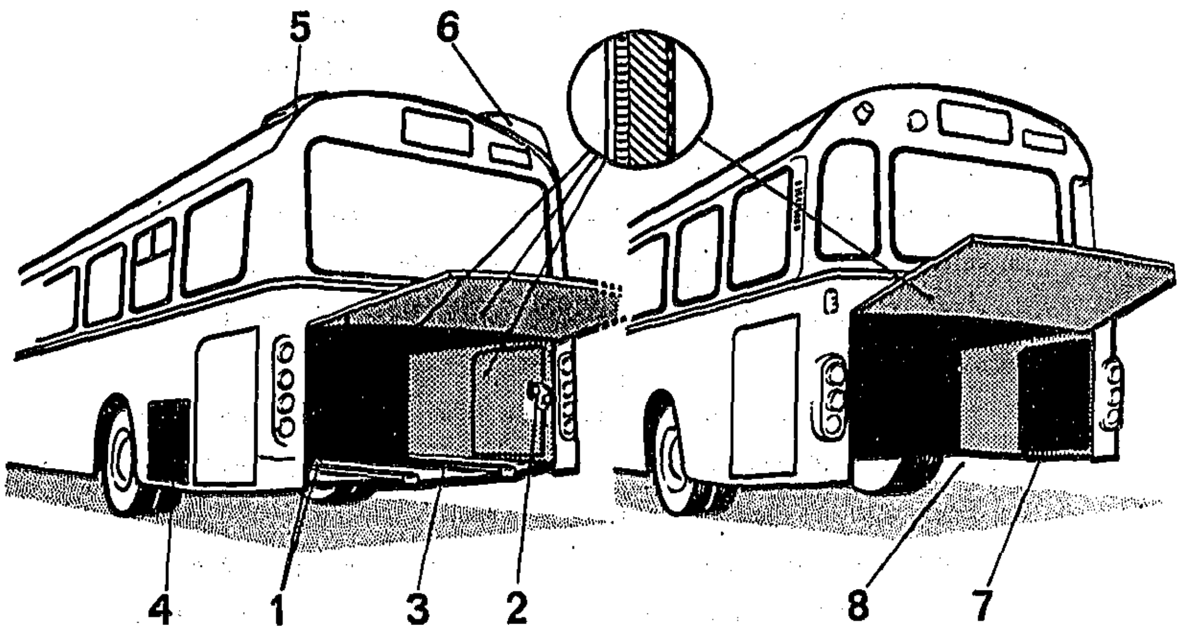
1. SAAB SCANIA CR111M BUSES

In 1971, Scania-Bussar AB, Katrineholm (Sweden) presented a bus in which the noise level had been effectively reduced. The bus is an integrally constructed city bus, the Scania CR111M, with a suburban version, the CR111MF.

Scania CR111M and CR111MF, the "quiet buses," have a reduced noise level as low as 77 dBA for buses with automatic transmission and 80 dBA for buses with standard transmission when measured in accordance with the ISO R362 procedure for noise measurement. Other non-quieted modern Swedish buses (CR110) generate noise levels of 86 to 87 dBA (ISO R362).

The reduction in noise level on the Scania CR111M (see Figure A-1) has been achieved primarily by insulating the engine compartment and relocating the cooling system. The engine compartment is lined with sound-insulating materials attached directly to the exterior panels. Within this sound-insulating wall is a thicker covering of sound-absorbent glass fiber which in turn is covered with perforated aluminum sheet. Insulated belly pans are mounted underneath the engine. The engine, consequently, is almost entirely encased in sound-absorbent material.

Figure A-1
Comparison of Scania CR111M City Bus
and the CR110M Standard Bus



1. Insulated Engine Compartment
2. Fan for Engine Compartment Ventilation
3. Belly Pan
4. Air Intake for Radiators, One on Each Side
5. Engine Air Intake
6. Ventilation Air Intake
7. Radiator Air Intake (Standard Version)
8. Bottom Opening

As a result of this insulation, problems arise in disposing of the heat generated by the engine. The bus has, therefore, been equipped with a water-cooled exhaust manifold and heat-insulated exhaust pipe up to the silencer. A special fan located on the roof provides the engine compartment, by way of a channel through the bus rear section, with effective ventilation.

The CR111M has two radiators (each 0.42 m^2 in area), instead of the one as is normal on U.S. transit buses. The radiators are mounted in front of the insulated engine compartment to cope with the increased cooling requirements caused by the insulation. By using two fans of 480 mm diameter, a lower peripheral speed is achieved than if only one fan was used for cooling. The fans are thermostatically controlled in three steps up to 1400 rpm. If required, the fans can run at full speed even while the engine is working at a minimum speed. For cross-country operation, 10 to 15 percent larger radiators are employed.

Noise levels within the bus vary in relation to the distance from the engine. The noise level at the driver's seat is as low as 68 dBA under acceleration. Levels of 78 dBA are reported at the rear seat. Further reductions are expected from development work currently in progress.

Due to the relocation of the radiators and a change in design of the rear overhang, the number of seats has been increased by four in comparison with other versions of the same bus type. The number of seats in the "quiet bus" is 36 to 41 depending on the type of bus.

The Scania CR111M is designed specifically as a city bus and is equipped with air suspension and power steering. The engine is a transversely mounted diesel providing 151 KW (205 hp), ISO 2534 gross.

The Scania CR111M is 11.55 m long (37.9 feet) and carries 36 seated and 45 standing passengers. As a comparison, the 35-foot GMC 45 series transit bus seats 45 passengers and the 40-foot GMC 53 series seats 53 passengers. It is not known whether the reduced seating capacity of the CR111M is due to compromises made for noise reduction, such as the fully encapsulated engine and remote cooling packages, or for other reasons. The cost increase due to engine encapsulation for noise reduction purposes is given to be 2% by Scania Engineers.

The CR111M engine is derated for urban operation on request. This is a compromise in performance that may not be acceptable in the U.S. On the other hand, derating the engine may cut down on maintenance and increase the life of the engine.

The cooling system of the CR111M is designed for an air-to-boil temperature of 85-90° F. This would not be acceptable for buses operating in the U.S.

Air-conditioning is not offered on Scania Buses, even as an option. Exclusion of air-conditioning reduces horsepower requirements and engine cooling requirements significantly. In contrast, almost all transit coaches in this country are air-conditioned.

There are a total of 360 single-decker and 300 double-decker CR111M Buses operating in the following:

Sweden: Stockholm, Gothenburg, Malmo, Vasteras, Orebro, and Uppsala

Norway: Oslo

Finland: Helsingfors

England: London, Leeds, Glasgow, New Castle, and Liverpool

2. BRITISH LEYLAND SUPER QUIET BUS

Research versions of a Super Quiet Leyland National were shown in December 1972 and April 1974. Work on developing this bus centers around modifications to the bus interior with prime advantage to the passengers, backed up by exterior modifications aimed at improving the acceptance of the bus in quiet suburban environments where background noise is vastly lower than in typical city centers.

These changes combine to obtain an external noise level of 76 dBA on a British standard 3425 "pass-by" test. Alteration of the torque characteristics of the turbocharged 510 engine to an alternative form achieves a more silent running power unit without detriment to available torque. A reworked engine air intake and exhaust system further contribute to noise attenuation.

A major item of the noise reduction treatment of the Super Quiet Leyland National is the structural enclosure around the engine, which is of laminated sheet metal construction spot welded in a way that permits the inner skin to reflect noise back to the engine. The outer skin of the bus is designed with an air gap to reduce the transmission of noise. Fitting of this enclosure involves the provision of an electric fan mounted in an aluminum duct on the left hand rear valance door with cooling air exiting around the flywheel housing. The radiator cooling fan features a fluid drive coupling effecting a maximum fan speed reduction and hence a lowering of fan noise. As a safety requirement, a thermostatically controlled fire extinguishing system is a safety measure incorporated in the specification of the engine enclosure.

Noise generated by the transmission of the bus has also been reduced by the specification of final drive gears designed to minimize whine on drive and over-run. The hot shift pneumocyclic gearbox is replaced by a fully automatic transmission involving reduced gear noise and jerk-free up-changing.

Reduction of "road noise" entering the structure is achieved by a more compliantly mounted Vee-frame rear axle location assembly tuned to isolate road vibration inputs.

Hatches to the engine compartment feature improved sealing. To this end, the hatches and the vehicle floor are lined with Revertex noise insulant.

Regarding the maintenance difficulties generally encountered with engine enclosure technology the semi-monocoque construction of the engine enclosure allows for acoustic panel suspension from brackets welded onto the engine support longitudinals. Panels are secured with quick-release fasteners for easy service access to the engine; a single panel gives access to inner and outer sump drain plugs and the oil filter. Vertical walls (panels) of the enclosure are fitted where possible with sheets of glass fiber "wool" held in position by perforated sheet aluminum.

Toward interior noise reduction, seats are fully upholstered and have squab backs trimmed in foam based moquette in the interests of covering any large reflective surface. The seat squab upper rails are shrouded by an enveloping safety crash pad and the vertical "grab" stanchions in the bus are nylon covered. Another aspect of interior noise control applies to the redesigned heater recirculation duct which has provided a "spin-off" of considerably improved air circulation. The noise reduction achieved on the vehicle is so considerable that "canned music" is provided in the vehicle to alay the uncanny feeling of sitting in what has been stated as virtually an anechoic chamber.

Subtle changes to the interior specification include stapling of a 25-mm closed cell pvc foam to the top of the floor over the rear saloon only; at the edges this is compressed between the lower stainless cover panel and the body side. Beneath the whole floor, aluminum trays enclosing glass wool insulant are suspended between floor support members. Teroform sheeting is bonded to the front of the saloon access step riser channel; similar treatment applies to the rear wheel arches and rear seat box. Interior trim panels have their 25 mm polyether heat insulating backing panels replaced by 66.5 mm expanded polyethylene foam with heat and very adequate noise insulation. Backing the rear corner cove panels are Teroform moulded shapes around the heater piping and air ducting entry points; these are overlaid with flexible polyether foam to a depth of 6 inches.

REFERENCES

Appendix A

1. "An Assessment of the Technology for Bus Noise Abatement," Draft Final Report submitted by Booz-Allen Applied Research, under EPA Contract No. 68-01-3509, prepared for the Office of Noise Abatement and Control, June 22, 1976.

APPENDIX B

NEW TECHNOLOGY BUSES

1. TRANSBUS

The Transbus program is a federally funded competitive development project aimed at the next generation of transit buses. The final Transbus design specification vehicle was intended to replace currently produced, 40 ft transit buses. The first prototype vehicles from each of three bus manufacturers were delivered in mid-1973. The final Transbus design was to enter full production in the last half of this decade as part of a program to reduce urban traffic congestion, improve urban air quality, and revitalize urban mass transportation.

The Transbus program is a major element of UMTA's (DOT) overall bus technology effort. Competitive prototype vehicle development subcontracts were awarded to three bus manufacturers: AM General Corp., Rohr Industries, and General Motors Truck and Coach Division. Each manufacturer developed a prototype bus. At the conclusion of testing and evaluation, a final design was to be selected for further development. The standard design was to be the property of the government, but the bus itself could be built by any qualified bus manufacturer. The three prototype bus designs currently built were selected from ten proposed designs.

(A) Transbus Specification

It was an objective of the Transbus program to develop an advanced bus design that can be used to stimulate an increase in bus ridership. Consequently, the specifications change many of the traditional priorities in bus design.

Some of the features required by the Transbus specification are listed for five key areas in Table B-1. The requirements shown were selected primarily on the basis of appealing to the passenger, while maintaining total vehicle cost/mile consistent with the increased benefits. This reverses traditional priorities on vehicle operating economy factors, such as fuel economy and low maintenance costs, which often result in a reduced level of passenger amenities.

(B) Transbus Sound Levels

The sound levels for Transbus were specified as follows:

1) Interior Noise Level

The vehicle-generated noise level experienced by a passenger at any seat location in the bus shall not exceed 75 dBA, and shall be designed to not exceed 75 dBA, under the following operating conditions:

- Acceleration of 0.10g (3.2 ft/sec/sec) at vehicle G.V.W.R.
- Constant speed of 65 mph on level road at vehicle G.V.W.R.
- Constant speed of 10 mph on level road at vehicle G.V.W.R.
- Deceleration at 0.10g (3.2 ft/sec/sec) at vehicle G.V.W.R. engine operating and engaged.

Table B-1
Original Transbus Specifications

Performance

Design Factor	Design Improvement Required
Top speed	Increased from 60 to 70 mph to be comparable with freeway traffic
Acceleration	Increased to 2.2 mph/s for greater maneuverability, the greatest desirable without sacrificing passenger comfort
Gradeability	Increased from 40 to 55 mph on a 2-1/2% grade for increased travel rates in hilly terrain
Boarding Time	Halved from 3 to 1.5 s/passenger for expeditious ingress and egress

Passenger Comfort and Convenience

Design Factor	Design Improvement Required
Interior noise level	Reduced to a maximum of 75 dBA under all operating conditions and at all passenger locations, 30% of the level of current vehicles
Air conditioning	To be standard equipment on all vehicles
Ventilation	Circulated air will consist of 25% fresh outside air, an increase over present vehicles in order to improve interior environmental quality
Interior lighting	A 100% increase in intensity at reading position over presently used lighting systems
Seat width	Increased from 16 to 18 in/passenger
Knee room	Increased from 8 to 10 in
Passenger information	Destination sign letter height increased from 4 to 5 in.with a minimum of three intermediate destinations per sign and 200 sign storage capability
Window area	A 100% increase in side window area for increased visibility for both seated and standing passengers
Jerk	Kept to a maximum of 3 mph/s^2 to provide smoothness of acceleration comparable to modern rail transit

Emissions

Design Factor	Design Improvement Required
Gases and smoke	Compliance with proposed 1973 California heavy-duty standards, and 1974 Federal standards. A target of the 1975 California standards.
Odor	Reduced by 50%
Exterior noise	Reduced over 30% of noise levels from present vehicles

Service Life and Maintenance

Design Factor	Design Improvement Required
Interior cleaning	Interior cleaning costs reduced with conversion from supported to cantilever seating
Glazing material	High-strength tempered glass and acrylic materials increase impact strength in order to reduce breakage caused by vandalism
Bumper impact	Withstand a 5 mph impact by a 4000 lb automobile without incurring damage to bus
Exterior panel replacement	Exterior panels to be quickly repairable or replaceable within 30 min

Table B-1 (Continued)
Original Transbus Specifications

Service Life and Maintenance

Design Factor	Design Improvement Required
Brake friction material	A 100% increase in friction material life from an average 50,000 to 100,000 miles for a reduction in brake maintenance costs

Safety

Design Factor	Design Improvement Required
Floor height	Reduced 50% from 34 to 17 in. above road surface to reduce boarding accidents, especially involving the aged
Boarding steps	Step from street reduced from 14 to 10 in, with interior step height reduced from 10 to 7 in, and number of interior steps reduced from two to one
Passenger windows	Converted from operable type to permanently fixed and sealed to insure that passenger limbs do not protrude from bus envelope and to protect passengers from flying objects
Crashworthiness	Interior dimensions to be altered by no more than 6 in in typical rollover and 3 in in side impact crashes for improved passenger protection
Emergency egress	Hatches in roof and side windows which can be opened in an emergency for rapid egress in event of rollover and fire

2) Sound Insulation

The combination of inner and outer panels and any material used between shall provide sufficient sound insulation such that a sound source with a level of 80 dBA measured at the outside skin of the bus will have sound level of 65 dBA or less at any point inside the bus with the doors closed, engine and auxiliaries switched off. The use of sound deadening materials within the bus may contribute to this.

3) Exterior Noise

Bus airborne noise shall not exceed 75 dBA under the following conditions when operated at or below 30 mph at G.V.W.R.:

- o Acceleration of 0.10g (3.2 ft/sec/sec)
- o Deceleration of 0.10g (3.2 ft/sec/sec)
- o Constant speed at 30 mph and full accessory load
- o Constant speed at 10 mph and full accessory load

The maximum noise level at a constant 65 mph shall not be greater than 3 dBA higher than the noise level under coast-by conditions with none of the operational equipment in operation. All noise readings shall be taken at 50 feet from, and parallel to, the center line of the bus.

4. Exhaust Location

The exhaust gases and waste heat shall not be discharged on the right-hand side of the bus, and shall be directed so that it may not cause discomfort to pedestrians.

The actual measured noise levels for the three prototype Transbuses and a present day GMC Coach are summarized in Tables B-2 and B-3.

Table B-2
Interior Noise Test Summary

Sound Pressure Level (dBA)

Test Description	Standing Position AM	Standing Position GM	Standing Position Rohr	Standing Position Coach 705	Seated Position AM	Seated Position GM	Seated Position Rohr	Seated Position Coach 705	Drivers Ear AM	Drivers Ear GM	Drivers Ear Rohr	Drivers Ear Coach 705
10 mph												
Front	69	67	66	74	63	67	67	73				
Middle	72	67	66	75	72	68	67	75				
Rear	77	72	72	79	76	72	71	78				
30 mph												
Front	74	70	71	75	73	73	72	74				
Middle	76	69	72	77	76	70	72	77				
Rear	79	75	75	85	79	75	74	84				
55 mph												
Front	76	76	81	77	76	77	82	78	77	78	82	77
Middle	80	74	78	79	81	76	77	80				
Rear	83	77	79	85	83	79	79	85				
0-55 Acceleration												
Front	78	76	81	78	78	77	82	78				
Middle	80	75	77	82	86	75	78	81				
Rear	83	80	80	89	83	80	82	86				
55-0 Deceleration												
Front	78	80	81	77	78	76	80	77				
Middle	81	75	76	77	82	75	76	79				
Rear	84	78	79	86	83	78	82	85				
Standing Idle - Accessories Off	--	--	--	--	61	65	60	--				
10 mph - Accessories Off	--	--	--	--	63	66	62	--				
30 mph - Accessories Off	--	--	--	--	76	71	71	--				
55 mph - Accessories Off	--	--	--	--	80	76	78	--				

Source: Booz Allen Applied Research
Design and Development

Table B-3
Exterior Noise Test Summary

Sound Pressure Level (dBA)

Test Description	Curb Side Test				Street Side Test			
	AM	GM	Rohr	Coach 705	AM	GM	Rohr	Coach 705
Curb Idle - 5 foot distance	79	83	84	77	--	--	--	--
0-5 mph Wide Open Throttle Rear Corner	86	93	90	88	--	--	--	--
0-5 mph Wide Open Throttle Rear Door	87	91	90	90	--	--	--	--
10 mph Drive By	66	69	68	66	70	72	71	73
30 mph Drive By	82	74	73	72	81	76	74	78
55 mph Drive By	82	79	78	78	84	79	80	87
25 mph Acceleration	83	79	77	75	83	82	79	81
50 mph Acceleration	82	80	79	78	83	83	81	86
30 mph Deceleration	73	75	72	71	75	75	73	77
55 mph Deceleration	83	77	79	77	82	79	79	84
55 mph Coast By	83	77	77	77	83	78	79	84

Source: Booz Allen Applied Research Design and Development

2. GAS TURBINE ENGINE APPLICATIONS

Gas turbine engines are currently being field tested as the prime power source for such applications as on-highway trucks, urban transit and intercity buses, and industrial and marine electrical generator sets.

The heaviest concentration of these engines is in trucks and buses. Turbine engine sizes, shapes, and weights, (such as the GT-404 engine) have ideal envelope dimensions for installation in a space that is designed for a diesel engine.

Only a few companies manufacture turbine engines with a rating below 500 brake horsepower (bhp) suitable for city and intercity bus and coach application. The turbine engine is higher in cost than a comparable diesel engine. However, it burns almost any type fuel, requires less maintenance and will have an extremely long life expectancy.

The gas turbine uses very little oil compared to a diesel engine. This difference is on the order of magnitude of a thousand to one; or 0.3 quarts for turbines to 300 quarts for diesels per 1000 hours of operation. Gas turbine engines are lighter and smaller than diesel engines. This is offset somewhat, however, by the requirement of the air or a filtration system and a regenerator unit in the turbine installation.

The gas turbine requires less maintenance than a diesel engine because of fewer wear parts and less vibration. The precise amount has not been established in commercial vehicles; however, under military conditions, the gas turbine engine costs approximately 25 to 40 percent less to maintain than a comparable diesel engine where the cost reflects labor, oil, repair parts, minor accessories, but not overhaul. Significant technological improvements in terms of reliability and life-cycle ownership costs are expected during the next three years.

The favorable influencing factors for the gas turbine engine are:

- o Cleaner exhaust emissions. Major pollution elements are minimized because of the turbine's highly efficient, low-pressure, continuous combustion.
- o Good serviceability. Gas turbines are simple in design. Cast iron one-piece blocks have the characteristics of a traditional industrial configuration. Engine components can be easily handled, maintained or replaced because of their modular design.
- o Smooth-power--high torque rise. The two-shaft turbine produces a torque curve that increases as output speed decreases--like a torque converter. The result is a high performance engine with high torque for load starting and fast acceleration. The two-shaft turbine torque characteristic provides a broad power curve in the operating speed range.
- o Effective engine-dynamic braking. Outstanding engine-dynamic braking is achieved in the GT404/505 design because of the unique Power Transfer feature. Braking effort equal to full rated engine output can be achieved by the automatic engagement of the Power Transfer clutch, which causes the compressor to act as a dynamic brake. This results in major cost saving in service brake maintenance in vehicles and--more important--gives the inherent safety of controlled engine braking.

- *Simplified transmission requirements*. Turbine equipped vehicles can utilize either a standard or an automatic transmission. A fewer number of gear ranges are required because of the inherent torque characteristics of the turbine and its broad power ranges.
- *Superior cold weather starting*. The gas turbine's ability to start at low temperatures quickly is superior to any conventional power plant. The engine has demonstrated the ability to start without aid in temperatures well below freezing.
- *Lower weight*. The gas turbine provides a 25 percent to 45 percent reduction in installation weight as compared to diesel engines in the 250 to 300 bhp power class.
- *Simple cooling system*. Gas turbines do not require a water jacket cooling system. Only lubricating oil requires cooling through a simple oil heat exchanger. This contributes to less maintenance and downtime.

The diesel engine with its ancillary components (cooling system, exhaust system, converter) weighs approximately 50 percent more than the comparable gas turbine and is 75 percent larger in cubic feet of volume. The favorable influencing factors for the diesel engine are:

- Lower fuel costs
- High reliability
- Lower mean time to overhaul
- Lower skill required to overhaul
- High altitude performance
- High durability
- Heat source (at no additional cost) for coach heating
- Lower fuel consumption when idling.

Pilot models of the gas turbine engine began going into service in 1972 for extensive field evaluation. The test engines have logged nearly two million miles in 24 trucks from 10 manufacturers; eight motor coaches from MCI-Greyhound and GMC Truck and Coach Division, and various watercraft and industrial applications.

Consignment engines currently are operational with Greyhound on the East and West Coasts; Binswanger Trucking in Los Angeles, California; Freightliner Corporation and Consolidated Freightways in Portland, Oregon; Acadian Marine Rentals in New Orleans, Louisiana; Terminal Transport in Atlanta, Georgia; Gardner-Denver in Quincy, Illinois; GMC Truck & Coach Division of General Motors in Pontiac, Michigan; and Detroit Diesel Allison in Indianapolis, Indiana.

The turbine is quiet and virtually vibration-free, and offers the added advantages of low air emissions, reduced maintenance costs, and excellent cold-weather starting performance. It appears to be a likely power source of future intercity buses if target reductions in fuel consumption and improvements in durability are realized.

3. <u>BATTERY POWERED BUSES</u>

This type of bus has seen several applications for urban revenue transit service as well as demonstration services in the United States, Canada, and France. These buses claim as their principal advantage low air emissions and noise levels.

In the U.S., Electrobus Division of Otis Elevator Co. and its successors are marketing a bus with two models. Model 20 has a curb weight of 13,500 lbs., is 25 ft. in length and seats 21 passengers. Model 26 has a curb weight of 14,300 lbs., is 30 ft. in length and seats 30 passengers.

The bus is driven by a single, separately ventilated 50 HP, 72 volt DC traction motor, mounted under the floor ahead of the rear axle. The motor was specifically developed for this bus with a long, small diameter (14") frame to provide adequate road clearance with an unusually low floor height (22").

The application of motor power is controlled by low voltage electro-mechanical switching in an eight step contactor controller designed for maximum simplicity and reliability with quiet operation. A timed sequence of battery and motor field switching in response to power pedal position regulates motor power and speed. No transmission or clutch is used.

A single unit, 72 volt, 36 cell, 880 AH at 6h, 4,250 lb. lead acid storage battery is used for propulsion power. The battery is fitted with fork lift slots. Rapid battery exchange is aided by a quick disconnect feature, allowing full transfer in five minutes or less. Recharging is done on or off the bus by automatic charging equipment.

A separate 150 AH, 12 volt battery provides power for accessories and controller. This battery is recharged from the traction battery by a dynamotor, which also drives the motor cooling and coach body ventilation blower.

The foot controlled service brake initially reconnects the DC traction motor as a three phase AC generator to provide dynamic braking. Secondarily, the brake pedal applies air-assisted tandem hydraulic drum service brakes. Even if the air supply should fail completely, a mechanical override would still operate these service brakes. A separate, mechanically actuated disc parking brake is also furnished.

Dashboard instruments, in addition to the conventional speedometer and air pressure gauge, include a voltmeter, ammeter and battery condition meter.

Outside of the electric traction motor and controller, the electric bus running gear and mechanical components are standard heavy service truck and bus types.

The electric traction motor and control system are similar to trolley coach or railway types except for being designed for lower voltages to suit storage battery operation rather than higher voltages needed for distribution efficiency on wire fed, fixed power systems.

4. <u>ARTICULATED AND DOUBLE DECK BUSES</u>

Articulated and double deck buses have been and are being used in transit bus applications to maximize the capacity of a public service vehicle suitable for use on existing roadways. In the United States, double deck buses were in use through the mid 1950's in New York and Chicago while articulated buses have been only used experimentally. Declining bus ridership since the 1920's has discouraged use and development of these unique forms of road transport, leaving the 40 ft. rigid single deck vehicle as the backbone of the North American transit fleet.

Now with the growing importance of economic and environmental pressures and concerns about energy consumption, the use of larger public service vehicles is being seriously considered. Negotiations for the joint purchase of at least 300 such vehicles is currently underway by a consortium of operators representing several large American cities. This bus will be a single operator, articulated vehicle having at least one and one half times the capacity of the 40 ft. standard coach with greater maneuverability and equal fuel consumption. The vehicle will undoubtedly be based on current European designs which have a pancake engine under the floor of the front section. There are significant drawbacks to this arrangement in considering its use in transit fleets in America. An upright engine at the rear has become established as the industry standard regardless of vehicle manufacturer. In addition, the present design trend is to lower the coach floor which is a major goal of the principal funding agent, the U.S. Department of Transportation.

Some development work (notably that which took place in Germany) with a low floor, rear engine, articulated vehicle is currently being undertaken, but production of such a vehicle is far in the future. Research in the U.S. has been conducted in areas that might benefit from the use of the larger buses. A recent study indicated that at least seven major U.S. cities had specific routes that could effectively now use articulated vehicles. With further development of priority bus lanes, greater acceptance by the ridership, and more improved accommodations, the number of articulated vehicles in the U.S. Transit fleet can be expected to increase rapidly in the not to distant future.

REFERENCES

APPENDIX B

1. "An Assessment of the Technology for Bus Noise Abatement," Draft Final Report submitted by Booz-Allen Applied Research, under EPA Contract No. 68-01-3509, prepared for the Office of Noise Abatement and Control, June 22, 1976.

APPENDIX C

BUS NOISE ABATEMENT COSTS

Presented in this appendix are the estimated cost increases (decreases) required to manufacture quieter buses as compared to currently produced buses for the various technology levels discussed in Section 5. This appendix is organized as follows:

I. Introduction
- Methodology
- Bus Classification

II. Gasoline Powered Conventional School Buses
- Manufacturing Process
- Estimated Costs

III. Diesel Powered Conventional School Buses
- Manufacturing Process
- Estimated Costs

IV. Forward Engine Forward Control School Buses
- Manufacturing Process
- Estimated Costs

V. Diesel Powered Integral Urban Transit Buses
- Manufacturing Process
- Estimated Costs

VI. Diesel Powered Integral Mid-Engine Buses
- Manufacturing Process
- Estimated Costs

I - INTRODUCTION

METHODOLOGY

Using information developed by Booz-Allen Applied Research under EPA contract number 68-01-3509, technology packages were developed and distributed to bus manufacturers and bus component suppliers. These packages described study levels of bus noise abatement and recommended approaches to achieve those study levels.

Bus manufacturers were asked to provide on a level-by-level basis, cost estimates to achieve the proposed levels of bus noise abatement. In addition to the technology packages each manufacturer received:

- Cost estimating forms
- Lead time estimating forms, and
- Enforcement scenarios necessary for assessing costs attributable to compliance testing by manufacturers

Telephone contacts were made with all manufacturers receiving the technology packages. In addition, visits were made by EPA personnel and EPA consultants to various manufacturers in order to gain a better understanding of the different manufacturing processes used throughout the bus industry.

Component manufacturers were contacted and supplied with a copy of the technology packages that pertained to their product. These manufacturers were asked to furnish cost information for their products based on the recommendations in the technology package.

Cost information requested from the manufacturers was based on a manufacturing tolerance of 2 1/2 - 3 dBA. For example, if the proposed study level was 83 dBA, the design level for manufacturing would be 80-80.5 dBA.

When submitting cost estimates, the manufacturers were asked to break the costs into:

- Product cost
- Channel Cost
- End-user cost

For each bus category, manufacturers were asked to identify each type of cost. The different types of costs were used to determine the impact on labor, material, quality control, investment and burden cost. No manufacturer supplied this information totally. A.M. General was the only manufacturer that provided some information on end-user costs, channel costs and product costs for transit buses.

Quality control and testing procedure costs were not broken out by any responding manufacturer. These costs were said to be built into their responses. For the automotive-truck industry, costs related to quality control and testing normally represent 5% - 8% of product cost. The estimated costs in this report include quality control and testing procedure costs.

A.M. General was the only responding company to indicate the additional investment required to meet the proposed study levels of noise. On a level-by-level basis the investment required 3% - 21% of total estimate cost. Typically, for the automotive-truck industry, for every dollar of investment three dollars of revenue are generated on an annual basis. The estimated costs in this report include investment cost.

The school bus body builders visited, except for Wayne Corp., have equipment and tooling that lend themselves to high flexibility. Many operations on different part configurations are possible. Wayne by using roll forming equipment have, to some extent, limited their flexibility.

Integral bus builders (intercity, transit, and school) have flexibility in their assembly process. No information was supplied by any integral bus manufacturers as to the impact of engine encapsulation on bus design.

Operation and maintenance estimated costs were based on interviews of end-users, industry supplied information and component vendors.

Estimated costs in this report are associated with levels of bus noise abatement. By initiating the actions outlined in the technology study, the corresponding level of noise was assumed to be achieved. The first study level for each bus type is designated as Level 1, the second study level is Level 2, etc. Levels do not mean years.

The development of the EPA estimated costs was based, as much as possible, on manufacturers' knowledge of the industry, cost structure and technology. Component costs received from vendors were used to cross-check manufacturers' data and to provide a basis for estimating costs when required.

Guidelines followed in the construction of EPA cost estimates were:

. Manufacturers' data was used as much as possible.

. Final costs were rounded to the nearest five dollars.

. An hourly rate of $15 per hour was used to cover direct labor and all burden charges.

. Labor hour changes were estimates.

Low and high estimated costs were, in most cases, based on manufacturer-supplied data. The basis for EPA cost estimates were outlined above.

Response to requests for cost estimates were slow with varying levels of participation by the companies. Companies that had chosen not to respond at all were:

. Chrysler Corporation
Detroit, Michigan

. Blue Bird Body Company
Fort Valley, Georgia

. Thomas Built Buses, Inc.
High Point, North Carolina

. Gillig Brothers
Hayward, California

- Ward School Bus Manufacturing, Inc.
  Conway, Arkansas

The remaining companies provided some information.

BUS CLASSIFICATION

Buses are normally classified into three major categories:

- School Buses
- Transit Buses
- Intercity Buses

Within each category various configurations of buses are possible. To estimate the cost impact of bus noise abatement buses were classified as follows:

- Gasoline Powered Conventional School Buses
- Diesel Powered Conventional School Buses
- Forward Engine Forward Control School Buses
- Diesel Powered Integral Urban Transit Buses
- Diesel Powered Integral Mid-Engine School Buses
- Diesel Powered Integral Rear-Engine School Buses
- Diesel Powered Integral Intercity Buses
- Parcel Delivery and Motor Home Chassis Buses

The definition of a bus used in this study was a vehicle with a Gross Vehicle Weight Rating (GVWR) in excess of 10,000 lbs. and a capacity of transporting 10 passengers or more, other than the driver. The vehicle's primary design is to transport passengers, not material, driver, etc.

II - GASOLINE POWERED CONVENTIONAL SCHOOL BUSES

MANUFACTURING PROCESS

A completed conventional school bus is assembled by mounting a body onto a chassis. The chassis and the body are produced by two separate manufactures. The school bus chassis is equipped with an engine located forward of the driver and passengers, a completed drive train, a completed steering mechanism and an engine cowl. The chassis itself is not a completed vehicle, per Federal specifications, that can be driven on a street or highway.

A conventional school bus chassis is similar to a medium duty truck chassis. As a result, school bus and truck chassis are/can be manufactured on the same assembly line utilizing many of the same components and manufacturing equipment. The primary differences between conventional school bus and truck chassis are the locations of the fuel and air tanks, the chassis rail configurations, the brake systems and the vehicle operator enclosures.

A typical assembly sequence for a bus chassis is:

- assemble frame and braces
- install front and rear axles
- mount engine and transmission
- locate chassis wire
- locate fluid lines
- bleed and test hydraulic system and air check
- paint frame
- install exhaust system
- mount tires
- hook up chassis wiring to lights and engine
- connect all chassis lines
- mount and hook up cowls
- install radiator

. mount front end and bumper
. mount temporary driver seat
. install steering wheel
. add coolant to radiator
. add gas
. inspect
. deliver to shipping lot

Normally the front and rear axles, engine and transmission, tires, cab trim, and front end are off line assemblies. Conveyor systems move these subassemblies to the main line to match the chassis used.

This assembly sequence is the same as truck assembly. An individual not familiar with the two chassis configurations or standing away from the assembly line cannot differentiate between the two.

After assembly the chassis is shipped to a body builder. Each chassis is accompanied by an incomplete vehicle document which states the Federal Standards to which the vehicles comply as built by the chassis builder.

The body builder mounts the body shell to the chassis and completes the interior of the shell. Body builders do not alter or change the chassis as received. Chassis builders maintain service representatives at the body builder's location to inspect the chassis after the body is mounted and to make repairs if required.

A typical assembly sequence for body builders is:

. fabricate, build and mate
  - floor
  - backend
  - side frames
  - front end
  - roof
  - interior side panels
  - exterior side panels
  - ceiling

- undercoat
- mount exterior trim
- paint exterior and interior
- install floor coverings
- mount shell to chassis
- install
  - seats
  - windows
  - lights
  - heater, etc.
- letter
- inspect
- road test
- deliver to shipping lot

Normal subassembly operations are: seats, lights, flooring, and frames. Subassembly operations are as close to the assembly line as practical.

High flexibility is present due to the variation in bus lengths, in chassis designs between manufacturers and in specifications from each buyer. Normally no two buses are identical on the assembly line.

Federal Certification tags are placed on the completed bus by the body builder. Chassis builders furnish tags and specification sheets listing what standards the chassis will meet as long as components are not changed.

Both chassis and body manufacturers have a high degree of flexibility in their assembly sequence primarily due to the various requirements for a bus. Federal, State and local governments plus each school district and school have individual standards that a school bus must meet. These standards can and do vary from state to state, local government to local government and school district to school district.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise abatement for gasoline conventional school buses are shown in Figure C-1. These costs are for a typical conventional school bus with a 60-66 passenger capacity. The costs are based on information supplied by chassis builders, body builders, component vendors and estimates. Table C-1 summarizes the estimated costs to reduce bus noise. Note that all costs are rounded to the nearest 5 dollars.

Table C-1

Estimated Cost to Achieve Bus Noise Abatement for Gasoline Powered Conventional School Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	83	83	$ 50
2	80	80	150
3	77	80	285
4	75	75	845
5	73	75	1,145

Source: Figure C-1

These costs are typical and variation between engine, transmission, drive train and shell construction will change the cost. For example, the GMC 350-V8 engine currently meets the 83 dBA level. The GMC 366-V8 and International Harvester MV442 engine do not. In order to meet an 83 dBA standard for school buses using these engines, GMC will add a viscous fan drive and International Harvester will add a wrapped muffler, fan spacer and absorption material for the splasher panels. Both actions, while different, cost approximately the same.

Body builders Thomas, Carpenter, Wayne and Superior have indicated that chassis changes will not increase their costs or change their

FIGURE C-1

GASOLINE POWERED CONVENTIONAL SCHOOL BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Chassis					EPA Chassis Cost Est.	Body		EPA Body Cost Est.	Low Cost Est.	High Cost Est.	EPA Total Cost Est.
			IH	Ford	GMC 366	GMC 350	Truck Reg		Carp**	Wayne				
1	83	83	$ 51	$175	$ 49.50	$-0-	$ 35	$ 50	$100	$ 5	$ 0	$-0-	$ 275	$ 50
2	80	80	111	749	143.00	143	180	125	150	200	25	110	950	150
3	77*	80	208	NS	NS	NS		260	150	200	25	210	1,045	285
4	75	75	865	NS	403.00	403		430	450	NS	415	405	1,955	845
5	73	75	1,101	NS	NS	NS		700	450	NS	415	700	2,190	1,145

Source: Companies Listed
Component Vendors

*Industry costs submitted were for a 78 dBA regulated level.

**Carpenter Body Works, Inc.

NS denotes the fact that no costing information pertaining to this study level was supplied.

methods of assembly. They feel interior noise is directly related to chassis noise, and as chassis noise is reduced, interior noise will be reduced.

The cost increase estimates for body builders are for installing an acoustical barrier between the engine compartment and driver for about $25. The change in body mounting to the chassis for this installation is estimated at $150. This cost is comparable to the installation of a plywood floor.

The introduction of a viscous fan clutch will have the positive impact of increasing gas mileage by an estimated 5%. Current miles per gallon average 3-5 miles or with viscous fan clutch 3.2-5.3 for an average increase of 0.25 miles per gallon.

Maintenance costs will increase with the changes suggested in each study level. The cost increases are due to more parts and increased labor. The labor costs are impacted not only by the parts increase but decreased access to the engine due to the installation of shielding for noise control.

The dollar amount of maintenance costs is dependent on bus usage, manpower costs and component costs. Each bus system's cost varies from another system. Based on information supplied by bus manufacturers and users, cost increases for maintenance are shown in Table C-2.

Table C-2

Maintenance Cost for
Gasoline Powered Conventional School Buses

Level	EPA Estimated Cost Per Year
1	$ 20
2	135
3	160
4	170
5	450

Source: User Interviews
GMC

Based on industry interviews, lead time for noise levels should correspond to the truck regulation. International Harvester has indicated that a level could be reached every 20-24 months as an ongoing process to the 73 dBA study level.

III - DIESEL POWERED CONVENTIONAL SCHOOL BUSES

MANUFACTURING PROCESS

Diesel Powered Conventional School Buses are basically the same as Gasoline Powered Conventional School Buses except for the engine. The same definitons of conventional school bus, chassis and body assembly methods can be used for the diesel bus. For the descriptions refer to Gasoline Powered Conventional School Buses.

Diesel and gasoline engine chassis are mixed on the chassis assembly line. Differences between the two engines normally impact the subassembly area of engine and transmission. Work content may vary on the assembly line, but production lines are balanced to account for these variations.

Body builders, as in gasoline powered buses, mount the body to the chassis. The type of engine does not impact their work methods.

Vehicle certification procedures are the same as gasoline powered buses.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise are shown in Figure C-2. These costs are for a typical conventional diesel school bus with a 60-66 passenger capacity. The costs are based on information supplied by chassis builders, body builders, component vendors and EPA estimates.

Table C-3 summarizes the estimated costs to reduce Diesel Powered Conventional School Bus noise.

FIGURE C-2

DIESEL POWERED CONVENTIONAL SCHOOL BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Chassis			EPA Chassis Cost Est.	Body		EPA Body Cost Est.	Low Cost Est.	High Cost Est.	EPA Total Cost Est.
			IH	Ford	Truck Reg		Carp**	Wayne				
1	83	86	$ 288	$ 550	$426	$ 215	$100	$ 5	$415	$ 165	$ 650	$ 630
2	80	83	380	1,926	850	315	150	200	415	260	2,125	730
3	77*	80	1,260	NS	NS	1,015	150	200	415	900	3,005	1,480
4	75	80	1,415	NS	NS	1,165	450	NS	415	1,010	3,410	1,580

Source: Companies Listed
Component Vendors

*Industry costs submitted were for a 78 dBA regulated level.

**Carpenter Body Works, Inc.

NS denotes the fact that no costing information to this study level was supplied.

Table C-3

Estimated Cost to Achieve
Bus Noise Abatement for Diesel
Powered Conventional School Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	83	86	$ 630
2	80	83	730
3	77	80	1,480
4	75	80	1,580

Source: Figure C-2

These costs are typical costs. Thus, variations of the type of engine, transmission drive train and shell construction can change costs. For example, concerning shell construction, Wayne uses a roll forming method to produce the panels for a bus. These panels are interlocked and fasten to the frame with "huckbolts." Carpenter fabricates each panel and fastens it to the frame by riveting and/or welding.

Body builders Thomas, Wayne, Carpenter and Superior have indicated that chassis changes will not increase their costs or change methods of assembly. They feel interior noise is directly related to chassis noise and as chassis noise is reduced interior noise will be reduced. Actions taken by the body builders to reduce noise will be based on the interior noise level at the exterior level.

At present diesel powered buses represent 3% - 4% of the school bus market. The market share is increasing. To offset the higher initial purchase price of diesel buses versus savings in operating costs, the bus must be driven an estimated 40,000 miles per year. The operating savings result primarily from increased fuel mileage and longer life. Estimated fuel mileage for diesels is 5 - 6 miles per gallon as compared to the 3 - 5 miles per gallon for gasoline engines.

No increase or decrease in fuel costs is expected with the addition of noise control technology to diesel powered conventional school buses.

The cost of maintenance affected by changes outlined in the technology packages. As with the gasoline powered conventional school bus, the cost changes are due to material and labor changes.

Based on information supplied by manufacturers and users, cost increases for maintenance are shown in Table C-4.

Table C-4

Maintenance Cost for Diesel Powered Conventional School Buses

Level	Estimated Cost
1	$ 20
2	155
3	215
4	450

Source: Industry Interviews

The sharp jump in maintenance costs after Level 1 is caused by the use of noise shields and belly pans causing increased labor time to gain access to the engine.

Based on industry interviews, the lead time for noise levels should correspond to the truck regulation. International Harvester has indicated that a level could be reached every 20 - 24 months in an ongoing process to the 75 dBA study level.

IV FORWARD ENGINE FORWARD CONTROL SCHOOL BUSES

MANUFACTURING PROCESS

Diesel Powered Forward Engine Forward Control School Buses, Gasoline Powered Forward Engine Forward Control School Buses and Forward Control Buses, gasoline and diesel, are being combined for cost estimating purposes. These types of buses have many of the same characteristics, construction methods and technology packages for noise abatement. A primary difference between these buses is the interior layout of the bus. The layout changes with the use, such as a transit coach, school bus, luxury bus, etc.

These types of buses are not of integral construction. A body shell is mounted onto a chassis with two manufacturers involved. The buses are produced by companies that manufacture school buses. For descriptions of the assembly sequence, refer to the Gasoline Powered Conventional School Bus.

It is important to remember that this type of bus is normally built on the same body assembly line as the conventional school bus. Extra work required is performed off the assembly line. Flexibility is present in the assembly process.

Federal Certification procedures are the same as for the conventional school bus.

Both manufacturers must be able to meet not only the Federal requirements but also State and local government as well as school district requirements. The State and local government and school district requirements can and do vary among themselves.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise are shown in Figures C-3, C-4, and C-5. These costs are for a typical bus. The costs are based on information from component vendors and

FIGURE C-3

DIESEL POWERED FORWARD ENGINE FORWARD CONTROL SCHOOL BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Low Cost Estimate	High Cost Estimate	EPA Chassis Cost Est.	EPA Body Est. Cost	EPA Total Est. Cost
1	83	86	$ 165	$ 650	$ 230	$ 25	$ 255
2	80	83	260	2,125	315	25	340
3	77*	80	900	3,005	1,065	25	1,090
4	75	75	1,010	3,410	1,165	415	1,580

Source: Diesel Powered Integral Urban Transit Bus
Diesel Powered Conventional School Bus
Gasoline Powered Conventional School Bus

*Industry costs submitted were for a 78 dBA regulatory level.

FIGURE C-4

FORWARD CONTROL BUSES - DIESEL
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Low Cost Estimate	High Cost Estimate	EPA Chassis Cost Est.	EPA Body Est. Cost	EPA Total Est. Cost
1	83	86	$ 165	$ 650	$ 230	$ 25	$ 255
2	80	83	260	2,125	315	25	340
3	77*	80	900	3,005	1,065	25	1,090
4	75	75	1,010	3,410	1,165	415	1,580

Source: Diesel Powered Forward Engine Forward Control School Bus

*Industry costs submitted were for a 78 dBA regulatory level.

FIGURE C-5

FORWARD CONTROL BUSES - GASOLINE
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Low Cost Estimate	High Cost Estimate	EPA Chassis Cost Est.	EPA Body Est. Cost	EPA Total Est. Cost
1	83	83	$-0-	$ 415	$ 50	$ 25	$ 75
2	80	80	20	915	120	25	145
3	77*	80	110	1,060	260	25	285
4	75	75	325	1,935	580	415	995

Source: Gasoline Powered Conventional School Bus

*Industry costs submitted were for a 78 dBA regulatory level estimates. The chassis builders and body builders contacted did not respond.

Table C-5 and Table C-6 summarize the estimated costs for both gasoline and diesel buses.

Table C-5

Estimated Cost to Achieve Bus Noise Abatement for Diesel Powered Forward Engine Forward Control School Buses and Diesel Powered Forward Control Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	83	86	$ 255
2	80	83	340
3	77	80	1,090
4	75	75	1,580

Source: Figure C-3 and C-4

Maintenance costs, operating costs and technology lead times are estimated to be the same as shown for Diesel Powered Conventional School Buses.

Table C-6

Estimated Cost to Achieve Bus Noise Abatement for Gasoline Powered Forward Control Buses

Level	EPA Estimated Cost Per Year
1	$ 75
2	145
3	285
4	995

Source: Figure C-5

Maintenance, lead times and operating costs changes are estimated to be the same as shown for Gasoline Powered Conventional School Buses.

V - DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES

MANUFACTURING PROCESS

Transit buses differ in their manufacture from conventional school buses. While conventional school buses are manufactured in a two-stage process (body on chassis) by two separate manufacturers, transit buses are manufactured by a single manufacturer who performs the entire assembly. For transit buses the floor, sides, ends and roof are joined into a one-piece construction to form the bus shell. The advantage to this type of construction is more efficient use of material and space. Intercity buses, rear and mid-engine diesel school buses also employ this type of construction.

A typical assembly sequence for an integral transit bus is:

- fabricate and assemble
  - understructure
  - right and left sides
  - front and back end
  - roof
- join sections together
- assemble exterior skin
- assemble interior floor base and rubber covering
- install interior wires, controls, etc.
- mount undercarriage items
- paint interior and exterior
- mount wheels
- install windows and doors
- test for water leaks
- complete interior
  - seats
  - lights
  - controls

- flooring
- trim, etc.

. install engine, transmission and drive train

- heating and cooling system
- gas lines
- air and hydraulic lines, etc.

. inspect bus

. road test

. deliver to shipping lot

Typical subassembly operations are: seats, windows, engine and transmission, front and rear axles, lights and air conditioners. The assembly sequency can overlap and many components not listed above are installed throughout the process.

High flexibility is present in the assembly process. Every bus order represents the specifications of that purchaser. As with the school buses, transit buses must meet Federal, State and local government standards. These standards can and do vary from state to state and local government to local government.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise abatement are shown in Figure C-6. These costs are for a typical transit bus either 35' or 40' long. The costs are based on information supplied by integral bus manufacturers, component vendors and EPA estimates.

Table C-7 summarizes the estimated costs to reduce bus noise.

FIGURE C-6

DIESEL POWERED INTEGRAL URBAN TRANSIT BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Rohr Industries (Flexible)	A.M. General	GMC	Low Cost Est.	High Cost Est.	EPA Cost Est.
1	86	84	$-0-	$ 84	$ 139	$-0-	$ 205	$ 52
2	83	83	-0-	195	465	-0-	505	165
3	81	83	-0-	403	1,683	-0-	1,683	380
4	80	80	350	906	2,900	350	2,900	875
5	77	80	650	2,091	4,200	650	4,200	1,670
6	75	78	-0-	4,089	5,500	950	5,500	3,270

Source: Companies Listed, Component Vendors

Note: EPA cost estimates and high cost estimates include interior noise reduction costs as follows: Level 1 (84 dBA)=$0, Levels 2 and 3 (83 dBA)=$10, Levels 4 and 5 (80 dBA)=$91, Level 6 (78 dBA)=$609.

Table C-7

Estimated Cost to Achieve
Bus Noise Abatement for Diesel
Powered Integral Urban Transit Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	86	84	$ 50
2	83	83	195
3	81	83	380
4	80	80	875
5	77	80	1,670
6	75	78	3,270

Source: Figure C-3

Rohr Industries has found that the maintenance of a bus plays a significant part in noise control. While performing tests for the Sound Attenuation Kit for Diesel Powered Buses (reference 1), a 35' bus powered by a Detroit Diesel 6V-71 engine was able to meet the first three study levels with no modification. Actions taken by Rohr were to tighten all loose bolts, nuts, clamps, etc.; to insure the specified parts were used; and that these parts were functional.

Rohr was able to meet Level 4 by using:

- double wrapped muffler
- two 3-inch diameter pipes into the muffler
- one 4-inch diameter pipe out of the muffler
- resonator
- 4-inch diameter tail pipe pointing down to the left center rear of the bus
- acoustical absorption material on inside of hood
- isolated valve rocker covers on engine

This bus was also tested with a vertical, roof-level exhaust.

In addition to the above, to meet Level 5, the following technology was used:

- contoured cooling fan shroud
- partition on left-hand side of the engine

These actions differ significantly from the technology study for those levels as costed by A.M. General and by GMC.

Level 4 was achieved by using parts of the technology from the Sound Attenuation Kit for Diesel Powered Buses and a new radiator grill. The costs associated with bringing the bus to the indicated Level 4 is estimated at $350. Using the Rohr Sound Attenuation Kit technology, an estimated cost of $650 for Level 5 appears to be a reasonable extrapolation.

Two major impacts on operating costs for transit buses in reducing bus noise will be reduced fuel mileage and reduced passenger capacity.

Table C-8 shows the estimated impact for fuel usage by level.

Table C-8

Transit Bus Miles Per Gallon

Level	EPA Estimated MPG
Current	3.8 - 4.8
1	3.8 - 4.8
2	3.8 - 4.8
3	3.8 - 4.8
4	3.6 - 4.6
5	3.4 - 4.4
6	2.8 - 3.8

Source: A.M. General
Industry Interviews

Passenger capacity should not be affected until study Level 6 is reached. At this level an estimated one row, or two seats, will be lost. This loss can vary by seating arrangement, bus length, and Federal Specifications. It is possible that buses, depending on the changes in design at Level 6, could absorb the increased engine compartment size and still maintain the same seating capacity.

Maintenance costs will be impacted with the changes suggested in the technology study levels. The cost increases are due to increased labor and some additional parts. Labor costs are affected by decreased access to the engine and replacement of additional parts.

The dollar amount of maintenance will vary between transit companies. Maintenance costs shown in Table C-9 are estimated costs for a typical bus and transit system.

Table C-9

Maintenance Cost for Diesel Powered Integral Urban Transit Buses

Level	EPA Estimated Cost Per Year
1	$-0-
2	70
3	140
4	305
5	520
6	830

Source: A.M. General
Industry Interviews

Based on industry interviews and on a continuous integrated program, the six levels can be achieved in an estimated 30 months, or one level every 5 months.

VI - DIESEL POWERED INTEGRAL MID-ENGINE SCHOOL BUSES

MANUFACTURING PROCESS

Diesel Powered Integral Mid-Engine School Buses are constructed with the same principles as the Urban Transit Bus. The entire bus supports the bus weight and provides strength.

A typical assembly sequence for this type of bus is:

. Chassis assembly

- drill side rails
- weld cross bars to the side rails
- mount front end and front axle
- mount rear axle and rear suspension
- install engine, transmission, exhaust, controls, cooling system, electrical system, etc.

. Body assembly

- build roof, both exterior and interior
- build left side
- build right side
- build rear end

. mate body and chassis

. weld outriggers

. assemble exterior skin on all sides

. run engine

. paint

. complete interior

- skin
- seats
- floors
- windows
- steering
- lights, etc.

. complete mechanical hookup

. final inspect

. road test

. deliver to shipping lot

Typical subassemblies are: seats, windows, engine and transmission, axles, and lights.

Flexibility is present in the assembly process. Each bus order is built to the individual state specifications and individual local school district specifications. In all cases Federal specifications must be met.

ESTIMATED COSTS

The estimated cost to achieve the proposed study levels of noise are shown in Figure C-7. These costs should be considered costs for a typical bus. Costs are based on component vendors and estimates.

Table C-10 summarizes the estimated costs to reduce bus noise.

FIGURE C-7

DIESEL POWERED INTEGRAL MID-ENGINE SCHOOL BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Crown Coach Cost Estimate	Low Cost Estimate	High Cost Estimate	EPA Cost Estimate
1	86	88	$ -0-	$ -0-	$ 260	$ -0-
2	83	86	2,828	195	2,828	248
3	80	83	5,097	800	5,097	3,027
4	77*	80	12,860	1,485	12,860	4,417
5	75	78	23,890	3,270	23,890	7,200

Source: A.M. General, Rohr Flexible, Crown Coach, Component Vendors.

Note: EPA and high cost estimates include interior noise reduction costs as follows: Level 2 (86 dBA) = $60, Level 3 (83 dBA) = $861, Level 4 (80 dBA) = $861, Level 5 (78 dBA) = $1,379.

*Industry costs submitted were for a 78 dBA regulatory level.

Table C-10

Estimated Cost to Achieve Bus Noise Abatement for Diesel Powered Integral Mid-Engine School Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	86	88	-0-
2	83	86	$ 248
3	80	83	3,027
4	77	80	4,417
5	75	78	7,200

Source: Figure C-4

A major cost impact for this type of bus is reduced fuel mileage for the various levels. Table C-11, shows the estimated impact for fuel usage by level.

Table C-11

Fuel Mileage

Leve Level	EPA Estimated MPG
Current	7 - 9
1	7 - 9
2	7 - 9
3	6.7 - 8.6
4	6.3 - 8.1
5	5.6 - 7.2

Source: Crown Coach
A.M. General
Industry Interviews

For the impact on maintenance refer to Diesel Powered Integral Urban Transit Bus.

Based on industry data and a continuous integrated program, lead time requirements for each level are:

Level	EPA Estimated Lead Time
1	Current
2	18 Months
3	18 Months
4	24 Months
5	36 Months

VII - DIESEL POWERED INTEGRAL REAR ENGINE SCHOOL BUSES

MANUFACTURING PROCESS

Diesel powered integral rear engine school buses have the same type of construction as urban transit buses. The floor, sides, ends and roof are joined together into a one piece construction.

As with the urban transit bus, the advantage to this type of construction is more efficient use of material and space.

A typical assembly sequence for this type of bus is:

- assemble side rails and cross members
- assemble to frame assembly
  - front and rear axles
  - suspension
  - side rails
  - fire wall
  - air piping
  - engine and transmission
  - radiator and fan
- mount front platform for driver
- install long half sections across frame
- install flooring
- mount side posts
- assemble roof
- assemble side panels
- hook up connections
  - from engine
  - electrical
  - gauges
- undercoat
- remove temporary tires and mount permanent
- paint bus

- install
  - windows
  - finished floors
  - seats
  - final trim, etc.
- final inspection
- road test
- delivery to shipping lot

Typical subassemblies are: seats, windows, engine and transmissions, roof exterior and interior, axles and lights.

Flexibility is present in the assembly process. Each bus order is built to the Federal, State and local government specifications. The specifications can and do vary from state to state and locality to locality. In addition, each school district can and does have their own additional specifications.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise are shown in Figure C-8. These costs should be considered costs for a typical bus. Costs were based on component vendors and estimates. Gillig Bros, Inc., the builder of this bus, chose not to participate in the study.

Table C-12 summarizes the estimated costs to reduce bus noise.

FIGURE C-8

DIESEL POWERED INTEGRAL REAR-ENGINE SCHOOL BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Low Cost Estimate	High Cost Estimate	EPA Cost Estimate
1	86	84	$-0-	$ -0-	Current Prod.
2	83	83	-0-	505	$ 195
3	81	83	-0-	630	380
4	80	80	350	1,395	875
5	77	80	650	2,090	1,670
6	75	78	590	4,090	3,270

Source: Diesel Powered Integral Urban Transit Bus

Note: EPA and high cost estimates include interior noise reduction costs as follows: Levels 2 and 3 (83 dBA) = $10, Level 4 (83 dBA) = $91, Level 5 (80 dBA) = $91, Level 6 (78 dBA) = $609.

Table C-12

Estimated Cost to Achieve Bus Noise Abatement for Diesel Powered Integral Rear Engine School Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	86	84	Currently building to
2	83	83	$ 195
3	81	83	380
4	80	80	875
5	77	80	1,670
6	75	78	3,270

Source: Figure C-8

For the impact on operating costs, maintenance costs and lead times refer to the Diesel Powered Integral Urban Transit Bus.

VIII - DIESEL POWERED INTEGRAL INTERCITY BUSES

MANUFACTURING PROCESS

Diesel Powered Integral Intercity Buses utilize the same type of construction as the Diesel Powered Integral Urban Transit Buses. The complete structure is load bearing and is a more efficient use of material and space as compared to a conventional school bus.

A typical assembly sequence for integral intercity buses is:

- fabricate component parts
- assemble floor structure
- assemble front and back ends
- assemble sides
- assemble roof
- joint floor, ends, sides and roof
- install air lines, electrical interior
- install insulation
- paint
- letter
- complete interior of bus
  - lavatory
  - inside side panels
  - inside roof panels
- install front and rear axles
- install air conditioning
- install cooling system
- complete steering
- complete instrumentation
- install engine and transmission
- install seats
- install windows
- complete air and electrical hookups

- inspect
- road test
- delivery to shipping lot

Typical subassemblies are: seats, windows, engine and transmission, axles, air conditioning, parts of cooling system, air lines and lights.

Quality control checks are maintained throughout the manufacturing process. Before a bus is moved to the next work station the production foreman and inspector must sign a check list.

The GMC intercity coach is assembled on the same production line as the GMC transit bus, starting with the paint operation.

Flexibility is present in the assembly process. Each bus is individually ordered and normally unique to that purchaser. The types of assembly lines employed lend themselves to variety in production and changes in mid-production.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise are shown in Figure C-9. These costs should be considered costs for a typical bus. Costs are based on information from component vendors and estimates.

GMC, MCI, and Eagle International have not provided any cost information.

Table C-13 summarizes the estimated costs to reduce bus noise.

FIGURE C-9

DIESEL POWERED INTEGRAL INTERCITY BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Low Cost Estimate	High Cost Estimate	EPA Cost Estimate
1	86	84	$-0-	$ 205	$ 50
2	83	83	-0-	505	195
3	80	80	350	1,395	875
4	77	80	650	2,090	1,670
5	75	78	750	4,090	3,270

Source: Diesel Powered Integral Urban Transit Bus

Note: EPA and high cost estimates include interior noise reduction costs as follows: Level 1 (84 dBA) = $0, Level 2 (83 dBA) = $10, Level 3 and 4 (80 dBA) = $91, Level 5 (78 dBA) = $609.

Table C-13

Estimated Cost to Achieve Bus Noise Abatement for Diesel Powered Integral Intercity Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	86	84	$ 50
2	83	83	195
3	80	80	875
4	77	80	1,670
5	75	78	3,270

Source: Figure C-9

Table C-14 presents estimated impact for fuel mileage.

Table C-14

Fuel Mileage

Level	EPA Estimated MPG
Current	6 - 7
1	6 - 7
2	6 - 7
3	5.7 - 6.7
4	5.4 - 6.3
5	4.8 - 5.6

Source: MCI Ltd.
A.M. General

Maintenance, lead times and passenger capacity changes are estimated to be the same as shown for Diesel Powered Integral Urban Transit Buses.

IX - PARCEL DELIVERY, MOTOR HOME CHASSIS BUSES

MANUFACTURING PROCESS

These buses are similar to conventional school buses in that they are not of integral construction. The Parcel Delivery and some Motor Home chassis are produced using a two-stage manufacturing process.

The chassis may not be built on the same assembly line as conventional school bus chassis, but the sequence of assembly would be the same. For a description of this sequence, refer to Gasoline Powered Conventional School Buses.

The body builder mounts the body shell onto the chassis and completes the interor of the shell. Body builders do not alter or change the chassis as received. Typically this size bus is produced on the same assembly line as the conventional school bus. For a description of this sequence, refer to Gasoline Powered Conventional School Buses.

The GMC Transmode chassis is offered as a conversion of the GMC Motor Home. The Transmode chassis can be converted into a bus. This chassis includes the shell. GMC currently does not have plans to offer a bus built on this chassis.

The actions required to reduce noise for the Parcel Delivery chassis are considered identical to Conventional Gasoline Powered School Buses except for some small details.

ESTIMATED COSTS

The estimated costs to achieve the proposed study levels of noise for Parcel Delivery chassis and motorhome chassis vehicles are shown in Figure C-10. These costs are for a typical bus. The costs are based on information from component vendors and estimates. The chassis builders and body builders contacted did not respond.

Table C-15 summarizes the estimated costs for this type of bus.

FIGURE C-10

PARCEL DELIVERY, MOTOR HOME CHASSIS BUSES
COST PER BUS
1976 DOLLARS

Level	Exterior dBA	Interior dBA	Low Cost Est.	High Cost Est.	EPA Chassis Cost Est.	EPA Body Cost Est.	EPA Total Cost Est.
1	83	83	$-0-	$ 275	$ 50	$-0-	$ 50
2	80	80	110	950	110	25	135
3	77*	80	210	1,045	335	25	365
4	75	75	405	1,955	405	415	820
5	73	75	655	2,190	590	445	1,035

Source: Gasoline Powered Conventional School Bus

* Industry costs submitted were for a 78 dBA regulatory level.

Table C-15

Estimated Cost to Achieve Bus Noise Abatement For Parcel Delivery and Motor Home Chassis Buses

Level	Exterior dBA	Interior dBA	EPA Estimated Cost
1	83	83	$ 50
2	80	80	135
3	77	80	360
4	75	75	820
5	73	75	1,055

Source: Figure C-10

The primary differences in costs between this bus and the gasoline conventional school bus are: this type of bus incorporates a mixture of technology packages from the school bus and transit bus, and different component noise level requirements.

Maintenance cost, lead times and operating cost changes are estimated to be the same as shown for the Gasoline Powered Conventional School Bus.

X - ENFORCEMENT COSTS

INTRODUCTION

Estimated costs for enforcement are included in the cost estimates presented in the preceding sections. Manufacturers contacted would not provide detailed information concerning enforcement costs, other than to say they are included in their cost estimates.

To understand the potential cost/impact of enforcement requirements the bus industry was divided into four segments:

- non-integral school buses
- integral school buses
- transit buses
- intercity buses

An estimated cost per bus was developed for each segment. Since some companies produce buses in more than one segment, each segment has been treated separately.

METHODOLOGY

The estimated costs have been based on the following points:

- Test requirements are based on an Enforcement Scenario developed by EPA, summarized in Figure C-11.
- Tests are conducted for compliance testing only, and not for gathering engineering data.
- When chassis and body tests are required, each test is considered a separate test.
- Construction of a test facility is not required.
- Cost per test for Product Verification or Selective Enforcement Auditing is $95 (Figure C-12).
- Equipment cost per year is $600 (Figure C-12).

FIGURE C-11

EPA ENFORCEMENT TEST REQUIREMENTS

Type of Bus	Integral Construction			Non-Integral Construction (Chassis)			Non-Integral Construction (Body)		
	PV Tests		SEA TESTS	PV Tests		SEA Tests	PV Tests		SEA Tests
	Low	High (1)	Max. (1)	Low	High (1)	Max. (1)	Low	High (1)	Max. (1)
Gasoline Powered Conventional School Bus	-	-	-	10	25	50	10	40	50
Diesel Powered Conventional School Bus	-	-	-	10	25	50	10	40	50
Diesel Powered Forward Engine Forward Control School Bus	8	20	50	-	-	-	-	-	-
Diesel Powered Forward Control School Buses	8	20	50	-	-	-	-	-	-
Gasoline Powered Forward Control School Buses	8	20	50	-	-	-	-	-	-
Diesel Powered Integral Urban Transit Bus	8	20	50	-	-	-	-	-	-
Diesel Powered Integral Mid-Engine School Bus	8	20	50	-	-	-	-	-	-
Diesel Powered Integral Rear Engine School Bus	8	20	50	-	-	-	-	-	-
Diesel Powered Integral Intercity Bus	8	20	50	-	-	-	-	-	-
Parcel Delivery and Motor Home Chassis Bus	-	-	-	5	10	50	10	20	50

(1) The maximum number is used in all cases except when the number of units sold may be less.

Source: EPA

FIGURE C-12

ESTIMATED COST PER TEST (EXTERIOR OR INTERIOR)
1976 DOLLARS

I. Manpower:

- 2 Technicians @ $35/day each	$70
- 1 Engineer @ $50/day each	50
	$120

II. Time required to set up, run, record and file necessary data — 4 Hours

III. Average miles driven: 20 @ cost of $1.75/mile which includes:

- Driver
- Gas and oil
- Other expenses related to a test, e.g., test site, etc.

IV. Cost per test:

($120 ÷ 2) + $35 = $95

V. Equipment cost $6,000 with a useful life of 10 years or a cost per year of $600.

Source: General Motors Corporation
A. M. General
International Harvester
General Radio

Based on the above points, a weighted average for each segment of the bus industry was made to develop an estimated cost per bus for enforcement purposes.

ESTIMATED COSTS

The estimated costs per bus for enforcement are shown in Figures C-14, C-16, C-18, and C-20. These costs should be considered as typical for a bus of that type.

Table C-16 summarizes the estimated costs for non-integral school buses.

Table C-16

Estimated Enforcement Cost for Non-Integral School Buses

Test	EPA Estimated Cost
Exterior (Chassis)	$ .46
Interior (Body)	.73
	$1.19

Source: Figures 14 and 16

Table C-17 summarizes the estimated costs for integral school buses.

Table C-17

Estimated Enforcement Cost for Integral School Levels for All Study Levels

Test	Estimated Cost/Test
Exterior and Interior	$8.70

Source: Figure C-16

FIGURE C-13

SCHOOL BUSES - CHASSIS

	1974			1975			Total '74 & '75 Domestic Prod.	Market Share of Total %	Units Produced/ Year Based on Market Share	SEA Tests by Market Share
	Total Prod.	Export	Domestic Prod.	Total Prod.	Export	Domestic Prod.				
Chevrolet	4,200	215	3,985	4,651	51	4,600	8,585	13.8	4,279	7
G.M.C.	3,088	153	2,885	3,274	737	2,537	5,422	8.7	2,698	4
Dodge	423	423	-0-	1,433	1,433	-0-	-0-	-0-	-0-	-0-
Ford	12,190	1,246	10,944	9,069	2,093	6,976	17,920	28.9	8,961	15
International Harvester	13,796	364	13,432	17,003	349	16,654	30,086	48.6	15,068	24
Total			31,246			30,767	62,013		31,006	50

Source: MVMA
Figure C-11

FIGURE C-14

ENFORCEMENT TEST COSTS
SCHOOL BUS CHASSIS
1976 DOLLARS

Company	Units Sold	Equipment Cost Per Year/Bus	SEA At High	PV Test			PV Cost Per Bus			SEA Test/Bus			Total Estimated Cost (1)		
				Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Chevrolet	4,279	$.14	$4,750	$950	$1,663	$2,375	$.22	$.39	$.56	$0	$.16	$1.11	$.36	$.69	$1.81
G.M.C.	2,698	.22	4,750	950	1,663	2,375	.35	.62	.88	0	.14	1.76	.57	.98	2.86
Dodge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ford	8.961	.07	4,750	950	1,663	2,375	.11	.19	.27	0	.16	.53	.18	.42	.87
International Harvester	15,068	.04	4,750	950	1,663	2,375	.06	.11	.16	0	.15	.32	.10	.30	.52
Average Based on Market Share													$.20	$.46	$1.00

(1) Includes Equipment Cost, PV and SEA Tests

Source: FIGURE C-11, C-12, and C-13

FIGURE C-15

SCHOOL BUSES - BODY

Company	Market Share %	Domestic Units Produced	SEA Tests by Market Share
Blue Bird	22.3	6,914	11
Superior	22.3	6,914	11
Wayne	17.1	5,302	8
Thomas	14.4	4,465	7
Carpenter	12.8	3,969	6
Ward	9.6	2,977	5
Crown	.8	248	1
Gillig	.7	217	1
Total	100%	31,006	50

Source: Section 3
FIGURES C-11 and C-13

FIGURE C-16

ENFORCEMENT TEST COSTS
SCHOOL BUS BODIES
1976 DOLLARS

Company	Units Sold	Equipment Cost Per Year/Bus	SEA At High	PV Test			PV Cost Per Bus			SEA Test/Bus			Total Estimated Cost (1)		
				Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Blue Bird	6,914	$ .09	$4,750	$950	$2,415	$3,880	$ .14	$ .35	$ .56	$0	$.15	$ .69	$ .23	$ .59	$ 1.34
Superior	6,914	.09	4,750	950	2,415	3,880	.14	.35	.56	0	.15	.69	.23	.59	1.34
Wayne	5,302	.11	4,750	950	2,415	3,880	.18	.46	.73	0	.14	.90	.29	.71	1.74
Thomas	4,465	.13	4,750	950	2,415	3,880	.21	.54	.87	0	.15	1.06	.34	.82	2.06
Carpenter	3,969	.15	4,750	950	2,415	3,880	.24	.61	.98	0	.14	1.20	.39	.90	2.33
Ward	2,977	.20	4,750	950	2,415	3,880	.32	.81	1.30	0	.16	1.60	.52	1.17	3.10
Crown	248	2.42	4,750	760	1,330	1,900	3.06	5.36	7.66	0	.38	19.15	5.48	8.16	29.23
Gillig	217	2.76	4,750	760	1,330	1,900	3.50	6.13	8.76	0	.44	21.89	6.26	9.33	33.41
Average based on total market share less Crown and Gillig													$ .30	$ .73	$ 1.80
Weighted Gillig and Crown Average													5.80	8.70	31.19

(1) Includes Equipment Cost, PV and SEA Tests

Source: Figures C-11, C-12 and C-15

FIGURE C-17

TRANSIT BUSES

Company	Market Share %	Units	SEA Tests by Market Share
General Motors	44.6	2,149	23
A.M. General	26.3	1,267	13
Flxible	22.4	1,079	11
Highway Products	2.7	130	1
Others	4.0	193	2
Total	100%	4,818	50

Source: Section 3
FIGURE C-11

FIGURE C-18

ENFORCEMENT TEST COSTS
TRANSIT BUSES
1976 DOLLARS

Company	Units Sold	Equipment Cost Per Year/Bus	SEA At High	PV Test			PV Cost Per Bus			SEA Test/Bus			Total Estimated Cost (1)		
				Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
General Motors	2,149	$ .30	$4,750	$760	$1,330	$1,900	$ .40	$ .60	$ .90	$0	$1.00	$ 2.80	$ .70	$ 1.90	$ 4.00
A.M. General	1,267	.50	4,750	760	1,330	1,900	.60	1.10	1.50	0	1.00	3.80	1.10	2.80	5.80
Flxible	1,079	.60	4,750	760	1,330	1,900	.70	1.20	1.80	0	1.00	4.40	1.30	2.80	6.80
Highway Products	130	4.60	4,750	760	1,330	1,900	5.90	10.20	14.60	0	.70	36.50	10.50	15.50	55.70
Others	193	3.10	4,750	760	1,330	1,900	3.90	6.90	9.80	0	1.00	24.60	7.00	11.00	37.50
Estimated Average Based on Market Share													$ 1.50	$ 3.00	$ 7.80

(1) Includes Equipment Cost, PV and SEA Tests

Source: FIGURES C-11, C-12, and C-17

FIGURE C-19

INTERCITY BUSES

Company	Market Share %	Units	SEA Tests by Market Share
Crown Coach	1.0	14	1
Eagle International	17.5	236	8
G.M.C.	32.1	434	16
Motor Coach	45.9	620	23
Prevost (1)	3.5	46	2
Total	100%	1,350	50

(1) Computed number. Total = 100%, other companies = 96.5%

Source: Section 3

FIGURE C-11

FIGURE C-20

ENFORCEMENT TEST COSTS
INTERCITY BUSES
1976 DOLLARS

Company	Units Sold	Equipment Cost Per Year/Bus	SEA At High	PV Test			PV Cost Per Bus			SEA Test/Bus			Total Estimated Cost (1)		
				Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Crown	14	$43	$1,330	$760	$1,045	$1,330	$54	$75	$95	$0	$7	$95	$97	$125	$233
General Motors	434	1	4,750	760	1,330	1,900	2	3	4	0	4	11	3	8	16
Motor Coach	620	1	4,750	760	1,330	1,900	1	2	3	0	4	8	2	7	12
Prevost	46	13	4,350	760	1,330	1,900	17	29	41	0	4	95	30	46	149
Eagle International	236	3	4,750	760	1,330	1,900	3	6	8	0	3	20	6	12	31
Weighted Average Based on Market Share													$ 5	$ 11	$ 24

(1) Includes Equipment Cost, PV and SEA Tests

Source: FIGURES C-11, C-12, and C-19

Table C-18 summarizes the estimated cost for transit buses.

Table C-18

Estimated Enforcement Cost for Transit Buses for All Study Levels

Test	Estimated Cost/Test
Exterior and Interior	$3.00

Source: Figure C-18

Table C-19 summarizes the estimated cost for Intercity buses.

Table C-19

Estimated Enforcement Cost for Intercity Buses for All Study Levels

Test	Estimated Cost/Test
Interior and Exterior	$11.00

Source: Figure C-20

Figures C-13, C-15, C-17, and C-19 provide backup information for the Summary Tables.

Appendix C

References

1. "Sound Attenuation Kit for Diesel Powered Buses," submitted by Rohr Industries, Inc., to the U.S. Department of Transportation, Report RII-SAK-402-0101, February 1975.

2. "A Study to Determine the Economic Impact of Noise Emission Standards in the Bus Manufacturing Industry," Draft Final Report submitted by A. T. Kearney, Inc., under EPA Contract No. 68-01-3512, prepared for the Office of Noise Abatement and Control, September 1976.

APPENDIX D

ESTIMATES OF DEMAND ELASTICITIES FOR URBAN BUS TRANSIT AND INTERCITY BUS TRANSPORTATION

This Appendix reviews some of the pertinent econometric literature and reports estimates made of the fare-elasticity of demand for both intracity and intercity bus transit. The estimating model is based on one developed by Nelson.[1] The cross-sectional test of intra-urban transit demand in a sample of U.S. metropolitan areas used in Nelson's model is repeated for the year 1974. Results are compared with Nelson's estimates for the years 1960 and 1968, and some tentative explanations for the observed lower fare elasticity in 1974 are offered.

For intercity bus travel demand, the same model is applied to time series of annual aggregate U.S. data. The fits are generally quite satisfactory, subject to the caveat that the time series sample may overstate the significance of the results when substantial autocorrelation is present.

Both time series and cross-section estimates reveal fare-elasticities of demand that are of the same order of magnitude, ranging from -0.20 to -0.80. This range is somewhat above the industry rule-of-thumb of -0.30, but is by no means contradictory, given the nature of the approximations and data involved. The data also exhibit positive cross-elasticities with respect to competing modes (auto and rail), though the precision of the estimates is not adequate for predictive purposes.

Part 1 of Appendix D reviews the econometric model and describes the notation. Parts 2 and 3 record the results of the statistical tests for urban transit demand and intercity bus travel demand, respectively. These results are applied in Parts 7-A and 7-B of the Economic Impact Analysis (Section 7).

D - I ECONOMETRIC MODEL OF TRANSIT DEMAND

Consider a given geographical area, such as an urban center or the United States intercity highway network. Bus service B, defined as vehicle miles of service provided per year, may be thought of as a factor input in the production of transportation services to the population of the given region. Since passengers are to some extent flexible as to trip schedules and destination points, but not perfectly so, bus service B encounters diminishing returns in the production of transportation services as saturation of the potential market increases.

Demand D for bus service, defined as revenue passenger miles of service obtained per year, depends both upon the quantity B of service provided and upon other demand characteristics of the market served: the age and income of the population, the availability of auto, rail, and other competing modes of transportation, the fare per mile F charged to revenue passengers (and fares on competing modes), and other exogenous factors which may differentiate one urbanized area from another or which reflect changes in the demand for bus transit over time.

EQUILIBRIUM IN THE TRANSIT MARKET

Transit firms experience total revenue equal to FD and total costs equal to CB, where C is the average cost per mile of vehicle operation. Nelson's paper[1] provides evidence that there are no scale economies in the operations of bus transit firms, hence that a linear approximation of the cost function does not misrepresent the empirical evidence.

Since transit firms operate in a regulated environment, equilibrium is not necessarily determined by the "competitive" condition that total revenues less total costs (FD-CB) yield profits just sufficient to give the firm a competitive return on its total invested capital. Rather, the regulatory authority imposes on the transit firm a constraint, such as a rate of return criterion or a set ratio of revenues to costs, and the firm responds accordingly. Nelson summarizes the action of the regulatory authority in terms of a target cost-revenue ratio k:

$$k = CB / FD.$$

If k is treated as an exogenous, predetermined component of the model, then equilibrium is determined by the condition CB = kFD.

The full model may be written:

Supply: B = B (POP, AREA, D,C,k) + u
Demand: D = D (B, POP, F,F', Area, Auto, Hway, GNI) + v
Equilibrium: CB = kFD

Here POP is the population of the given geographical region, AREA its area, HWAY its highway capacity per capita, F' the fare per passenger mile on competing modes of transportation, and GNI the level of real per capita income. B (bus service supplied), D (ridership demanded), and F (fare per passenger mile) are endogenous, jointly determined variables, while the remaining quantities, including C (cost per vehicle mile) and k (cost/revenue criterion), are exogenous (predetermined). The symbols u and v represent random, independent error terms.

DETERMINANTS OF THE COST/REVENUE RATIO K

Urban bus transit systems have undergone a significant revolution in ownership and profitability during the post World War II period, and a general perspective is useful to understanding the nature of the regulatory constraint, k. Tables D-1 and D-2 record some pertinent statistics. As indicated in Table D-1, there has been a persistent decline in the operational profitability of bus transit operations, both at a local level and in terms of national aggregates. The assumption that k is exogenous to the transit system is at best a crude approximation, since other regulatory constraints on service B and the fare F certainly come into play.

Nelson finds that for the 1960 and 1968 cross-section samples of urban bus transit systems, the variable k is better "explained" in terms of regulatory variables such as private-versus-public ownership and the locality of regulatory control than by the various operating characteristics such as costs of operation, highway capacity, etc. His finding justifies treatment of k as exogenous, but it also suggests that conclusions

TABLE D-1

TREND OF TRANSIT OPERATIONS, 1940-1975

Calendar Year	Operating Revenue (millions)	Operating Expense (millions)	Cost-Revenue Ratio
1940	$ 737.0	$ 660.7	0.896
1945	1,380.4	1,231.7	0.892
1950	1,452.1	1,385.7	0.954
1955	1,426.4	1,370.7	0.961
1960	1,407.2	1,376.5	0.978
1965	1,443.8	1,454.4	1.007
1966	1,478.5	1,515.6	1.025
1967	1,556.0	1,622.6	1.043
1968	1,562.7	1,723.8	1.103
1969	1,625.6	1,846.1	1.136
1970	1,707.4	1,995.6	1.169
1971	1,740.7	2,152.1	1.236
1972	1,728.5	2,241.6	1.297
1973	1,797.6	2,536.1	1.411
1974	1,939.7	3,239.4	1.670
1975p	2,002.4	3,705.9	1.851

Source: American Public Transit Association, Transit Fact Book '75-'76 Table 4. p:preliminary.

of the empirical tests may be affected by the rapid increase in public ownership of transit systems that has occurred during the past two decades (Tables D-2 and D-3).

ESTIMATION OF THE ECONOMETRIC MODEL

The above model is an example of an (over-) identified simultaneous equations model with endogenous variables B, D, and F, and exogenous variables POP, HWAY, C, k, AUTO,F', and GNI. The standard technique for estimating such models is two-stage least squares (2SLS), an adaptation of ordinary least squares (OLS) wherein correlations between jointly determined endogenous variables and the error terms u and v are eliminated prior to estimation of the structural relationships.

It should be noted, however, that the 2SLS technique is not necessarily preferable to OLS, particularly where specification error is involved.[2] For this reason both methods of estimation are reported below.

REVIEW OF RECENT STUDIES OF URBAN TRANSIT DEMAND

Two significant studies have examined urban bus transit demand within a given locale instead of for aggregate cross-section or time-series data. Kraft and Domencich[3] use an origin-and-destination survey from the Boston area to estimate travel demand elasticities with respect to both service (time) and fare. What small effects they determine fall mainly on the

TABLE D-2

PUBLIC OWNERSHIP OF U.S. MASS TRANSIT
SYSTEMS, SELECTED STATISTICS, 1967-75

Statistic	1967	1969	1971	1973	1975
Number of Systems	98 (9%)	131 (12%)	151 (14%)	185 (18%)	333 (35%)
Operating Revenue (mil)	930 (60%)	1,219 (75%)	1,445 (83%)	1,581 (88%)	1,729 (86%)
Vehicle Miles Operated (mil)	1,027 (51%)	1,239 (63%)	1,292 (70%)	1,431 (78%)	1,706 (86%)
No. of Employees (thous)	87 (60%)	108 (77%)	118 (85%)	126 (90%)	138 (86%)
Passenger Vehicles Owned	30,026 (48%)	38,590 (63%)	41,301 (68%)	47,508 (79%)	51,964 (83%)
Motor Buses	19,527 (39%)	27,110 (55%)	29,982 (61%)	35,732 (74%)	40,583 (80%)
Subway & Elevated	1,794 (95%)	9,343 (100%)	9,325 (100%)	9,276 (100%)	9,608 (100%)
Surface Railway	734 (59%)	1,190 (90%)	1,176 (96%)	1,037 (96%)	982 (93%)
Trolley Coaches	971 (78%)	947 (88%)	913 (88%)	1,013 (100%)	703 (100%)

Note: Percentages are with respect to estimated industry total.

Source: American Public Transit Association, Transit Fact Book, various issues.

TABLE D-3

DATE OF INITIAL PUBLIC OWNERSHIP: MAJOR U.S. MASS TRANSIT SYSTEMS

Urbanized Area	Population of Urbanized Area	Date of Public Ownership
Seattle-Everett, WA	1,238.107	1911
San Francisco, CA	2,987,850	1912
New York, NY	16,206,841	1922
Cleveland, OH	1,959,880	1935
Boston, MA	2,652,575	1947
Chicago, IL	6,714,578	1947
Kalamazoo, MI	152,083	1957
Los Angeles, CA	8,351,266	1958
San Antonio, TX	772,513	1959
Dallas, TX	1,338,684	1960
Memphis, TN	663,976	1961
Grand Rapids, MI	352,703	1964
Wichita, KS	302,334	1966
San Diego, CA	1,198,323	1967

Source: American Public Transit Association service variable, and their estimates of the fare elasticity are low, between -0.09 and -0.33. Notably, cross elasticities with respect to automobile operating costs are neglible.

A more recent study by Schmenner[4] analyzes patronage data on a route-by-route basis for the cities of Hartford, New Haven, and Stamford, Connecticut. Time series regressions for data provided by a local bus company indicate an elasticity of demand with respect to fare per mile of between -0.80 and -1.03. Schmenner attributes his higher estimates of fare elasticity to reduced error due to aggregation in his sample. His data also exhibit a positive cross-elasticity with respect to automobile operating costs.

The Nelson study (1972) is subject to Schmenner's criticism that the estimates are probably biased towards zero due to aggregation, since the unit of observation is the transit system for an entire urbanized area. Information on a cross-section of transit systems (e.g., Table D-4) is published annually by the American Public Transit Association in its Transit Operating Report. The sample each year consists of member firms whose transit operations are devoted solely to bus transportation, without competition from rail or trolley. While the total sample size (number of firms) has stayed relatively constant over the years, it is subject to relatively high turnover from one year to the next, so that cross-sectional comparisons for different years are not strictly equivalent. The 1974 sample for the present study contains 19 (of 52) firms that were not present in either the 1960 or 1968 (Nelson) samples.

TABLE D-4

1974 Sample of Bus Firms and Urbanized Areas

Location	Company Name
Akron, OH	Metro Regional Transit Authority
Albany, NY	Capital District Transportation Authority
Albuquerque, NM	Albuquerque Transit System
Amarillo, TX	Amarillo Transit System
Atlanta, GA	Metropolitan Atlanta Rapid Transit Authority
Baltimore, MD	Maryland Department of Transportation Mass Transit District
Binghamton, NY	Broome County Transit
Charleston, SC	South Carolina Electric and Gas Company
Charleston, WV	Karawha Valley Regional Transportation Authority
Charlotte, NC	Charlotte City Coach Lines, Inc.
Chattanooga, TN	Chattanooga Area Regional Transportation Authority
Cincinnati, OH	Southwest Ohio Regional Transit Authority
Columbia, SC	South Carolina Electric and Gas Company
Columbus, OH	Central Ohio Transit Authority
Corpus Christi, TX	Corpus Christi Transit System
Dallas, TX	Dallas Transit System
Duluth, MN	Duluth Transit Authority
El Paso, TX	Country Club Bus Lines, Inc.
Fort Worth, TX	McDonald Transit, Inc. dba CITRAN
Greenville, SC	Greenville City Coach Lines, Inc.
Harrisburg, PA	Cumberland-Dauphin-Harrisburg Transit Authority
Huntington, WV	Tri-State Transit Authority
Houston, TX	Houston Transit System/Rapid Transit Lines, Inc.
Jacksonville, FL	Jacksonville Transportation Authority
Kansas City, MO	Kansas City Area Transportation Authority
Lewiston, ME	Hudson Bus Lines
Lincoln, NE	Lincoln Transportation System
Madison, WI	City of Madison Department of Transportation
Memphis, TN	Memphis Area Transit Authority
Miami, FL	Metropolitan Dade County Transit Agency
Milwaukee, WI	Milwaukee & Suburban Transport Corporation
Minneapolis-St. Paul, MN	Twin Cities Area Metropolitan Transit Commission
Monterey, CA	Monterey Peninsula Transit
Muskegon, MI	Muskegon Area Transit System
Nashville, TN	Metropolitan Transit Authority
Norfolk, VA	Tidewater Metro Transit
Omaha, NE	Transit Authority of the City of Omaha
Portland, OR	Tri-County Metropolitan Transportation District of Oregon

TABLE D-4 (Continued)

Location	Company Name
Raleigh, NC	Raleigh City Coach Linės, Inc.
Rochester, NY	Regional Transit Service, Inc.
St. Louis, MO	Bi-State Transit System
San Diego, CA	San Diego Transit Corporation
Savannah, GA	Savannah Transit Authority
Springfield, MO	City Utilities of Springfield
Stockton, CA	Stockton Metropolitan Transit District
Syracuse, NY	CNY Centro, Inc.
Toledo, OH	Toledo Area Regional Transit Authority
Tulsa, OK	Metropolitan Tulsa Transit Authority
Waco, TX	Waco Transit System
Wichita, KS	Wichita Metropolitan Transit Authority
Wilmington, DE	Delaware Authority for Regional Transportation
Winston-Salem, NC	Winston-Salem Transit Authority

D-II CROSS SECTION ESTIMATES OF URBAN BUS TRANSIT MODEL

Nelson's results for 1960 and 1968 are presented in Tables D-6 and D-7, along with parallel regression results for 1974. Data sources for the 1974 regressions are reviewed in Tables D-8 and D-9 for the Urban Transit Bus model.

SUPPLY EQUATION ESTIMATES

The supply equations for 1974 conform well to Nelson's previous estimates, with the significant exception of variables C and k, both related to the cost of operations. As indicated in Table D-2, the last decade has witnessed a significant increase in the number of publicly owned and subsidized urban mass transit systems, particularly in connection with the Urban Mass Transportation Act of 1964, which subsidized both purchases of new equipment and conversion of private transit firms to private ownership.

Whereas the cost/revenue ratio k is negatively associated with supply of service in 1960, the reverse appears to be true in 1974: firms with greater service B, holding constant population, demand, etc., experience higher ratios of cost to revenue. This change highlights the importance of the shift from private to public ownership.

TABLE D-6

Estimates of the Supply Equation For Urban Bus Transit Service

Statistic	1960[a] (2SLS)	1968[a] (2SLS)	1974 (OLS)	1974 (2SLS)
Dependent Variable	ln B	ln B	ln B	ln B
Independent Variable				
Constant	-1.05	1.42	.448	.359
(t-statistic)	(-1.75)	(1.41)	(1.68)	(1.00)
ln POP	.055	.248	.193	.406
	(0.42)	(1.75)	(1.54)	(1.73)
ln AREA	.008	.055	.142	.151
	(0.13)	(0.76)	(1.36)	(1.14)
ln D	.927	.727	.648	-.007
	(7.08)	(7.08)	(14.13)	(-0.03)
ln C	-.446	-.601	-.043	.490
	(-2.70)	(-3.66)	(-0.26)	(3.64)
ln R	-.511	-.065	.230	.575
	(-2.09)	(-0.34)	(2.06)	(2.03)
R^2	.971	.982	.972	.958
Standard Error	.133	.170	.217	.268
Number of Observations	44	51	52	52

Note: [a]From Gary R. Nelson, "An Econometric Model of Urban Transit Operations." Table 4.5 of John D. Wells, et al, Economic Characteristics of the Urban Transportation Industry (Washington, D.C.: U.S. Government Printing Office, 1972).

TABLE D-7

Estimates of the Demand Equation For Urban Bus Transit Service

Statistic	1960[a] (2SLS)	1968[a] (2SLS)	1974 (OLS)	1974 (2SLS)
Dependent Variable	ln D	ln D	ln D	ln D
Independent Variables				
Constant (t-statistic)	NR	NR	7.412 (6.94)	9.485 (3.31)
$-(B/POP)^{-0.3}$	6.54 (5.84)	8.81 (4.41)	6.81 (14.19)	9.458 (2.91)
F	-4.52 (-3.70)	-3.06 (-1.91)	-.669 (-1.25)	-0.183 (-0.20)
ln POP	1.11 (17.34)	1.10 (8.46)	1.037 (6.51)	0.974 (4.36)
ln AREA	.002 (0.03)	.0208 (0.19)	.0809 (0.52)	-.0069 (-0.03)
ln AUTOS	-.106 (-0.96)	-.175 (-0.44)	-.175 (-.51)	.0691 (0.13)
ln HWAY	--	.156 (0.98)	.784 (4.12)	1.022 (2.68)
POURTY[b]	-1.61 (-1.49)	-3.02 (-2.93)	1.215 (0.65)	-.743 (-0.22)
INC 15[c]	-0.40 (-0.33)	-3.57 (-1.81)	.0798 (0.05)	-2.393 (-0.63)
AGE 18[d]	-1.74 (-1.53)	-5.95 (-2.44)	-4.149 (-2.02)	-1.029 (-0.22)
AGE 65[e]	-0.87 (-0.54)	-8.17 (-2.39)	-3.607 (-1.33)	-5.623 (-1.30)

TABLE D-7 (Continued)

Statistic	1960[a] (2SLS)	1968[a] (2SLS)	1974 (OLS)	1974 (2SLS)
R^2	.986	.976	.974	.954
Standard Error	.113	.227	.270	.356
Number of Observations	44	51	52	52
Fare Elasticity Evaluated At Mean Fare	-0.81 (-3.70)	-0.67 (-1.91)	-0.20 (-1.25)	-0.05 (-0.20)

Notes: [a]From Gary R. Nelson, "An Econometric Model of Urban Transit Operations." Table 4.6 of John D. Wells et al, Economic Characteristics of the Urban Transportation Industry (Washington, D.C.: U.S. Government Printing Office, 1972).

[b]Percent of households below poverty level ($3,000 for 1960 and 1968).

[c]Percent of households with income above $15,000 ($10,000 in 1960 & 1968).

[d]Percent of population under 18 years of age.

[e]Percent of population over 65 years of age.

TABLE D-8

TREND OF AVERAGE FARE, MOTOR BUS URBAN TRANSIT, 1940 - 75

Calendar Year	Average Fare	Consumer Price Index (1967=100)	Average Real Fare
1940	6.87¢	42.0	16.36¢
1945	7.07	53.9	13.12
1950	9.56	72.1	13.26
1955	14.41	80.2	17.97
1960	17.96	88.7	20.25
1965	20.55	94.5	21.75
1966	21.23	97.2	21.84
1967	22.39	100.0	22.39
1968	23.20	104.2	22.26
1969	25.71	109.8	23.42
1970	29.41	116.3	25.29
1971	32.23	121.3	26.57
1972	33.07	125.3	26.39
1973	32.40	133.1	24.34
1974	31.70	147.7	21.50
1975p	32.10	161.2	19.91

Source: American Public Transit Association, Transit Fact Book '75-'76, Table 13. p: preliminary

TABLE D-9

Cross-Section Urban Transit Regressions:
Definition of Variables and Their Sources

Variable	Definition and Source
AGE 18	Fraction of Population Under Age 18 years in 1970. U.S. Census of Population (1970), Vol. I, Part 1, Table 66 (Urbanized Areas).
AGE 65	Fraction of Population over Age 65 years in 1970. U.S. Census of Population (1970), Vol. I, Part 1, Table 66 (Urbanized Areas).
AREA	Land Area of Urbanized Area. U.S. Census of Population (1970), Vol. I, Part A, Section 1, Table 20.
AUTOS	Automobiles per Capita, by County, 1973. Rand McNally & Co., Commercial Atlas and Marketing Guide, 107th edition. (New York, 1976).
B	Line Service Bus Miles. American Public Transit Association, Transit Operating Report (1974): Section D, Operating Statistics, Item 3.
CPM	Operating Expense per Total Bus Mile. American Public Transit Association, Transit Operating Report (1974): Section D, Derived Statistics, Item 2.
D	Total Revenue Passengers. American Public Transit Association. Transit Operating Report (1974): Section D, Operating Statistics, Item 27.
F	Revenue per Revenue Passenger. American Public Transit Association, Transit Operating Report (1974): Section D, Operating Statistics, Item 27 and Operating Revenues and Operating Expenses, Item 1.
HWAY 68	Population Per Unit of Highway Capacity, 1968. Highway capacity estimated by the formula: $8720x + 2500y$, where x is miles of freeways and expressways and y is all other road miles. Federal Highway Administration, National Highway Needs Report, 1970 (91st Congress). Washington, D.C., U.S. Government Printing Office: 49-840-ø.

TABLE D-9 (Continued)

Variable	Definition and Source
INC15	Fraction of Households with Income in Excess of $15,000 per year in 1970. U.S. Census of Population (1970), Vol. I, Part 1, Table 183.
k	Ratio of Expenses to Revenues. American Public Transit Association, Transit Operating Report (1974): Section D, Income Statement, Items 1 and 2.
MPH	Bus Miles per Bus Hour (Line Service). American Public Transit Association, Transit Operating Report (1974): Section D, Derived Statistics, Item 4.
POP	Population of Urbanized Area. American Public Transit Association, Transit Operating Report (1974): Section D, Operating Statistics, Item 1.
POVRTY	Fraction of Households Below Poverty Level in 1970. U.S. Census of Population (1970), Vol. I, Part 1, Table 183.

DEMAND EQUATION ESTIMATES

The same phenomenon may explain the relatively poor performance of the two-stage least squares fits for the demand equation in 1974. Apparently, Nelson's sophisticated model is misspecified as applied to the 1974 urban setting, and ordinary least squares estimation is probably preferable (that is, treating service B and average fare F as exogenous, predetermined variables).

The following results may be concluded from Table D-7:

1) Improved service levels B relative to population POP holding constant the fare per mile F and highway capacity per capita HWAY, attract greater ridership. This result has been found in virtually all empirical studies of urban transit.

2) Demand D is inelastic with respect to the fare F, and the fare elasticity has declined in absolute value since 1968. In part, this decline may be attributed to a fall in the real fare (Table D-8) relative to rising real wages (which measure the opportunity cost of travel time). In the economic impact analysis covering transit buses (Section 7, Part B) an average (-0.5) of the three 2SLS point estimates (1960, 1968, 1974) in Table D-7 was used for the demand (fare) elasticity estimate.

3) Bus patronage is unresponsive to measures of income dispersion (PVRTY and INC15), but is significantly increased in cities

where the population in the 19 to 64 age group is greater. This result is consistent with Nelson's finding that bus transit demand is determined primarily by trips to and from people's places of employment.

4) The coefficients on per-capita automobile ownership are not significantly different from zero, but they are mostly negative, indicating a very slight positive cross elasticity with respect to the automobile mode of travel.

D-III TIME SERIES ESTIMATES OF INTERCITY BUS TRANSPORTATION DEMAND

Table D-10 records regression coefficients for the demand model as applied to time series of intercity bus transportation statistics. Data sources are reviewed in Table D-11 for the Intercity Bus Model.

The fits are generally satisfactory. Due to the presence of significant autocorrelation in the residuals of the log-log form of the regressions (Durbin-Watson statistic = 1.31), a first-difference formulation was tried with somewhat better results (Durbin-Watson statistic = 1.77).

The following results are concluded from Table D-10:

1) Intercity bus patronage D is responsive to service B, as with urban transit.

2) The fare elasticity of intercity bus travel demand is about -0.50, holding constant the availability and fare

TABLE D-10

ESTIMATES OF THE DEMAND EQUATION FOR INTERCITY BUS TRANSPORTATION, 1948 - 73

Statistic	OLS	2SLS	OLS[a]
Dependent Variable	ln D	ln D	Δ ln D
Independent Variables			
Constant	-16.14	-16.03	.044
(t-statistic)	(-3.25)	(-2.99)	(1.72)
ln B	.953	.959	1.003
	(10.95)	(6.90)	(8.12)
ln POP	.493	.501	-.143
	(2.08)	(1.78)	(-.13)
ln F	-.448	-.446	-17.47
	(-3.10)	(-3.00)	(-3.30)
F/FRAIL	-.026	-.026	-.030
	(-1.14)	(-1.13)	(-1.46)
ln AUTO	-.693	-.685	-2.283
	(-3.25)	(-2.61)	(-2.37)
ln GNI	.207	.201	.332
	(1.30)	(1.03)	(2.34)
ln HWAY	-.142	-.135	--
R^2	.985	.985	.919
Standard Error	.015	.015	.017
Durbin-Watson	1.31	1.31	1.77
Number of Observations	26	26	25

Note: The 2SLS estimates treat ln B as a jointly determined dependent variable, identified by the excluded variables ln C and ln K.

[a]First-difference form of the demand equation: the constant reflects a trend coefficient; ln F is replaced by the first difference in F; F/FRAIL is replaced by the first difference in F/FRAIL; all other variables are replaced by the first differences in natural logarithms. The coefficient ΔF implies a fare elasticity of -0.497, evaluated at the mean fare.

TABLE D-11

INTERCITY BUS TRANSIT TIME SERIES REGRESSIONS: DEFINITION OF VARIABLES AND THEIR SOURCES

VARIABLE	DEFINITION AND SOURCE
AUTO	Passenger Car and Taxi Registrations, U.S., per capita. Department of Transportation, Summary of Transportation Statistics, Table 9.
B	Vehicle Miles Operated. Regular-Route Intercity Service, Class I Carriers. National Association of Motor Bus Owners, Fact Book, Table 4.
C	Cost per mile of bus service. Regular Route Intercity Service, Class I Carriers. Estimated as: C = CPMB = (E-(TR-R))/B, where TR is total operating revenues, R is passenger revenues on intercity regular routes, E is total operating expenses, and B is vehicle miles operated. National Association of Motor Bus Owners, Fact Book, Tables 3 and 4. Deflated by the Consumer Price Index (1967=1.00).
CPI	Consumer Price Index, 1967=1.00. U.S. Department of Commerce, Bureau of Economic Analysis.
D	Revenue Passenger Miles, Regular-Route Intercity Service, Class I Carriers. National Association of Motor Bus Owners, Fact Book, Table 4.
F	Revenue per Passenger Mile, Regular-Route Intercity Service, Class I Carriers. F=R/D, where R is passenger revenue on intercity routes and D is revenue passenger miles. National Association of Motor Bus Owners, Fact Book, Tables 3 and 4. Deflated by the Consumer Price Index (1967=1.00).
FRAIL=FPMR	Rail Fare Per Passenger Mile. Class I rail, other than commutation. Department of Transportation, Summary of Transportation Statistics, Table 1.
GNI	Real per Capita U.S. National Income. U.S. Department of Commerce, Bureau of Economic Analysis.

TABLE D-11 (Continued)

VARIABLE	DEFINITION AND SOURCE
HWAY	U.S. Intercity Highway Mileage per Capita. Department of Transportation, Summary of Transportation Statistics, Table 8.
k	Cost/Revenue, Intercity Buses. Regular Route Intercity Service, Class I Carriers: k = CPMB/RPMB.
POP	U.S. Total Population. U.S. Department of Commerce, Bureau of the Census.
RPMB	Revenue per Mile, Buses. Regular-route intercity service: revenue from Table 3 of National Association of Motor Bus Owners, Fact Book, Miles Operated = B.

on competing modes (auto and rail). A one percent increase in bus fares relative to rail fares results in an additional 0.03 percent decrease in bus patronage. Automobile ownership per capita is significantly related, in a negative direction, to bus patronage.

3) The income elasticity of intercity bus demand is small but positive (around 0.20), indicating that distributional impacts of fare increases do not necessarily affect only lower income groups.

REFERENCES

Appendix D

1. Gary R. Nelson, "An Econometric Model of Urban Bus Transit Operations". Chapter IV of John D. Wells et al, Economic Characteristics of the Urban Public Transportation Industry (Washington, D.C.: U.S. Government Printing Office, 1972).

2. J. Johnston, Econometric Methods, Chapter 10 (New York, 1963).

3. G. Kraft and T. Domencich, Free Transit, Boston, Mass.: D. C. Heath and Company, 1971.

4. R. Schmenner, "The Demand for Urban Bus Transit", Journal of Transport Economics and Policy (January, 1976) 9:68-66.

5. "A Study to Determine the Economic Impact of Noise Emission Standards in the Bus Manufacturing Industry", Draft Final Report submitted by A. T. Kearney, Inc. under Contract No. 68-01-3512, prepared for the Office of Noise Abatement and Control, September, 1976.

APPENDIX E

UNIFORM ANNUALIZED COSTS OF BUS NOISE ABATEMENT

Equivalent annual cost or annualized cost as applied to the bus noise regulation was calculated as the sum of the incremental operating and maintenance costs due to the usage of additional noise abatement equipment, the annual amortization of noise abating equipment, and the annual cost of capital for this equipment as calculated using the prevailing discount rate.

Uniform annualized cost is precisely defined by the following formula:

$$A = \frac{r}{1 - (1+r)^{-n}} \cdot \sum_{i=1}^{n} \frac{C_i}{(1+r)^i}$$

where A = uniform annualized cost

C_i = actual cost incurred in the i^{th} year

r = annual discount rate

n = number of years which have elapsed from the start to the end of the entire transaction

The uniform annualized costs presented in this Appendix utilized a discount rate of 0.10 and the year 2000 as the end year of calculation. The other inputs (projected changes in the number of buses produced and changes in operating, maintenance and equipment costs) may be found either in Section 3, Section 7, or in Appendix C for the various types of buses considered.

Uniform annualized costs for 15 exterior and 15 interior bus noise abatement regulatory schedules are presented in this Appendix. Tables E-1 and E-2 present the 30 exterior and interior regulatory schedules (respectively) considered in these calculations. It should be noted that Tables E-1 and E-2 are identical to Tables 6-1 and 6-2 respectively, which were used as keys to the presentation of Health and Welfare data in Section 6.

Table E-3 shows the annualized cost figures across all buses for the 15 exterior noise regulatory schedules. Table E-3 also presents the contributions of operating, maintenance, and equipment costs to the total cost figures. Tables E-4 to E-6 show the annualized cost figures regarding the 15 exterior schedules for the three main bus types: intercity buses, transit buses and school buses, respectively.

Table E-7 presents annualized cost figures for the 15 interior noise regulatory schedules across all buses. Table E-7 also indicates the breakdown of the interior schedule costs by bus type. Note that only increased equipment costs were considered for the interior regulatory schedules. No increases in operating or maintenance costs were projected as a result of the implementation of any interior regulatory schedule.

Regulation 15 for both the exterior and interior regulation schedules (Tables E-1 and E-2, respectively) do not have increased costs associated with them. These schedules were used for assessing the maximum health and welfare benefits associated with bus noise abatement. Since these two schedules were never under real consideration as regulatory schedules, except in a theoretical vein, no attempt was made to attribute costs to them.

Table E-1

Regulatory Schedules Considered in the Health and Welfare Analysis of Exterior Bus Noise						
Exterior Regulatory Schedule	Not to Exceed Regulatory Level for All Bus Types Unless Noted, (dBA)					
	Calendar Year					
	1979	1981	1983	1984	1985	1986
1	--	--	--	--	--	--
2	83	--	--	--	--	--
3	--	83	--	--	--	--
4	--	80	--	--	--	--
5	--	--	80	--	--	--
6	83	80	--	--	--	--
7	83	--	80	--	--	--
8	83	80	--	78	--	--
9	83	--	80	--	78	--
10	83	80	--	--	77	--
11	83	--	80	--	77	--
12	83	80	--	--	--	75
13	83	--	80	--	--	75
14	83	80	--	78	--	75 (1)
15	55	55	55	55	55	55

(1) Gasoline Powered School Buses 73 dBA

Table E-2

Regulatory Schedules Considered In the Health and Welfare Impact Analysis of Interior Bus Noise						
Interior Regulatory Schedule	Not To Exceed Regulatory Level For All Bus Types Unless Noted, (dBA)					
	Calendar Year					
	1979	1981	1983	1984	1985	1986
1	--	--	--	--	--	--
2	86	--	--	--	--	--
3	84	--	--	--	--	--
4	--	83	--	--	--	--
5	86	83	--	--	--	--
6	86	83	80	--	--	--
7	86	83	--	80	--	--
8	84	--	80	--	--	--
9	86	--	84	--	80	--
10	86	--	83	--	80	--
11	86	83	80	--	--	78
12	86	83	--	80	--	78
13	84	--	80	--	--	78
14	86	83	--	80 (1)	-	78 (1)
15	55	55	55	55	55	55

(1) Gasoline Powered School Buses 75 dBA

Table E-3

Exterior Regulatory Schedule	Uniform Annualized Costs (All Buses) Exterior Regulatory Schedules				
	$ (Millions)				
	Equipment Costs	Operating Costs	Maintenance Costs	Operating and Maintenance Costs	Total Costs
1	-	-	-	-	-
2	3.604	0	7.874	7.874	11.478
3	2.979	0	6.338	6.338	9.317
4	8.673	4.172	37.835	42.007	50.680
5	7.094	3.036	30.210	33.246	40.340
6	9.298	4.172	39.371	43.542	52.840
7	8.252	3.098	33.041	36.140	44.392
8	15.577	11.347	46.883	58.230	73.807
9	13.457	8.116	38.644	46.761	60.217
10	20.105	10.373	47.649	58.021	78.126
11	15.657	9.348	41.651	50.999	66.656
12	30.774	24.002	54.443	78.446	109.220
13	29.727	22.867	48.036	70.903	100.631
14	36.647	25.862	84.211	110.073	146.720
15	-	-	-	-	-

Table E-4

Exterior Regulatory Schedule	Uniform Annualized Costs (Intercity Buses) Exterior Regulatory Schedules ($ Millions)				
	Equipment	Operating	Maintenance	Operating and Maintenance	Total Cost
1	-	-	-	-	-
2	0.233	0	0.640	0.640	0.873
3	0.187	0	0.499	0.499	0.686
4	0.790	5.634	2.175	7.809	8.599
5	0.630	4.319	1.667	5.986	6.616
6	0.836	5.634	2.316	7.950	8.786
7	0.713	4.319	1.925	6.244	6.957
8	1.403	10.451	3.336	13.787	15.190
9	1.116	7.734	2.592	10.326	11.442
10	1.340	9.785	3.195	12.981	14.321
11	1.216	8.471	2.804	11.275	12.491
12	5.242	17.060	4.151	21.211	26.453
13	5.119	15.746	3.759	19.505	24.624
14	5.364	18.331	4.420	22.751	28.115
15	-	-	-	-	-

Table E-5

Exterior Regulatory Schedule	Uniform Annualized Costs (Transit Buses) Exterior Regulatory Schedules				
	$ (Millions)				
	Equipment	Operating	Maintenance	Operating and Maintenance	Total
1	-	-	-	-	-
2	0.743	0	1.994	1.994	2.737
3	0.586	0	1.529	1.529	2.115
4	2.485	3.167	6.661	9.828	12.313
5	1.989	2.452	5.157	7.609	9.598
6	2.642	3.167	7.126	10.293	12.935
7	2.263	2.452	5.967	8.419	10.682
8	4.442	5.457	10.302	15.759	20.201
9	3.548	4.056	8.058	12.114	15.662
10	4.244	5.156	9.885	15.041	19.285
11	3.866	4.440	8.726	13.166	17.032
12	11.820	11.411	12.936	24.347	36.167
13	11.442	10.695	11.776	22.472	33.914
14	12.197	11.985	13.733	25.718	37.915
15	-	-	-	-	-

Table E-6

Exterior Regulatory Schedule	Uniform Annualized Costs (School Buses) Exterior Regulatory Schedules				
	$ (Millions)				
	Equipment	Operating	Maintenance	Operating and Maintenance	Total
1	-	-	-	-	-
2	2.620	0	5.240	5.240	7.860
3	2.206	0	4.310	4.310	6.516
4	5.398	-4.629	28.999	24.370	29.768
5	4.465	-3.725	23.386	19.661	24.126
6	5.820	-4.624	29.923	25.299	31.119
7	5.276	-3.673	25.149	21.476	26.752
8	9.732	-4.561	33.245	28.684	38.416
9	8.792	-3.673	27.994	24.321	33.113
10	14.521	-4.568	34.567	29.999	44.520
11	10.555	-3.563	30.121	26.558	37.113
12	13.713	-4.469	37.357	32.888	46.601
13	13.166	-3.574	32.501	28.927	42.093
14	19.085	-4.448	66.053	61.605	80.690
15	-	-	-	-	-

Table E-7

Interior Regulatory Schedule	Uniform Annualized Costs Interior Regulatory Schedules			
	$ (Millions)			
	Intercity	Transit	School	Total
1	-	-	-	-
2	-	-	0.878	0.878
3	0.040	0.013	2.016	2.069
4	0.032	0.010	0.981	1.023
5	0.032	0.010	1.128	1.170
6	0.237	0.075	1.740	2.052
7	0.786	0.528	1.047	2.361
8	0.231	0.073	2.207	2.511
9	0.058	0.183	1.582	1.823
10	0.189	0.405	1.582	2.176
11	1.165	0.365	8.569	10.999
12	1.142	0.358	8.512	10.012
13	1.282	0.403	10.628	12.313
14	1.142	0.358	10.125	11.625
15	-	-	-	-

APPENDIX F

ADDITIONAL SUPPORTING INFORMATION

FOR

HEALTH AND WELFARE ANALYSES

(SECTION 6)

Table F-1

Exterior Bus Noise Levels, by Operational Mode and Bus Type
(Data from Reference 1 Unless Noted)

Bus Type		50 Ft. Maximum Passby Levels, dBA*			
		Acceleration	Deceleration and Cruise		Idle
			30 mph	55 mph	
Transit	Range	76-83	70-72	78	66[12]
	Mean	80	72	78	66
School-Gas	Range	74-84[2]	--	--	
	Mean	80	(72)	(78)	(66)
School-Diesel Front Engine	Range	83-92	78[3]	--	66[3]
	Mean	87	78	(85)	66
Middle Engine	Range	81-84	--	--	
	Mean	83	(75)	(81)	(66)
Rear Engine	Range	81-84	--	--	
	Mean	83	(75)	(81)	(66)
Inter-City	Range	81-86	73-77[4,5]	79-80[4,5]	
	Mean	84	75	80	66[7]

*Data in parentheses extrapolated from transit bus data.

Table F-2

Interior Bus Noise Levels Near Driver, by Operational Mode and Bus Type
(Data from Reference 1 Unless Noted)

Bus Type		Interior Noise Level Near Driver, dBA*			
		Acceleration	Deceleration and Cruise 30 mph	Deceleration and Cruise 55 mph	Idle
Transit	Range	78-79	74	78	60[6]
	Mean	79	74	78	60
School-Gas	Range	80-90[2]	--	--	--
	Mean	85	(80)	(84)	(66)
School-Diesel Front Engine	Range	88-95	80[3]	--	70[3]
	Mean	92	80	(84)	70
Middle Engine	Range	87	--	--	--
	Mean	87	(75)	(79)	(65)
Rear Engine	Range	87	--	--	--
	Mean	87	(75)	(79)	65
Inter-City	Range	70-78	69[4,5]-75[6]	73-75[4,5]	60[7]
	Mean	74	72	74	60

*Data in parentheses extrapolated from transit bus data.

Table F-3

Interior Bus Noise Levels in Rear Seat, by Operational Mode and Bus Type (Data from Reference 1 Unless Noted)

Bus Type	Interior Noise Level in Rear dBA*			
	Acceleration	Deceleration and Cruise		Idle
		30 mph	55 mph	
Transit				
Range	80-90	81-84[8]	83-85[8]	69[6]
Mean	84	83	84	69
School Gas				
Range	77-84[2]	--	--	69-78[2]
Mean	81	(80)	(81)	74
School Diesel				
Front Engine Range	--	75[3]	--	65[3]
Front Engine Mean	(87)	75	(76)	65
Middle Engine Range	--	--	--	--
Middle Engine Mean	(87)	(75)	(76)	(65)
Rear Engine Range	--	--	81-83[13]	--
Rear Engine Mean	(92)	(80)	82	(70)
Inter-city				
Range	70-84[4,5]	69-78[4,5,8]	73-78[4,5]	64-72[8]
Mean	79	73[4,5]	75[4,5]	68

*Data in parenthesis extrapolated from transit bus data.

Table F-4

Derivation of Percent of Traffic Composed of Bus and Non-Bus Vehicles, by Land Use[9]
Billions of 1973 Vehicle Miles

Vehicle	Urban					Rural		
	Street			Highway		Sub.	Main Road	Local Road
	HD	LD	Sub.	HD	LD			
Non-Bus	223	147	60.7	77.8	51.2	21.2	461	137
Transit	1.20	.41	.13	.06	.02	.01	--	--
School - Gas	.04	.12	.31	--	--	--	.86	.93
School - Diesel	--	--	.01	--	--	--	.03	.03
Intercity	.01	.01	--	.02	.02	--	1.11	--
Total	224	147	61.1	77.9	51.2	21.2	463	138
Percent								
Non-Bus	99.4	99.6	99.3	99.9	99.9	100	99.6	99.3
Transit	.5	.3	.2	.1	.04	--	--	--
School - Gas	.1	.1	.5	--	--	--	.2	.7
School - Diesel	--	--	--	--	--	--	--	--
Intercity	--	--	--	--	.04	--	.2	--
Total	100	100	100	100	100	100	100	100

Table F-5

Percent of Trucks of Model Year Remaining in Calendar Year[10]

Model Year	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
Prior to 1978	86	57	35	22	14	7	3	0
1978-1979*	14	29	21	14	7	3	00	0
1980-2000**	0	14	44	64	79	90	97	100

*Estimated from data for 1982-1984 in Reference[10].
**Remainder of percent.

Table F-6

Percent of Autos and Motorcycles of Model Year Remaining in Calendar Year[10]

Model Year	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
Prior to 1979	91	71	49	26	2	0	0	0
1979-2000	9	29	51	74	98	100	100	100

Table F-7

Average Traffic Passby Levels Without Bus Regulation by Non-bus Regulation Scenario, Land Use Area, and Calendar Year[11]

Non-bus Regulation Scenario	Land Use Area	Average Traffic Passby Level, dBA							
		Calendar Year							
		1979	1981	1983	1985	1987	1990	1995	2000
Regulation of New Trucks, Autos, and Motorcycles	High Density	71.83	70.89	69.76	68.73	67.59	66.96	66.60	66.37
	Low Density	71.82	70.88	69.74	68.70	67.55	66.91	66.55	66.32
	Suburb	71.82	70.88	69.75	68.71	67.57	66.94	66.58	66.35
Regulation of New Trucks Only	High Density	71.93	71.25	70.53	70.05	69.65	69.31	69.11	68.98
	Low Density	71.92	71.23	70.51	70.02	69.63	69.29	69.08	68.95
	Suburb	71.92	71.24	70.52	70.03	69.64	69.30	69.09	68.97
No Regulation of Non-bus Vehicles	High Density	72.09							
	Low Density	72.08							
	Suburb	72.08							

Table F-8

Exterior Regulation Schedule	Reduction of Urban Traffic Noise in High Density Urban Areas With Regulation of New Trucks							
	Reduction of Average Traffic Passby Level (dBA at 50 ft.)							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.16	.84	1.56	2.22	2.43	2.98	3.20	3.33
2	.16	.84	1.56	2.22	2.44	2.99	3.21	3.33
3	.16	.84	1.56	2.22	2.44	2.99	3.21	3.33
4	.16	.84	1.56	2.23	2.45	3.00	3.22	3.36
5	.16	.84	1.56	2.22	2.44	3.00	3.22	3.35
6	.16	.84	1.56	2.25	2.45	3.00	3.22	3.36
7	.16	.84	1.56	2.23	2.45	3.00	3.22	3.35
8	.16	.84	1.56	2.23	2.45	3.01	3.23	3.37
9	.16	.84	1.56	2.23	2.45	3.01	3.23	3.37
10	.16	.84	1.56	2.23	2.45	3.01	3.24	3.37
11	.16	.84	1.56	2.23	2.45	3.01	3.24	3.37
12	.16	.84	1.56	2.23	2.45	3.01	3.24	3.38
13	.16	.84	1.56	2.23	2.45	3.01	3.24	3.38
14	.16	.84	1.56	2.23	2.45	3.02	3.24	3.38
15	.20	.89	1.62	2.29	2.51	3.07	3.29	3.42

Table F-9

Exterior Regulation Schedule	Reduction of Urban Traffic Noise Level in Low Density Urban Areas With Regulation of New Trucks							
	Reduction in Average Traffic Passby Level (dBA at 50 ft.)							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.16	.85	1.57	2.23	2.45	3.00	3.22	3.55
2	.16	.85	1.57	2.24	2.45	3.01	3.23	3.35
3	.16	.85	1.57	2.24	2.45	3.01	3.23	3.35
4	.16	.85	1.57	2.24	2.40	3.02	5.24	3.37
5	.16	.85	1.57	2.24	2.46	3.02	3.24	3.37
6	.16	.85	1.57	2.24	2.46	3.02	3.24	3.37
7	.16	.85	1.57	2.24	2.46	3.02	3.24	3.37
8	.16	.85	1.57	2.24	2.46	3.02	3.24	3.38
9	.16	.85	1.57	2.24	2.46	3.02	3.24	3.38
10	.16	.85	1.57	2.24	2.46	3.02	3.25	3.38
11	.16	.85	1.57	2.24	2.46	3.02	3.24	3.38
12	.16	.85	1.57	2.24	2.46	3.02	3.25	3.38
13	.16	.85	1.57	2.24	2.46	3.02	3.25	3.38
14	.16	.85	1.57	2.24	2.46	3.02	3.25	3.38
15	.19	.88	1.61	2.28	2.50	3.06	3.28	3.41

Table F-10

Exterior Regulation Schedule	Reduction of Urban Traffic Noise Level in Suburban Areas With Regulation of New Trucks							
	Reduction of Average Traffic Passby Level (dBA at 50 ft.)							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.15	.83	1.56	2.22	2.43	2.99	3.29	3.33
2	.15	.84	1.56	2.22	2.44	2.99	3.21	3.33
3	.15	.84	1.56	2.22	2.44	2.99	3.21	3.33
4	.15	.84	1.56	2.23	2.45	3.00	3.22	3.35
5	.15	.83	1.56	2.22	2.44	3.00	3.22	3.35
6	.15	.84	1.56	2.23	2.45	3.00	3.22	3.35
7	.15	.84	1.56	2.22	2.44	3.00	3.22	3.35
8	.15	.84	1.56	2.23	2.45	3.01	3.23	3.36
9	.15	.84	1.56	2.22	2.45	3.00	3.23	3.36
10	.15	.84	1.50	2.23	2.45	3.01	3.23	3.36
11	.15	.84	1.56	2.23	2.45	3.01	3.23	3.36
12	.15	.84	1.56	2.23	2.45	3.01	3.24	3.37
13	.15	.84	1.56	2.22	2.45	3.01	3.23	3.37
14	.15	.84	1.56	2.23	2.45	3.01	3.24	3.37
15	.15	.88	1.61	2.28	2.50	3.06	3.28	3.41

Table F-11

Exterior Regulation Schedule	Reduction of Urban Traffic Noise Level in High Density Urban Areas With No Regulation of Non-Bus Vehicles							
	Reduction of Average Traffic Passby Level (dBA at 50 ft.)							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.00	.00	.00	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.00	.00	.01	.01	.01
5	.00	.00	.00	.00	.00	.01	.01	.01
6	.00	.00	.00	.00	.01	.01	.01	.01
7	.00	.00	.00	.00	.00	.01	.01	.01
8	.00	.00	.00	.00	.01	.01	.01	.02
9	.00	.00	.00	.00	.01	.01	.01	.01
10	.00	.00	.00	.00	.01	.01	.02	.02
11	.00	.00	.00	.00	.01	.01	.01	.02
12	.00	.00	.00	.00	.01	.01	.02	.02
13	.00	.00	.00	.00	.01	.01	.02	.02
14	.00	.00	.00	.00	.01	.01	.02	.02
15	.04	.04	.04	.04	.04	.04	.04	.04

Table F-12

Exterior Regulation Schedule	Reduction of Urban Traffic Noise Level in Low Density Urban Areas With No Regulation on Non-Bus Vehicles							
	Reduction of Average Traffic Passby Level (dBA at 50 ft.)							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.00	.00	.00	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.01	.01	.01	.01	.01
5	.00	.00	.00	.00	.01	.01	.01	.01
6	.00	.00	.01	.01	.01	.01	.01	.01
7	.00	.00	.00	.01	.01	.01	.01	.01
8	.00	.00	.01	.01	.01	.01	.01	.01
9	.00	.00	.00	.01	.01	.01	.01	.01
10	.00	.00	.01	.01	.01	.01	.01	.02
11	.00	.00	.00	.01	.01	.01	.01	.02
12	.00	.00	.01	.01	.01	.01	.02	.02
13	.00	.00	.00	.01	.01	.01	.01	.02
14	.00	.00	.01	.01	.01	.01	.02	.02
15	.03	.03	.03	.03	.03	.03	.03	.03

Table F-13

Exterior Regulation Schedule	Reduction of Urban Traffic Noise Level in Suburban Areas With No Regulation on Non-Bus Vehicles							
	Reduction of Average Traffic Passby Level (dBA at 50 ft.)							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.00	.00	.00	.00	.00	.00	.00	.00
2	.00	.00	.00	.00	.00	.00	.00	.00
3	.00	.00	.00	.00	.00	.00	.00	.00
4	.00	.00	.00	.00	.00	.00	.00	.00
5	.00	.00	.00	.00	.00	.00	.00	.00
6	.00	.00	.00	.00	.00	.00	.00	.00
7	.00	.00	.00	.00	.00	.00	.00	.00
8	.00	.00	.00	.00	.00	.00	.01	.01
9	.00	.00	.00	.00	.00	.00	.01	.01
10	.00	.00	.00	.00	.00	.00	.01	.01
11	.00	.00	.00	.00	.00	.00	.01	.01
12	.00	.00	.00	.00	.00	.00	.01	.01
13	.00	.00	.00	.00	.00	.00	.01	.01
14	.00	.00	.00	.00	.00	.01	.01	.01
15	.03	.03	.03	.03	.03	.03	.03	.03

Table F-14

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise in High Density Urban Areas with Regulation of New Trucks							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	2.95	2.72	2.50	2.30	2.24	2.07	2.01	1.97
2	2.95	2.72	2.50	2.30	2.23	2.07	2.01	1.97
3	2.95	2.72	2.50	2.30	2.24	2.07	2.01	1.97
4	2.95	2.72	2.50	2.30	2.23	2.07	2.01	1.97
5	2.95	2.72	2.50	2.30	2.23	2.07	2.01	1.97
6	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.97
7	2.95	2.72	2.50	2.30	2.23	2.07	2.01	1.97
8	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
9	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
10	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
11	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
12	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
13	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
14	2.95	2.72	2.50	2.30	2.23	2.07	2.00	1.96
15	2.93	2.71	2.48	2.28	2.21	2.05	1.99	1.95

Table F-15

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Street Traffic Noise in Low Density Urban Areas with Regulation of New Trucks							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	8.44	7.79	7.14	6.57	6.39	5.92	5.74	5.63
2	8.44	7.79	7.14	6.57	6.38	5.92	5.74	5.63
3	8.44	7.79	7.14	6.57	6.38	5.92	5.74	5.63
4	8.44	7.78	7.14	6.56	6.38	5.91	5.73	5.62
5	8.44	7.79	7.14	6.57	6.38	5.91	5.73	5.62
6	8.44	7.78	7.14	6.56	6.38	5.91	5.73	5.62
7	8.44	7.79	7.14	6.57	6.38	5.91	5.73	5.62
8	8.44	7.78	7.14	6.56	6.38	5.91	5.72	5.61
9	8.44	7.79	7.14	6.56	6.38	5.91	5.72	5.61
10	8.44	7.78	7.14	6.56	6.38	5.91	5.72	5.61
11	8.44	7.79	7.14	6.56	6.38	5.91	5.72	5.61
12	8.44	7.78	7.14	6.56	6.38	5.90	5.72	5.61
13	8.44	7.79	7.14	6.56	6.38	5.91	5.72	5.61
14	8.44	7.78	7.14	6.56	6.37	5.90	5.72	5.61
15	8.41	7.76	7.11	6.53	6.34	5.87	5.69	5.58

Table F-16

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise in Suburban Areas with Regulation of New Trucks							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	22.53	20.79	19.08	17.56	17.07	15.83	15.35	15.07
2	22.53	20.79	19.07	17.55	17.06	15.82	15.34	15.06
3	22.53	20.79	19.07	17.55	17.06	15.82	15.34	15.06
4	22.53	20.79	19.07	17.54	17.04	15.80	15.31	15.02
5	22.53	20.79	19.07	17.54	17.05	15.80	15.31	15.02
6	22.53	20.79	19.06	17.54	17.04	15.80	15.31	15.02
7	22.53	20.79	19.07	17.54	17.05	15.80	15.31	15.02
8	22.53	20.79	19.06	17.53	17.03	15.78	15.29	15.00
9	22.53	20.79	19.07	17.54	17.04	15.79	15.29	15.00
10	22.53	20.79	19.06	17.53	17.03	15.78	15.28	14.99
11	22.53	20.79	19.07	17.54	17.04	15.79	15.29	14.99
12	22.53	20.79	19.06	17.54	17.03	15.78	15.28	14.98
13	22.53	20.79	19.07	17.54	17.04	15.78	15.28	14.98
14	22.53	20.79	19.06	17.53	17.03	15.77	15.27	14.98
15	22.42	20.68	18.95	17.41	16.92	15.66	15.18	14.89

Table F-17

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise in All Urban Areas with Regulation of New Trucks							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	33.92	31.30	28.72	26.43	25.69	23.83	23.10	22.68
2	33.92	31.30	28.71	26.42	25.68	23.81	23.09	22.66
3	33.92	31.30	28.71	26.42	25.68	23.81	23.09	22.66
4	33.92	31.29	28.70	26.40	25.65	23.78	23.04	22.60
5	33.92	31.30	28.71	26.41	25.66	23.78	23.04	22.61
6	33.92	31.29	28.70	26.40	25.65	23.78	23.04	22.60
7	33.92	31.30	28.71	26.41	25.66	23.78	23.04	22.61
8	33.92	31.29	28.70	26.39	25.64	23.76	23.01	22.57
9	33.92	31.30	28.71	26.40	25.65	23.77	23.02	22.58
10	33.92	31.29	28.70	26.39	25.64	23.75	23.00	22.56
11	33.92	31.30	28.71	26.40	25.65	23.76	23.01	22.57
12	33.92	31.29	28.70	26.40	25.64	23.75	22.99	22.55
13	33.92	31.30	28.71	26.41	25.65	23.76	23.00	22.55
14	33.92	31.29	28.70	26.39	25.63	23.74	22.99	22.54
15	33.77	31.14	28.54	26.22	25.48	23.59	22.85	22.42

Table F-18

Exterior Regulation Schedule	Percent Reduction in Total Equivalent Number of People Impacted by Urban Traffic Noise with Regulation of New Trucks							
	Percent Reduction in Total Equivalent People Impacted							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	1.98	9.54	17.00	23.62	25.76	31.14	33.23	34.46
2	1.98	9.55	17.02	23.64	25.79	31.17	33.27	34.51
3	1.98	9.54	17.01	23.64	25.78	31.17	33.27	34.51
4	1.98	9.55	17.05	23.70	25.86	31.28	33.41	34.67
5	1.98	9.54	17.02	23.67	25.84	31.26	33.40	34.66
6	1.98	9.56	17.05	23.70	25.87	31.28	33.41	34.67
7	1.98	9.55	17.03	23.68	25.85	31.27	33.40	34.65
8	1.98	9.56	17.05	23.72	25.90	31.34	33.49	34.76
9	1.98	9.55	17.03	23.69	25.87	31.31	33.47	34.74
10	1.98	9.56	17.05	23.71	25.90	31.35	33.51	34.78
11	1.98	9.55	17.03	23.69	25.88	31.33	33.50	34.78
12	1.98	9.56	17.05	23.70	25.90	31.36	33.54	34.83
13	1.98	9.55	17.03	23.68	25.88	31.34	33.52	34.82
14	1.98	9.56	17.05	23.72	25.91	31.38	33.56	34.84
15	2.41	9.99	17.52	24.21	26.37	31.82	33.94	35.19

Table F-19

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise In High Density Urban Areas With No Regulation of Non-Bus Vehicles							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
2	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
3	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
4	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
5	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
6	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
7	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
8	3.01	3.01	3.01	3.01	3.01	3.01	3.00	3.00
9	3.01	3.01	3.01	3.01	3.01	3.01	3.00	3.00
10	3.01	3.01	3.01	3.01	3.01	3.01	3.00	3.00
11	3.01	3.01	3.01	3.01	3.01	3.01	3.00	3.00
12	3.01	3.01	3.01	3.01	3.01	3.00	3.00	3.00
13	3.01	3.01	3.01	3.01	3.01	3.01	3.00	3.00
14	3.01	3.01	3.01	3.01	3.01	3.00	3.00	3.00
15	2.99	2.99	2.99	2.99	2.99	2.99	2.99	2.99

Table F-20

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise In Low Density Urban Areas With No Regulation of Non-Bus Vehicles							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	8.62	8.62	8.62	8.62	8.62	8.62	8.62	8.62
2	8.62	8.62	8.62	8.62	8.62	8.62	8.62	8.62
3	8.62	8.62	8.62	8.62	8.62	8.62	8.62	8.62
4	8.62	8.62	8.62	8.61	8.61	8.60	8.60	8.60
5	8.62	8.62	8.62	8.62	8.61	8.60	8.60	8.60
6	8.62	8.62	8.61	8.61	8.61	8.60	8.60	8.60
7	8.62	8.62	8.62	8.61	8.61	8.60	8.60	8.60
8	8.62	8.62	8.61	8.61	8.60	8.60	8.60	8.60
9	8.62	8.62	8.62	8.61	8.60	8.60	8.60	8.60
10	8.62	8.62	8.61	8.61	8.60	8.60	8.60	8.60
11	8.62	8.62	8.62	8.61	8.60	8.60	8.60	8.60
12	8.62	8.62	8.61	8.61	8.60	8.60	8.60	8.59
13	8.62	8.62	8.62	8.61	8.60	8.60	8.60	8.59
14	8.62	8.62	8.61	8.61	8.60	8.60	8.60	8.59
15	8.58	8.58	8.58	8.58	8.58	8.58	8.58	8.58

Table F-21

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise In Suburban Areas With No Regulation of Non-Bus Vehicles							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
2	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
3	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
4	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
5	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
6	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
7	22.97	22.97	22.97	22.97	22.97	22.97	22.97	22.97
8	22.97	22.97	22.97	22.97	22.97	22.97	22.95	22.95
9	22.97	22.97	22.97	22.97	22.97	22.97	22.96	22.96
10	22.97	22.97	22.97	22.97	22.97	22.97	22.95	22.94
11	22.97	22.97	22.97	22.97	22.97	22.97	22.95	22.94
12	22.97	22.97	22.97	22.97	22.97	22.97	22.94	22.94
13	22.97	22.97	22.97	22.97	22.97	22.97	22.95	22.94
14	22.97	22.97	22.97	22.97	22.97	22.95	22.94	22.93
15	22.88	22.88	22.88	22.88	22.88	22.88	22.88	22.88

Table F-22

Exterior Regulation Schedule	Equivalent Number of People Impacted by Urban Traffic Noise In All Urban Areas With No Regulation of Non-Bus Vehicles							
	Equivalent Number of People Impacted (Millions) per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	34.60	34.60	34.60	34.60	34.60	34.60	34.60	34.60
2	34.60	34.60	34.60	34.60	34.60	34.60	34.60	34.60
3	34.60	34.60	34.60	34.60	34.60	34.60	34.60	34.60
4	34.60	34.60	34.60	34.59	34.59	34.59	34.58	34.58
5	34.60	34.60	34.60	34.60	34.59	34.59	34.58	34.58
6	34.60	34.60	34.59	34.59	34.59	34.59	34.58	34.58
7	34.60	34.60	34.60	34.59	34.59	34.59	34.58	34.58
8	34.60	34.60	34.59	34.59	34.58	34.58	34.55	34.55
9	34.60	34.60	34.60	34.59	34.59	34.58	34.56	34.55
10	34.60	34.60	34.59	34.59	34.58	34.58	34.55	34.54
11	34.60	34.60	34.60	34.59	34.59	34.58	34.55	34.54
12	34.60	34.60	34.59	34.59	34.58	34.58	34.54	34.53
13	34.60	34.60	34.60	34.59	34.59	34.58	34.55	34.53
14	34.60	34.60	34.59	34.59	34.58	34.56	34.54	34.53
15	34.45	34.45	34.45	34.45	34.45	34.45	34.45	34.45

Table F-23

Exterior Regulation Schedule	Percent Reduction in Total Equivalent Number of People Impacted by Urban Traffic Noise With No Regulation of Non-Bus Vehicles							
	Percent Reduction in Equivalent Number of People Impacted							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.02	0.03	0.04	0.05	0.05
5	0.00	0.00	0.00	0.00	0.02	0.04	0.05	0.05
6	0.00	0.00	0.02	0.03	0.04	0.04	0.05	0.05
7	0.00	0.00	0.00	0.02	0.04	0.04	0.05	0.05
8	0.00	0.00	0.02	0.03	0.05	0.06	0.13	0.15
9	0.00	0.00	0.00	0.02	0.04	0.05	0.12	0.14
10	0.00	0.00	0.02	0.03	0.05	0.06	0.15	0.17
11	0.00	0.00	0.00	0.02	0.04	0.05	0.14	0.17
12	0.00	0.00	0.02	0.03	0.05	0.04	0.17	0.20
13	0.00	0.00	0.00	0.02	0.04	0.06	0.16	0.19
14	0.00	0.00	0.02	0.03	0.05	0.12	0.18	0.21
15	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44

Table F-24

Exterior Regulation Schedule	Sleep Disturbance ENI Due to Bus Passbys in High Density Urban Areas							
	Sleep Disturbance ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	211.53	211.53	211.53	211.53	211.53	211.53	211.53	211.53
2	209.98	207.34	205.11	203.37	201.80	200.08	196.44	195.44
3	211.53	209.98	207.34	205.11	203.37	201.15	198.75	197.36
4	211.53	207.30	199.63	193.09	187.46	180.45	172.76	162.65
5	211.53	211.53	207.30	199.63	193.09	184.91	175.57	169.90
6	209.98	204.53	197.37	191.04	185.73	179.38	172.16	162.63
7	209.98	207.34	202.28	195.48	190.02	183.01	175.18	171.50
8	209.98	204.53	197.37	187.48	178.78	168.25	149.63	140.08
9	209.98	207.34	202.28	193.68	185.09	173.59	161.17	150.34
10	209.98	204.53	197.37	188.72	178.58	165.91	143.32	131.57
11	209.98	207.34	202.28	193.03	183.27	170.19	154.09	141.16
12	209.98	204.53	197.37	191.04	178.78	163.20	134.95	120.08
13	209.98	207.34	101.18	195.48	183.57	167.66	145.77	129.42
14	209.98	204.53	197.37	187.48	175.53	160.59	132.82	118.79
15	6.36	6.36	6.36	6.36	6.36	6.36	6.36	6.36

Table F-25

Exterior Regulation Schedule	Sleep Disturbance ENI Due to Bus Passbys in Low Density Urban Areas							
	Sleep Disturbance ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	31.85	31.85	31.85	31.85	31.85	31.85	31.85	31.85
2	31.54	31.03	30.58	30.23	29.91	29.56	28.70	28.43
3	31.85	31.54	31.03	30.58	30.23	29.78	29.28	28.98
4	31.85	30.97	29.41	28.13	27.04	25.71	24.16	22.14
5	31.85	31.85	30.97	29.41	28.13	26.55	24.73	23.58
6	31.54	30.43	28.98	27.72	26.69	25.48	24.00	22.13
7	31.54	31.03	29.98	28.60	27.51	26.15	24.53	23.46
8	31.54	30.43	28.98	27.04	25.44	23.55	20.55	19.79
9	31.54	31.03	29.98	28.24	26.58	24.46	22.44	21.38
10	31.54	30.43	28.98	27.28	25.40	23.17	20.10	19.14
11	31.54	31.03	29.98	28.11	26.24	23.88	21.85	20.64
12	31.54	30.43	28.98	27.72	25.44	22.75	19.47	18.17
13	31.54	31.03	29.98	28.60	26.30	23.46	21.19	19.62
14	31.54	30.43	28.98	27.04	24.88	22.36	19.32	18.05
15	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63

Table F-26

Exterior Regulation Schedule	Sleep Disturbance ENI Due to Bus Passbys in Suburban Areas							
	Sleep Disturbance ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
2	2.43	2.41	2.40	2.39	2.38	2.37	2.36	2.35
3	2.44	2.43	2.41	2.40	2.39	2.37	2.36	2.35
4	2.44	2.40	2.32	2.26	2.20	2.14	2.06	2.01
5	2.44	2.44	2.40	2.32	2.26	2.18	2.09	2.03
6	2.43	2.38	2.31	2.25	2.19	2.13	2.05	2.01
7	2.43	2.41	2.37	2.30	2.24	2.17	2.09	2.03
8	2.43	2.38	2.31	2.20	2.11	1.99	1.83	1.72
9	2.43	2.41	2.37	2.28	2.18	2.06	1.90	1.77
10	2.43	2.38	2.31	2.22	2.11	1.96	1.76	1.62
11	2.43	2.41	2.37	2.27	2.16	2.01	1.81	1.66
12	2.43	2.38	2.31	2.25	2.11	1.93	1.66	1.48
13	2.43	2.41	2.37	2.30	2.17	1.98	1.71	1.52
14	2.43	2.38	2.31	2.20	2.07	1.89	1.63	1.46
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table F-27

Exterior Regulation Schedule	Sleep Disturbances ENI Due to Bus Passbys in Rural Areas							
	Sleep Disturbance ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
2	1.17	1.14	1.12	1.10	1.09	1.07	1.00	0.98
3	1.19	1.17	1.14	1.12	1.10	1.08	1.05	1.03
4	1.19	1.17	1.12	1.09	1.06	1.03	0.97	0.63
5	1.19	1.19	1.17	1.12	1.09	1.05	0.99	0.65
6	1.17	1.13	1.10	1.07	1.05	1.01	0.96	0.62
7	1.17	1.14	1.11	1.08	1.05	1.02	0.97	0.63
8	1.17	1.13	1.10	1.07	1.04	0.99	0.63	0.60
9	1.17	1.14	1.11	1.08	1.05	1.00	0.72	0.65
10	1.17	1.13	1.10	1.07	1.03	0.99	0.62	0.60
11	1.17	1.14	1.11	1.08	1.04	1.00	0.68	0.62
12	1.17	1.13	1.10	1.07	1.04	0.98	0.61	0.59
13	1.17	1.14	1.11	1.08	1.05	0.99	0.61	0.59
14	1.17	1.12	1.10	1.07	1.03	0.98	0.62	0.59
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table F-28

Exterior Regulation Schedule	Sleep Disturbance ENI Due to Transit Bus Passbys in All Land Use Areas							
	Sleep Disturbance ENI (Million) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	214.64	214.64	214.64	214.64	214.64	214.64	214.64	214.64
2	213.66	212.11	210.76	209.80	208.84	207.88	206.74	205.98
3	314.64	213.66	212.12	210.76	209.80	208.46	207.12	206.36
4	214.64	210.76	203.72	197.77	192.68	186.28	179.03	174.49
5	214.64	214.64	210.76	203.72	197.77	190.35	181.76	176.41
6	213.66	209.03	202.41	196.49	191.60	185.76	178.69	174.64
7	213.66	212.11	207.69	201.29	196.26	189.72	182.07	177.24
8	213.66	209.03	202.41	192.50	183.84	173.21	159.86	150.31
9	213.66	212.11	207.69	199.25	190.74	179.15	165.10	154.39
10	213.76	209.20	202.54	193.91	183.62	170.62	153.23	141.31
11	213.66	212.11	207.69	198.51	188.70	175.34	157.66	144.83
12	213.66	209.03	202.41	196.49	183.84	167.61	144.41	129.10
13	213.66	212.11	207.69	201.29	189.04	172.53	148.95	132.57
14	213.66	209.03	202.41	192.50	180.22	164.74	142.10	127.71
15	6.57	6.57	6.57	6.57	6.57	6.57	6.57	6.57

Table F-29

Exterior Regulation Schedule	Sleep Disturbance ENI Due to Intercity Bus Passbys in All Land Use Areas							
	Sleep Disturbance ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	32.36	32.36	32.36	32.36	32.36	32.36	32.36	32.36
2	31.46	29.81	28.45	27.29	26.34	25.19	21.75	21.21
3	32.36	31.46	29.81	28.45	27.29	25.92	24.31	23.36
4	32.36	31.07	28.77	26.80	25.08	23.03	20.92	12.93
5	32.36	32.36	31.07	28.77	26.80	24.34	21.62	20.05
6	31.46	29.44	27.35	25.38	23.50	21.41	12.57	11.61
7	31.46	29.81	28.05	26.17	24.57	22.62	20.69	19.15
8	31.46	29.44	27.35	25.30	23.53	21.57	12.78	11.89
9	31.46	29.81	28.05	26.03	24.16	21.95	21.42	20.07
10	31.46	29.44	27.35	25.38	23.50	21.41	12.57	11.61
11	31.46	29.81	28.05	25.98	24.01	21.74	21.09	19.59
12	31.46	29.44	27,35	25.59	23.53	21.24	12.27	11.22
13	31.46	29.81	28.05	26.17	24.04	21.57	20.17	18.92
14	31.46	29.44	27.35	25.30	23.29	21.08	12.28	11.18
15	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42

Table F-30

Exterior Regulation Schedule	Sleep Awakening ENI Due to Bus Passbys in High Density Urban Areas							
	Equivalent Number of Sleep Awakenings (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	26.31	26.31	26.31	26.31	26.31	26.31	26.31	26.31
2	26.08	25.70	25.37	25.13	24.89	24.64	24.16	23.97
3	26.31	26.08	25.70	25.37	25.13	24.80	24.45	24.24
4	26.31	25.53	24.15	23.01	22.07	20.91	19.64	18.59
5	26.31	26.31	25.53	24.15	23.01	21.64	20.09	19.30
6	26.08	25.12	23.83	22.72	21.82	20.76	19.57	18.58
7	26.08	25.70	24.80	23.56	22.61	21.40	20.04	19.26
8	26.08	25.12	23.83	22.05	20.88	19.12	17.12	16.17
9	26.08	25.70	24.80	23.21	21.69	19.76	18.24	17.13
10	26.08	25.12	23.83	22.08	20.54	18.83	16.51	15.28
11	26.08	25.70	24.80	23.08	21.35	19.35	17.53	16.19
12	26.08	25.12	23.83	22.12	20.58	18.51	15.65	13.95
13	26.08	25.70	24.80	25.56	21.41	19.05	16.69	14.88
14	26.08	25.12	23.83	22.05	20.02	18.20	15.42	13.79
15	.00	.00	.00	.00	.00	.00	.00	.00

Table F-31

Exterior Regulation Schedule	Sleep Awakening ENI to Bus Passbys in Low Density Urban Areas							
	Sleep Awakening ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71
2	3.67	3.60	3.54	3.50	3.46	3.41	3.31	3.28
3	3.71	3.67	3.60	3.54	3.50	3.44	3.37	3.34
4	3.71	3.60	3.42	3.26	3.12	2.95	2.75	2.43
5	3.71	3.71	3.60	3.42	3.26	3.05	2.83	2.67
6	3.67	3.53	3.36	3.20	3.07	2.92	2.73	2.43
7	3.67	3.60	3.47	3.31	3.17	3.01	2.80	2.65
8	3.67	3.53	3.36	3.12	2.91	2.64	2.09	1.87
9	3.67	3.60	3.47	3.27	3.06	2.78	2.44	2.19
10	3.67	3.53	3.36	3.15	2.91	2.57	1.95	1.69
11	3.67	3.60	3.47	3.25	3.02	2.70	2.28	1.99
12	3.67	3.53	3.36	3.20	2.91	2.50	1.77	1.45
13	3.67	3.60	3.47	3.31	3.02	2.63	2.10	1.74
14	3.67	3.53	3.36	3.12	2.84	2.42	1.73	1.42
15	.00	.00	.00	.00	.00	.00	.00	.00

Table F-32

Exterior Regulation Schedule	Sleep Awakening ENI Due to Bus Passbys in Suburban Areas							
	Sleep Awakening ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.20	.20	.20	.20	.20	.20	.20	.20
2	.19	.19	.19	.18	.18	.18	.18	.18
3	.20	.19	.19	.19	.18	.19	.18	.18
4	.20	.19	.17	.16	.15	.13	.12	.12
5	.20	.20	.19	.17	.16	.14	.13	.12
6	.19	.18	.17	.15	.14	.13	.12	.12
7	.19	.19	.18	.16	.15	.14	.13	.12
8	.19	.18	.17	.15	.13	.12	.10	.10
9	.19	.19	.18	.16	.14	.12	.11	.11
10	.19	.18	.17	.15	.13	.11	.10	.09
11	.19	.19	.18	.16	.14	.12	.10	.09
12	.19	.18	.17	.15	.13	.11	.09	.07
13	.19	.19	.18	.16	.14	.12	.09	.08
14	.19	.18	.17	.15	.12	.11	.09	.07
15	.00	.00	.00	.00	.00	.00	.00	.00

Table F-33

Exterior Regulation Schedule	Sleep Awakening ENI Due to Bus Passbys in Rural Areas							
	Sleep Awakening ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	.17	.17	.17	.17	.17	.17	.17	.17
2	.17	.16	.15	.15	.14	.14	.12	.11
3	.17	.17	.16	.15	.15	.14	.13	.13
4	.17	.16	.15	.14	.14	.13	.11	.11
5	.17	.17	.16	.15	.14	.13	.12	.11
6	.17	.16	.15	.14	.13	.12	.11	.11
7	.17	.16	.15	.14	.13	.12	.11	.11
8	.17	.16	.15	.14	.13	.12	.06	.06
9	.17	.16	.15	.14	.13	.12	.06	.06
10	.17	.16	.15	.14	.13	.12	.06	.05
11	.17	.16	.15	.14	.13	.12	.06	.05
12	.17	.16	.15	.14	.13	.11	.06	.05
13	.17	.16	.15	.14	.13	.12	.06	.05
14	.17	.16	.15	.14	.13	.11	.06	.05
15	.00	.00	.00	.00	.00	.00	.00	.00

Table F-34

Exterior Regulation Schedule	Sleep Awakening ENI Due to Transit Bus Passbys in All Land Use Areas							
	Sleep Awakening ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	26.85	26.85	26.85	26.85	26.85	26.85	26.85	26.85
2	26.65	26.33	26.06	25.86	25.67	25.48	25.25	25.10
3	26.85	26.65	26.33	26.06	25.86	25.59	25.33	25.18
4	26.85	26.06	24.66	23.52	22.59	21.45	20.24	19.68
5	26.85	26.85	26.06	24.66	23.52	22.17	20.67	19.92
6	26.65	25.71	24.41	23.29	22.39	21.36	20.19	19.63
7	26.65	26.33	25.44	24.19	23.24	22.05	20.61	19.88
8	26.65	25.71	24.41	22.55	21.02	19.51	17.88	16.82
9	26.65	26.33	25.44	23.80	22.23	20.25	18.48	17.28
10	26.65	25.71	24.41	22.81	20.98	19.18	17.15	15.77
11	26.65	26.33	25.44	23.66	21.87	19.78	17.64	16.19
12	26.65	25.71	24.41	23.29	21.02	18.80	16.14	14.25
13	26.65	26.33	25.44	24.19	21.93	19.42	16.67	14.70
14	26.65	25.71	24.41	22.55	20.41	18.43	15.87	14.07
15	.00	.00	.00	.00	.00	.00	.00	.00

Table F-35

Exterior Regulation Schedule	Sleep Awakening ENI Due to Intercity Bus Passbys in All Land Use Areas							
	Sleep Awakening ENI (Millions) Per Night							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	3.54	3.54	3.54	3.54	3.54	3.54	3.54	3.54
2	3.46	3.32	3.20	3.09	3.00	2.89	2.51	2.43
3	3.54	3.46	3.32	3.20	3.09	2.96	2.80	2.70
4	3.54	3.45	3.23	3.04	2.88	2.67	2.39	1.52
5	3.54	3.54	3.43	3.23	3.04	2.80	2.49	1.78
6	3.46	3.29	3.10	2.93	2.78	2.58	2.34	1.49
7	3.46	3.32	3.16	2.98	2.83	2.62	2.36	1.71
8	3.46	3.29	3.10	2.90	2.72	2.48	1.50	1.37
9	3.46	3.32	3.16	2.97	2.79	2.54	1.56	1.43
10	3.46	3.29	3.10	2.91	2.72	2.46	1.47	1.33
11	3.46	3.32	3.16	2.91	2.77	2.51	1.52	1.38
12	3.46	3.29	3.10	2.93	2.72	2.44	1.43	1.27
13	3.46	3.32	3.16	2.98	2.78	2.48	1.47	1.29
14	3.46	3.29	3.10	2.90	2.70	2.41	1.43	1.27
15	.00	.00	.00	.00	.00	.00	.00	.00

Table F-36

Exterior Regulation Schedule	Speech Interference ENI Due to Transit Bus Passbys for Pedestrians, People Indoors and People Outdoors							
	Speech Interference ENI (Millions) Per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94
2	13.84	13.68	13.54	13.44	13.34	13.24	13.12	13.05
3	13.94	13.84	13.68	13.54	13.44	13.30	13.16	13.08
4	13.94	13.54	12.80	10.97	10.36	9.83	9.37	9.07
5	13.94	13.94	13.54	12.80	10.97	10.10	9.54	9.20
6	13.84	13.36	12.67	10.81	10.23	9.80	9.34	9.06
7	13.84	13.68	13.22	12.56	10.78	10.06	9.53	9.19
8	13.84	13.36	12.67	10.34	9.68	8.98	8.07	7.49
9	13.84	13.68	13.22	11.14	10.12	9.37	8.45	7.74
10	13.84	13.36	12.67	10.51	9.66	8.81	7.67	6.92
11	13.84	13.68	13.22	11.06	9.99	9.12	7.94	7.15
12	13.84	13.36	12.67	10.81	9.68	8.61	7.12	6.07
13	13.84	13.68	13.22	12.56	10.01	8.93	7.41	6.32
14	13.84	13.36	12.67	10.34	9.44	8.43	6.98	5.99
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table F-37

Exterior Regulation Schedule	Speech Interferences Due to Intercity Bus Passbys for Pedestrians, People Indoors and People Outdoors							
	Speech Interference ENI (Millions) Per Day							
	Calendar Year							
	1979	1981	1983	1985	1987	1990	1995	2000
1	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
2	0.64	0.62	0.60	0.57	0.55	0.52	0.45	0.44
3	0.66	0.64	0.62	0.60	0.57	0.54	0.50	0.48
4	0.66	0.64	0.60	0.56	0.51	0.48	0.44	0.25
5	0.66	0.66	0.64	0.60	0.56	0.50	0.45	0.40
6	0.64	0.61	0.57	0.52	0.50	0.47	0.42	0.25
7	0.64	0.62	0.58	0.55	0.50	0.47	0.42	0.39
7	0.64	0.61	0.57	0.52	0.49	0.45	0.25	0.22
8	0.64	0.62	0.58	0.54	0.50	0.46	0.26	0.24
10	0.64	0.61	0.57	0.52	0.49	0.45	0.25	0.21
11	0.64	0.62	0.58	0.54	0.50	0.46	0.25	0.23
12	0.64	0.61	0.57	0.52	0.49	0.44	0.23	0.20
13	0.64	0.62	0.58	0.55	0.50	0.45	0.24	0.21
14	0.64	0.61	0.57	0.52	0.48	0.44	0.23	0.20
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table F-38

Exterior Regulation Schedule	Speech Interference ENI Due to School Bus Passbys for Pedestrians, People Indoors and People Outdoors							
	Speech Interference ENI (Millions) Per Day							
	Calendar Year							
	1979	1981	1988	1985	1987	1990	1995	2000
1	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
2	0.94	0.93	0.91	0.91	0.91	0.90	0.89	0.87
3	0.96	0.94	0.93	0.91	0.91	0.90	0.89	0.88
4	0.96	0.92	0.87	0.83	0.79	0.76	0.70	0.68
5	0.96	0.96	0.92	0.87	0.83	0.79	0.71	0.70
6	0.94	0.91	0.86	0.82	0.79	0.75	0.70	0.67
7	0.94	0.93	0.90	0.86	0.82	0.77	0.72	0.69
8	0.94	0.91	0.86	0.79	0.74	0.67	0.60	0.55
9	0.94	0.93	0.90	0.84	0.79	0.71	0.63	0.58
10	0.94	0.91	0.86	0.81	0.74	0.66	0.58	0.52
11	0.94	0.93	0.90	0.84	0.77	0.68	0.60	0.54
12	0.94	0.91	0.86	0.88	0.74	0.64	0.53	0.44
13	0.94	0.93	0.90	0.86	0.77	0.67	0.56	0.48
14	0.94	0.91	0.86	0.79	0.72	0.61	0.48	0.41
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE F-39

Bus Type	Contributions of Different Types of Buses to the Reduction of Hearing Loss and Speech Interference Impacts		
	Impact Reduction %		
	Speech Interference	Hearing Loss (Operator)	Hearing Loss (Passengers)
Inter-City	1	1	1
Transit	63	24	63
School	36	75	36

FIGURE F-1

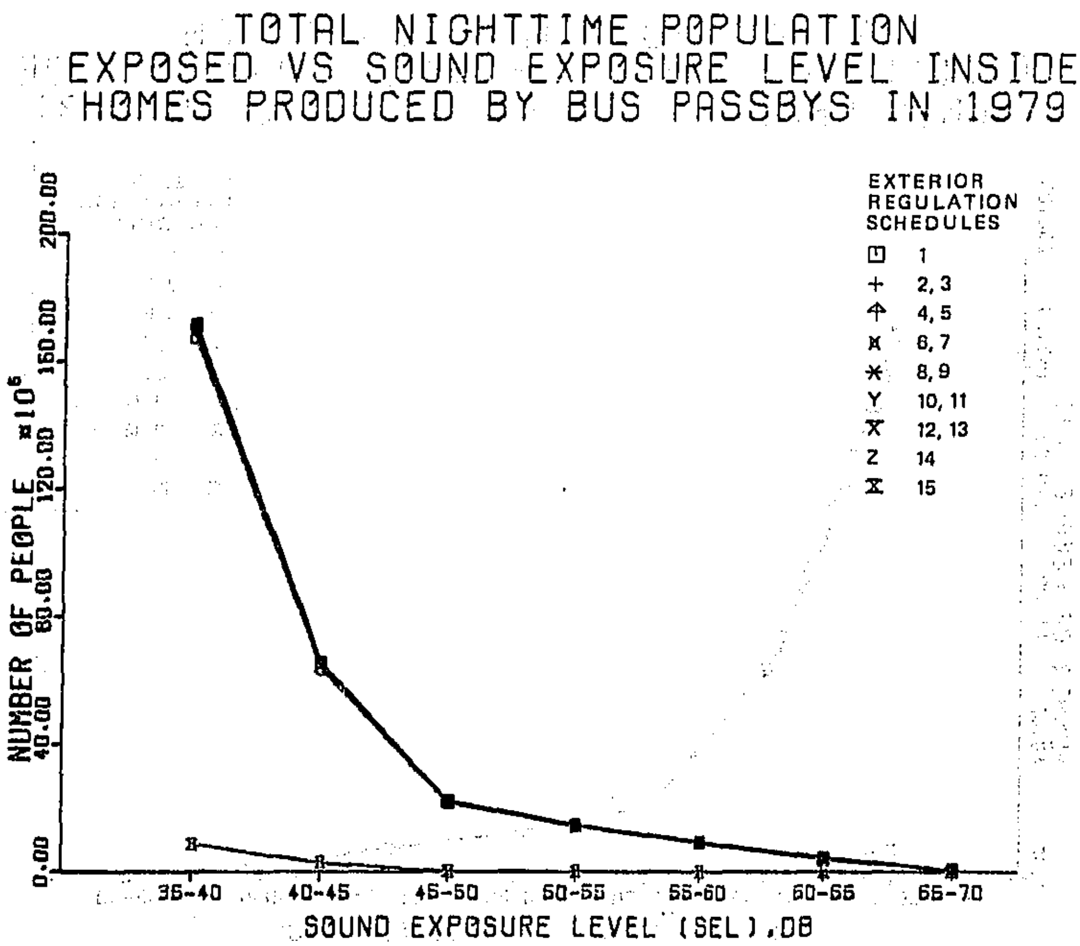

TOTAL NIGHTTIME POPULATION
EXPOSED VS SOUND EXPOSURE LEVEL INSIDE
HOMES PRODUCED BY BUS PASSBYS IN 1979
EXTERIOR
REGULATION
SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15
NUMBER OF PEOPLE ×10⁶
0.00
40.00
80.00
120.00
160.00
200.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
SOUND EXPOSURE LEVEL (SEL), DB

FIGURE F-2

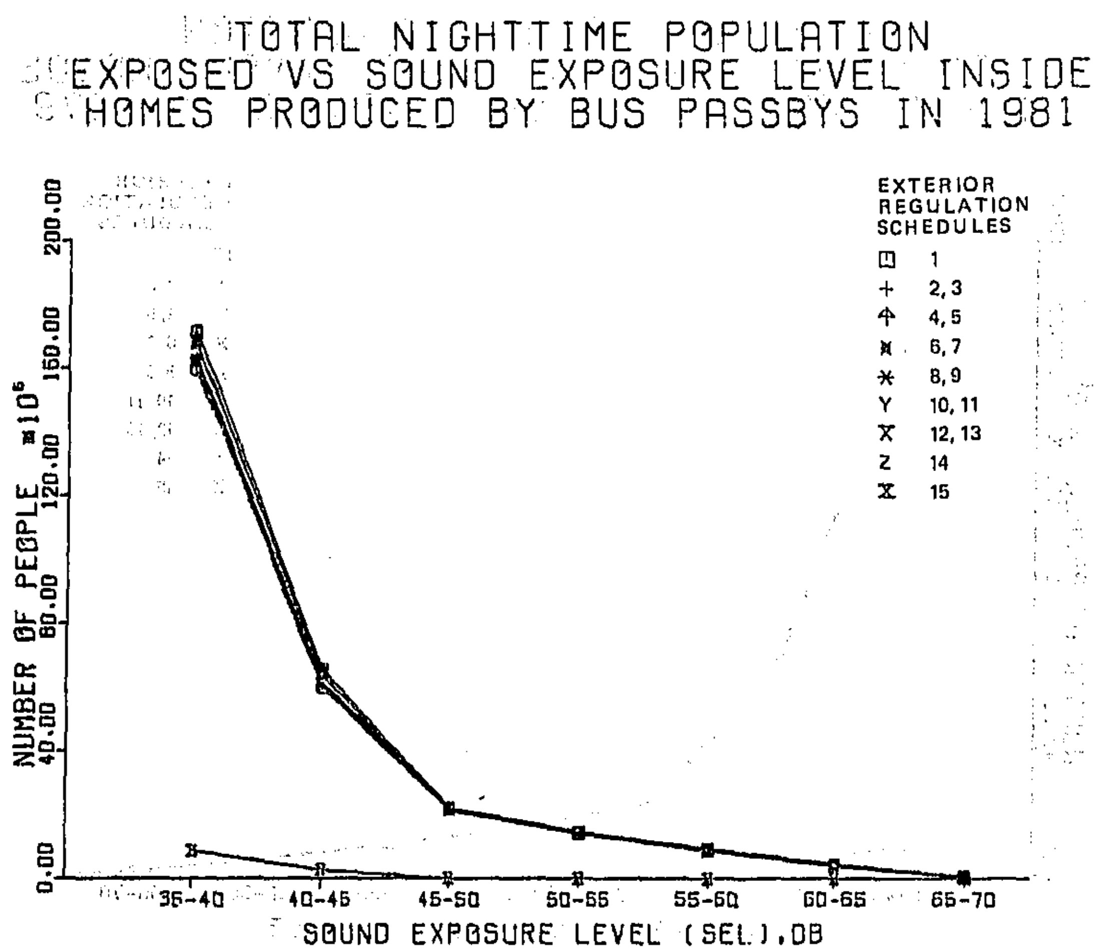

TOTAL NIGHTTIME POPULATION
EXPOSED VS SOUND EXPOSURE LEVEL INSIDE
HOMES PRODUCED BY BUS PASSBYS IN 1981
NUMBER OF PEOPLE x10^6
200.00
160.00
120.00
80.00
40.00
0.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
SOUND EXPOSURE LEVEL (SEL),DB
EXTERIOR
REGULATION
SCHEDULES
1
2,3
4,5
6,7
8,9
10,11
12,13
14
15

FIGURE F-3

TOTAL NIGHTTIME POPULATION EXPOSED VS SOUND EXPOSURE LEVEL INSIDE HOMES PRODUCED BY BUS PASSBYS IN 1983

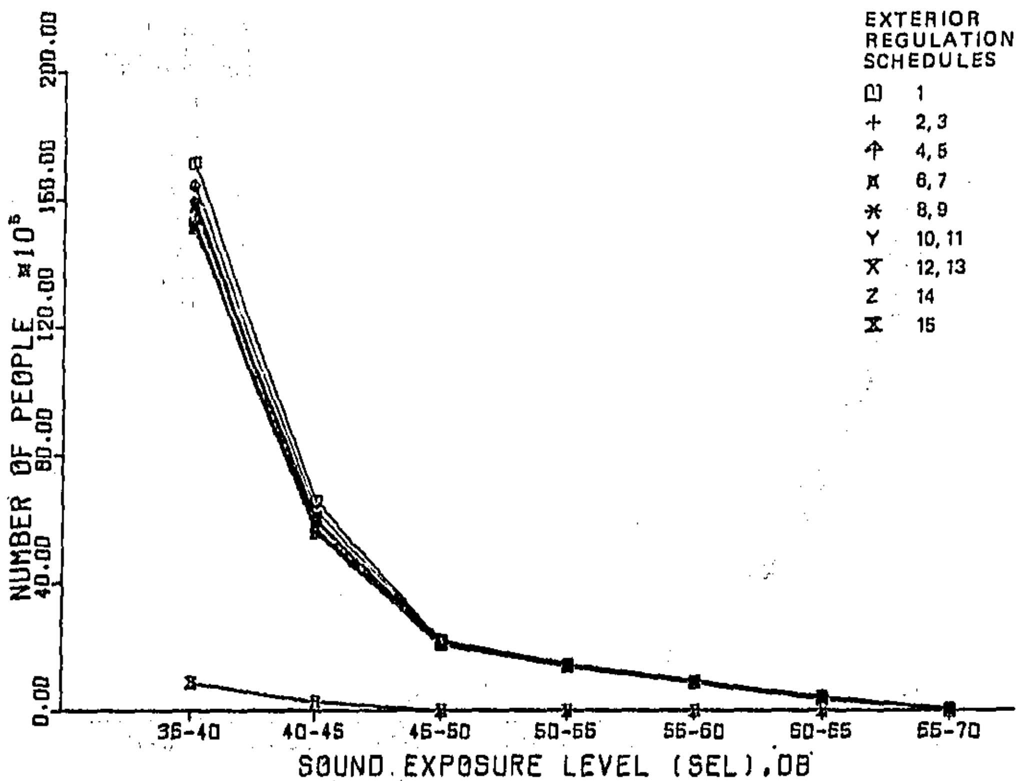


FIGURE F-4

TOTAL NIGHTTIME POPULATION EXPOSED VS SOUND EXPOSURE LEVEL INSIDE HOMES PRODUCED BY BUS PASSBYS IN 1985

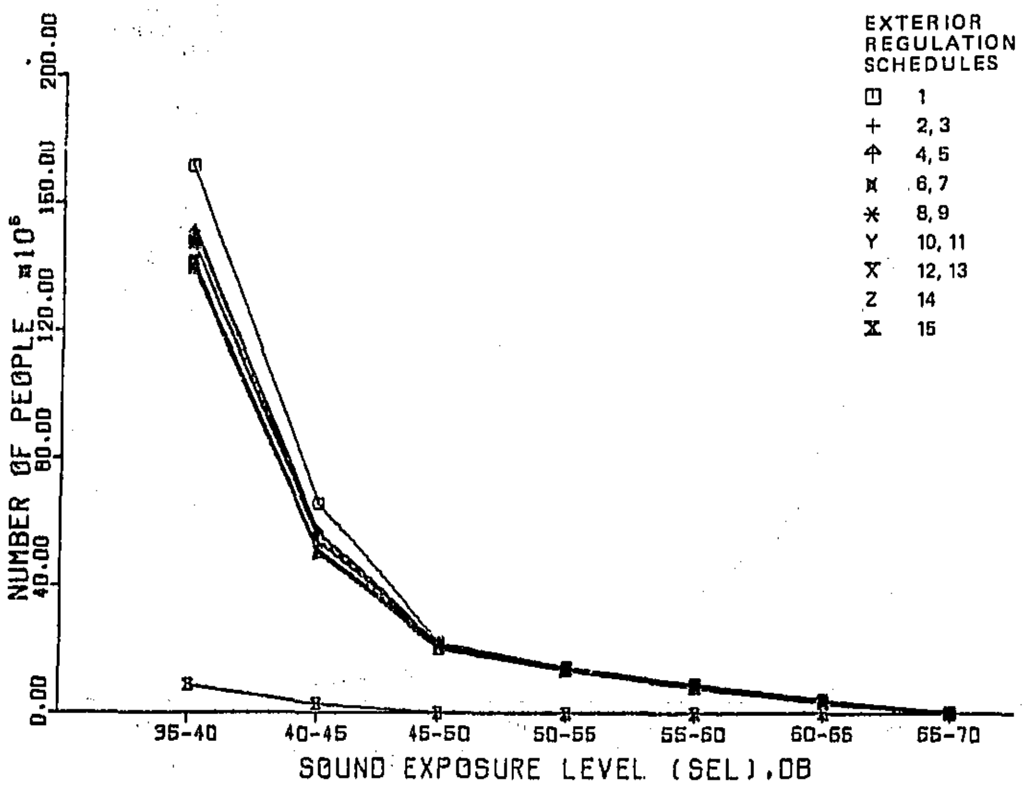


FIGURE F-5

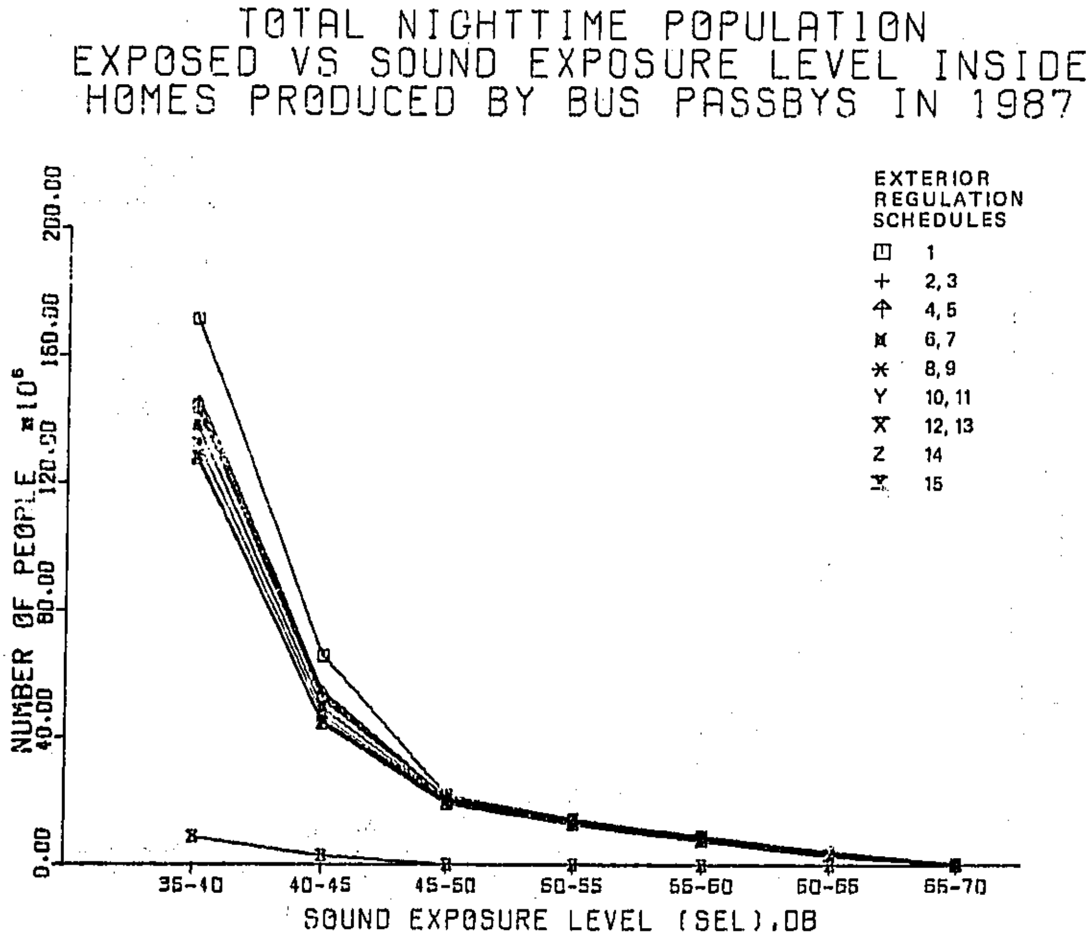

TOTAL NIGHTTIME POPULATION
EXPOSED VS SOUND EXPOSURE LEVEL INSIDE
HOMES PRODUCED BY BUS PASSBYS IN 1987
EXTERIOR
REGULATION
SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15
NUMBER OF PEOPLE x10^6
0.00
40.00
80.00
120.00
160.00
200.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
SOUND EXPOSURE LEVEL (SEL), DB

FIGURE F-6

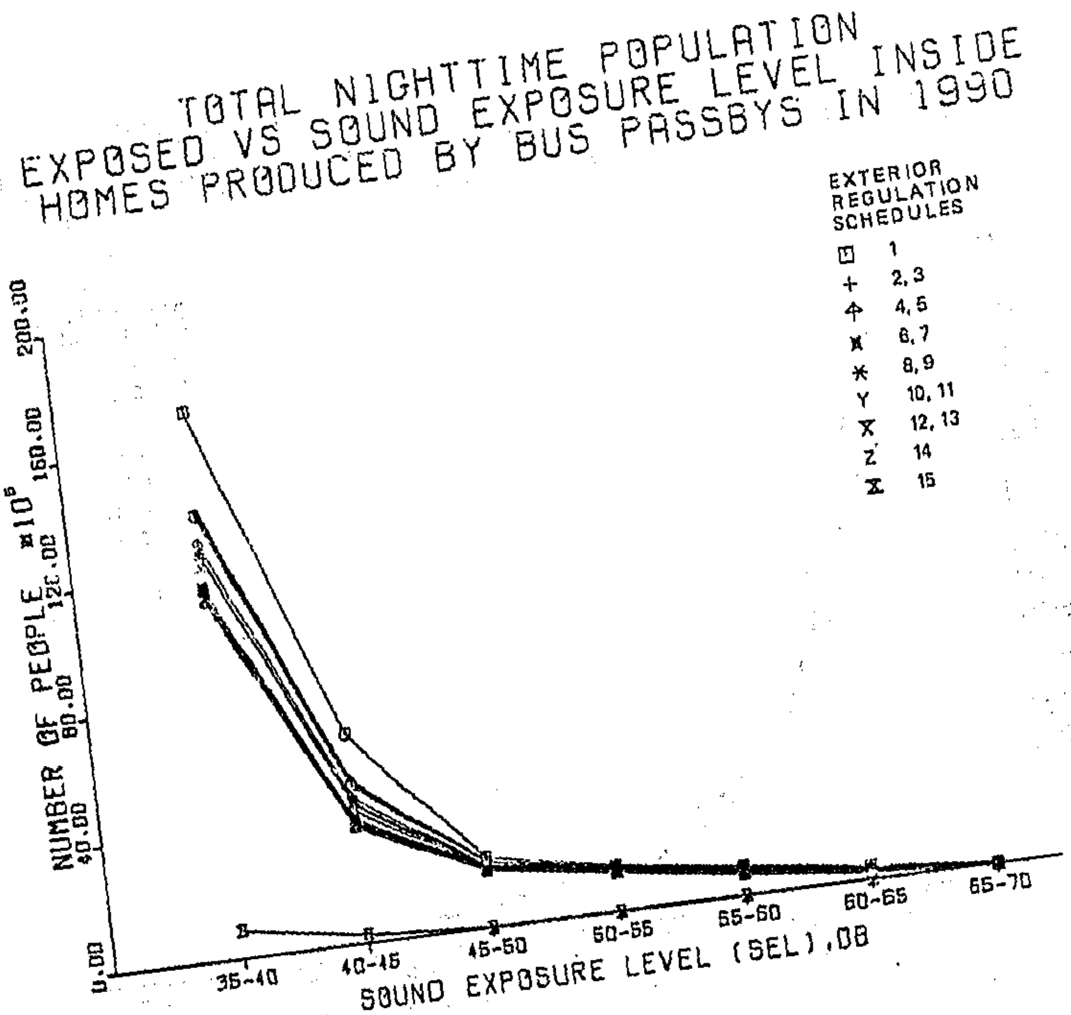

TOTAL NIGHTTIME POPULATION
EXPOSED VS SOUND EXPOSURE LEVEL INSIDE
HOMES PRODUCED BY BUS PASSBYS IN 1990
EXTERIOR
REGULATION
SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15
NUMBER OF PEOPLE ×10
0.00
40.00
80.00
120.00
160.00
200.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
SOUND EXPOSURE LEVEL (SEL),DB

FIGURE F-7

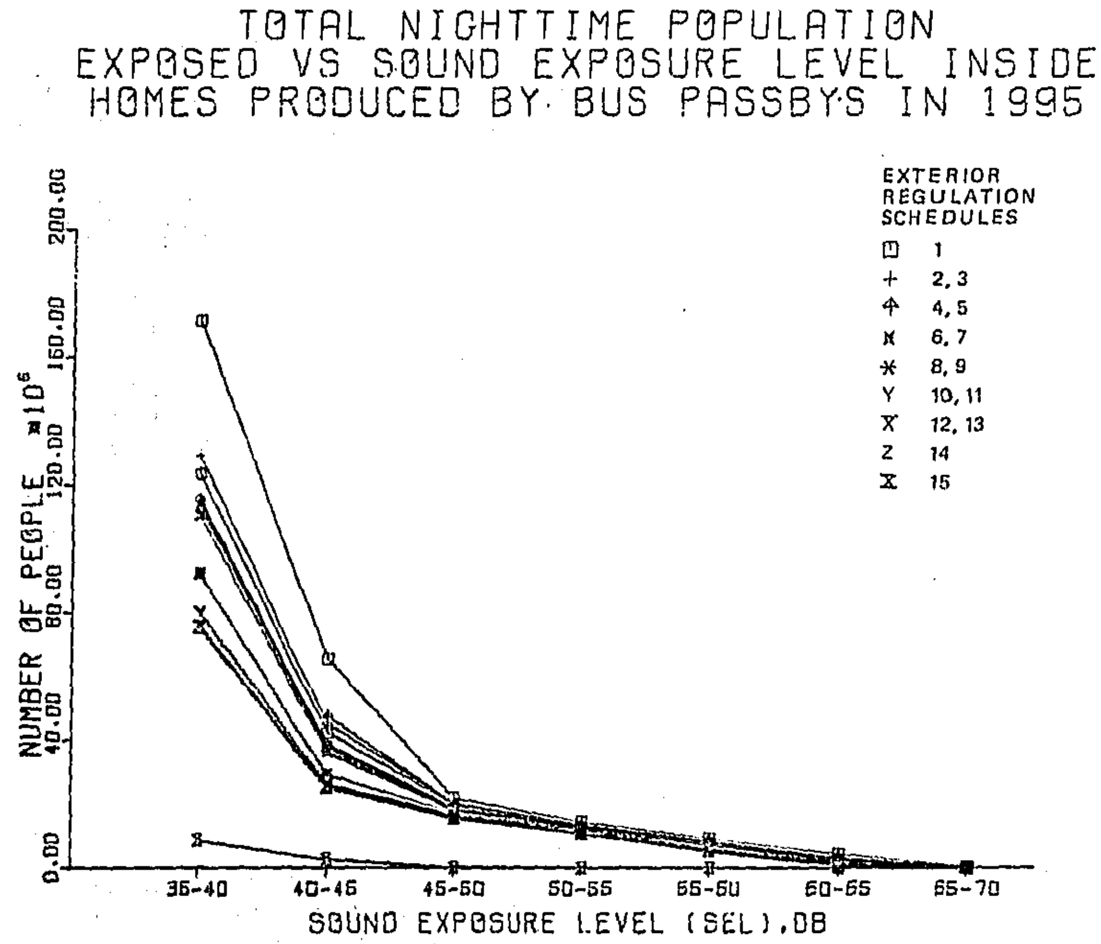

TOTAL NIGHTTIME POPULATION EXPOSED VS SOUND EXPOSURE LEVEL INSIDE HOMES PRODUCED BY BUS PASSBYS IN 1995
EXTERIOR REGULATION SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15
NUMBER OF PEOPLE ×10⁶
0.00
40.00
80.00
120.00
160.00
200.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
SOUND EXPOSURE LEVEL (SEL),DB

FIGURE F-8

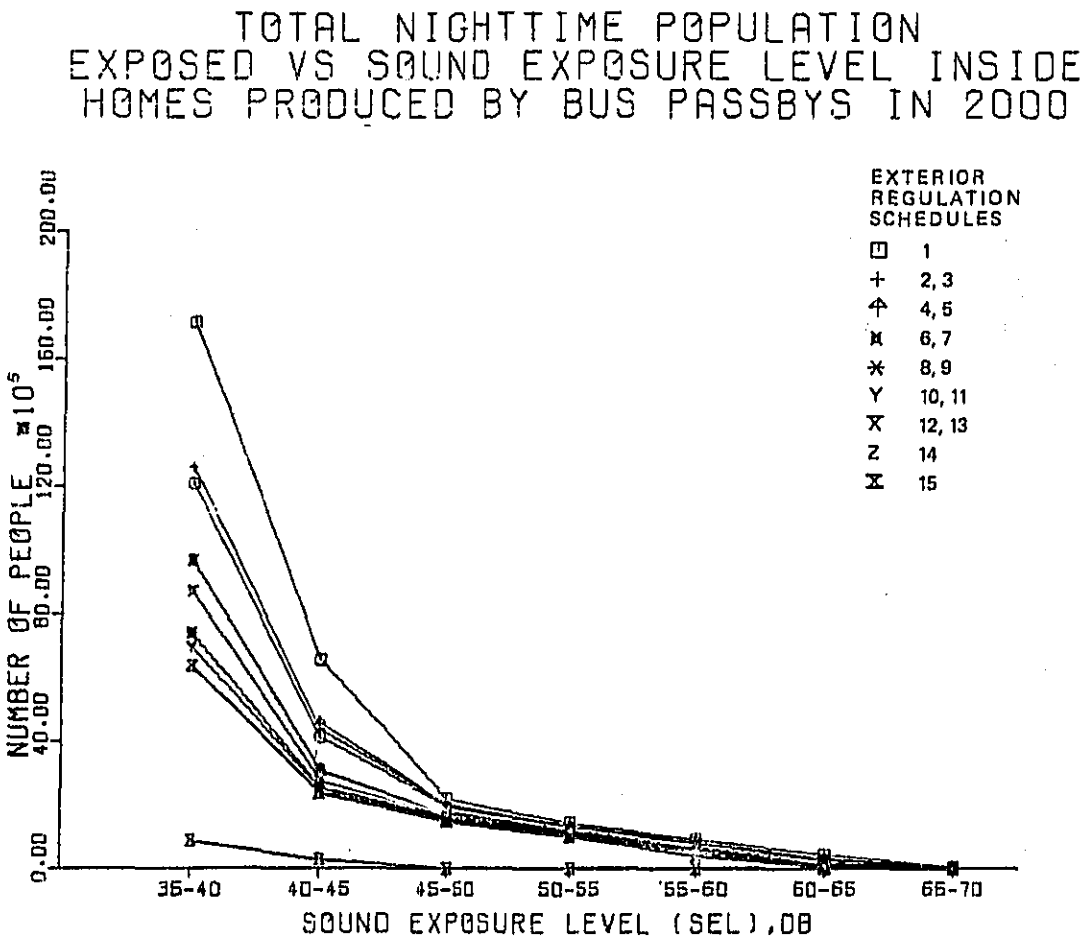

TOTAL NIGHTTIME POPULATION
EXPOSED VS SOUND EXPOSURE LEVEL INSIDE
HOMES PRODUCED BY BUS PASSBYS IN 2000
NUMBER OF PEOPLE ×10⁵
0.00
40.00
80.00
120.00
160.00
200.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
SOUND EXPOSURE LEVEL (SEL),DB
EXTERIOR REGULATION SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15

FIGURE F-9

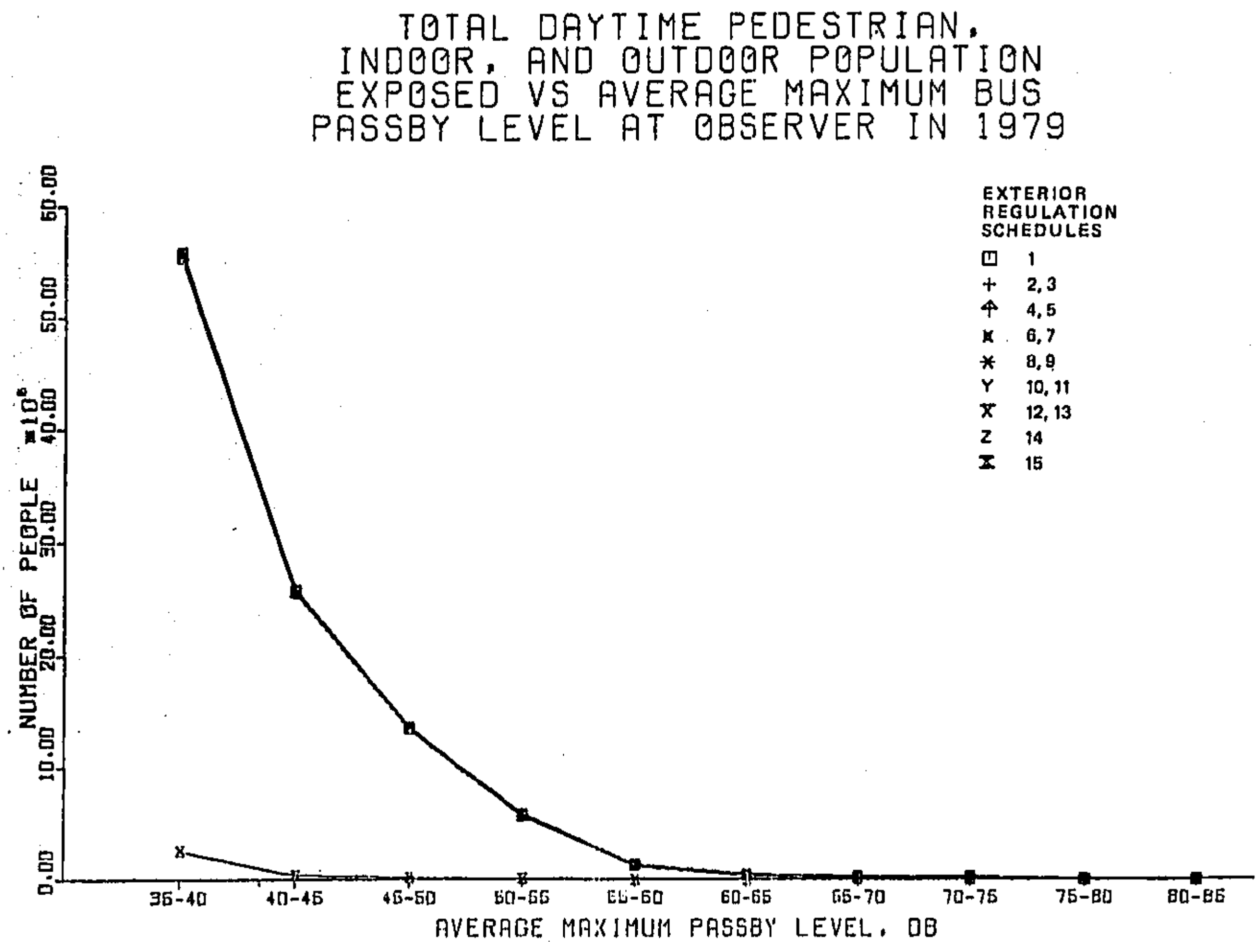
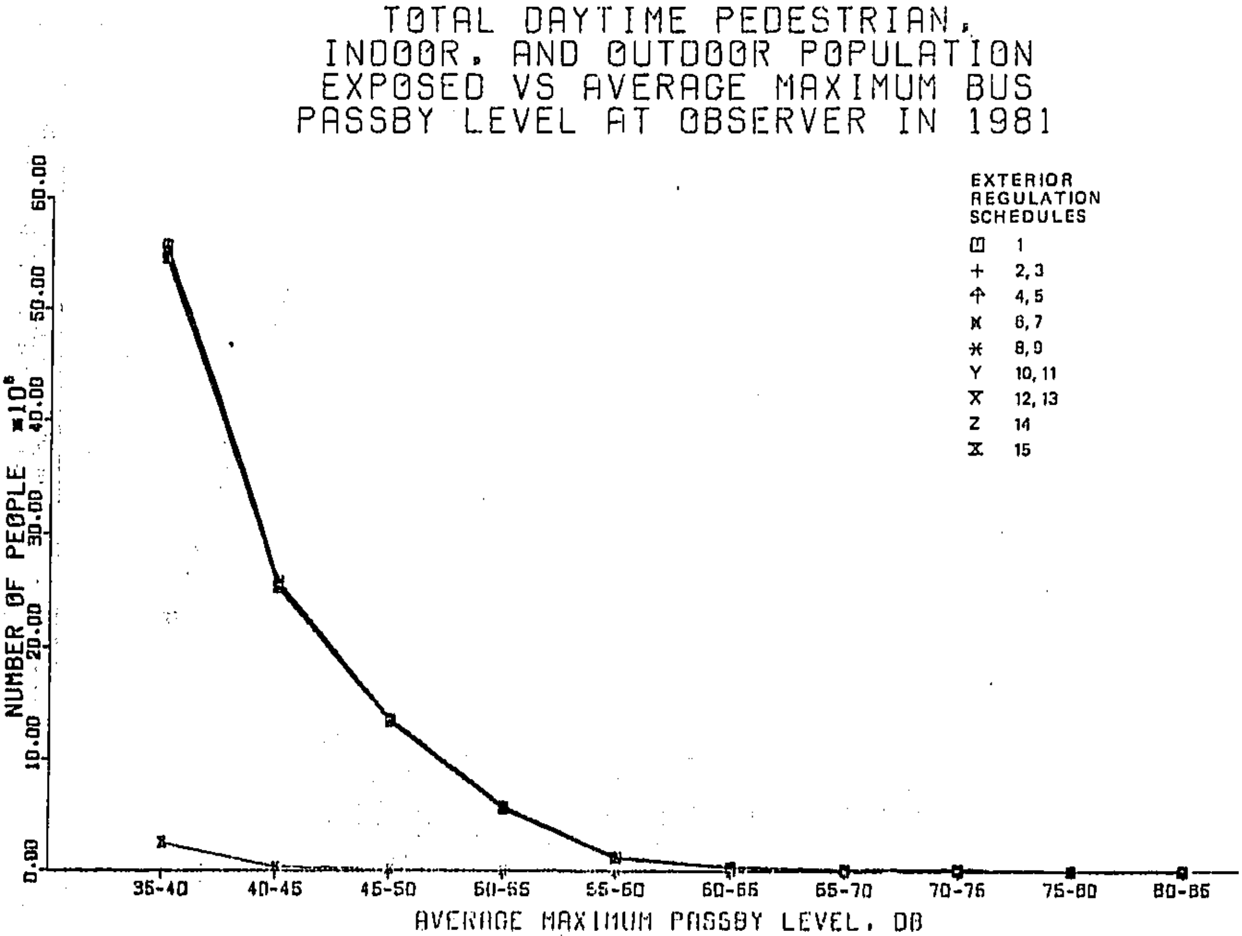

TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1979
NUMBER OF PEOPLE ×10⁶
0.00
10.00
20.00
30.00
40.00
50.00
60.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
AVERAGE MAXIMUM PASSBY LEVEL, DB
EXTERIOR REGULATION SCHEDULES
1
2,3
4,5
6,7
8,9
10,11
12,13
14
15

FIGURE F-10



TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1981
NUMBER OF PEOPLE ×10⁶
0.00
10.00
20.00
30.00
40.00
50.00
60.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
AVERAGE MAXIMUM PASSBY LEVEL, DB
EXTERIOR REGULATION SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15

FIGURE F-11

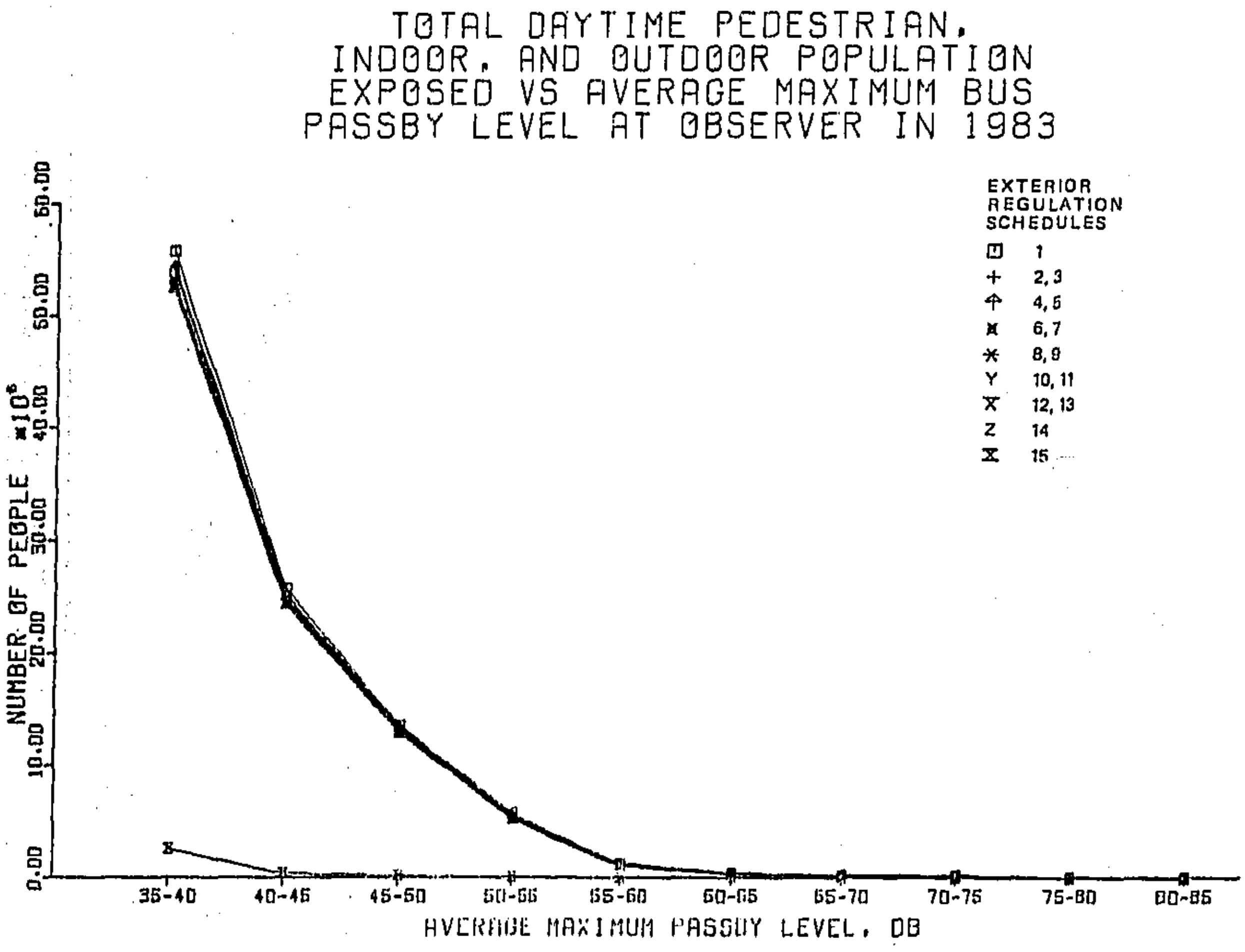
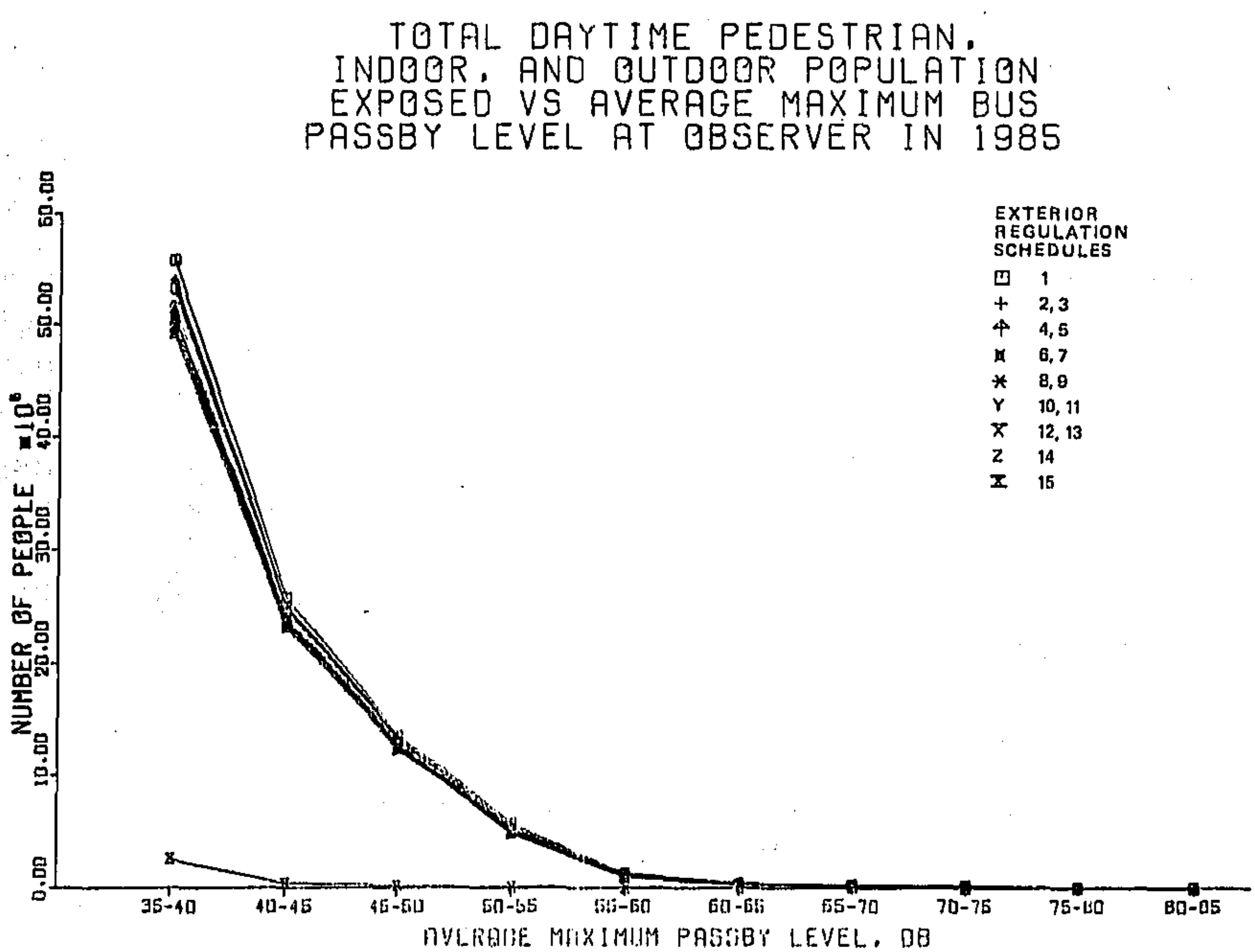

TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1983
NUMBER OF PEOPLE ×10⁶
0.00
10.00
20.00
30.00
40.00
50.00
60.00
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
AVERAGE MAXIMUM PASSBY LEVEL, DB
EXTERIOR REGULATION SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15

FIGURE F-12



TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1985
NUMBER OF PEOPLE x10⁶
0.00
10.00
20.00
30.00
40.00
50.00
60.00
EXTERIOR REGULATION SCHEDULES
1
2, 3
4, 5
6, 7
8, 9
10, 11
12, 13
14
15
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
AVERAGE MAXIMUM PASSBY LEVEL, DB

FIGURE F-13

TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1987

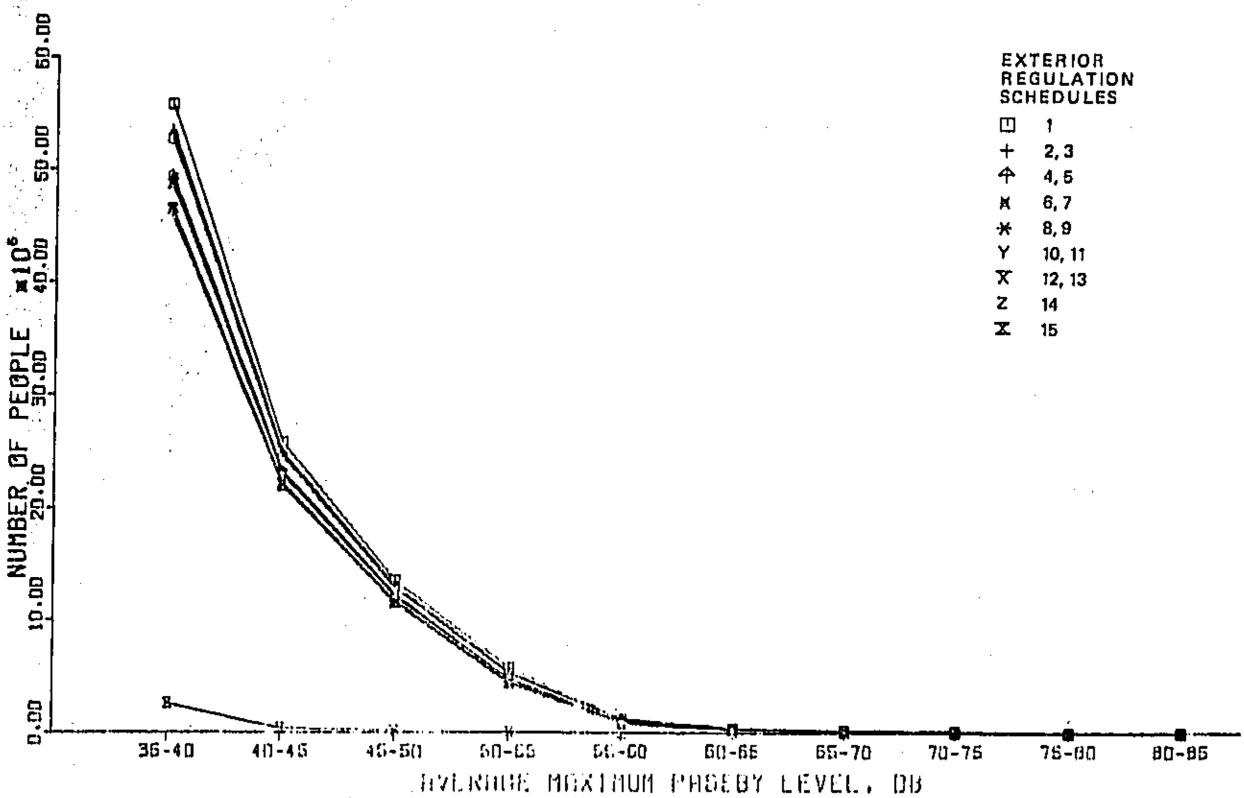


FIGURE F-14

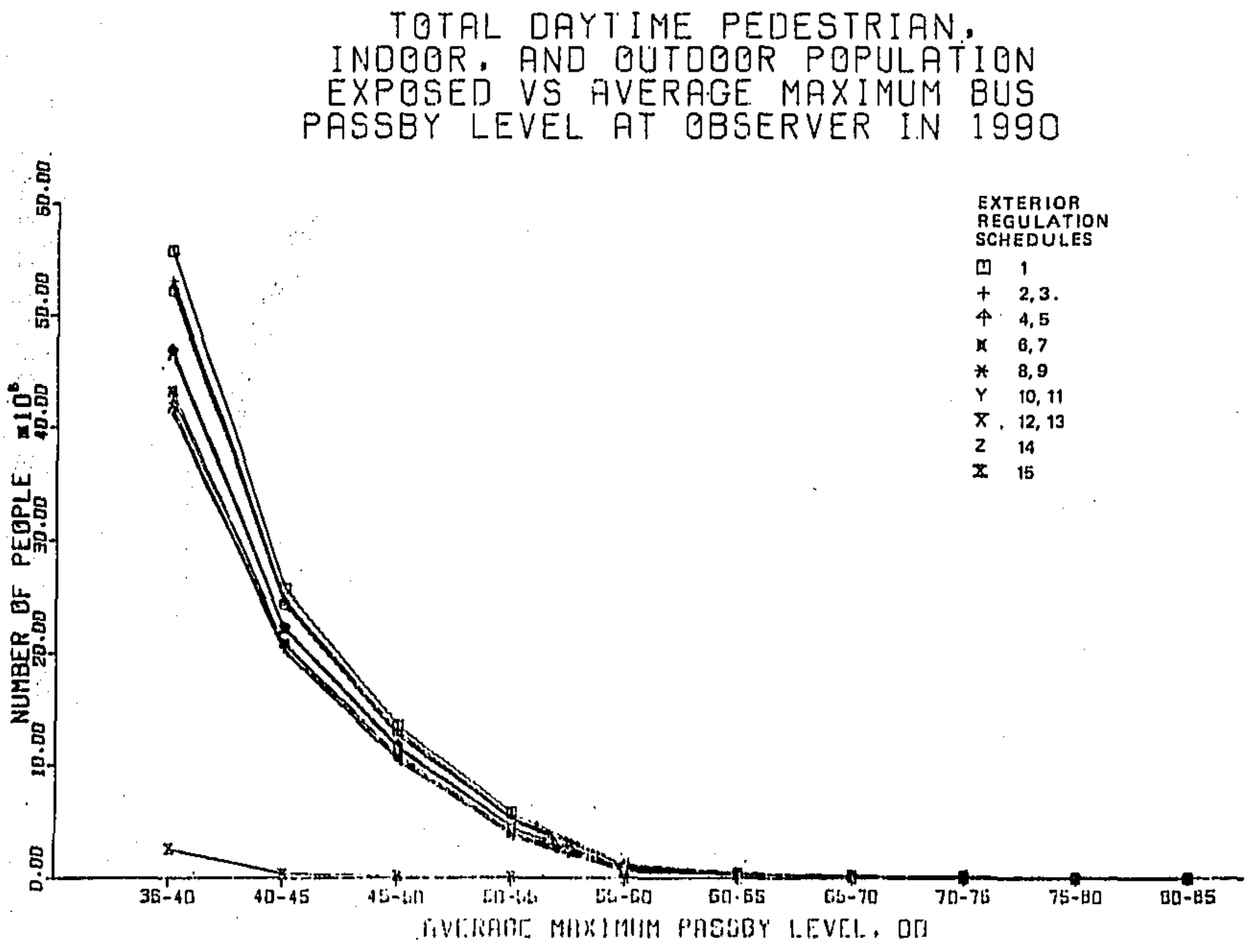

TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1990
EXTERIOR REGULATION SCHEDULES
1
2, 3.
4, 5
6, 7
8, 9
10, 11
12, 13
14
15
NUMBER OF PEOPLE ×10^6
0.00
10.00
20.00
30.00
40.00
50.00
60.00
35-40
40-45
70-75
75-80
80-85
AVERAGE MAXIMUM PASSBY LEVEL, DB

FIGURE F-15

TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 1995

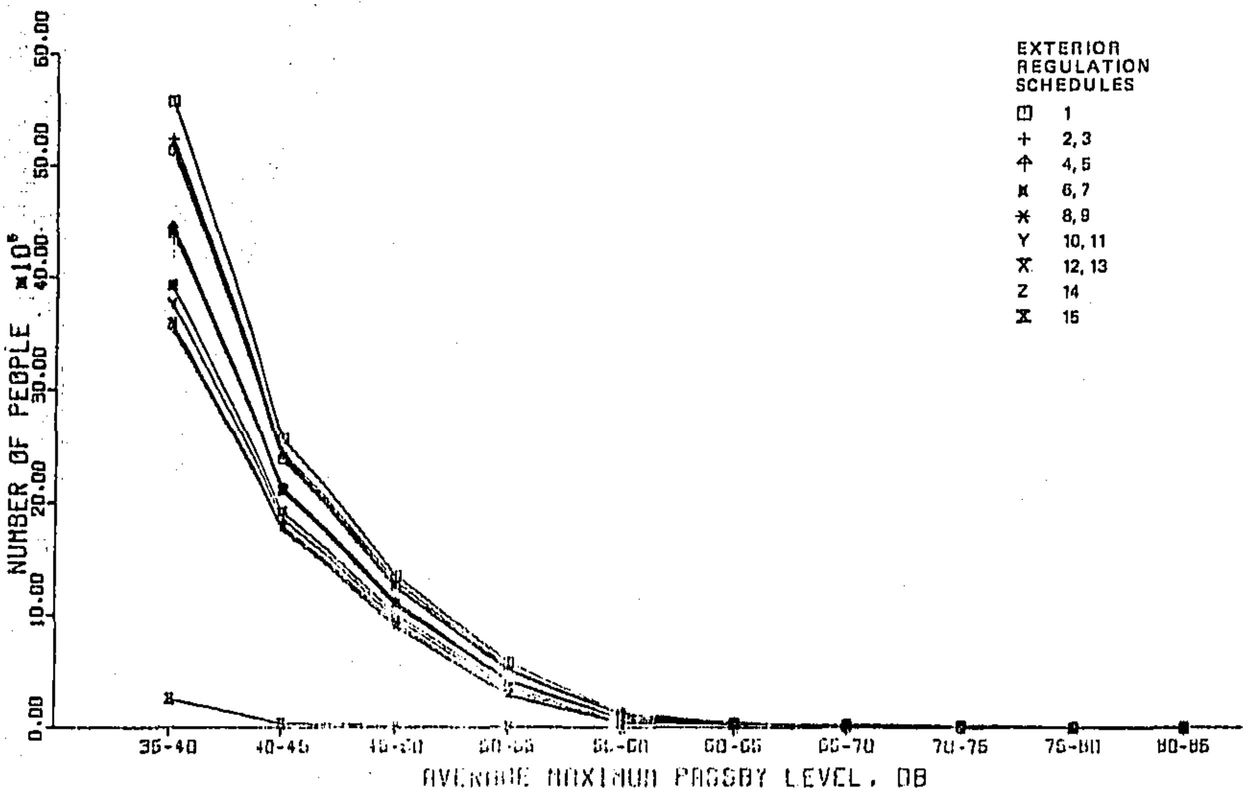


FIGURE F-16

TOTAL DAYTIME PEDESTRIAN, INDOOR, AND OUTDOOR POPULATION EXPOSED VS AVERAGE MAXIMUM BUS PASSBY LEVEL AT OBSERVER IN 2000

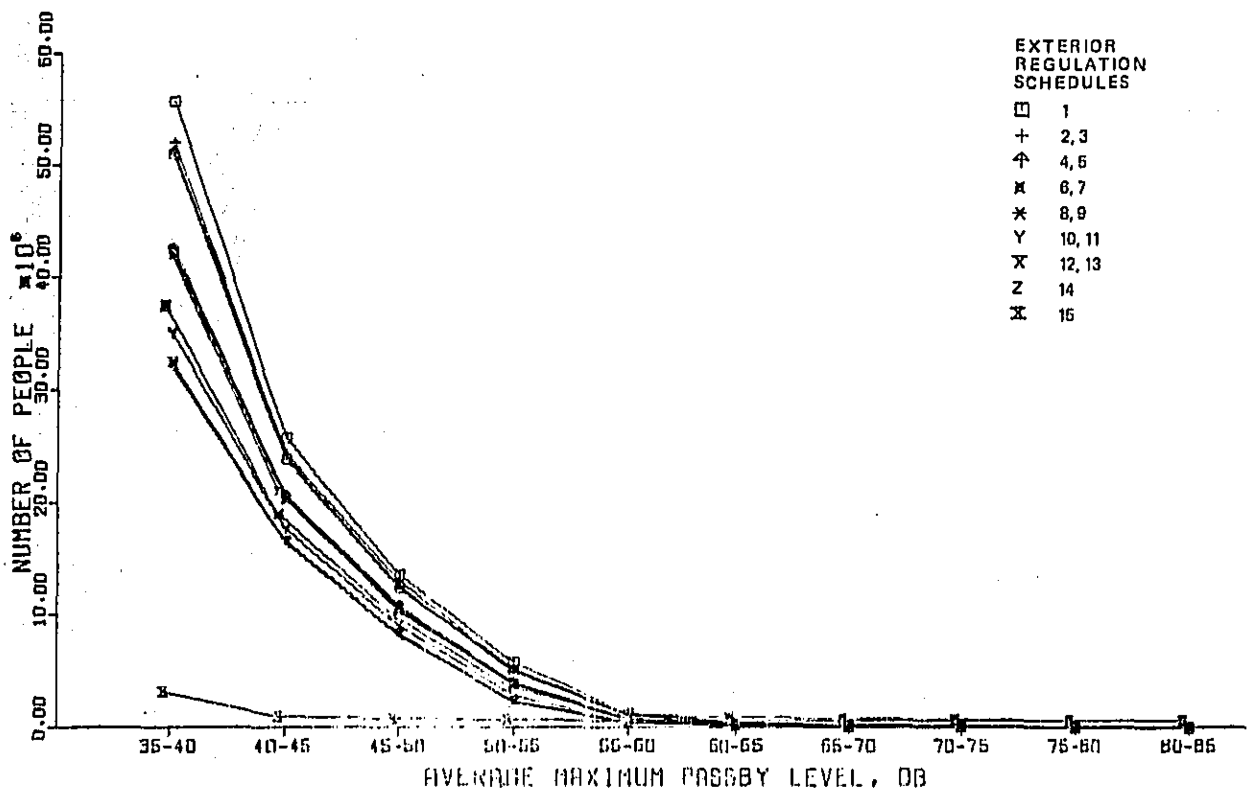


FIGURE F-17

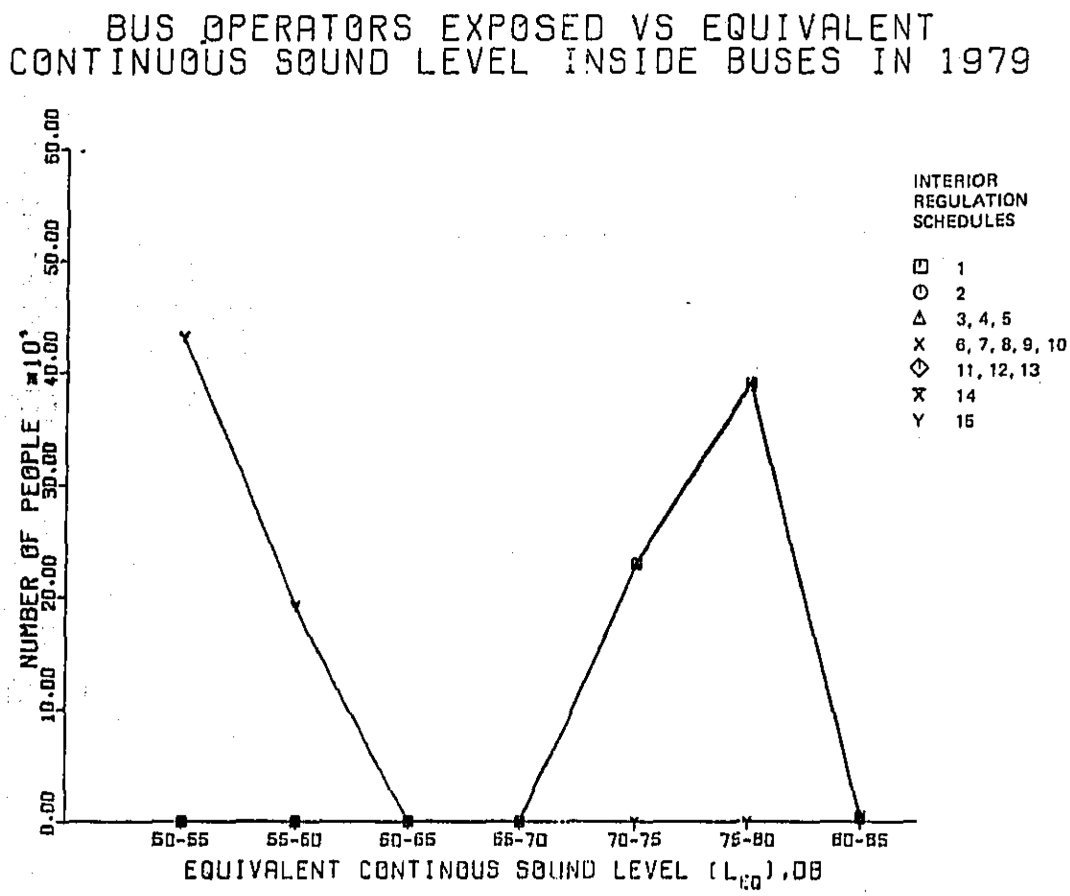

BUS OPERATORS EXPOSED VS EQUIVALENT
CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1979
NUMBER OF PEOPLE ×10¹
0.00
10.00
20.00
30.00
40.00
50.00
60.00
50-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINOUS SOUND LEVEL (LEQ),DB
INTERIOR
REGULATION
SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
15

FIGURE F-18

BUS OPERATORS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1981

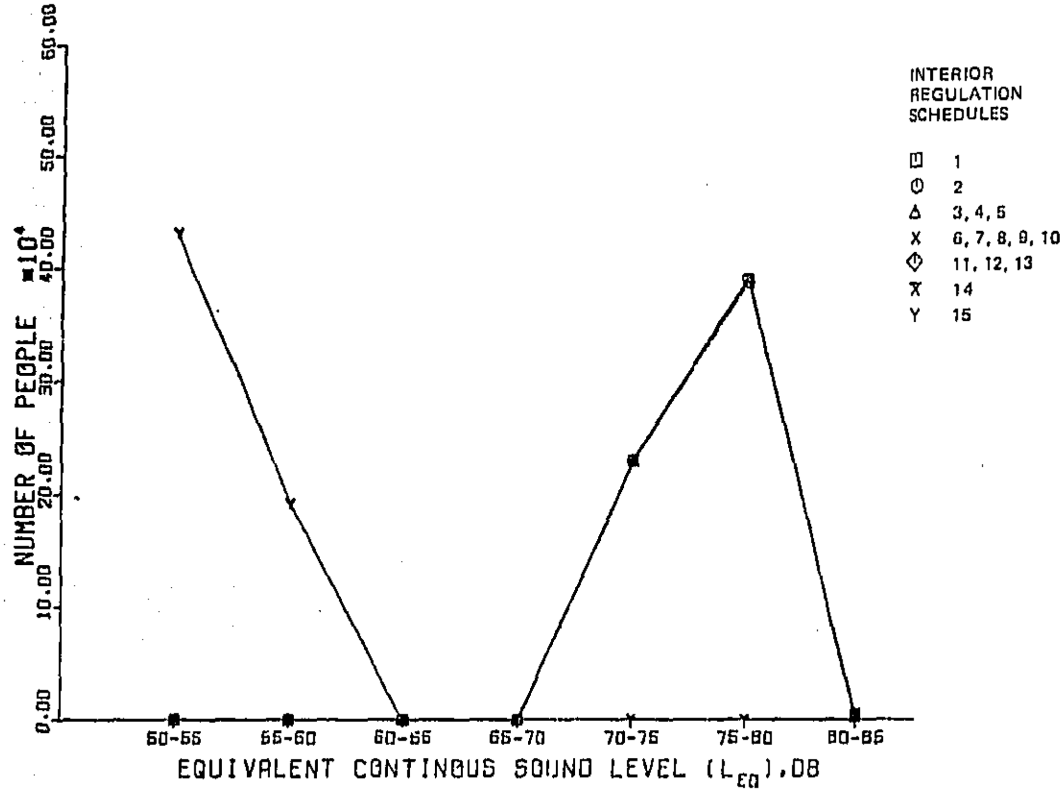


FIGURE F-19

BUS OPERATORS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1983

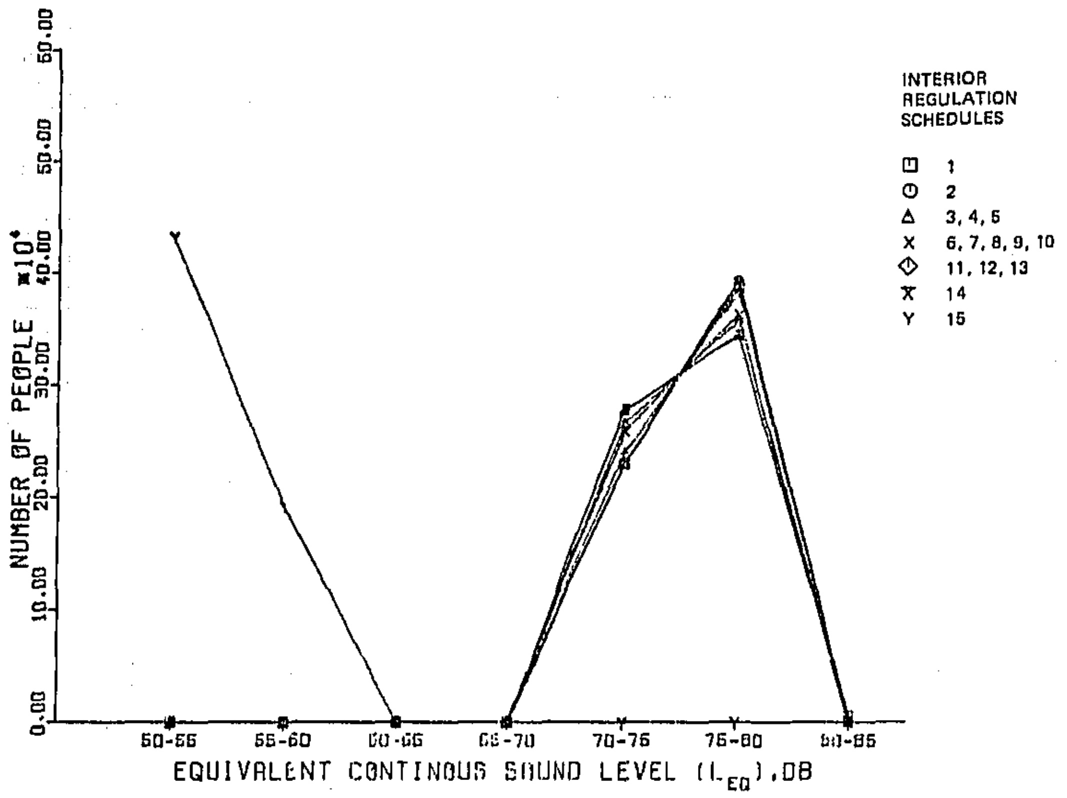


FIGURE F-20

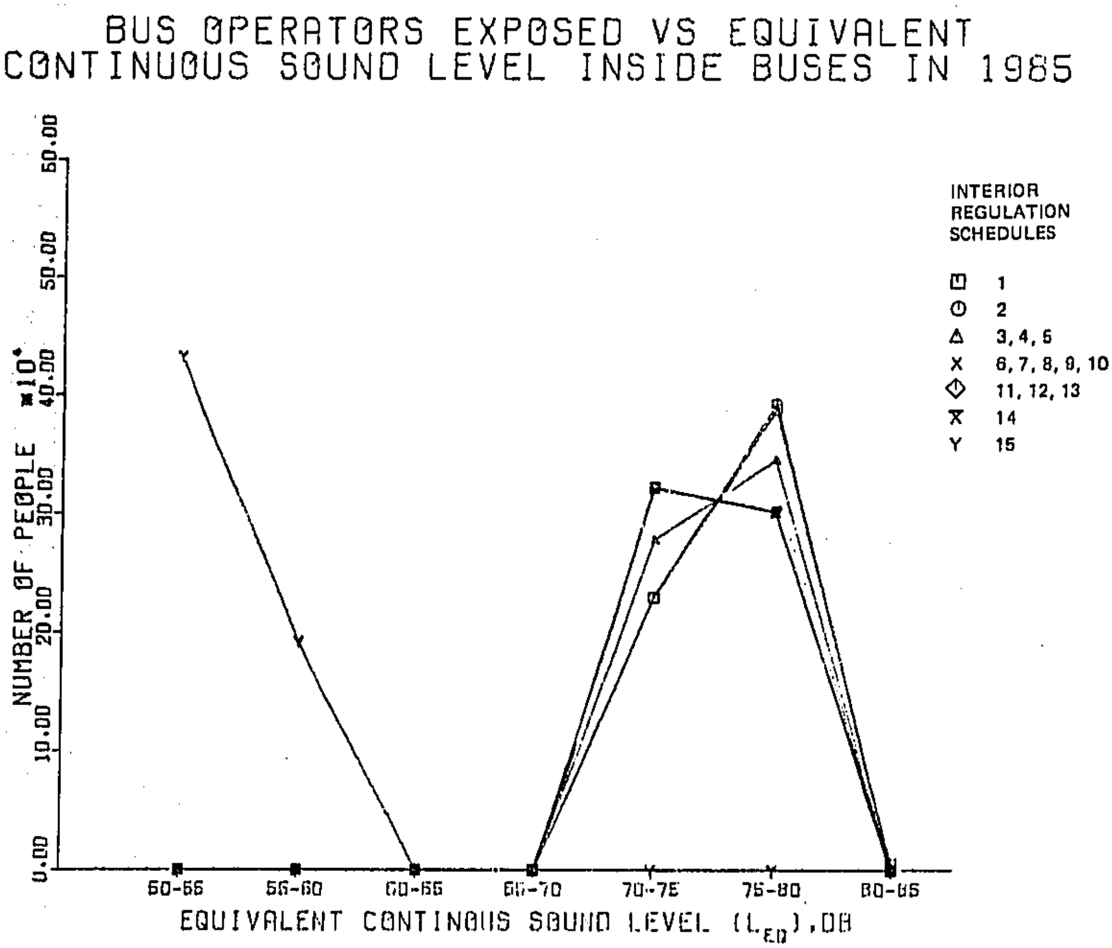

BUS OPERATORS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1985
NUMBER OF PEOPLE ×10⁴
0.00
10.00
20.00
30.00
40.00
50.00
50-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINOUS SOUND LEVEL (L_EQ), DB
INTERIOR REGULATION SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
Y 15

FIGURE F-21

BUS OPERATORS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1987

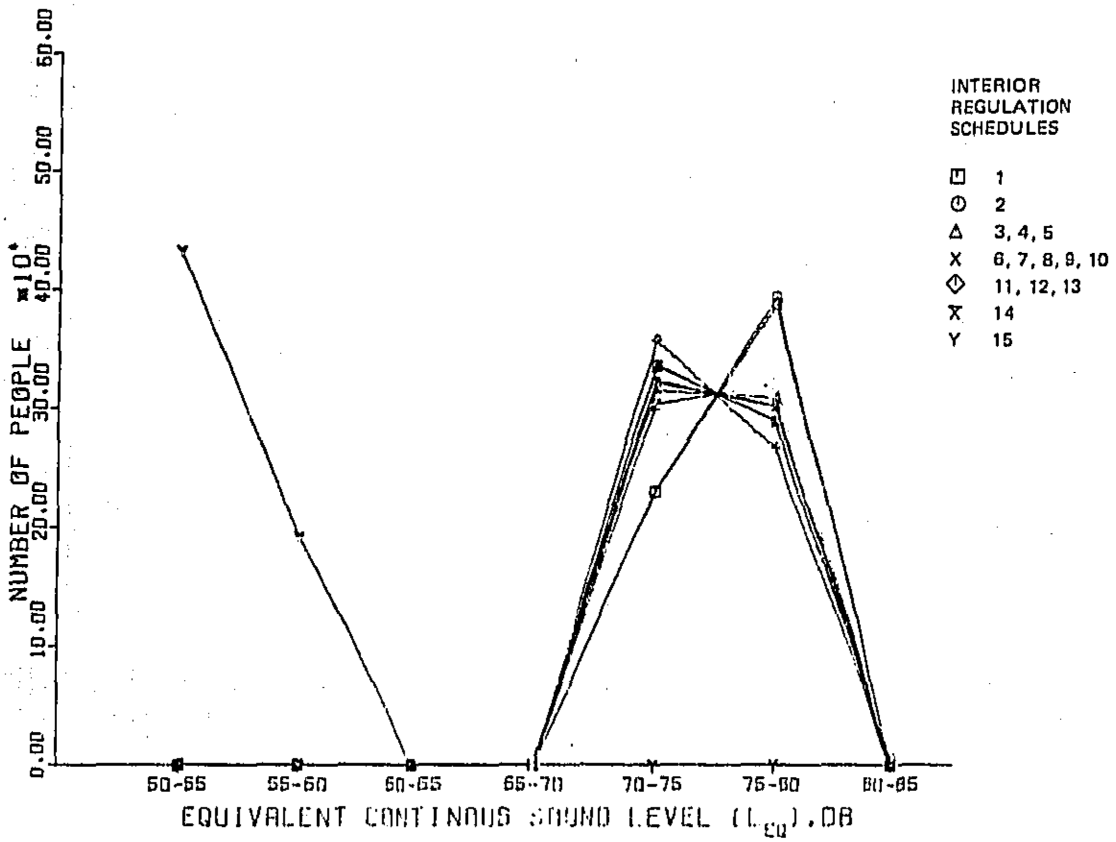


FIGURE F-22

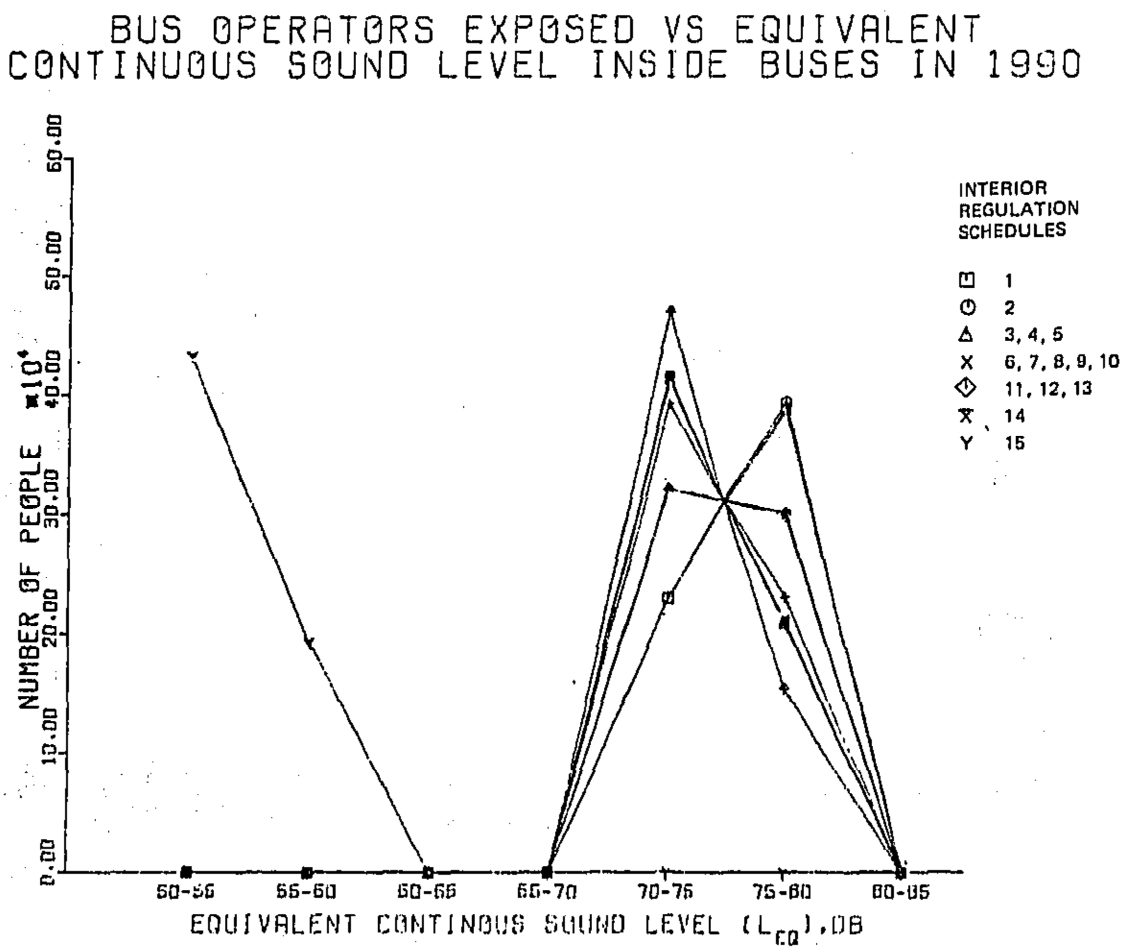

BUS OPERATORS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1990
NUMBER OF PEOPLE x10⁴
0.00
10.00
20.00
30.00
40.00
50.00
60.00
50-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINOUS SOUND LEVEL (LEQ),DB
INTERIOR REGULATION SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
15

FIGURE F-23

BUS OPERATORS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1995

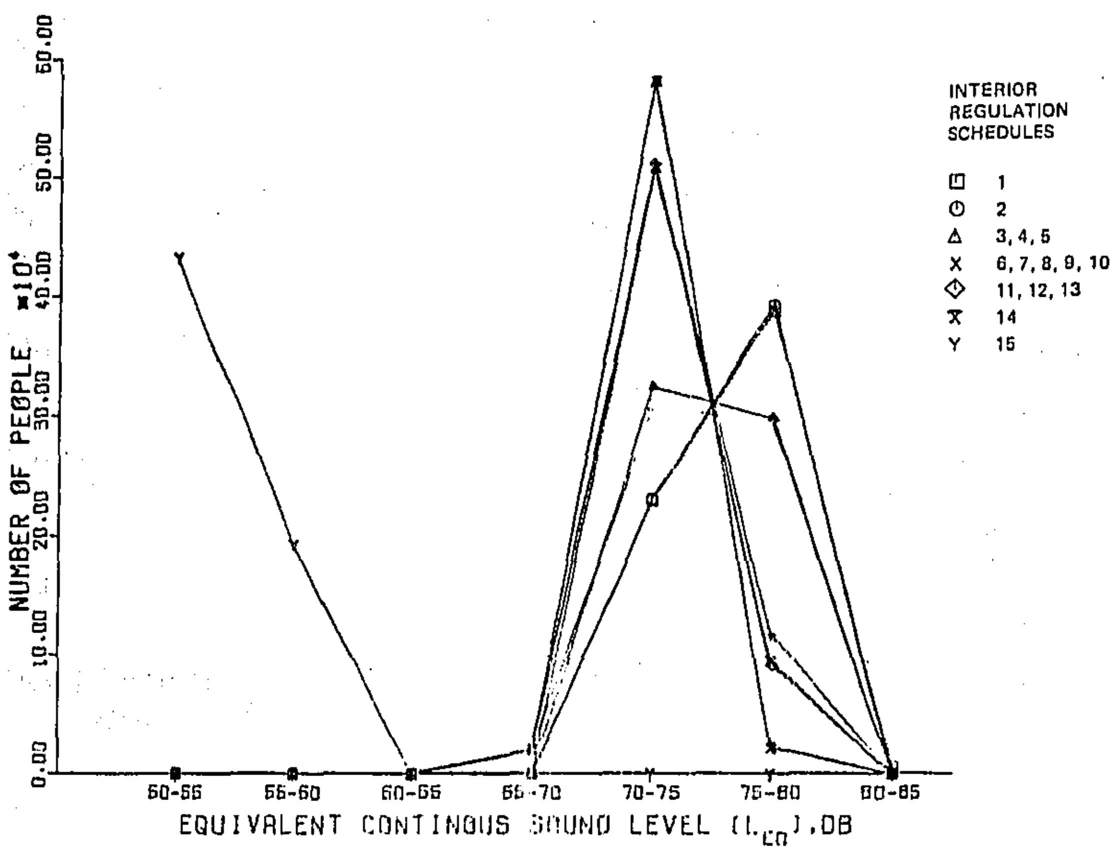


FIGURE F-24

BUS OPERATORS EXPOSED VS EQUIVALENT
CONTINUOUS SOUND LEVEL INSIDE BUSES IN 2000

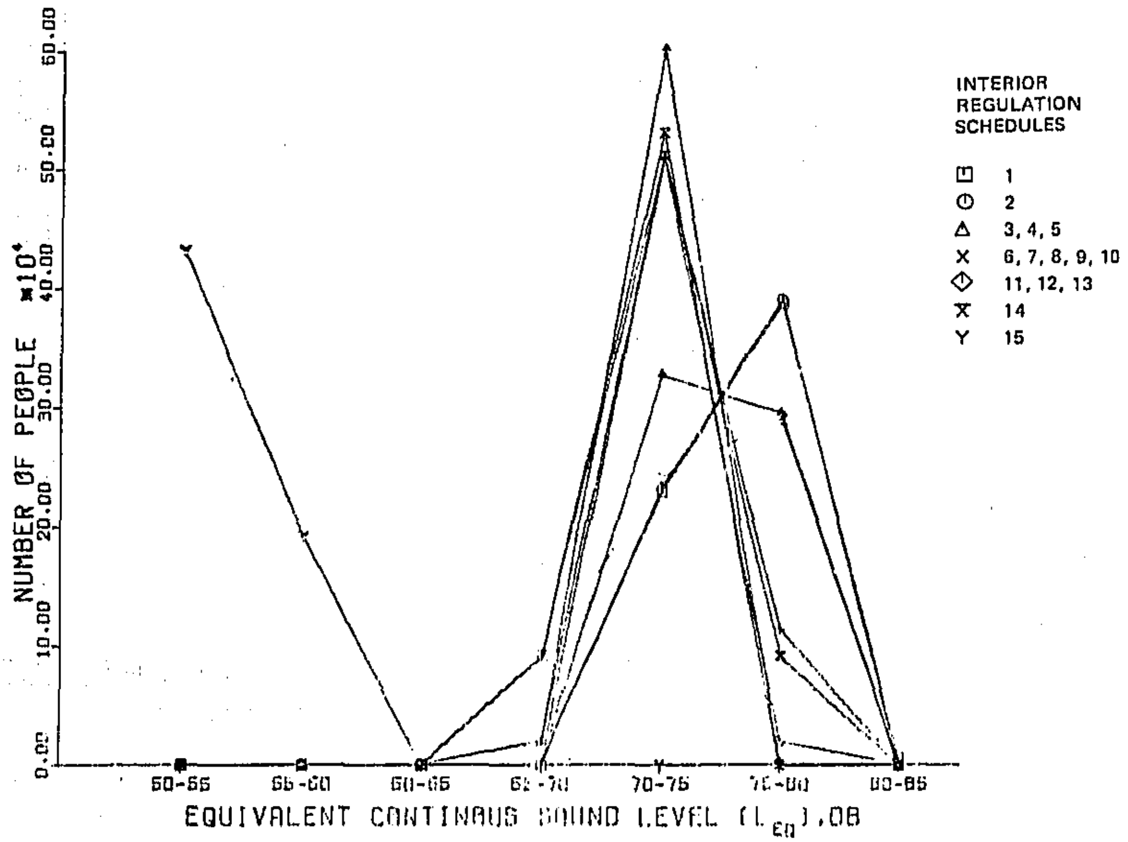


FIGURE F-25

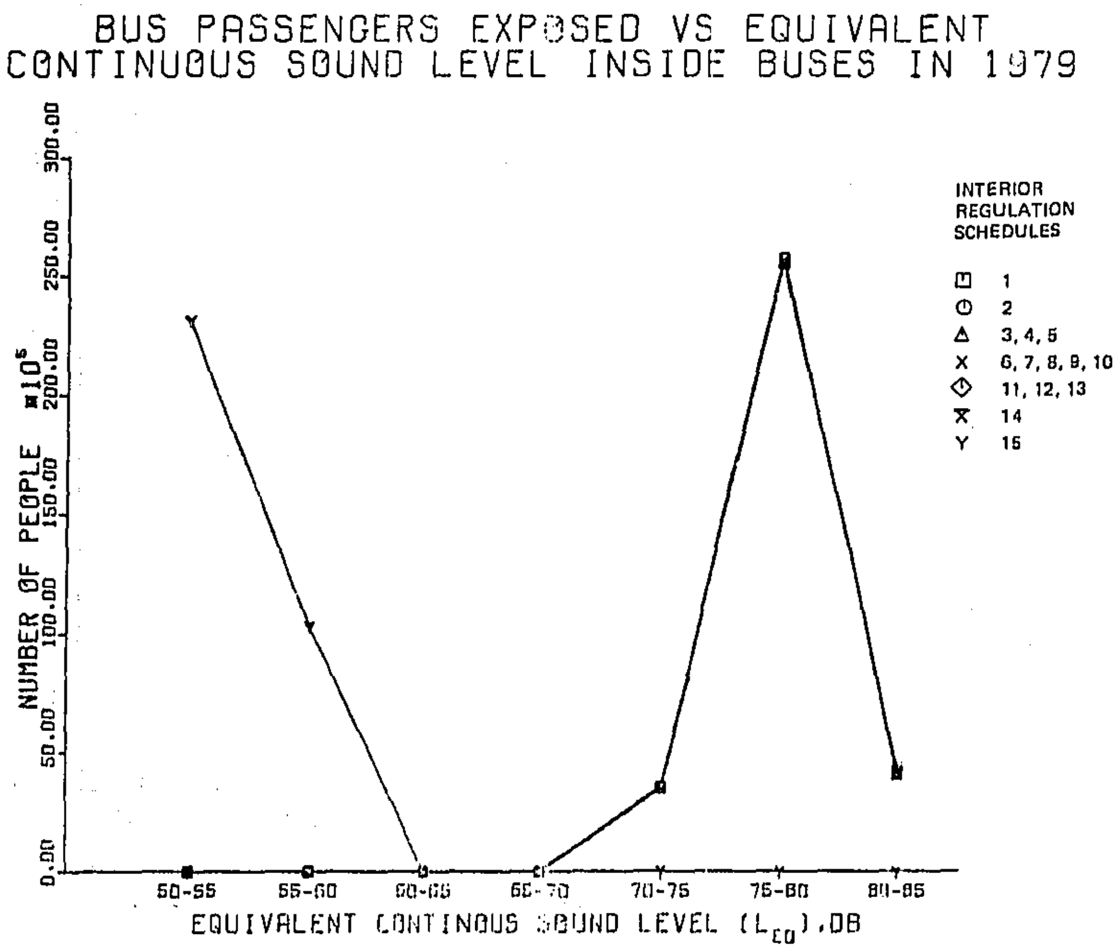
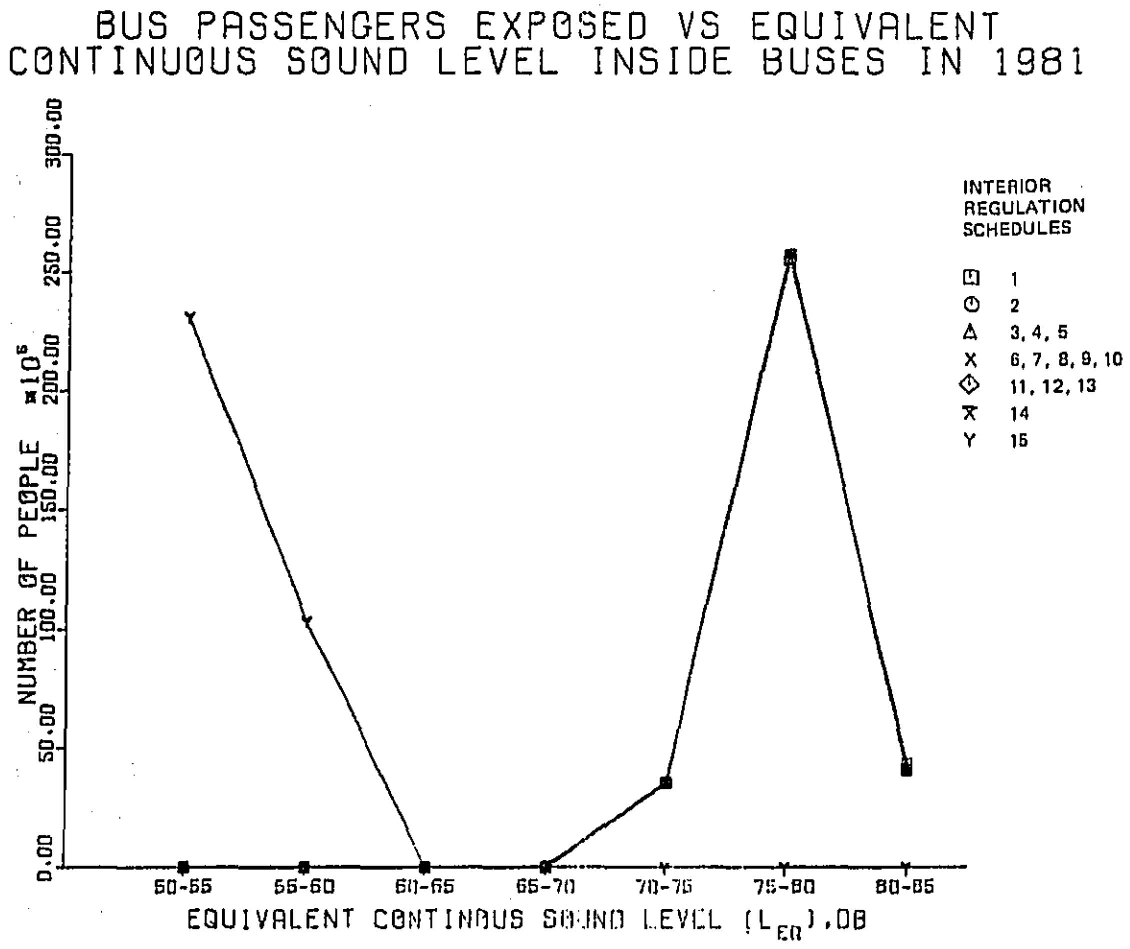

BUS PASSENGERS EXPOSED VS EQUIVALENT
CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1979
NUMBER OF PEOPLE x10⁶
0.00
50.00
100.00
150.00
200.00
250.00
300.00
50-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINOUS SOUND LEVEL (LEQ),DB
INTERIOR
REGULATION
SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
15

FIGURE F-26



BUS PASSENGERS EXPOSED VS EQUIVALENT
CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1981
NUMBER OF PEOPLE x10⁶
0.00
50.00
100.00
150.00
200.00
250.00
300.00
50-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINOUS SOUND LEVEL (LEQ),DB
INTERIOR
REGULATION
SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
15

FIGURE F-27

BUS PASSENGERS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1983

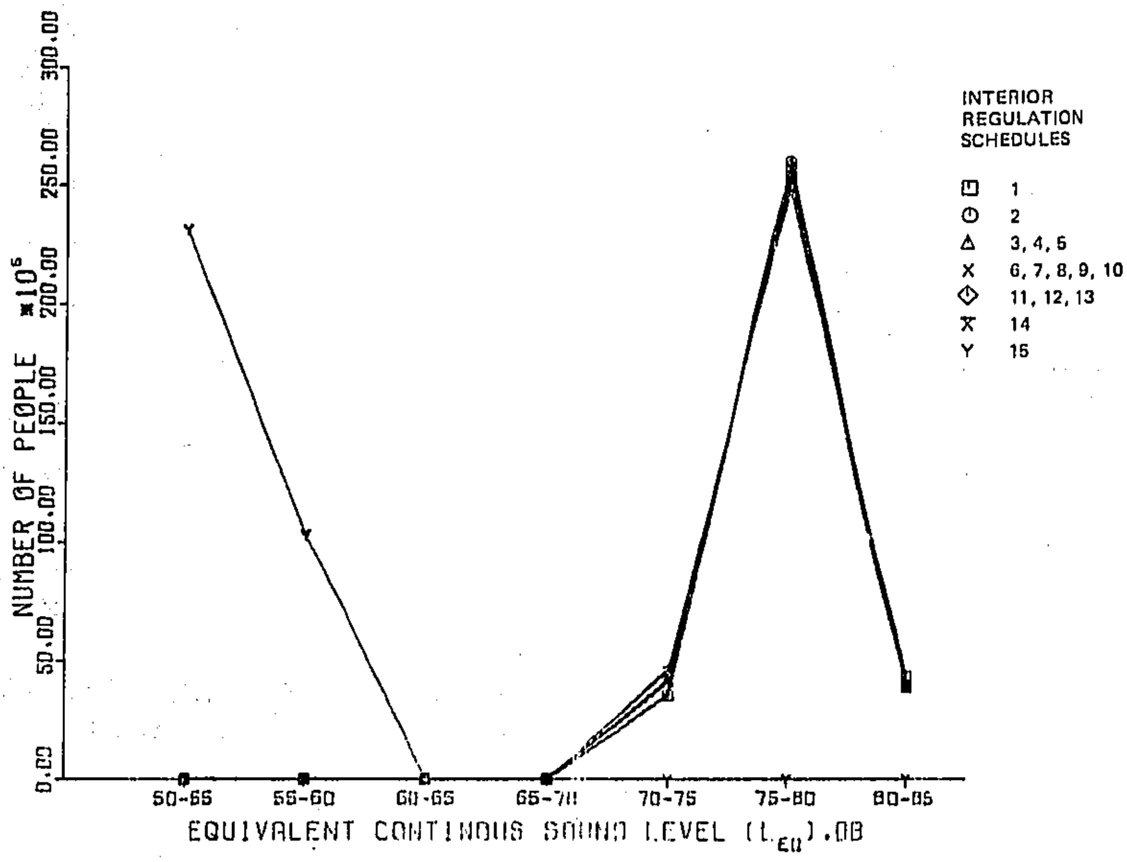


FIGURE F-28

BUS PASSENGERS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1985

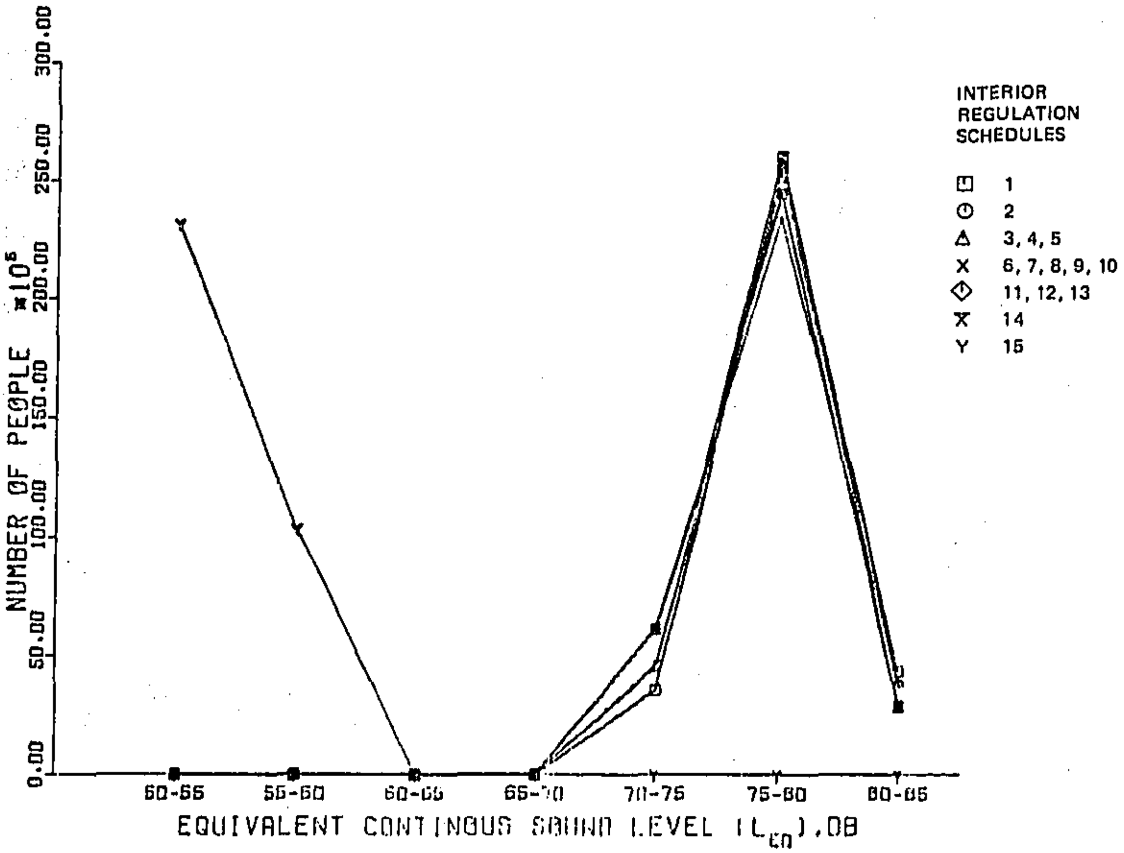


FIGURE F-29

BUS PASSENGERS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1987

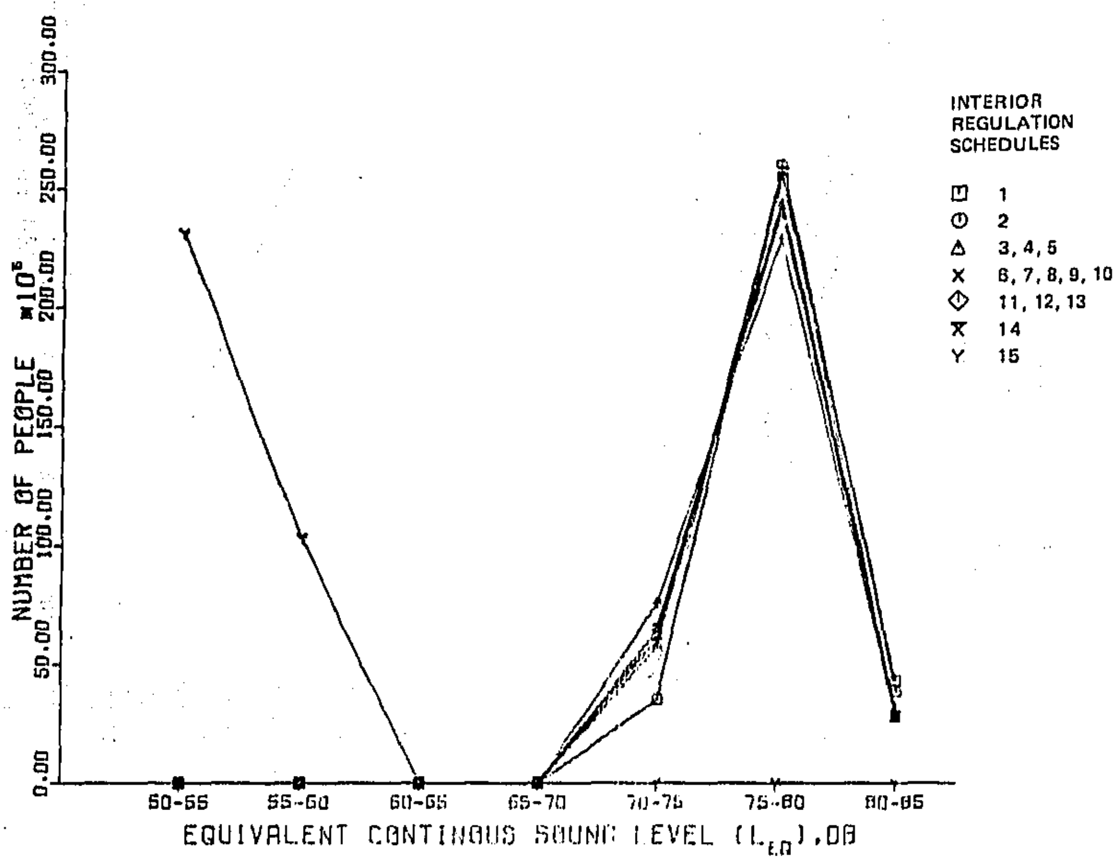


FIGURE F-30

BUS PASSENGERS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1990

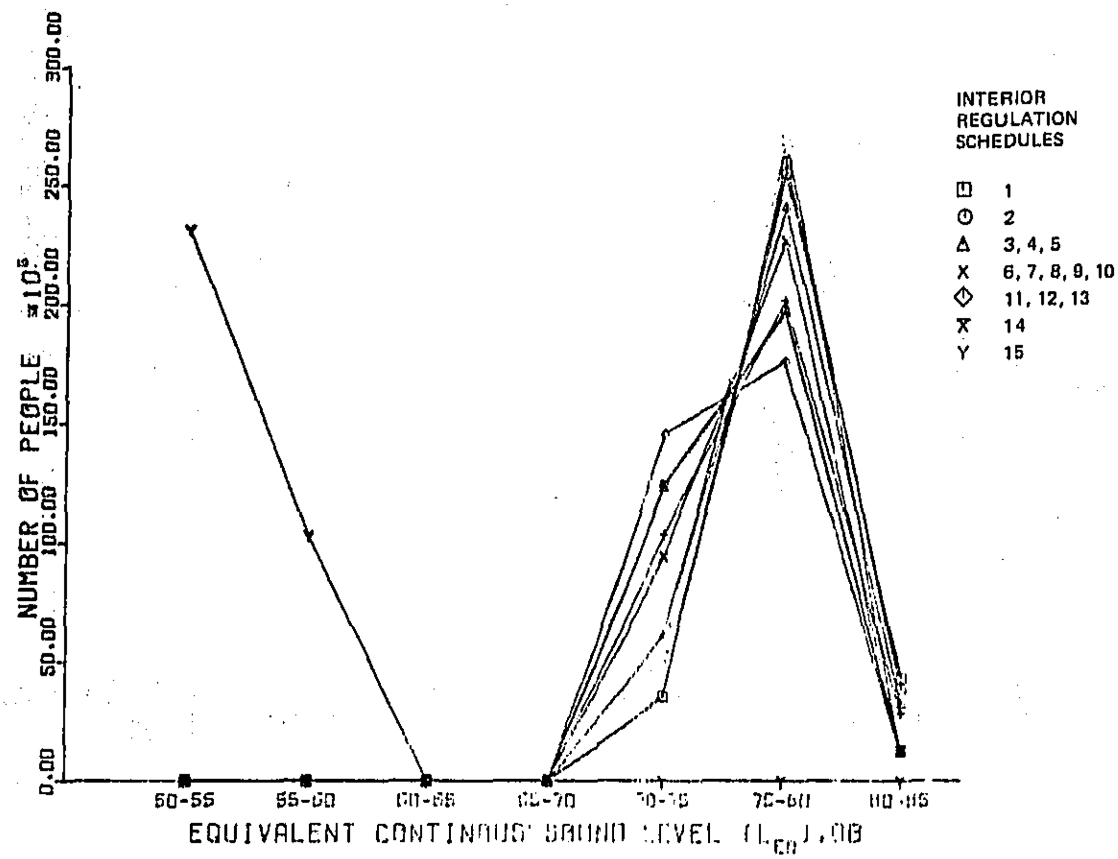
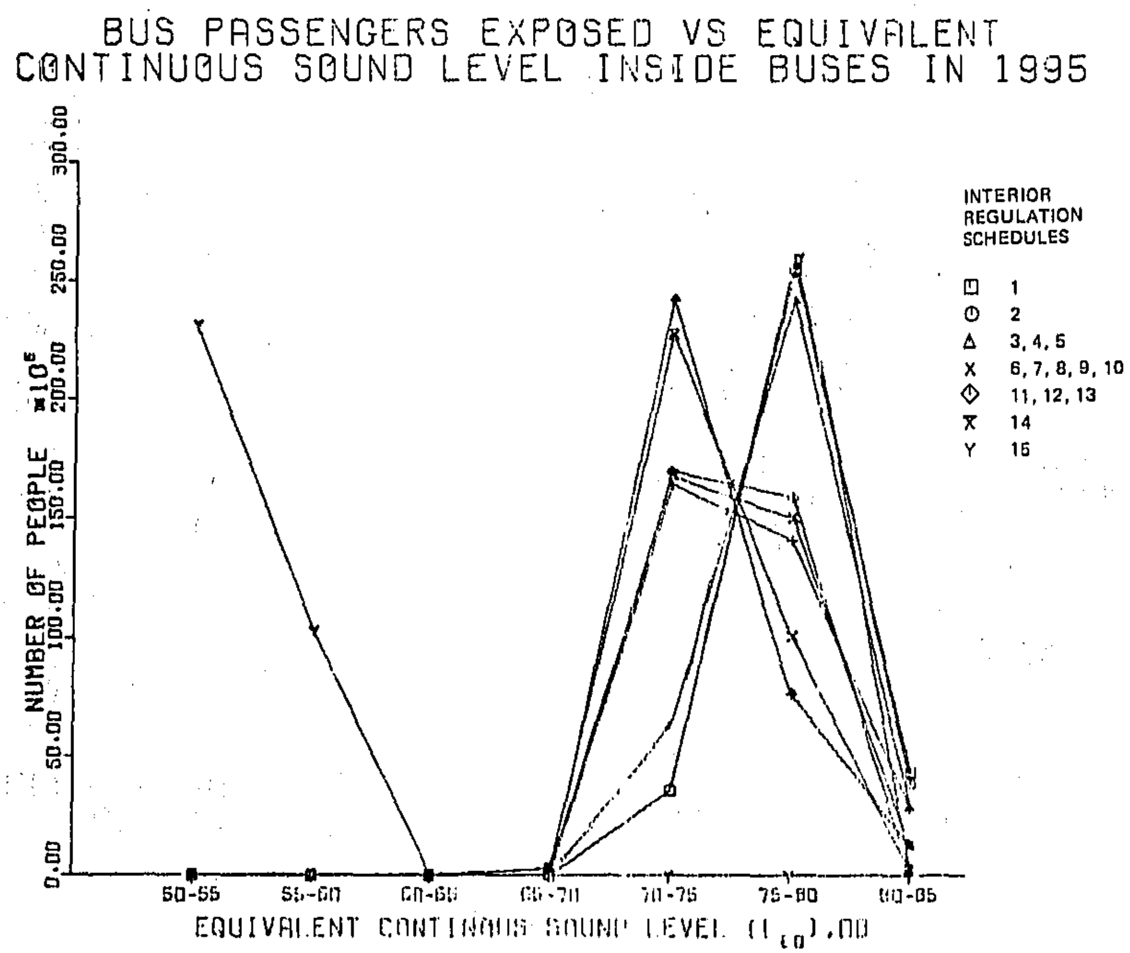
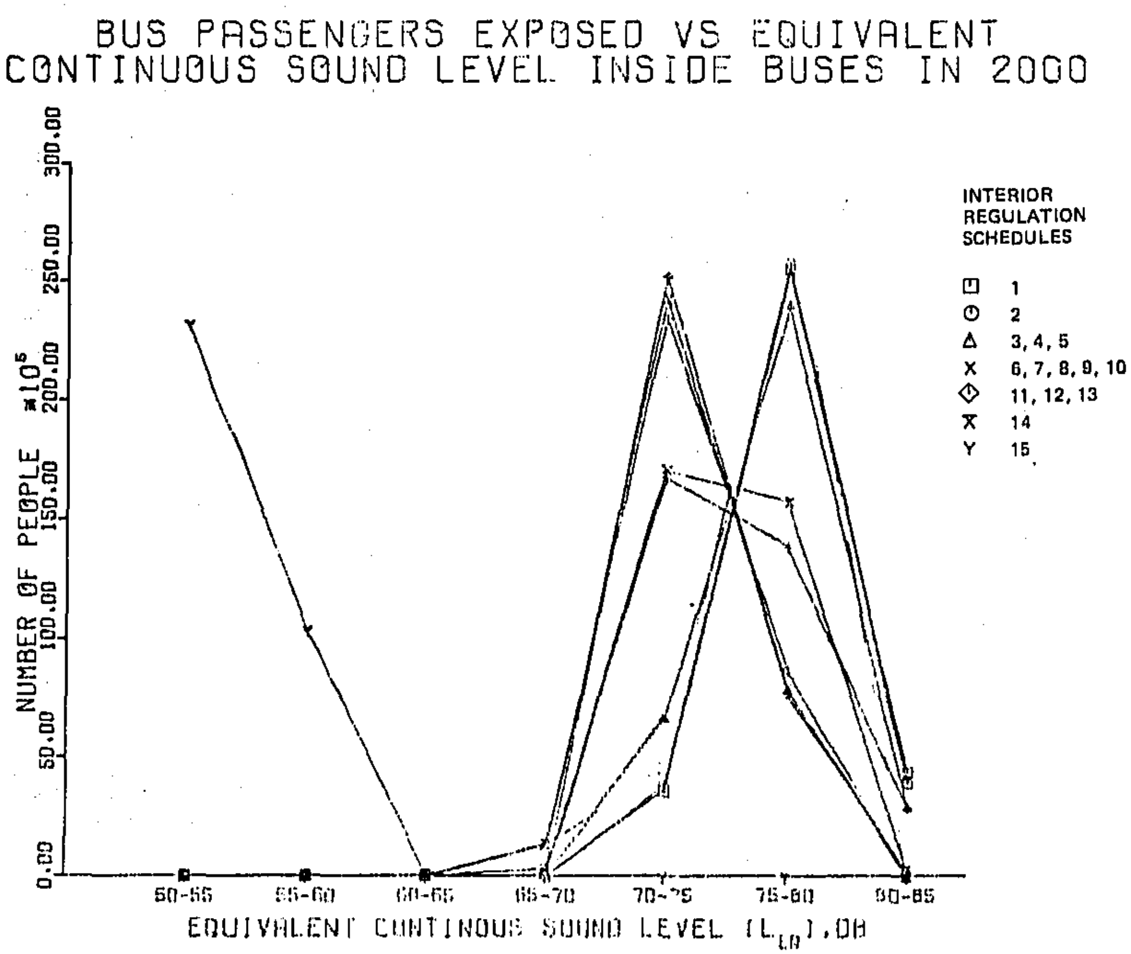


FIGURE F-31



BUS PASSENGERS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 1995
NUMBER OF PEOPLE x10^6
0.00
50.00
100.00
150.00
200.00
250.00
300.00
50-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINUOUS SOUND LEVEL
INTERIOR REGULATION SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
15

FIGURE F-32


BUS PASSENGERS EXPOSED VS EQUIVALENT CONTINUOUS SOUND LEVEL INSIDE BUSES IN 2000
NUMBER OF PEOPLE x10^5
0.00
50.00
100.00
150.00
200.00
250.00
300.00
60-55
55-60
60-65
65-70
70-75
75-80
80-85
EQUIVALENT CONTINOUS SOUND LEVEL (L_EQ),DB
INTERIOR REGULATION SCHEDULES
1
2
3, 4, 5
6, 7, 8, 9, 10
11, 12, 13
14
15

APPENDIX F

REFERENCES

1. Booz/Allen Applied Research, "An Assessment of the Technology for Bus Noise Abatement," draft final report submitted to U.S. Environmental Protection Agency, Office of Noise Abatement and Control, June 22, 1976.

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4. U.S. Environment Protection Agency, "Noise Levels of New MCI Buses," Advance Report, July 23, 1976.

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6. U.S. Environmental Protection Agency, "Passenger Noise Environments of Enclosed Transportation Systems," Report Number 550/9-75-025, June 1975.

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8. Booz/Allen Applied Research, memo to Wyle Research, March 12, 1976.

9. U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, Washington, D.C., Government Printing Office, 1975.

10. U.S. Environmental Protection Agency, "Background Document for Medium and Heavy Truck Noise Emission Regulations." EPA Report 550/9-76-008, March 1976.

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12. House Noise -- Reduction Measurements for Use in Studies of Aircraft Noise, SAE Report AIR 1081, October 1971.

13. Warnix, J. L. and Sharp, B. H., "Cost-Effectiveness Study of Major Sources of Noise. Vol. IV - Buses," Wyle Research Report WR 73-10, April 1974.

APPENDIX G

MODEL NOISE ORDINANCE

A. ELEMENTS OF A MODEL ORDINANCE

In view of the previous lack of state and local interest in regulating the noise emissions of buses, it is useful to note their possible future interest in enforcing a model ordinance to be developed by EPA specifically for buses. In general, the response is positive depending, of course, on the recommended noise standards, i.e., provided they are not less restrictive than those presently in force. However, the question often raised is that there may be difficulties in the adoption of a model ordinance by local governmnents when the enforcement will be directed towards the procurement of additional facilities or equipment of a city agency; namely, the local transit authority. It is to be expected that the adoption will be resisted if the enforcement interferes significantly with the operation of the fleet. This means that the test procedure must be as simple as possible, and yet consistent with good acoustical practice. Basically, there are three methods available, namely:

- <u>SAE J366b Test</u>--involving a full throttle acceleration past a microphone to measure near maximum noise level.
- <u>Stationary Test</u>--involving a rapid acceleration to governed engine speed in neutral gear, followed by a rapid deceleration.

- <u>Pass-By Test</u>--involving a measurement of the noise level in a highway situation as the bus passes by operating under normal conditions.

In addition to the tests involving noise measurements, an effective method of enforcement can involve a careful vehicle maintenance checking procedure. A statement of the advantages and disadvantages of the four possible methods of enforcement are given in Table G-1.

In enforcing the model ordinance for newly manufactured buses, it is not necessarily essential to test every bus in a fleet. A sample of identical buses is all that is required to identify a common factor that results in an increase in noise with time--a poor muffler design, for example. All other factors causing degradation can be identified by correct vehicle maintenance at regular intervals. With this simplification, the optimum enforcement procedure can be stated as follows:

- A stationary test on a sample of diesel-powered buses (mainly transit buses).
- A unmodified SAE 366b test for gasoline-powered buses (mainly school buses).
- A comprehensive procedure for bus maintenance (this will also be to the prevention of noise degradation of the older buses in the fleet).

With this background, it is possible to develop a simple, proposed model ordinance for buses.

Table G-1

Bus Noise Enforcement Methodology

Procedure	Advantages	Disadvantages
1. Controlled SAE Test	• Suitable for application to all bus types • Fairly repeatable • Well documented	• Large amount of space required • Time consuming
2. Stationary Test	• Simple • Quick • Only limited space required	• Difficult for application to ungoverned engines (school buses)
3. Uncontrolled Pass-By	• Simple • Expedient	• Not as accurate as other methods • Requires driver cooperation
4. Vehicle Maintenance Check	• Expedient • Strong possibility of adoption by local agencies	• Does not provide quantitative results

B. PROPOSED MODEL ORDINANCE

Applicability

The provisions of the model ordinance shall apply to any motor vehicle having a Gross Vehicle Weight Rating (GVWR) in excess of 10,000 lbs. designed for the transportation of 10 or more people, other than the driver, that is manufactured after the year ____.

Standards For Buses Equipped With An Engine Governor

No person shall operate a motor vehicle as defined above that is powered by an engine with an engine speed governor which generates a noise level in excess of ___ dBA when measured with fast response with the vehicle stationary at a distance of 50 feet from the vehicle centerline, on a line perpendicular to the exhaust outlet, when the engine is accelerated in neutral gear from idle with wide-open throttle to the governed engine speed.

Standards For Buses Not Equipped With An Engine Governor

No person shall operate a motor vehicle as defined above that is not equipped with an engine speed governor which generates a noise level in excess of ___ dBA when measured according to the test procedures defined by the EPA Procedure for Measurement of the Noise Emissions of New Buses (modified SAE J366b).

Vehicle Maintenance Procedure (Recommended Practice Rather Than Part Of An Ordinance)

Regular vehicle maintenance for all buses shall include inspection and necessary repair of the following equipment in addition to normal running maintenance:

1. Exhaust Systems

- o Mufflers and connecting pipes should be in normal working order, be free of visible corrosion and external carbon deposits.
- o Flexible joints should be free of carbon deposits and should not exude smoke, fumes, etc.
- o Exhaust manifold bolts and gaskets should be checked for tightness and replaced where necessary.

2. Body Work

- o All access doors and panels should be checked for proper closure and weatherstripping.
- o Where applicable, "under-belly" pans should be in place and correctly fitted.

GENERAL REFERENCES

APPENDIX G

1. U.S. Environmental Protection Agency, "Noise Source Regulation in State and Local Noise Ordinances," Report No. 550/9-75-020, February 1975.

2. Society of Automotive Engineers, "Exterior Sound Level for Heavy Trucks and Buses," SAE Standard J366b.

3. "Interstate Motor Carrier Noise Emission Standards," Federal Register, Vol. 38, No. 144, July 27, 1973.

4. "Interstate Motor Carrier Noise Emission Standards--Final Regulations on Compliance," Federal Register, Vol. 40, No. 178, September 12, 1975.

5. "Existing Noise Regulations Applicable to Buses," Draft Final Report submitted by Wyle Laboratories under EPA Contract No. 68-01-3516, prepared for the Office of Noise Abatement and Control, June 24, 1976.

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