Battelle
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Report

REPORT

on

THE CONTRIBUTION OF MEDIUM AND HEAVY TRUCKS TO COMMUNITY NOISE ON A NATIONAL SCALE

to

MOTOR VEHICLE MANUFACTURERS' ASSOCIATION

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by

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EXECUTIVE SUMMARY

Some of the community noise modelling techniques developed by Battelle for the Motor Vehicle Manufacturers' Association over the past three years have been applied to the problem of calculating the benefits, in terms of community noise reduction, of various promulgated, proposed, and hypothetical medium and heavy truck noise emission regulations. The study involved modelling the national traffic noise exposure, initially for a baseline case, and then for a sequence of different cases in which the model inputs corresponding to the medium and heavy truck noise emission levels were varied to simulate the effect of the regulations on community noise levels.

It was found that the contribution of medium and heavy truck powertrains in a pre-regulatory national scenario accounted for nearly one-third of the total community noise exposure resulting from road traffic of all kinds. The 1978 (83 dBA) regulation potentially removes nearly half of the noise exposure of medium and heavy trucks. The 1983 (80 dBA) regulation brings about a less pronounced additional benefit, potentially removing somewhat more than one-fourth of the noise exposure. Still more stringent regulations bring about smaller and smaller additional benefits.

The medium and heavy truck noise emission data base was complied from recent literature. The remainder of the comprehensive data base employed was taken from a single source (EPA, Reference 12) and included: (1) noise emission characteristics of automobiles, light trucks, buses and motorcycles, (2) physical description of road types, including lane number and spacing, (3) attenuation rates for noise propagation through the community, (4) driving characteristics for all vehicle types on all road types, (5) traffic denisties, (6) total miles for each road type, and (7) population densities. No attempt was made to verify the data given in Reference 12. It was expedient to perform the calculations with conditions similar to those assumed in EPA's modelling efforts.

Not only in the case of input data was it desired to maximize the overlap with EPA calculations, but also in the reporting of the results. Therefore, the number of people exposed to average day-night weighted outdoor community noise levels (L_{dn}) in excess of 55 decibels (A-weighted) was the number used to quantify traffic noise exposure on a national scale. However, because we believe that this method of quantification is insufficient when used alone, our national traffic noise exposures were further defined in terms of exceedance levels and other criterion values for L_{dn}. The EPA is currently modifying its community noise modelling methodology to make it more sensitive to community noise characteristics not well represented by L_{dn}.

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INTRODUCTION

The contribution of medium and heavy trucks to community noise is a subject which has elicited considerable interest (References 1-4). New medium and heavy trucks are currently subject to noise emission regulations which were promulgated in 1974 to take effect in 1978. These regulations stipulate that the noise level measured according to the SAE J366 standard shall not exceed 83 dBA. A more stringent regulation scheduled for promulgation in 1983 would limit the noise level to 80 dBA. Still more stringent regulations are under consideration.

While it is true that each reduction in the noise level of any source in general and of medium and heavy trucks in particular will result in lower community noise levels, two critical issues arise which must be addressed before noise regulatory policy can be adequately evaluated. The first issue is the quantification of the benefits which are expected to accrue from the promulgation of the regulation. This issue is critical because it provides a necessary input for the consideration of the second issue which is cost versus benefit. Only the first issue is addressed in this study. For this reason, any suggestion or recommendation with respect to the desirability of any particular regulation or policy is clearly beyond the scope of this study. What the study does provide, however, is a quantification of community noise reduction which would be expected to result from the promulgation of particular regulations or the adoption of particular policies.

BACKGROUND

Beginning in October, 1977, the Motor Vehicle Manufacturers' Association has supported an ongoing study entitled "The Automobile as a Component of Community Noise", conducted by Battelle Columbus Laboratories. The progress of this study has been previously reported (References 5-7). The modelling/simulation techniques which have been developed have been applied primarily to the study of automobile noise. Interest in that particular noise source provided the initial impetus for the study, as the title aptly indicates. However, the techniques are equally suitable for the study of other vehicle noise sources.

It was agreed at the beginning of Phase IV of the ongoing study that the sponsor's primary interest in community noise modelling at that particular time was "the truck as a component of community noise". This report describes the application of the models to that subject and presents the analysis of the results.

APPROACH

In order to quantify the community noise reduction expected to result from various regulatory policies, a number of national traffic noise simulations have been accomplished and the results have been evaluated. Each simulation included not only the noise from medium and heavy trucks, but the noise from automobiles, light trucks, buses, and motorcycles as well. In order to normalize the simulations to a common base, all input variables other than medium and heavy truck noise emissions were held constant.

A wide range of scenarios has been studied. In all, twenty different national scenarios were examined using the L_{dn}-based model. Graphical results appear in Appendix A. Of the twenty, three scenarios were further examined using the exceedance level model. These results are given in Appendix B. In some of the scenarios the powertrain noise of medium and heavy trucks was successively limited by increasingly stringent regulations. In other scenarios the effect of truck tire noise was explicitly considered. In still other scenarios both powertrain and tire noise levels were simultaneously varied.

The suggestion of quantification necessarily implies reference to some noise metric. The regulatory agencies customarily report noise exposure in terms of numbers of people exposed to daily average noise levels greater than some criterion value. For convenience in presentation and for compatibility with the format of reports presented by the regulatory agencies, this report presents national traffic noise exposure in terms of numbers of people potentially exposed to outdoor community noise levels in excess of L_{dn} = 55.* The numbers of people exposed to selected greater values of L_{dn} are also presented. In addition, for some of the scenarios, the exceedance levels are given for peak traffic conditions. Generally, the exceedance level information is supplementary to the L_{dn} analysis and serves to illustrate some points

* We do not necessarily endorse this criterion.

which may not be revealed by merely examining the average noise levels.

CONCLUSIONS

Without vehicle noise emission regulations, approximately fifty-seven percent of the Nation's population would be potentially exposed daily to outdoor noise levels in excess of L_{dn}=55. The potential benefit of the 1978 (83 dBA) medium and heavy truck regulation is such that one can predict that the number of people exposed to such levels will be reduced to forty-eight percent. Similarly, the potential benefit of the 1983 (80 dBA) regulation could further reduce the number to forty-two percent. A more stringent, hypothetical regulation (75 dBA) further reduces the number to thirty-eight percent. Thirty-six percent is the limit below which is unattainable by regulations which limit only medium and heavy truck powertrain noise emissions. Thus, the 1978 regulation has the potential to accomplish forty-three percent of what can be accomplished by such regulations. The 1983 regulation accomplishes seventy-one percent of what can be accomplished; the more stringent hypothetical 75 dBA regulation accomplishes ninety percent of the possible benefit.

The potential benefits of the 80 dBA regulation could be approximately realized by the 83 dBA regulation if lug tires were replaced by radial rib tires. Similarly, the 75 dBA regulation yields the same potential benefit as can be obtained by the 80 dBA regulation with lug tires replaced by radial rib tires. These points are illustrated in Table 1.

Traffic on arterials is responsible for most of the exposure to $L_{dn} \geq 55$, accounting for approximately one-half of the exposure to such levels. Interstates and other freeways account for approximately one-fourth of the exposure. Collectors and local streets account for the remaining one-fourth. In terms of exposure to higher noise levels, interstates and other freeways become increasingly important. They are responsible for nearly all exposure to L_{dn}'s greater than 80 dBA.

TABLE 1. ALTERNATIVE PATHS TO COMMON GOALS

Scenario	Percent of National Population Exposed to $L_{dn} \geq 55$
Pre-regulatory baseline	57
83 dBA regulation w/baseline tires	48
83 dBA regulation w/radial rib tires	43]
80 dBA regulation w/baseline tires	42]
80 dBA regulation w/radial rib tires	38]
75 dBA regulation w/baseline tires	38]
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INPUT DATA FOR MODELS

This section of the report describes the data which was used in the exercising of the various traffic noise models which were used to calculate the national noise exposure for a variety of scenarios. The data has been conveniently divided into two categories (1) data which is changed to define the various scenarios, and (2) data which is scenario-invariant. The noise emissions of medium and heavy trucks constitute data of the first category. All other data is of the second category.

Noise Emissions of Medium and Heavy Trucks

Noise emissions of medium and heavy trucks consist of two basic components. There are (1) powertrain noise, and (2) tire/aerodynamic noise. Since the nature of the noise emission standard (SAE J366) which is used to test compliance essentially ignores tire/aerodynamic noise, it is assumed that progressivley more stringent regulations will have the effect of lowering only the powertrain noise. Therefore, it is necessary to consider powertrain noise and tire/aerodynamic noise separately in the analysis of the potential benefits of the regulations. The noise emissions from medium and heavy trucks are presented in detail in Appendix C.

Truck Tire Noise

Data for the noise emission levels of truck tires has been compiled from four independent sources (References 8-11). The first source is the 1979 report from the National Bureau of Standards authored by Roger D. Kilmer. The data in Table 2 is taken from Figure 10 of Kilmer's report. The second source used is the 1977 joint report of the Department of Transportation/Motor Vehicle Manfucaturers' Association which covered both noise and traction characteristics of tires for heavy trucks. Table 2 utilizes the information given in Figure 7 of that report. The third source is a working paper developed at General Motors during 1980 and considers both tire noise and engine noise separately. The fourth source is a paper presented at the 1976 SAE Tire Noise Symposium in San Francisco by D. M. Corley. The information included in Table 2 is from Figure 1 of that paper.

TABLE 2. TIRE NOISE FOR 6-WHEEL (MEDIUM) TRUCKS

Source*	Tire Type	Level (dBA)** Range	Level (dBA)** Average
Kilmer, 1979	Bias rib	72-78	75
	Bias lug	74-87	80.5
	Radial rib	71-75	73
	Radial lug	71-83	77
DOT/MVMA, 1977	Bias rib	73-76	74.5
	Bias lug	80-84	82
	Radial rib	74-76	75
	Radial lug	77-79	78
GM, 1980	Bias rib	74.5	74.5
Corley, 1976	new rib***	74	74
	new lug***	82	82
	worn lug***	91	91

* References 8-11, respectively, as given at the end of this report. Corley's data has been corrected from 18-wheel to 6-wheel for consistency by the method described in the text.
** Coastby peak level at 50 feet, 50 miles per hour.
*** On drive axles only (8 tires), all other tires new rib.

From the first two sources it is possible to read directly noise levels resulting from a coastby of a six-wheel truck fitted with any one of the many tires examined in these experiments. The speed of the coastby is in every case 50 miles per hour and the microphone is located 50 feet from the centerline of the vehicle trajectory. Four different basic types of tires were investigated, differentiated by ply construction (bias or radial) and tread design (rib or lug*). The data for the four basic types are given as ranges in Table 2. The ranges resulted from the testing of different specific makes and models of tires of the same basic type. The averages for each basic type is given in Table 2.

The third source revealed no specific experimental results. Instead, it presented an empirical formula for tire noise which is based upon a number of experimental results for bias rib tires. The formula given for the peak coastby noise at 50 feet is

$$L = 9.8 + 34 \log_{10} S + 9.0 \log N$$

where S is the speed in miles per hour, N is the number of tires on the vehicle, and L is in dBA. It is evident from the other data given in Table 2 that the formula agrees well with the experimental data reported in the other sources for bias-ply rib tires.

The fourth source reported considered only bias-ply tires. The data for new ribs and new lugs is in good agreement with the other sources. The data for 1/2-worn lugs doesn't seem directly comparable with the data from the other sources; consequently, this particular data was not used. For consistency with the data from the other sources, all data from the fourth source was adjusted from 18 to 6 wheels according to the formula given above.

Table 2 contains four independent estimates of the tire noise from bias-ply ribs; these estimates all lie within a 1 dB interval. There are three independent estimates of noise from bias-ply lugs; these lie within a 1.5 dB interval. There are two estimates for noise from radial ribs and two for radial lugs also; these estimates differ by 2 and 1 dB, respectively.

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* Lug tires have a crossbar tread pattern.

It is possible to compute from Table 2 two differences between ribs and lugs for bias-ply tires. These differences are 5.5 and 7.5; therefore, it was concluded that bias lugs are approximately 6 dB louder than bias ribs. Similarly, it is possible to differentiate between ribs and lugs for radial tires. These differences are 4 and 3; it was concluded that radial lugs are approximately 4 dB louder than radial ribs. Two differences can be computed between bias-ply and radial lugs. These are 3.5 and 4 so that it is concluded that bias lugs are approximately 4 dB louder than radial lugs.

Using the information developed in the preceeding paragraph, the tire noise formula given above was modified by the addition of a constant term, Δ, for the purpose of differentiating among the four basic tire types. Thus, Δ attains the following values:

Δ	Tire type
0	Bias rib
6	Bias lug
-2	Radial rib
2	Radial lug

The tire noise so calculated is added to the engine noise to characterize noise levels of each truck as a function of speed and operating mode.

If the adjustment terms (the Δ's) just derived are employed directly, one calculates the tire noise which one could expect if all six tires (on medium trucks) or all eighteen tires (on heavy trucks) were the same type. In practice, lug tires are generally limited to use on the drive wheels. One would rarely encounter a truck which had lug tires on every wheel. For these calculations it has been assumed that trucks (either medium or heavy) may be categorized by four descriptions with respect to tires. These are illustrated in Table 3.

Table 4 presents the truck tire population distribution. These fractions refer to the relative numbers of the four types of tires which are sold on an industry-wide basis. In the absence of quantitative data to the contrary, it has been assumed that the same fractions characterize the actual tire fleet extant at any particular time; that is, the various tire types are assumed to wear at identical rates.

According to Reference 12 the relative populations of medium and heavy trucks is approximately 61 to 39. With these assumptions and restrictions it is possible to derive the mix of the four truck tire configurations given in Table 3 which are actually to be found. In a representative collection of 100 trucks one would expect to find 61 medium trucks and 39 heavy trucks. On the 100 trucks there would be found 1068 tires. Of these, the medium trucks would account for 366 (61 x 6) and the heavy trucks would account for 702 (39 x 18). Since each medium truck has 4 tires on powered axles and each heavy truck has 8 tires on powered axles, there are 556 tires out of the 1068 which could possibly be lug tires. If such were the case, approximately 52 percent of the tires would be lug tires. But according to Table 4, only one third (.278 + .052) of the tires are lug tires. Therefore, not every truck can have lug tires on its powered axles.

If the fraction of medium trucks which have lug tires (on the powered axles) is F_M and the analogous fraction for heavy trucks is F_H, then

$$F_M\ (61 \times 4) + F_H\ (39 \times 8) = .330 \times 1068 \quad .$$

F_M and F_H are thus defined each in terms of the other. The requirement of consistency with Table 4 prevents their independent definition. In simplest terms

$$F_M = 1.44 - 1.28\ F_H \quad .$$

Two cases have been addressed in this study. Case A has been defined by the assumption that $F_M = F_H$. This assumption means that medium trucks and heavy trucks are equally likely to be found with lug tires. It leads to the conclusion that 63 percent of medium trucks and 63 percent of heavy trucks have lug tires (on the powered axles).

TABLE 3. TRUCK TIRE CONFIGURATIONS

Configuration #	Tires on Powered Axles	Other Tires
1	bias rib	bias rib
2	bias lug	bias rib
3	radial rib	radial rib
4	radial lug	radial rib

TABLE 4. TRUCK TIRE POPULATION DISTRIBUTION

Tire Type	Fraction of Total Population
Bias rib	.553
Bias lug	.278
Radial rib	.117
Radial lug	.052

From independent sources, the value .5 was suggested for F_H. With this assumption it follows that F_M = .80. Case B, the second of the two national exposure calculations performed with trucks of every configuration listed in Table 3, has these two values for F_M and F_H. The comparison of the results for Case A versus Case B was expected to provide an estimate of the sensitivity of the calculation of national exposure to the particular assumptions made about the values of F_M and F_H. That it did. The results for Cases A and B are presented, together with other results, later in this report.

The formula previously given, together with the Δ values which differentiate the various tire types, allows the direct calculation of tire noise whenever all the tires on a truck are of the same type. If there are tires of different types on a single truck, then the calculation of tire noise from that truck is somewhat more complicated than the simple addition of the correction constant Δ.

In order to derive the tire noise emission from a representative medium truck it is necessary to know the mixture of the four tire types which is likely to be found on that truck. On 100 medium trucks one would find 600 tires, of which 400 would be mounted on powered axles. For Case A, F_M = .63 so that there would be 252 lug tires (.63 x 400) out of 600 tires total. But since, according to Table 4, approximately one sixth (.117 + .052) of all truck tires are radial, there would be 42 radial lug tires. The remaining lug tires would be bias tires so that there would be 210 bias lug tires (252 - 42).

Of the 348 tires (600 - 252) which are not lug tires, again, one sixth would be radial. Therefore, there would be 58 radial rib tires (348/6) and 290 bias rib tires (248 - 58).

In summary, there would be found on 100 representative medium trucks a mixture of all four tire types. Lug tires, when found, would always be mounted on powered axles. There would be 600 tires in all, apportioned according to the rational in the preceeding paragraph. These numbers can be scaled to represent fractions of the total tire population found on the medium truck fleet. When this is done one obtains the fractions .483, .350, .097, .070 which represent the relative populations on the medium trucks of bias rib, bias lug, raidal rib, and radial lug tires, respectively.

In terms of an energy-equivalent correction to be added to the previously given tire noise formula, one has

$$10 \log \left[.483 \times 10^{0/10} + .350 \times 10^{6/10} + .097 \times 10^{-2/10} + .070 \times 10^{2/10} \right]$$

$$= 3.11 \text{ dB} \quad .$$

If instead of a fleet of medium trucks which have only bias rib tires one assumes a fleet of medium trucks which consists of trucks of every tire configuration given in Table 3 in the relative proportions described above, then the energy average tire noise emission levels of each truck is increased 3.11 dB.

The analogous correction for heavy trucks was similarly calculated and is equal to 2.25 dB. For Case B, the corrections are 3.72 dB and 1.84 dB for medium and heavy trucks, respectively.

Truck Powertrain Noise

Data for the noise emission levels of truck engines has been compiled from a number of independent sources. Of major importance is the correlation of regulated noise emission levels (by SAE J366) with actual operating levels. In this regard, the third source listed in Table 2 develops some rules for computing operating levels from test levels. These rules were considered and assimilated into the algorithm eventually adopted in the present study. In addition to the GM data, two other manufacturers of heavy and medium trucks supplied detailed noise measurement data for a number of individual trucks under both test and nominal operating conditions. Data from these two manufacturers was also considered in the development of the present algorithm.

For the purposes of this report, medium trucks are understood to be powered by gasoline engines and to have six wheels mounted on two axles. Thus, four wheels are powered. Heavy trucks are understood to be powered by diesel engines and to have eighteen wheels. The tractor portion has ten wheels mounted on three axles. The eight wheels mounted on the second and third axles are powered. The trailer portion has eight wheels mounted on two axles.

For medium trucks with gasoline engines, the engine noise emission in the acceleration mode is assumed to be 2.5 dB below the regulated level. It corresponds rather closely to the J366 test level which is generally somewhat below the regulated level. This is so becuase the vehicles are normally built to meet the regulation with some "tolerance" for manufacturing variance. Cruise and deceleration modes are equated in terms of noise emission levels; at speeds below 35 miles per hour, the engine noise is 9.4 dB below the regulated level. Above that speed the noise emission level rises with a slope of .07 dB per mile per hour. The idle level is 23.2 dB below the regulated level.

For heavy trucks, the engine noise emission level in the acceleration mode is 2.5 dB below the regulated level. For the cruise mode at speeds below 35 miles per hour, the engine noise is 6.5 dB below the regulated level, increasing with a slope of .15 dB per mile per hour above that speed. The idle level is 15.5 dB below the regulated level.

Composite Noise from Trucks

The previous sections have discussed the way in which source emission levels have been calculated for trucks for both tire/aerodynamic noise and powertrain noise. The actual noise level recorded at a microphone or heard by an individual will be the composite level resulting from both sources simultaneously*. If there are other noise sources besides the single vehicle under consideration here, then the noise from the other sources will also be combined with the noise from the single truck. Indeed, the function of the community noise models developed at Battelle is to perform the calculations necessary to correctly combine the various sources. The way in which the models accomplish this has been previously discussed at length (References 5-7).

* It is assumed throughout this report that trucks are point noise sources. In the acoustic far field, of course, every source is a point source. Generally, individuals in the community are in the acoustic far field of each of the individual vehicles they hear.

The procedure for combining the tire and powertrain components of truck noise to obtain the complete noise from a single vehicle has been automated. The automation was accomplished in order to most expediently generate the input data for the community noise models.

Invariant Input Data

The invariant input data used in the traffic noise exposure calculations include: (1) noise emission characteristics of automobiles, light trucks, buses and motorcycles, (2) physical description of road types, including lane number and spacing, (3) attenuation rates for noise propagation through the community, (4) driving characteristics for all vehicles on all road types, (5) traffic densities, (6) total miles for each road type, and (7) population densities. All this data is described in detail in Reference 12: values of these invariant parameters are set equal to their 1974 values given there*.

Twenty different scenarios have been examined. They were defined in terms of both engine and tire noise for medium and heavy trucks. Automobiles, light trucks, buses, and motorcycles were included in traffic which was simulated; however, only the noise characteristics of the medium and heavy trucks were varied from one scenario to the next.

The twenty different scenarios resulted from all possible combinations of 4 engine noise scenarios with 5 tire noise scenarios. The four engine-related scenarios assumed regulated levels (by SAE J366) of 83 dBA, 80 dBA, and 75 dBA, as well as a scenario in which engine noise was "completely" eliminated** from medium and heavy trucks so that only tire/aerodynamic noise remained. The five tire-related scenarios consisted of Cases A and B, followed by scenarios in which all medium and heavy trucks had exclusively bias rib or radial rib tires, and finally by a scenario in which medium and heavy trucks have exclusively hypothetical tires which were assumed to be 30 dB quieter than bias rib tires. The reason for examining the scenarios involving hypothetical "silent" engines and tires was to establish limits for the community noise reduction which can be obtained by quieting those particular sources.

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* This is not meant to imply concurence with the values reported. It was simply judged convenient to obtain maximum overlap with the EPA calculations.

** The regulated level for the medium and heavy trucks was actually set at 30 dBA.

NATIONAL TRAFFIC NOISE EXPOSURE IN TERMS OF L_{dn}

Table 5 shows the national noise exposure in terms of numbers of people exposed to L_{dn}'s in excess of indicated criteria, for each of the twenty scenarios. Cases A and B are seen to lead to quite similar results, indicating that the assumption by which they differ is not very signifcant, at least over the given range. For the purposes of the remainder of this report, the phrase "baseline scenario" refers to the average of Cases A and B.

In the baseline case with the 83 dBA regulation, nearly 102 million people are exposed to $L_{dn} \geq 55$. It must be understood that the scenario assumes that all medium and heavy trucks satisfy the 80 dBA criterion. In fact, it is assumed that every truck in the ntaional fleet immediately satisfies the criterion. For this reason, the exposures reported in Table 5 should be interpreted as somewhat optimistic with respect to the benefits achievable through the regulations. There may be a number of individual trucks which are not in compliance with the regulation; this issue has not been addressed in the study reported here. Within the same constraints and limitations, the 80 dBA criterion would bring about a reduction in community noise such that somewhat fewer than 90 million people would experience outdoor potential L_{dn}'s in excess of 55.

In order to establish perspective, it is beneficial to consider a pre-regulatory national scenario. Some EPA calculations* show that the estimated number of people who would be exposed to $L_{dn} \geq 55$ in the absence of any truck regulations would be approximately 122 million. This corresponds to 57 percent of the Nation's population as shown earlier in Table 1. The successive reduction brought about by the 83 dBA and 80 dBA regulations and by the hypothetical 75 dBA and 30 dBA regulations are approximately 20 million, 12 million, 7.5 million, and 5 million, respectively. Thus, the 1978 (83 dBA) medium and heavy truck regulations have the potential to achieve 45 percent of the

* The calculations referred to are reported in a series of draft volumes of which Reference 12 is a part. The calculations reported there actually predict 57 percent of the population in some future year. Normalization to 1974 conditions leads to the number 122 million. Independent calculations by Battelle for an 88 dBA Case A scenario confirm this.

community noise reduction possible through regulations of this type. The 1983 (80 dBA) medium and heavy truck regulations have the potential to achieve an additional 27 percent. A hypothetical 75 dBA criterion would have the potential of an additional 17 percent reduction and complete elimination of medium and heavy truck powertrain noise could potentially achieve the final 11 percent reduction possible*.

With respect to noise exposure from all vehicles, the elimination of medium and heavy truck powertrain noise reduces the number of people from 122 million to 77.5 million, a 36 percent reduction. Of this, nearly half (16 percent) is attributable to the 83 dBA regulation and nearly one third (10 percent) to the 80 dBA regulation. Approximately one sixth (6 percent) is attributable to the 75 dBA criterion, the remaining ninth (4 percent) to the complete elimination of medium and heavy truck powertrain noise.

For another perspective, one can compute the reduction in the number of people exposed to $L_{dn} \geq 55$ relative to the actual reduction in the regulated levels. The lowering of noise emission levels from 88 dBA (average, unregulated) to 83 dBA (1978 regulation) resulted in a reduction of exposed population from 122 million to 102 million. Thus, the benefit was 4 million persons per dB of truck powertrain noise reduction.

The lowering of noise emission levels from 83 dBA to 80 dBA reduces exposed population from 102 million to 82 million; thus the same 4 million people per dB of truck powertrain noise reduction is calculated. The hypothetical 75 dBA regulation achieves a benefit of only 1.5 million people per dB of truck powertrain noise reduction. Clearly, this hypothetical regulation is not as effective a way to reduce community noise levels as were the 83 dBA and 80 dBA regulations.

It has already been shown that a 80 dBA criterion lowers the exposure from the baseline 102 million to just under 90 million. A comparable reduction is possible (to about 92 million) if the criterion is maintained at 83 dBA and radial rib tires are substituted for the baseline mix of tires. Analogously, starting from the baseline tire 80 dBA criterion, a 75 dBA criterion brings about approximately the same reduction (to approximately 82 million) that can be achieved by retaining the 80 dBA criterion and substituting radial rib tires for the baseline mix of tires.

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* 45% + 27% + 17% + 11% = 100%, a total reduction of 44.5 million people from the elimination of truck powertrain noise.

TABLE 5. POPULATION EXPOSED ABOVE GIVEN L_{dn}'s

Tire Scenario	Regulated Level (dBA)	Population Exposed (millions)			
		L_{dn}=55	L_{dn}=60	L_{dn}=65	L_{dn}=70
Case A	83	101.9	38.4	11.8	2.7
	80	89.7	29.4	8.0	2.2
	75	82.1	26.2	6.5	1.6
	30	77.9	23.8	6.0	1.2
Case B	83	101.6	37.9	11.7	2.9
	80	89.5	29.5	8.0	2.2
	75	81.8	25.8	6.5	1.4
	30	77.1	23.5	5.7	1.2
Bias Rib	83	96.0	34.4	10.8	2.9
	80	84.2	26.5	7.5	1.8
	75	74.6	21.4	5.5	1.4
	30	70.6	18.7	5.2	1.3
Radial Rib	83	92.4	31.7	9.7	2.4
	60	81.9	24.8	6.9	1.5
	75	72.8	21.0	4.8	1.2
	30	67.5	18.2	4.8	0.8
"Silent"	83	88.8	28.5	8.3	1.7
	80	76.5	22.7	5.8	0.7
	75	65.4	17.6	4.8	0.9
	30	60.8	15.6	3.2	0.7

It is interesting to compare the relative contributions of traffic on the different road types. There are six types: they are: (1) interstates, (2) other freeways, (3) major arterials, (4) minor arterials, (5) collectors, and (6) local streets. Table 6 presents the apportionment of exposure for the various road types for the 83 dBA, 80 dBA, and 75 dBA scenarios with Case A tires. In terms of numbers of people exposed to $L_{dn} \geq 55$, the six road types are all significant. Arterials account for approximately one-half of the exposure. Interstates and other freeways account for about one-fourth of the exposure. Collectors and local streets account for the remaining one-fourth.

If the relative contributions of the various road types are compared in terms of numbers of people exposed to higher L_{dn}'s the importance of collectors and local streets diminishes. In terms of numbers of people exposed to $L_{dn} \geq 70$, their combined contribution is approximately one-thousandth (contrasted with one-fourth for $L_{dn} \geq 55$). The contribution of interstates and other freeways rises to sixty-one percent with arterials accounting for thirty-nine percent. Interstates and other freeways are essentially responsible for all exposure to $L_{dn} \geq 80$.

TABLE 6. APPORTIONMENT OF EXPOSURE BY ROAD TYPES

Road Type	Population Exposed Above Given L_{dn} (thousands)					
	55	60	65	70	75	80
(83 dBA Regulation)						
Interstate	14497	5829	2260	928	275	15
Other Freeway	8016	3187	1280	493	120	6
Major Arterial	21650	9391	3836	877	18	0
Minor Arterial	15478	6612	1767	25	0	0
Collector	11913	4676	886	2	0	0
Local Street	11265	409	0	0	0	0
(80 dBA Regulation)						
Interstate	13031	5218	2008	832	229	0
Other Freeway	6425	2544	1035	371	71	2
Major Arterial	18639	8200	3166	604	15	0
Minor Arterial	13034	5267	1112	12	0	0
Collector	9675	3427	395	2	0	0
Local Street	9577	357	0	0	0	0
(75 dBA Regulation)						
Interstate	12185	4867	1891	768	199	0
Other Freeway	5653	2240	897	308	56	1
Major Arterial	16996	7372	2724	465	10	0
Minor Arterial	10967	4126	646	5	0	0
Collector	7931	2492	171	0	0	0
Local Street	8691	314	0	0	0	0

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APPENDIX A

GRAPHICAL PRESENTATION OF NATIONAL TRAFFIC NOISE EXPOSURES BASED UPON L_{dn}

APPENDIX A:

GRAPHICAL PRESENTATION OF NATIONAL TRAFFIC NOISE EXPOSURES BASED UPON L_{dn}

Table 5 of the text presented the National traffic noise exposures which were calculated when the community noise models were exercised for twenty different National scenarios. Table 6 presented the apportionment among the various road types for the 83 dBA, 80 dBA, and 75 dBA Case A scenarios. In order to more clearly illustrate some of the points made in the text, three graphs are given in this appendix which compare and contrast the various scenarios.

Figure A-1 shows, for Case A, the National traffic noise exposure resulting from 88 dBA, 83 dBA, 80 dBA, 75 dBA regulations (J366) and from completely quieted medium and heavy truck powertrains. Figure A-2 shows the effect of various tire configurations. It illustrates the sensitivty of exposure to tire configurations. Figure A-3 presents the graphical evidence for the conclusions drawn from Table 1 of the Conclusions section of this report.

FIGURE A-1. NATIONAL TRAFFIC NOISE EXPOSURE FOR VARIOUS REGULATORY SCENARIOS WITH CASE A TIRES

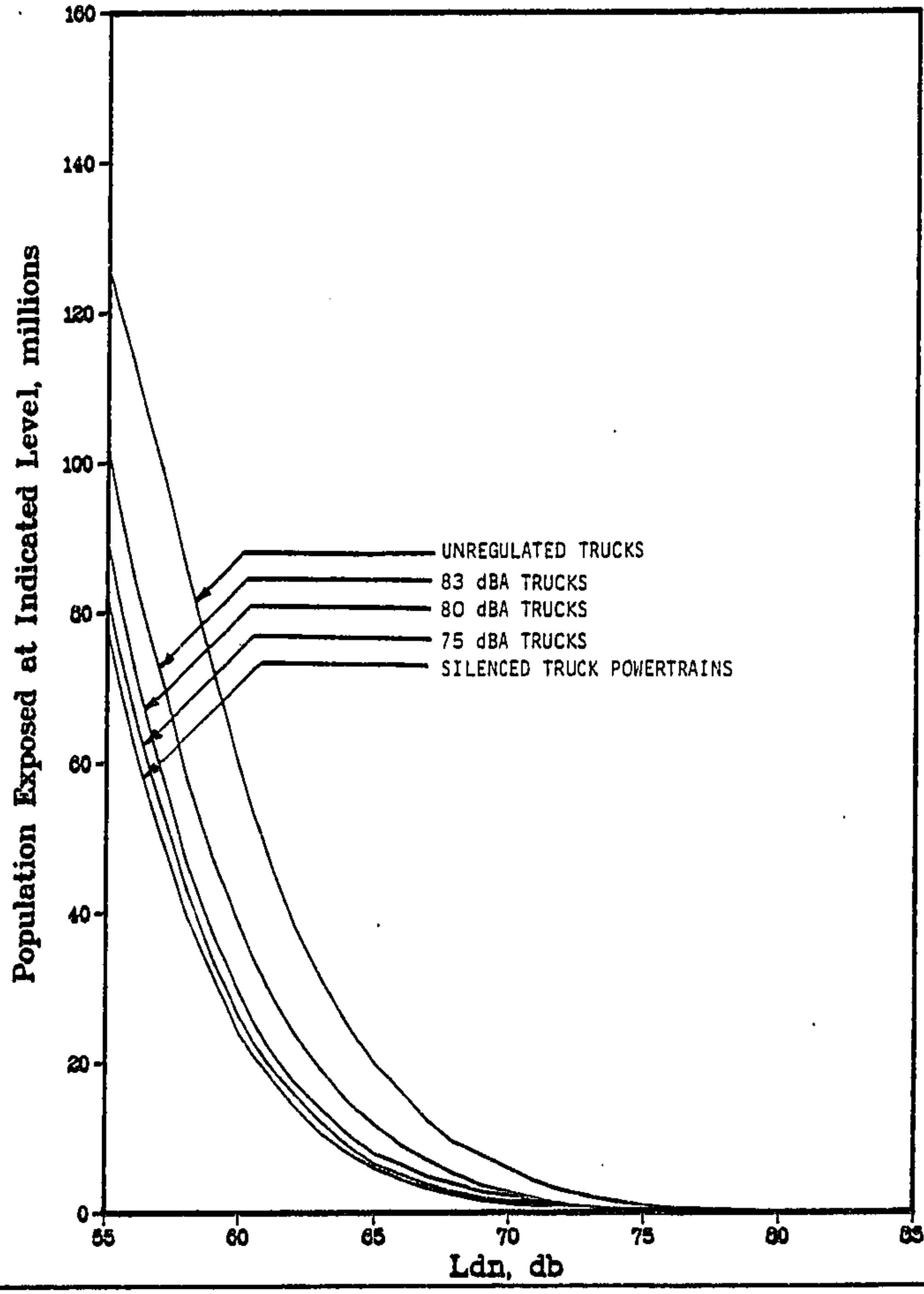


FIGURE A-2. NATIONAL TRAFFIC NOISE EXPOSURE FOR VARIOUS TIRE CONFIGURATIONS

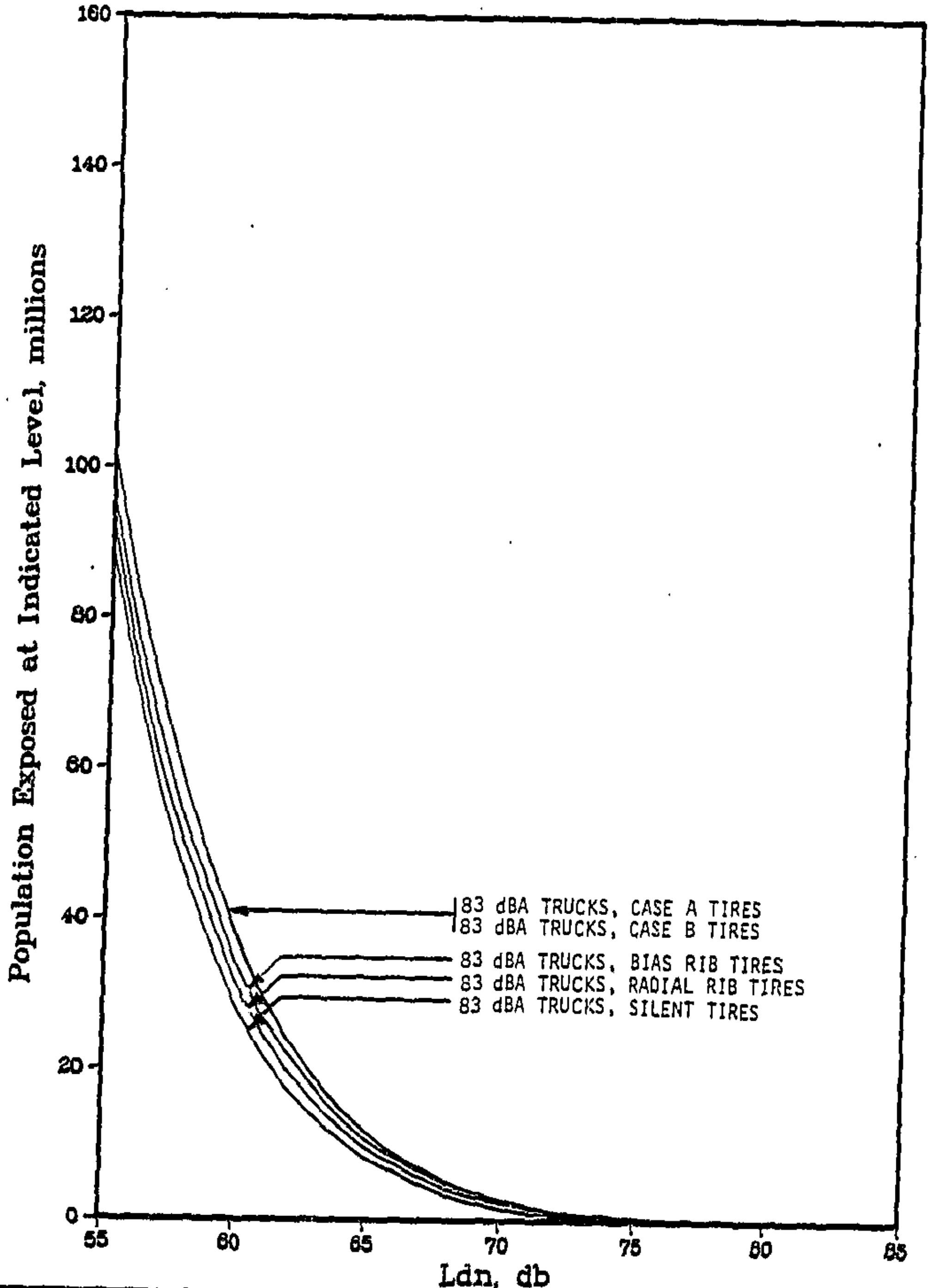
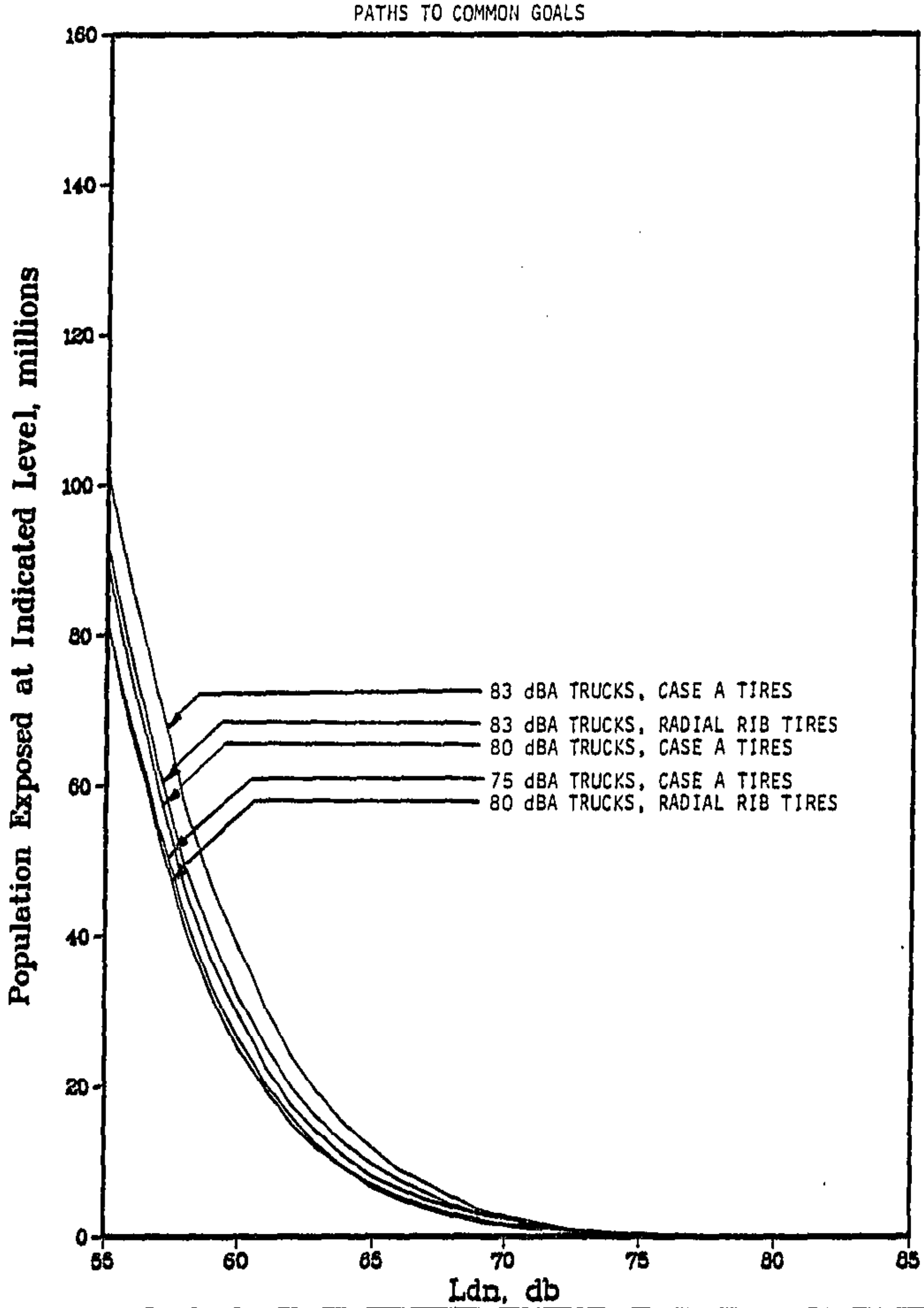


FIGURE A-3. NATIONAL TRAFFIC NOISE EXPOSURE FOR VARIOUS REGULATORY SCENARIOS ILLUSTRATING ALTERANTE PATHS TO COMMON GOALS



APPENDIX B.

NATIONAL TRAFFIC NOISE EXPOSURE DURING PEAK TRAFFIC CONDITIONS BASED UPON EXCEEDANCE LEVELS

APPENDIX B.

NATIONAL TRAFFIC NOISE EXPOSURE DURING PEAK TRAFFIC CONDITIONS BASED UPON EXCEEDANCE LEVELS

In deciding to proceed beyond the L_{eq}, L_{dn}, or other energy-based noise descriptors as a basis for a national traffic noise exposure model, one introduces a variety of complications into the overall methodology. The trade-off is, of course, that one hopes to obtain a more accurate description of the noise exposure -- one which somehow correlates with experience and intuition and that reveals certain features of noise exposure which may be "transparent" to energy-based methodologies. But the demand for more detail imposes upon the investigator a need for a more comprehensive data base. Unfortunately, at the national level at least, the data base one wants and that which exists in accessible form are very different.

It was desirable to base the input for the exceedance-level-based national traffic noise exposure calculations upon the input which had been used for the energy-based calculations, or at least to maximize the compatibility between the two. Just as the energy-based calculation had imbedded within it simplifying assumptions, the adapted data base incorporates those same assumptions plus some others made necessary by practical considerations. L_{dn} by definition characterizes a daily exposure. A noise measure like L_{10} is somewhat ambiguous in that the time under consideration is not specific. It may be the entire 24-hour day, the time of peak traffic conditions, or some other time period of interest. Proper consideration of each of several time periods would require the modelling of each of the several time periods which, in turn, would require a knowledge of the traffic density fluctuations as a function of time of day for each combination of road type, place size, etc. Not only would the traffic densities vary with time of day, the operating modes and speed ranges on a given segment of roadway could be expected to vary as well. In order to alleviate the need for such detailed traffic data, several specific assumptions were made. Among these were:

(1) The worst-case scenario with respect to traffic noise occurs when the traffic density is greatest. This occurs during the so-called "peak traffic" periods.

(2) The traffic conditions during peak traffic periods is identical to the daily average conditions with respect to fleet composition, vehicle operating modes, and speed ranges. However, the traffic density is greater than the daily average. Specifically, the number of vehicles which pass per hour is ten percent of the average daily traffic (ADT) total. If, for example, 20,000 vehicles per day pass on a certain roadway, then during peak traffic conditions the traffic count is 2,000 vehicles per hour.

(3) To obtain a preliminary estimate of national noise exposure it is necessary only to calculate the exposure under peak traffic conditions. It is of course obvious that the noise levels under these conditions are greater than would be observed under average daily traffic conditions.

The first of these assumptions is the most defensible. The second assumptions is probably wrong but is nevertheless necessitated by an absence of contrary data in sufficient and verifiable detail. The third assumption is complementary to the first in that, taken together, they obviate the need for modelling traffic other than that representative of peak conditions. No buses or motorcycles were considered.

The calculated results given in this Appendix are based upon noise exposures given in terms of exceedance levels. Therefore, they are not directly comparable to results based upon noise exposures given in terms of L_{dn}. Generally, the calculated populations exposed in the results reported here are numerically greater than would be the case if L_{dn} were the measure of exposure. This follows from two observations: (1) the people who experience, for example, an average level of 70 dBA are only a subset of the people who ever experience an instantaneous level of 70 dBA, and (2) the exposures reported in this section are for peak traffic conditions not daily average conditions.

Table B-1 presents the number of people who are exposed to given levels of traffic noise during peak traffic conditions for the 83 dBA Case A scenario. The two major vertical divisions of the table correspond to noise levels of 70 dBA and 80 dBA. These refer to instantaneous levels rather than average levels. The column headed "Fraction of Time Level Exceeded" gives the fraction of time during the peak traffic conditions that the given level

TABLE B-1. POPULATION EXPOSED* ABOVE SELECTED NOISE LEVELS DURING PEAK TRAFFIC CONDITIONS: 83 dBA CASE A SCENARIO

Noise Level (dBA)	Fraction of Time Level Exceeded	Roadway Type: Interstate	Other Freeway	Major Arterial	Minor Arterial	Collector	Local Street
70	0.01	2.73M	1.22	5.33	4.77	3.63	1.25
	0.02	2.63	1.15	4.67	3.86	2.53	.18
	0.05	2.45	1.07	3.67	1.79	.54	.01
	0.10	2.34	.94	2.39	.47	.07	--
	0.20	2.21	.80	1.15	.03	--	--
	0.50	1.57	.45	.16	--	--	--
	0.90	.89	.16	--	--	--	--
80	0.10	.53	.14	.33	.08	.16	--
	0.20	.47	.11	.13	.01	.04	--
	0.50	.41	.08	.02	--	--	--
	0.10	.31	.04	.01	--	--	--
	0.20	.20	.02	--	--	--	--
	0.50	--	--	--	--	--	--
	0.90	--	--	--	--	--	--

* An individual is considered exposed to Level L if his $L_1 \geq L$. Populations are in millions of people.

is exceeded. The other column headings correspond to roadway types. For each of the two noise levels and for each of the six roadway types, the table tells how many people are exposed for a given fraction of the time. For example, approximately 2.7 million people are exposed to 70 dBA or above for a least 1 percent of the time as a result of traffic on interstates. Proceeding down any column of a given noise level the number of people decreases. In the case of interstates, approximately 890,000 people are exposed to levels of 70 dBA or above for 90 percent of the time. These same people are also exposed to 70 dBA or above for 1 percent of the time. In other words, the people referred to by an entry in Table B-1 are a subset of the people referred to in the entry immediately above.

Table B-1 points out one characteristic of interstate and other freeway traffic noise which distinguishes noise from those sources from noise from other roadway types. That characteristic is the relatively limited dynamic range of the exposure. According to the "Interstate" column more than 2.3 million people are exposed to noise levels in excess of 70 dBA for at least 10 percent of the time. But only about 2.7 million are "ever" exposed to levels above 70 dBA. Therefore, for every seven people exposed tolevels higher than 70 dBA, six of those people experience such levels for at least 10 percent of the time. In fact, four of them experience such levels for at least half of the time. The situation is similar for other freeways. Of the 1.2 million people who are exposed to traffic noise in excess of 70 dBA from freeways (other than interstates), approximately 1/2 million people are exposed to such levels for at least one half the time.

For the remaining road types, a very different situation exists. For every 33 people exposed to 70 dBA from major arterials only 1 person experiences it for as much as one half the time. In the case of minor arterials, collectors, and local streets, no one experiences 70 dBA for as much as one half the time. Nearly 15 million people are exposed to noise levels above 70 dBA by non-freeway traffic while only 4 million are exposed to those levels from interstate and freeway traffic.

In Phase I of the current project, it was suggested that the fraction of time that one is exposed to noise levels greater than some threshold value may be a critical parameter in determining the degree of some types of impact. In Phase II, evidence was presented which tended to identify 70 dBA as the noise level above which people suffer annoyance, speech interference, and a variety of other adverse welfare-type (as opposed to health-type) responses. It was shown that the number of people, in a population experiencing a common exposure, who report adverse response is proportional to the fraction of time that 70 dBA is exceeded. In considering a general population, which can be sub-divided into a number of sub-populations within which noise exposure is identical, one requires an algorithm whereby the number of people reporting adverse response can be predicted within each subgroup. These numbers of people can then be summed to represent the total impact upon the general population.

Referring again to Table B-1 it is possible to construct sub-populations of approximately identical exposures. For example, in the case of interstate noise exposure there are 2.73 million people who experience 70 dBA or greater for 1 percent of the time. 2.63 million people experience 70 dBA or greater for 2 percent of the time. The difference, 0.10 million, is the number of people who experience 70 dBA or greater more than 1 percent of the time but less than 2 percent of the time. If the assumption is made that these 0.10 million people experience levels greater than 70 dBA for 1.5 percent of the time, then a sub-population of persons with identical exposures is defined. Similarly, the second and third numbers in the same column of the table define a sub-population of 0.18 million people who are exposed to levels above 70 dBA for 3.5 percent of the time.

This process was repeated for each adjacent pair of numbers in each column of Table B-1. The 0.89 million people who experience interstate noise in excess of 70 dBA for 90 percent of the time cannot be subjected to those levels for more than 100 percent of the time. Weighted sums were formed for each of the columns in Table B-1. These sums, together with their components are given in Table B-2. The sums may be interpreted either as (1) the number of person-hours of exposure to levels in excess of 70 dBA, or (2) a number proportional to the amount of annoyance, speech interference or other noise impact which is related critically to the threshold level 70 dBA. Tables B-3 and B-4 present analogous information for the 80 dBA Case A scenario, as do Tables B-5 and B-6 for the 75 dBA Case A scenario.

TABLE B-2. POPULATION EXPOSED* TO SELECTED NOISE LEVELS AND THEIR WEIGHTED SUMS: 83 dBA CASE A SCENARIO

Noise Level (dBA)	Fraction of Time Level Exceeded	Road Type: Interstate	Other Freeway	Major Arterial	Minor Arterial	Collector	Local Street
70	0.015	.10M	.07	.66	1.57	1.10	1.07
	0.035	.18	.08	1.00	2.08	1.99	.17
	0.075	.11	.13	1.28	1.32	.47	.01
	0.150	.13	.14	1.24	.44	.07	--
	0.350	.64	.35	.99	.03	--	--
	0.700	.68	.29	.16	--	--	--
	0.950	.89	.16	--	--	--	--
Weighted Sum		1.58	.51	.79	.27	.13	.02
80	0.015	.06	.03	.20	.07	.12	--
	0.035	.06	.03	.11	.01	.04	--
	0.075	.10	.04	.01	--	--	--
	0.150	.11	.02	.01	--	--	--
	0.350	.20	.02	--	--	--	--
	0.700	--	--	--	--	--	--
	0.950	--	--	--	--	--	--
Weighted Sum		.10	.01	.01	.00	.00	--

* An individual is considered exposed to Level L if his $L_1 \geq L$. Populations are in millions of people.

TABLE B-3. POPULATION EXPOSED* ABOVE SELECTED NOISE LEVELS DURING PEAK TRAFFIC CONDITIONS: 80 dBA CASE A SCENARIO

Noise Level (dBA)	Fraction of Time Level Exceeded	Road Type					
		Interstate	Other Freeway	Major Arterial	Minor Arterial	Collector	Local Street
70	0.01	2.72M	1.12	4.64	3.33	2.74	1.34
	0.02	2.60	1.05	3.98	2.46	1.72	.89
	0.05	2.39	.94	3.04	.87	.24	--
	0.10	2.25	.81	1.83	.13	.06	--
	0.20	2.09	.65	.82	.02	--	--
	0.50	1.51	.33	.15	--	--	--
	0.90	.84	.13	--	--	--	--
80	0.01	.46	.11	.21	.04	.08	--
	0.02	.39	.07	.08	--	.02	--
	0.05	.33	.04	.01	--	--	--
	0.10	.22	.02	--	--	--	--
	0.20	.11	.01	--	--	--	--
	0.50	--	--	--	--	--	--
	0.90	--	--	--	--	--	--

* An individual is considered exposed to Level L if his $L_1 \geq L$. Populations are in millions of people.

TABLE B-4. POPULATION EXPOSED* TO SELECTED NOISE LEVELS AND THEIR WEIGHTED SUMS: 80 dBA CASE A SCENARIO

Noise Level (dBA)	Fraction of Time Level Exceeded	Road Type: Interstate	Other Freeway	Major Arterial	Minor Arterial	Collector	Local Street
70	0.015	.12M	.07	.66	.87	1.02	.45
	0.035	.21	.11	.94	1.59	1.48	.89
	0.075	.14	.13	1.21	.74	.18	--
	0.150	.16	.16	1.01	.11	.06	--
	0.350	.58	.32	.67	.02	--	--
	0.700	.67	.20	.15	--	--	--
	0.950	.84	.13	--	--	--	--
Weighted Sum		1.51	.41	.62	.15	.09	.04
80	0.015	.07	.04	.13	.04	.06	--
	0.035	.06	.03	.07	--	.02	--
	0.075	.11	.02	.01	--	--	--
	0.150	.11	.01	--	--	--	--
	0.350	.11	.01	--	--	--	--
	0.700	--	--	--	--	--	--
	0.950	--	--	--	--	--	--
Weighted Sum		.07	.01	.01	.00	.00	--

* An individual is considered exposed to Level L if his $L_i \geq L$. Populations are in millions of people.

TABLE B-5. POPULATION EXPOSED* ABOVE SELECTED NOISE LEVELS DURING PEAK TRAFFIC CONDITIONS: 75 dBA CASE A SCENARIO

Noise Level (dBA)	Fraction of Time Level Exceeded	Road Type					
		Interstate	Other Freeway	Major Arterial	Minor Arterial	Collector	Local Street
70	0.01	2.50M	.85	3.25	1.38	1.25	.95
	0.02	2.42	.80	2.66	.76	.63	.06
	0.05	2.30	.70	1.91	.24	.18	--
	0.10	2.14	.58	1.22	.10	.05	--
	0.20	1.97	.46	.66	.02	--	--
	0.50	1.42	.26	.14	--	--	--
	0.90	.82	.08	--	--	--	--
80	0.01	.39	.06	.13	.01	.03	--
	0.02	.34	.05	.05	--	.01	--
	0.05	.28	.03	.01	--	--	--
	0.10	.20	.02	--	--	--	--
	0.20	.11	--	--	--	--	--
	0.50	--	--	--	--	--	--
	0.90	--	--	--	--	--	--

* An individual is considered exposed to Level L if his $L_1 \geq L$. Populations are in millions of people.

TABLE B-6. POPULATION EXPOSED* TO SELECTED NOISE LEVELS AND THEIR WEIGHTED SUMS: 75 dBA CASE A SCENARIO

Noise Level (dBA)	Fraction of Time Level Exceeded	Road Type					
		Interstate	Other Freeway	Major Arterial	Minor Arterial	Collector	Local Street
70	0.015	.08M	.05	.59	.62	.62	.89
	0.035	.12	.10	.75	.52	.45	.06
	0.075	.16	.12	.69	.14	.13	--
	0.150	.17	.12	.56	.08	.05	--
	0.350	.55	.20	.52	.02	--	--
	0.700	.60	.18	.14	--	--	--
	0.950	.82	.08	--	--	--	--
Weighted Sum		1.42	.30	.45	.06	.04	.02
80	0.015	.05	.01	.08	.01	.02	--
	0.035	.06	.02	.04	--	.01	--
	0.075	.08	.01	.01	--	--	--
	0.150	.09	.02	--	--	--	--
	0.350	.11	--	--	--	--	--
	0.700	--	--	--	--	--	--
	0.950	--	--	--	--	--	--
Weighted Sum		.06	--	--	--	--	--

* An individual is considered exposed to Level L if his $L_1 \geq L$. Populations are in millions of people.

APPENDIX C

NOISE EMISSION DATA FOR MEDIUM AND HEAVY TRUCKS

APPENDIX C

NOISE EMISSION DATA FOR MEDIUM AND HEAVY TRUCKS

In this Appendix the noise characteristics of the medium and heavy trucks used in the various scenarios are summarized. The algorithms for deriving the operating noise levels as a function of speed and mode from the regulated level were previously discussed in the text. Here, the resulting noise emission levels are presented.

Table C-1 presents the noise levels at 50 feet which result when a medium truck designed to satisfy an 83 dBA criterion (J366) is operated at various speeds in both acceleration and cruise modes. The deceleration mode is not presented in this discussion because it is always assumed to correspond to the cruise mode at the equivalent speed. The speeds selected for inclusion in the table are at 10 mile-per-hour increments. Noise levels for idle are not given since they are so easily calculated from the regulated level by the algorithm discussed in the text.

The powertrain component of the composite truck noise is given by the "silent" tire configuration portion of the table. Regardless of the tire configuration, each "83 dBA" medium truck has noise emission levels at 10 miles per hour which approximate those of a similar truck with "silent" tires. This is because at low speeds the noise level resulting from tires alone is considerably lower than that generated by the powertrain.

As speed increases, the noise attributable to tires increases. At 60 miles per hour in a cruise mode the difference in noise levels from two different "83 dBA" medium trucks can be nearly 5 dB. The loudest tire configuration has bias rib tires except for bias lug tires on the powered axle. The tire noise from this configuration is 82.0 dBA. When this is combined with the 75.4 dBA powertrain noise, the composite level is 82.9 dBA. An 83 dBA medium truck with six radial rib tires, however, generates a tire noise level of only 75.2 dBA -- nearly 7 dB quieter than the previous example. When this tire noise is combined with the 75.4 dBA powertrain noise level, the composite 78.3 dBA is 4.6 dB lower than in the previous example.

TABLE C-1. NOISE EMISSIONS FROM 83 dBA MEDIUM TRUCKS*

Speed (MPH) =	10	20	30	40	50	60	Mode
Configuration**							
all bias rib	80.5	80.5	80.7	81.0	81.5	82.2	accel
	73.6	73.8	74.5	75.8	77.6	79.4	cruise
bias rib w/	80.5	80.6	81.0	81.8	83.0	84.3	accel
powered lugs	73.7	74.3	75.8	78.1	80.6	82.9	cruise
all radial rib	80.5	80.5	80.6	80.8	81.1	81.6	accel
	73.6	73.7	74.2	75.2	76.7	78.3	cruise
radial rib w/	80.5	80.6	80.7	81.1	81.7	82.5	accel
powered lugs	73.6	73.9	74.7	76.2	78.2	80.1	cruise
"silent"	80.5	80.5	80.5	80.5	80.5	80.5	accel
	73.6	73.6	73.6	74.0	74.7	75.4	cruise

* Table entries in dBA at 50 feet.

** Configuration refers to tire description. First and Third configurations assume identical tires on all wheels. Second and Fourth configurations assume lugs on powered wheels with ply characteristics of other tires. Fifth configuration assumes no tire noise.

Tables C-2 and C-3 are analogous to Table C-1. They present the operating noise levels of 80 dBA and 75 dBA medium trucks, respectively. The same general observations apply to these cases. It is interesting to compare the operating noise levels of trucks represented in different tables. If, for example, one compares the noise levels of the 83 dBA and 75 dBA medium trucks (Tables C-1 and C-3) equipped with bias lug tires, the difference in noise levels in the 60 miles per hour cruise condition is less than 1 dB even though the difference in the regulated levels is 8 dB. This is because, even though the powertrain noise level has been reduced from 75.4 dBA to 67.4 dBA, the difference is minimized by the 82.0 dBA tire noise.

At lower speeds, of course, the difference between trucks designed to comply with different regulated levels corresponds more directly with the reduction in the regulated level. Thus, for example, the 80 dBA medium truck is approximately 3 dB quieter than the 83 dBA medium truck at 10 miles per hour. The six curves form three pairs at low speeds. To which pair a particular curve belongs is determined by the regulated level. At high speeds the curves form two groups of three each. To which triplet a given curve belongs is determined by its tire configuration. This effect at the higher speeds decreases as tire noise decreases and would not be observed at all in the case of "silent" tires.

Tables C-4, C-5 and C-6 are analogous to the tables already considered but refer to heavy trucks rather than medium trucks. The trends and characteristics of the heavy truck noise data is similar to those of the medium truck data. They are, however, even more pronounced because tire noise is relatively more important for heavy trucks.

TABLE C-2. NOISE EMISSIONS FROM 80 dBA MEDIUM TRUCKS*

Speed (MPH) =	10	20	30	40	50	60	Mode
Configuration**							
all bias rib	77.5	77.6	77.9	78.4	79.3	80.4	accel
	70.6	71.1	72.2	74.1	76.4	78.5	cruise
bias rib w/	77.5	77.8	78.5	79.8	81.5	83.3	accel
powered lugs	70.7	71.8	74.2	77.2	80.0	82.5	cruise
all radial rib	77.5	77.6	77.7	78.1	78.7	79.5	accel
	70.6	70.9	71.7	73.2	75.1	77.1	cruise
radial rib w/	77.5	77.6	78.0	78.6	79.7	80.9	accel
powered lugs	70.7	71.2	72.5	74.7	77.1	79.3	cruise
"silent"	77.5	77.5	77.5	77.5	77.5	77.5	accel
	70.6	70.6	70.6	71.0	71.7	72.4	cruise

* Table entries in dBA at 50 feet.

** Configuration refers to tire description. First and Third configurations assume identical tires on all wheels. Second and Fourth configurations assume lugs on powered wheels with phy characteristics of other tires. Fifth configuration assumes no tire noise.

TABLE C-3. NOISE EMISSIONS FROM 75 dBA MEDIUM TRUCKS*

Speed (MPH) =	10	20	30	40	50	60	Mode
Configuration**							
all bias rib	72.5	72.8	73.6	74.9	76.7	78.5	accel
	65.7	66.9	69.4	72.4	75.2	77.7	cruise
bias rib w/	72.6	73.3	75.2	77.6	80.1	82.5	accel
powered lugs	66.0	68.7	72.7	76.4	79.5	82.2	cruise
all radial rib	72.5	72.7	73.2	74.2	75.5	77.1	accel
	65.7	66.5	68.3	70.9	73.6	75.9	cruise
radial rib w/	72.5	72.9	73.8	75.4	77.3	79.3	accel
powered lugs	65.8	67.2	70.0	73.2	76.1	78.6	cruise
"silent"	72.5	72.5	72.5	72.5	72.5	72.5	accel
	65.6	65.6	65.6	66.0	66.7	67.4	cruise

* Table entries in dBA at 50 feet.

** Configuration refers to tire description. First and Third configurations assume identical tires on all wheels. Second and Fourth configurations assume lugs on powered wheels with phy characteristics of other tires. Fifth configuration assumes no tire noise.

TABLE C-4. NOISE EMISSIONS FROM 83 dBA HEAVY TRUCKS*

Speed (MPH) =	10	20	30	40	50	60	Mode
Configuration**							
all bias rib	80.5	80.6	81.0	81.7	82.8	84.1	accel
	76.5	76.8	77.7	79.5	81.8	84.0	cruise
bias ribs w/	80.5	80.8	81.6	82.9	84.6	86.5	accel
powered lugs	76.6	77.2	78.8	81.4	84.0	86.4	cruise
all radial ribs	80.5	80.6	80.8	81.3	82.1	83.1	accel
	76.5	76.7	77.3	78.8	80.9	82.9	cruise
radial ribs w/	80.5	80.6	81.0	81.8	82.9	84.2	accel
powered lugs	76.5	76.8	77.7	79.6	81.9	84.1	cruise
"silent"	80.5	80.5	80.5	80.5	80.5	80.5	accel
	76.5	76.5	76.5	77.3	78.8	80.3	cruise

* Table entries in dBA at 50 feet.

** Configuration refers to tire description. First and Third configurations assume identical tires on all wheels. Second and Fourth configurations assume lugs on powered wheels with phy characteristics of other tires. Fifth configuration assumes no tire noise.

TABLE C-5. NOISE EMISSION FROM 80 dBA HEAVY TRUCKS*

Speed (MPH) =	10	20	30	40	50	60	Mode
<u>Configuration</u>**							
all bias rib	77.5	77.8	78.4	79.7	81.2	83.0	accel
	73.6	74.1	75.6	78.0	80.6	82.9	cruise
bias ribs w/	77.6	78.1	79.4	81.5	83.7	85.9	accel
powered lugs	73.6	74.8	77.3	80.4	83.4	85.9	cruise
all radial rib	77.5	77.7	78.1	79.0	80.2	81.7	accel
	73.5	73.9	74.9	76.9	79.4	81.6	cruise
radial rib w/	77.5	77.6	78.0	78.6	79.7	80.9	accel
powered lugs	70.7	71.2	72.5	74.7	77.1	79.3	cruise
"silent"	77.5	77.5	77.5	77.5	77.5	77.5	accel
	73.5	73.5	73.5	74.3	75.8	77.3	cruise

* Table entries in dBA at 50 feet.

** Configuration refers to tire description. First and Third configurations assume identical tires on all wheels. Second and Fourth configurations assume lugs on powered wheels with ply characteristics of other tires. Fifth configuration assumes no tire noise.

TABLE C-6. NOISE EMISSION FROM 75 dBA HEAVY TRUCKS*

Speed (MPH) =	10	20	30	40	50	60	Mode
Configuration**							
all bias rib	72.6	73.3	75.0	77.3	79.8	82.1	accel
	68.7	70.2	73.1	76.5	79.5	82.0	cruise
bias rib w/	72.7	74.1	76.9	80.1	82.9	85.4	accel
powered lugs	68.9	71.8	75.9	79.6	82.8	85.4	cruise
all radial rib	72.5	73.0	74.2	76.1	78.2	80.3	accel
	68.6	69.7	71.9	74.9	77.8	80.3	cruise
radial rib w/	72.6	73.3	75.1	77.5	80.0	82.3	accel
powered lugs	68.7	70.3	73.3	76.7	79.7	82.2	cruise
"silent"	72.5	72.5	72.5	72.5	72.5	72.5	accel
	68.5	68.5	68.5	69.3	70.8	72.3	cruise

* Table entries in dBA at 50 feet.

** Configuration refers to tire description. First and Third configurations assume identical tires on all wheels. Second and Fourth configurations assume lugs on powered wheels with ply characteristics of other tires. Fifth configuration assumes no tire noise.