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16. ABSTRACT

Calculations have been performed to assess the potential effectiveness of barriers toward reducing noise exposure from the federal-aid highway system. Noise exposure, in terms of the numbers of people exposed to L_{dn} greater than 60, 65, 70, and 75 dB, from the primary federal-aid system was computed for present traffic flow and projected traffic through the year 2000. Reductions in noise exposure were computed for several scenarios of constructing barriers along urban interstate highways. It was found that significant reduction of noise exposure would require barriers along most of the urban interstate system. The benefit (in terms of reduction of exposed population) per mile of barrier construction was found to be greatest at high noise levels ($L_{dn} \geq 75$ dB). It was concluded that barriers would not provide a feasible method for abating noise on a national scale. Their main benefit is to provide relief in extremely noisy local applications.

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POTENTIAL EFFECTIVENESS OF BARRIERS TOWARD REDUCING HIGHWAY NOISE EXPOSURE ON A NATIONAL SCALE

JULY 1978

CONTRACT NO. 68-01-4374

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Arlington, Virginia 22202

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Metric Conversions

All of the source data used in this study, obtained from federal government agencies, were available only in English units. To permit this study to be directly keyed to these source data, calculations were performed in English units. Final results have been converted to metric, and are presented in both metric and English units. The following conversion factors may be used to convert source data and intermediate calculations from English to metric units:

1 foot	=	0.305 meters (m)
1 mile	=	1.609 kilometers (km)
1 square mile	=	2.589 square km

1.0 INTRODUCTION

Highway noise can be controlled by reducing vehicle noise levels, by altering highway use and/or design, or by providing protection to exposed areas. These three methods are listed above in decreasing order of generality, i.e., reduced vehicle levels provide a nationwide benefit, modifying highway design or use benefits a particular highway element or corridor, while protection to exposed areas benefits only specific receivers. Potential nationwide benefits from vehicle noise reductions have been evaluated in a number of studies, for example Reference 1. These studies provide supporting information for national vehicle noise standards which are the responsibility of the United States Environmental Protection Agency.[2]

Part of the responsibility for abating highway noise lies with the Federal Highway Administration (FHWA) through its noise policy for federally funded projects.[3] Federal-aid systems consist of over 850,000 miles (1,370,000 kilometers), 22 percent of the nation's total highway mileage, and handle approximately three-quarters of all highway travel in the country.[4] Although a variety of abatement measures are available, the majority of highway noise abatement effected by FHWA has been achieved with barriers. Barrier design procedures have been widely circulated by FHWA,[5] and federal funding is available for approved projects. Barriers are currently being constructed near noise-sensitive areas along federally funded highway projects.

The intent of a barrier is to provide noise abatement in a particular area which would otherwise receive excessively high noise levels. Barriers are thus inherently local solutions, and are the primary noise control method used by FHWA. The purpose of the present study is to examine barriers to determine whether they can provide a feasible method for abating traffic noise on a national scale. This study estimates the number of people exposed to noise from federal-aid highways from 1974 through 2000, and the reduction of this exposure for several alternatives of barrier construction on a national scale in 1974 and 2000. Calculations are limited to federal-aid highways because these are the ones for which funding is generally available.

2.0 TRAFFIC ON FEDERALLY FUNDED HIGHWAYS

The federal-aid highway system consists of the following three systems of roads:[6]

- Primary System — Rural routes and their urban extensions which are classified as arterials. This includes the Interstate System.
- Secondary System — Rural routes which are classified as major collectors such as farm-to-market roads.
- Urban System — All arterial and collector routes in urban areas (places of 5,000 or more population) which are not in the primary systems.

The highest traffic densities, hence the greatest potential for noise problems, are associated with the primary system. The present study therefore considers only the primary system.

Because of the difference in character between interstate and non-interstate highways, and the population density difference between rural and urban areas, the primary system has been divided into four parts for the purposes of this study:

- Urban interstate
- Urban primary, excluding interstate
- Rural interstate
- Rural primary, excluding interstate

Table 1 shows the traffic volume in 1974, in terms of average daily traffic (ADT). Data for ADT up to 40,000 are from Reference 7; distributions above this value are extrapolated within the constraint that total road and vehicle mileage are consistent with values given in Reference 7. Table 2 gives roadway configuration, speed, and the percentage of medium- and heavy-duty trucks for each type of road. Truck percentages are from Reference 8; other data in Table 2 are assumed values typical of each type of road. Speeds in Table 2 are consistent with data in Reference 9.

Traffic volumes on these four systems have been predicted for future years through 2000. The projections are based on a growth factor for total traffic volume and a growth factor for road mileage for each system. The tabulated distributions shown in Table 1

Table 1

Traffic on Federal-Aid Highways in 1974[7]

Average Daily Traffic (ADT) (Thousands)	Miles of Road			
	Urban Interstate	Urban Primary*	Rural Interstate	Rural Primary*
0.4	38	242	83	8,610
0.4-1	2	223	448	32,259
1-2	23	858	1,756	50,386
2-3	31	1,267	2,511	33,911
3-4	82	1,573	2,788	21,064
4-5	137	1,520	3,075	12,895
5-10	902	7,556	11,077	21,115
10-15	1,076	5,391	6,364	4,373
15-20	1,093	3,424	2,834	1,318
20-30	1,742	3,253	2,059	705
30-40	1,129	1,109	472	122
40-60	1,100	660	204	48
60-80	840	450	---	---
80-100	600	335	---	---
100-120	125	---	---	---
120-150	70	---	---	---
Total Mileage	8,990	27,861	33,671	186,806

* Excluding Interstate

Table 2

Road and Traffic Parameters

	Urban Interstate	Urban Primary	Rural Interstate	Rural Primary
Speed (mph/kph)	55/88.5	35/56.3	55/88.5	55/88.5
Percent Trucks[8]	8.7	3.4	15.6	8.2
Number of Lanes	8	4	3	2
Median Width (feet/meters)*	0	0	50/15	0

* Median strip widths estimated here are the minimum which would normally be found on each type highway.

are first increased according to road mileage growth, then shifted upward so as to satisfy the traffic volume growth. Growth factors used are based on the following:

- Total traffic (vehicle miles) increases at a rate of 2.3 percent per year. This is a composite value between estimated annual growths of 2.4 percent for trucks[10] and 2.0 percent for automobiles.[11] The composite value is a weighted average based on the relative contributions of these two vehicle types to highway noise.[12]

- Volume (ADT) on rural interstates increases at a rate of 3.8 percent per year, while road mileage remains approximately fixed. This is based on data in Table I-1 of Reference 10.

- Total volume and road mileage of rural primaries increase at approximately 0.5 percent per year. This is based on the "full needs" case in Table I-1 of Reference 10.

- Mileage of urban primary roads is assumed to increase at a rate of 1 percent per year, the rate of growth of the population. This is consistent with the growth projections in Reference 13.

- Urban interstate mileage is fixed at approximately 9,000 miles (14,480 km).

- Traffic mix remains the same as given in Table 2.

Table 3 shows the projected traffic for the year 2000.

Table 3

Projected Traffic on Federal-Aid Highways in 2000

Average Daily Traffic (ADT) (Thousands)	Miles of Road			
	Urban Interstate	Urban Primary*	Rural Interstate	Rural Primary*
<0.4	7	224	31	9,802
0.4-1	6	241	47	36,726
1-2	14	614	284	59,639
2-3	12	869	421	38,606
3-4	17	1,172	665	23,981
4-5	24	1,398	665	14,680
5-10	290	7,035	4,894	24,039
10-15	494	6,588	5,177	4,978
15-20	528	4,986	4,196	1,500
20-30	1,164	6,033	7,106	803
30-40	1,138	3,009	4,714	139
40-60	1,827	2,160	3,267	55
60-80	1,102	611	1,574	---
80-100	1,167	333	358	---
100-120	591	374	100	---
120-150	545	308	---	---
150-200	173	---	---	---
200-300	67	---	---	---
Total Mileage	9,166	35,955	33,499	214,948

* Excluding Interstate

3.0 NOISE EXPOSURE FROM FEDERAL-AID HIGHWAYS

The noise exposure to noise levels above L_{dn} = 60, 65, 70, and 75 dB from the federal-aid primary system has been computed.* The computation was performed on the following basis:

- Distances to L_{dn} = 60, 65, 70, and 75 dB contours were computed for each ADT range using the method of Reference 14. This model includes lane-by-lane detail which is important for barrier calculation.
- Vehicle noise levels used are given in Table 4, and are based on roadside noise data in Reference 15 for automobiles, and Reference 16 for trucks.
- The distance to each contour, less an assumed 50-foot (15-meter) setback distance, was multiplied by the number of miles of road carrying each ADT, then by 2, to obtain area exposed on both sides of the road. It is assumed that noise exposure at a given point is from one road only.
- The number of people exposed was then obtained by multiplying the area by 4,500 people per square mile (1,737 per square km) in urban areas (this is the median value of density in Table A-1 of Reference 18) and 56 people per square mile (22 per square km) in rural areas (total U.S. population divided by total U.S. area).

Table 5 summarizes the calculated exposure for 1974** for the four road types.

Table 6 shows the exposure in 2000 for the four systems. Figure 1 shows exposure to $L_{dn} \geq$ 60, 65, 70, and 75 dB as a function of time for the urban interstate system.

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* Previous EPA studies have identified levels above L_{dn} = 55 dB as significant when considering public health and welfare.[17] Calculations in the present study are presented only for $L_{dn} \geq$ 60 dB because highway barriers are usually practical for alleviating only higher noise levels.

** The most recent year for which traffic and highway statistics were available at the time of this calculation.

Table 4

Vehicle Noise Levels
(Energy-Average Maximum Pass-By Levels
at 50 Feet (15 meters))

	Energy-Average Maximum Pass-By Level at 50 Feet (15 meters)	
Vehicle Type	35 mph (56.3 kph)	55 mph (88.5 kph)
Automobiles[15]	65.1 dB	71.4 dB
Trucks[16]	83.6 dB	87.5 dB

Table 5

Area* and People** (Millions) Exposed to Noise Greater Than Various L_{dn} Values From Federally Funded Highways in 1974

	L_{dn} Exceeded							
	60 dB		65 dB		70 dB		75 dB	
Road System	Area	People	Area	People	Area	People	Area	People
Urban Interstate (8,990 miles)	3,033 (7,852)	13.6	1,216 (3,148)	5.5	337 (872)	1.5	79 (205)	0.36
Urban Primary*** (27,861 miles)	1,590 (4,117)	7.2	431 (1,116)	1.94	54 (140)	0.24	1 (2.6)	0.005
Rural Interstate (33,671 miles)	5,130 (13,282)	0.29	2,238 (5,794)	0.13	565 (1,463)	0.032	51 (132)	0.003
Rural Primary*** (186,806 miles)	8,871 (22,964)	0.50	2,255 (5,838)	0.13	364 (942)	0.020	14 (36)	0.001

* Square miles (square kilometers).

** People impacted based on 4,500 people/mi^2 (1,738 per km^2) in urban areas, and 56 people/mi^2 (22 per km^2) in rural areas.

*** Excluding interstate.

Table 6

Area* and People** (Millions) Exposed to Noise Greater Than Various L_{dn} Values From Federally Funded Highways in 2000

Road System	L_{dn} Exceeded							
	60 dB		65 dB		70 dB		75 dB	
	Area	People	Area	People	Area	People	Area	People
Urban Interstate (9,166 miles)	4,682 (12,122)	21.1	1,964 (5,085)	8.8	696 (1,802)	3.1	197 (510)	0.87
Urban Primary*** (35,955 miles)	2,814 (7,285)	12.7	809 (2,095)	3.6	136 (352)	0.61	12 (31)	0.05
Rural Interstate (33,499 miles)	13,154 (34,056)	0.74	5,724 (14,819)	0.32	1,954 (5,059)	0.11	488 (1,263)	0.03
Rural Primary*** (214,948 miles)	10,174 (26,340)	0.57	2,487 (6,439)	0.14	418 (1,082)	0.023	16 (41)	0.001

* Square miles (square kilometers).

** People impacted based on 4,500 people/mi^2 (1,738 per km^2) in urban areas, and 56 people/mi^2 (22 per km^2) in rural areas.

*** Excluding interstate.

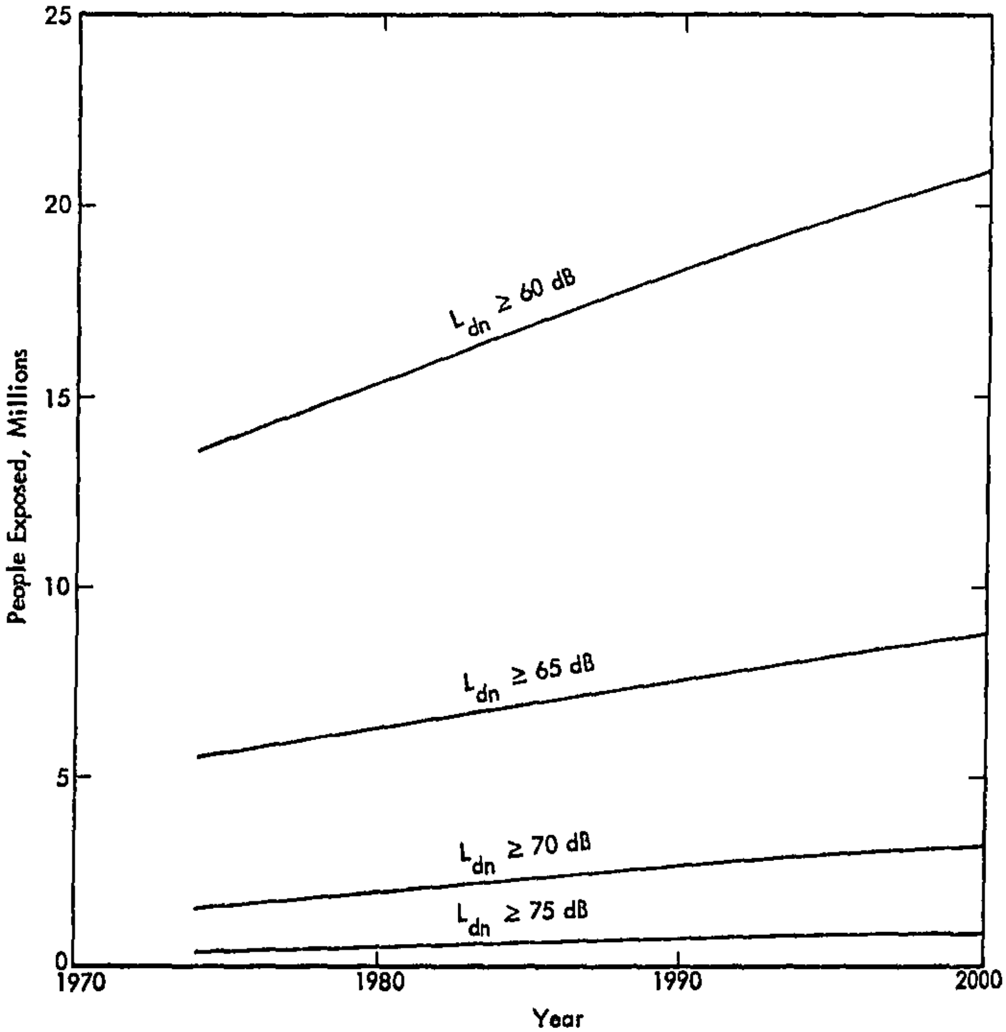

Figure 1. Numbers of People Exposed to Noise from Urban Interstates, 1974-2000.

4.0 BARRIERS ON URBAN INTERSTATE HIGHWAYS

The noise abatement potential of barriers has been evaluated by calculating reduced exposure for several scenarios. The calculations are limited to urban interstates. Rural highways are not included because their total exposure is small compared to urban. Urban primary roads are not included because barriers are rarely practical on them due to cross-streets, need for access, etc.

Tables 7 and 8 show the distribution of noise exposure in 1974 and 2000 for no barriers and for 10-foot (3-meter), 15-foot (4.5-meter), and 20-foot (6-meter) high barriers.* Barriers higher than 20 feet (6 meters) would give little or no additional benefit. Shown for each ADT range are the distances to the L_{dn} = 60, 65, 70, and 75 dB contours with no barriers, and the areas exposed for no barriers and for the 3 height barriers. The barrier calculations were performed using the method of Reference 19, and include the following assumptions:

- Level terrain. Shielding by existing buildings is not accounted for.
- All receivers are at first-story level, i.e., high-rise residences are not accounted for.
- Barriers are vertical walls parallel to the road, with sound transmission through the wall negligible.
- Barriers located 25 feet (7.5 meters) to each side of the road.

Four barrier-use scenarios have been considered, each with the goal of eliminating (where feasible) exposure to L_{dn} above a given value. These are:

A. Eliminate exposure above L_{dn} = 75 dB. This requires construction of 15-foot (4.5-meter) barriers where ADT > 100K, and 10-foot (3-meter) barriers where 30K < ADT < 100K.

B. Eliminate exposure above L_{dn} = 70 dB. This requires 20-foot (6-meter) barriers where ADT > 80K, 15-foot (4.5-meter) barriers where 30K < ADT < 80K, and 10-foot (3-meter) barriers where 10K < ADT < 30K.

* Only these three heights were considered in the calculations and in the ensuing discussion. Equivalent reduction to exposure could be achieved in some cases with lower barriers, e.g., 4.5-meter barriers are assumed here in places where barriers taller than 3 meters but less than 4.5 meters would suffice.

Table 7

Distribution of Areas Exposed to Noise From Urban Interstates in 1974
For Several Barrier Heights

Average Daily Traffic (ADT)	Miles of Road	Distance (Feet) From Center of Outer Lane to L_{dn} Contour, No Barrier				Exposed Area, Square Miles															
						No Barrier				10 ft (3m) Barrier				15 ft (4.5m) Barrier				20 ft (6m) Barrier			
		60	65	70	75	60	65	70	75	60	65	70	75	60	65	70	75	60	65	70	75
<400	38	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
400-1K	2	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2K	23	84	---	---	---	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-3K	31	138	---	---	---	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-4K	82	180	70	---	---	4	0.6	0	0	2.3	0	0	0	0	0	0	0	0	0	0	0
4-5K	137	219	80	---	---	8.8	1.6	0	0	5.1	0	0	0	0	0	0	0	0	0	0	0
5-10K	902	310	135	---	---	88	29	0	0	71.3	0	0	0	0	0	0	0	0	0	0	0
10-15K	1,076	450	195	72	---	163	59	8	0	150	28	0	0	14.6	0	0	0	0	0	0	0
15-20K	1,093	600	245	93	---	227	80	17	0	227	53	0	0	33	0	0	0	14	0	0	0
20-30K	1,742	800	325	125	50	494	181	49	0	494	141	0	0	92	3	0	0	92	0	0	0
30-40K	1,129	1,050	430	172	68	427	162	52	7	427	148	18	0	94	12	0	0	67	0	0	0
40-60K	1,100	1,350	590	230	94	541	225	75	18	541	223	41	0	137	32	0	0	108	13	0	0
60-80K	840	1,650	740	300	120	509	219	79	22	509	219	62	0	141	38	0	0	120	21	0	0
80-100K	600	1,300	880	350	150	397	188	68	22	397	188	54	0	113	37	1.8	0	99	24	0	0
100-120K	125	2,300	1,000	420	185	106	44	17	6	106	44	15	2.5	32	9	1.3	0	27	5	0	0
120-150K	70	2,600	1,100	520	220	67	27	12	4	12	27	26	10	20	6	1.5	0	18	4.7	0.4	0

Table 8

Distribution of Areas Exposed to Noise From Urban Interstates in 2000
For Several Barrier Heights

Average Daily Traffic (ADT)	Miles of Road	Distance (Feet) From Center of Outer Lane to L_{dn} Contour, No Barrier				Exposed Area, Square Miles															
						No Barrier				10 ft (3m) Barrier				15 ft (4.5m) Barrier				20 ft (6m) Barrier			
		60	65	70	75	60	65	70	75	60	65	70	75	60	65	70	75	60	65	70	75
<400	7	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
400-1K	6	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-2K	14	84	---	---	---	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-3K	12	138	---	---	---	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-4K	17	180	70	---	---	0.8	0.1	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0
4-5K	24	219	80	---	---	1.5	0.3	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0
5-10K	290	310	135	---	---	28.5	9.3	0	0	23	0	0	0	0	0	0	0	0	0	0	0
10-15K	494	450	195	72	---	74	27	4.1	0	69	12.9	0	0	6.7	0	0	0	0	0	0	0
15-20K	528	600	245	93	---	110	39	8.6	0	110	25.7	0	0	16	0	0	0	6.8	0	0	0
20-30K	1,164	800	325	125	50	330	121	33	0	330	94	0	0	61	2.5	0	0	61	0	0	0
30-40K	1,138	1,050	430	172	68	431	163	52	7	431	150	18	0	94	12	0	0	68	0	0	0
40-60K	1,827	1,350	590	230	94	899	373	124	30	899	370	68	0	227	53	0	0	179	22	0	0
60-80K	1,102	1,650	740	300	120	667	287	104	29	667	287	82	0	184	49	0	0	157	14	0	0
80-100K	1,167	1,800	880	350	150	773	336	132	44	773	366	106	0	220	73	3.5	0	193	46	0	0
100-120K	591	2,300	1,000	420	185	503	212	82	30	503	212	70	11	151	42	6.3	0	127	23	0	0
120-150K	545	2,600	1,100	520	220	526	216	97	35	526	216	21	20	157	48	11.4	0	145	36	2.9	0
150-200K	173	3,500	1,600	660	280	226	101	39	15	226	101	39	11	65	62	6.6	0	65	22	3.6	0
200-300K	67	4,500	2,000	840	360	112	49	20	7	112	49	20	6	29	26	3.9	0	29	13	3.4	0

C. Eliminate exposure above L_{dn} = 65 dB. This requires 20-foot (6-meter) barriers where ADT > 20K, 15-foot (4.5-meter) barriers where 10K < ADT < 20K, and 10-foot (3-meter) barriers where 3K < ADT < 10K.

D. Eliminate exposure above L_{dn} = 60 dB. This requires 20-foot (6-meter) barriers where ADT > 10K, 15-foot (4.5-meter) barriers where 3K < ADT < 10K, and 10-foot (3-meter) barriers where 1K < ADT < 3K.

Tables 9 and 10 show the distance required of each height barrier (in miles and kilometers), and the exposure for each scenario, in 1974 and 2000. Note that the goal of each scenario is not necessarily achieved because of the limit of effectiveness of barriers limited to a practical height of no more than 20 feet (6 meters).

Figure 2 shows the 1974 exposure data from Table 9 in graphical form. The first application of barriers (Scenario A) has its greatest effect at high noise levels. The other scenarios, with more extensive barriers, tend to shift the distribution downward, with a residual tail at high levels which cannot be eliminated with barriers.

Because barriers provide larger noise reduction at close locations where noise levels are highest, the benefit of barrier application is first seen at higher noise levels, but the benefit at high levels does not increase with greater application of barriers. All four scenarios have the same reduction to population exposure above L_{dn} = 75 dB. A more modest scenario of eliminating half the exposure above 75 dB in 1974 (half the goal of Scenario A) would require 2,163 miles (3,476 kilometers) of barrier, about one-quarter that required for Scenario A.

Table 9

Noise Exposure From Urban Interstates in 1974
For Several Barrier Scenarios

Scenario	Miles (Kilometers) of Barriers			People Exposed to Greater L_{dn} (Millions)			
	10 ft (3m)	15 ft (4.5m)	20 ft (6m)	60 dB	65 dB	70 dB	75 dB
Baseline — No Barrier	0	0	0	13.6	5.5	1.5	0.36
A — Eliminate Exposure Above L_{dn} = 75 dB	7,338 (11,792)	390 (627)	0	13.1	5.1	1.1	0
B — Eliminate Exposure Above L_{dn} = 70 dB	7,822 (12,570)	6,138 (9,864)	1,590 (2,555)	6.7	1.7	0.002*	0
C — Eliminate Exposure Above L_{dn} = 65 dB	2,242 (3,603)	4,338 (6,971)	11,212 (18,018)	3.0	0.31*	0.002	0
D — Eliminate Exposure Above L_{dn} = 60 dB	108 (174)	2,242 (3,603)	15,550 (24,989)	2.5*	0.31	0.002	0

* Not feasible to eliminate completely exposure with barriers.

Table 10

Noise Exposure From Urban Interstates in 2000
For Several Barrier Scenarios

Scenario	Miles (Kilometers) of Barriers			People Exposed to Greater L_{dn} (Millions)			
	10 ft (3m)	15 ft(4.5m)	20 ft (6m)	60 dB	65 dB	70 dB	75 dB
Baseline — No Barriers	0	0	0	21.1	8.8	3.1	0.87
A — Eliminate Exposure Above L_{dn} = 75 dB	10,468 (15,822)	2,752 (4,422)	0	16.7	7.0	1.6	0
B — Eliminate Exposure Above L_{dn} = 70 dB	4,372 (7,026)	8,134 (13,071)	5,086 (8,173)	7.2	1.8	0.045*	0
C — Eliminate Exposure Above L_{dn} = 65 dB	662 (1,064)	2,044 (3,285)	15,548 (24,986)	4.8	0.79*	0.045	0
D — Eliminate Exposure Above L_{dn} = 60 dB	52 (84)	662 (1,064)	17,592 (28,270)	4.6*	0.79	0.045	0

* Not feasible to eliminate completely exposure with barriers.

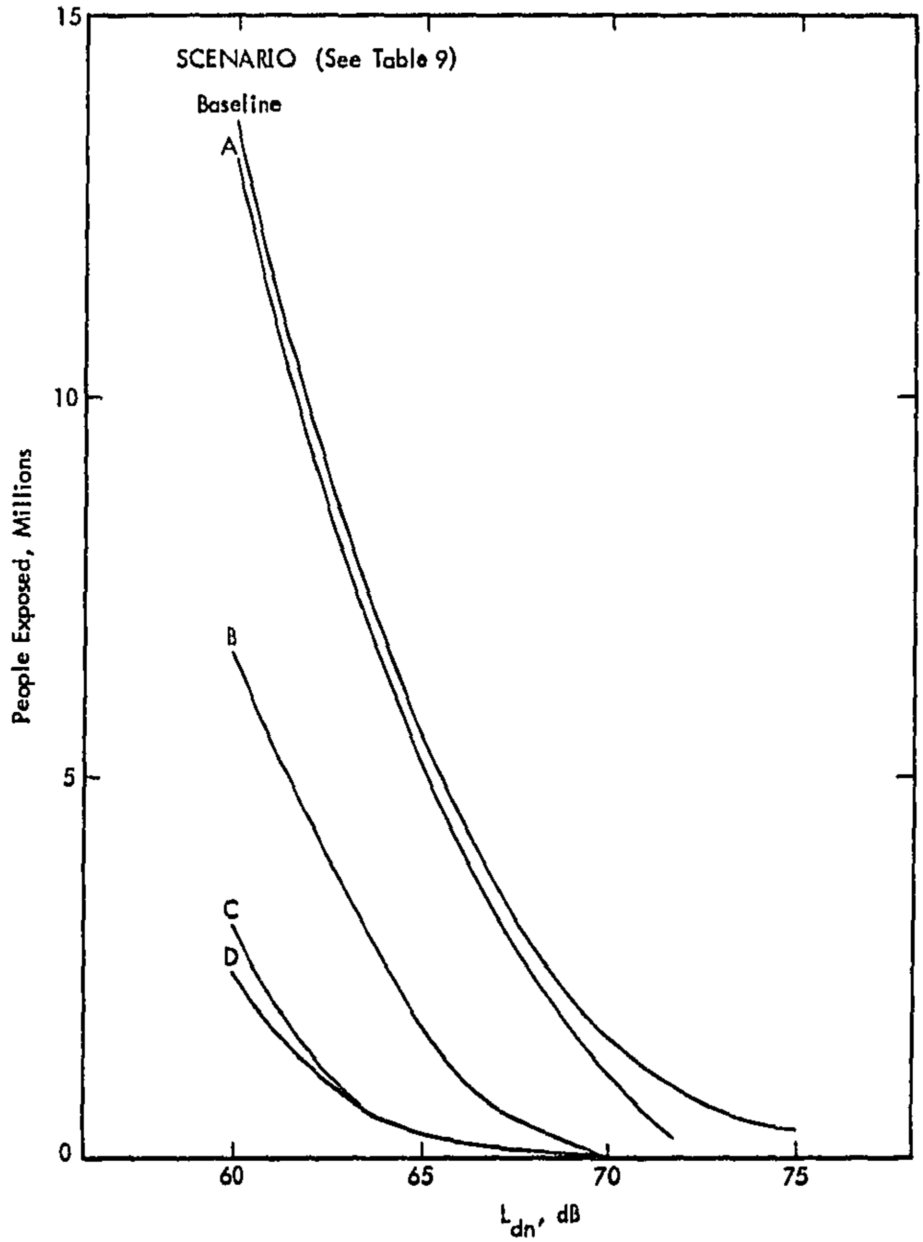

Figure 2. Changes in Noise Exposure From Urban Interstates in 1974 for Four Barrier Scenarios.

5.0 CONCLUSIONS

Calculations have been performed of the numbers of people exposed to noise from the federal-aid highway system. It was found that the majority of exposure to high noise levels ($L_{dn} \geq 75$ dB) is due to traffic on urban interstates.

The potential effectiveness of barrier construction toward reducing noise exposure from federal-aid highways was evaluated by considering wide-scale construction of barriers along urban interstate highways. Four scenarios considered were constructing barriers to eliminate exposure above L_{dn} = 60, 65, 70, and 75 dB. It was found that these four scenarios would require extraordinarily large mileages of barriers — both sides of more than half of the urban interstates.

The present calculation is not sufficiently detailed to permit calculation of scenarios involving exposure only to levels higher than those noted above. However, a trend was seen that the benefits (in terms of reduction of exposed population) per mile of barrier are greatest when applied to relieve extremely high noise levels. This has been the intended purpose of barriers in virtually all applications. General reduction of highway noise at moderate levels would require clearly impractical magnitudes of construction.

It is therefore concluded that barriers constructed along federal-aid highways would not provide a feasible method for abating traffic noise on a national scale. Their main benefit is to provide relief in extremely noisy local applications.

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