THRESHOLD NOISE LEVELS

by

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Research Report Number 166-1

Urban Traffic Noise Reduction

Research Study Number 2-8-71-166

Sponsored By

The Texas Highway Department
In Cooperation with the
U. S. Department of Transportation
Federal Highway Administration

December, 1970

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY
College Station, Texas

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ABSTRACT

Human tolerance to noise levels created by vehicular traffic has been examined. A review of available literature indicated that there are numerous suggested maximum highway noise levels, although general consensus indicates that for a noise beyond 70 dBA, complaints are likely. Most investigations pertain only to daytime noise levels; therefore, it appears that future studies are necessary to determine acceptable nighttime levels.

In his critique of the symposium "Evaluating the Noises of Transportation," Hirsh noted that there was little agreement as to the methods for measuring highway noise and the acceptable noise levels for highways. Included in the study reported here are considerations of conflicting studies, reviews of the latest state-of-the-art and recommendations for maximum sound pressure levels for highways.

Consideration is also given to the sources of highway noise, to those individuals who are affected by highway noise and to the role various land uses have in selecting maximum highway sound levels.

SUMMARY

Introduction

The reaction of people to highway noise is a complex problem that involves a combination of physical and psychological factors, which vary from person to person. This research effort has assimilated facts from many sources and determined realistic maximum sound pressure levels for individual vehicles, as well as for various land use activities.

The Problem

This research indicates that the primary source of highway noise complaints is the heavy truck. Therefore, the problem is primarily one of controlling peak noise levels from these vehicles. The current state-of-the-art of automotive design probably cannot reduce the noise level from heavy trucks below 85 dBA, without a substantial technological breakthrough in muffler design.

Automobile traffic will not normally produce noise levels which are objectionable. However, it is important to note that automobile traffic does contribute significantly to the ambient noise level. Therefore, it is important to establish reasonable maximum values on transportation-associated noises which the public can reasonably be expected to tolerate.

The sound pressure level associated with a single passenger vehicle is approximately 65 dBA, while a dense traffic stream of many lanes would be approximately 75 dBA. The primary noise source for the automobile is the noise associated with the tire-roadway interaction. For heavy

trucks, the sound pressure level may approach 95 dBA (well above the objectionable range), the principal noise source being the exhaust system. A combined traffic stream of 180 vehicles per mile density operating at 50 miles per hour and containing 5 percent heavy trucks, would produce a mean noise level of 73 dBA with infrequent peak values of 90 dBA or more measured at a distance of 50 feet.

Human Response to Noise

The response of a human being to highway noise is psychological rather than physical. To sustain physical damage to the auditory system, the individual must be subjected to high noise levels for extended periods of time. For example, a noise level of 85 dBA for eight hours per work day for 20 years would produce some hearing damage in only approximately six percent of the individuals exposed. Continuous noise levels of this magnitude are not possible from highway sources. There is some indication that a small percentage of the population is hypersensitive to noise, but there appears little evidence that mental distress results from highway-associated noises. It is also important to note that some physiological changes do occur in humans when subjected to lower noise levels for extended periods of time; however, no conclusive research results on the effects of these changes have been found.

The psychological effect of highway noise is a relatively new field. However, preliminary studies have shown that the psychological impact of a freeway is far more dramatic for higher socio-economic groups. These groups also feel that the lack of adequate landscaping is the major cause of freeway intrusiveness. Good landscaping of highways has been found to reduce complaints and, since bushes and trees are very poor acoustical barriers, this reinforces the argument that highway noise is a psychological, as well as a physical problem.

Recommended Noise Levels

This report recommends noise levels for various land uses. These noise levels vary between 55 dBA at the property line for hospitals during the "nighttime hours" (11 p.m. - 7 a.m.) to 75 dBA at the property line for business, commercial and industrial zones. A complete summary of recommended noise levels is shown in Table 1. These levels are based on the fact that the ambient or background noise that already exists in urban areas is approximately 60 dBA during the day and 50 dBA during the night. It is difficult to differentiate between the ambient level and a noise source level which is 10 dBA or greater than the ambient level. Consequently, the values recommended all fall within this 10 dBA range, giving the highway engineer some latitude in his designs, but limiting the values to those which cannot be readily identified. It should be noted that these values are recommended as design guides for new highways and not as maximum values for existing systems. It must also be noted that these recommended values will be exceeded by peak noises, usually caused by trucks on grade, motorcycles and passenger vehicles with improper mufflers.

This report recommends that individual trucks and motorcycles have a maximum daytime sound pressure level of 85 dBA and automobiles 77 dBA,

TABLE 1

SUMMARY OF RECOMMENDED NOISE LEVELS
FOR VARIOUS LAND USES

Land Use Activity	Time of Day	Recommended Maximum Mean Sound Pressure Level (dBA)	
		At Property Line	Inside a Structure
Residential (single and multiple family)	Day	70	65
	Night	65	55*
Business, Commercial and Industrial	All	75	65
Educational Institutions	All	70	60
Hospitals and Rest Homes	Day	60**	55
	Night	50**	45
Public Parks	All	70	55

*Air conditioning systems commonly operate at 55 dBA. For non-air-conditioned residential structures it may be desirable to reduce this value by 5 dBA.

**Expected ambient noise level.

all measured 50 feet from the source and under heavy acceleration conditions. It is further recommended that consideration be given to legislating a maximum urban nighttime (11 p.m. - 7 a.m.) sound pressure level of 77 dBA for all vehicles, measured 50 feet from the source and under heavy acceleration conditions. The daytime values recommended above are similar to those presently existing in California which have been successfully applied.

RECOMMENDATIONS FOR IMPLEMENTATION

Based on the review of the many studies undertaken in this country, the United Kingdom and Europe, it is recommended that consideration be given to adopting a maximum sound level of 85 dBA from trucks and motorcycles and 77 dBA for automobiles measured 50 feet from the source under heavy acceleration. These levels are recommended for daytime conditions, and it is suggested that further study be undertaken to investigate the feasibility of lowering these values during nighttime hours in urban areas.

Many states have attempted to legislate maximum noise levels from vehicles, but to date, with the exception of California, these efforts have not met with any great success. Enforcement of noise levels could be considered to be the long-term answer, but for immediate action acoustic barriers, soundproofing of homes, and selective landscaping appear to be necessary for the reduction of highway noise to acceptable levels.

RECOMMENDATIONS FOR FURTHER RESEARCH

The report indicates that further research is necessary in the following areas:

1. Maximum noise levels from urban freeways during nighttime hours
2. Means of decreasing noise from existing freeways
3. Design criteria to decrease noise from new freeways
4. Practical methods of measuring the sound pressure levels from highways

INTRODUCTION

Noise pollution has been added to the list of our environmental ills, and attention is now being directed toward the causes of noise and how it can be reduced. The problem of highway noise is rather complex, as there are many variables which are not directly interrelated. Some of the factors affecting highway noise are density and composition of traffic, vehicle speed, temperature, humidity, wave frequency, pavement texture, tire tread, highway grade and wind velocity.

The measurement of these variables is further complicated by the fact that noise must be considered in both physical and psychological terms. The former can be measured in terms of decibels on electronic equipment, but the latter can be measured only indirectly.

Absolute values for noise threshold tolerances vary according to the adjacent land use. For example, residential areas are more adversely affected by highway noise than, say, industrial and commercial areas. The noise tolerance level in urban-residential areas will vary depending on the time of day or night. Commercial and industrial areas are usually only concerned with daytime noise levels, and the ambient noise level within these buildings must be taken into account when considering acceptable traffic noise levels. Few complaints are voiced from commercial and industrial areas adjacent to highways.[(1)]

MAGNITUDE OF THE PROBLEM

1. What Is Noise and How Can It Be Measured

Noise is caused by vibrations which excite the surrounding air particles, forming a compression wave. This compression wave is propagated through the air in the form of a spherical shape which increases in size with time.[(2)] The propagation of sound from a point source in a free field follows the inverse square law, i.e., the "loudness" of the noise is inversely proportional to the square of the distance from the source. However, in practice this has been found to be incorrect. In fact, for high density traffic the subjective noise level at 100 feet is only a little more than twice the noise at 1000 feet.[(3)] This is due to the decrease of about 3 dBA when doubling the distance from the source. Hence, from 100 feet to 1000 feet there will be about a 10-dBA reduction which the ear perceives to be a halving of the loudness level.

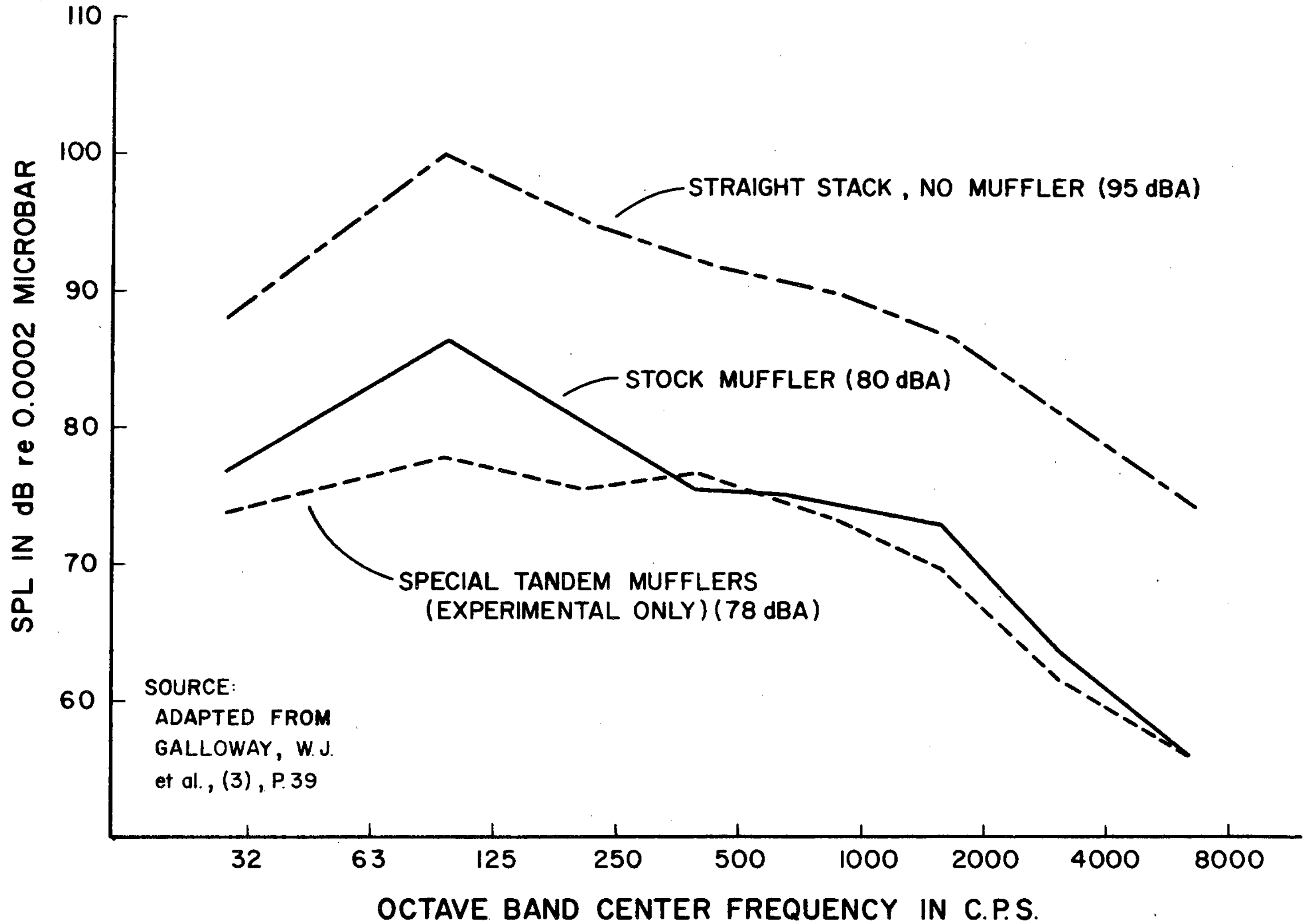
The physical effect of noise can be measured in units of decibels. These units are usually measured on the "A" weighted network of a precision sound level meter.[(3)] This method of measurement of highway noise has the approval of the International Standards Organization and the Acoustical Society of America.[(1)] It should be noted that the decibel is not a direct measure of loudness, but when applied to highway noise it correlates closely to that which the human ear hears. The use of the "A" scale for the evaluation of highway noise has been found to be the most practical measure.[(1-9)] The perceived noise level (PNdB) is a more precise measurement of the different frequency characteristics of a sound, but the "A" scale lends itself to field measurements.

Galloway[3] investigated the psychological aspects of freeway noise and found that he was able to predict, with amazing accuracy, people who would express irritation to highway noise. This is further discussed in the latter part of the section.

2. Source of Highway Noise

Highway noise is basically caused by exhausts and tire-roadway interaction. There is very little variation in automobile noise, but this is not true for trucks.[3] Automobile noise is mainly due to tire-roadway interaction, while for trucks the engine-exhaust noises predominate. Figure 1 shows that by simply adapting special mufflers to truck exhaust, the noise reduction is not significant. California studies[22] have noted that some manufacturers have improved muffler systems to reduce the noise from former values in excess of 92 dBA at 50 feet to 86 dBA during open throttle tests. This value probably represents the lower bound with existing automotive technology.

Tire-roadway interaction noise depends mainly on the road texture, but other factors such as tread, pavement wetness and tire loading also affect this noise level. Noise by tire-pavement interaction can be significant on high density urban freeways, but it is the noise from diesel trucks that is the main source of highway noise peaks.[1] This can be shown by considering the equivalent lane technique as developed by Galloway, W. J., et al., [3] for a six-lane freeway with speeds of 50 miles per hour and volume per lane of 1500 vehicles per hour. Therefore, the density per lane is 30 vehicles per mile or 180 vehicles per mile for the six lanes. From Figure 2, this represents a noise level of only 71 dBA at 100 feet from the source.



DIESEL TRUCK NOISE SPECTRUM AT 50 FEET

Figure 1

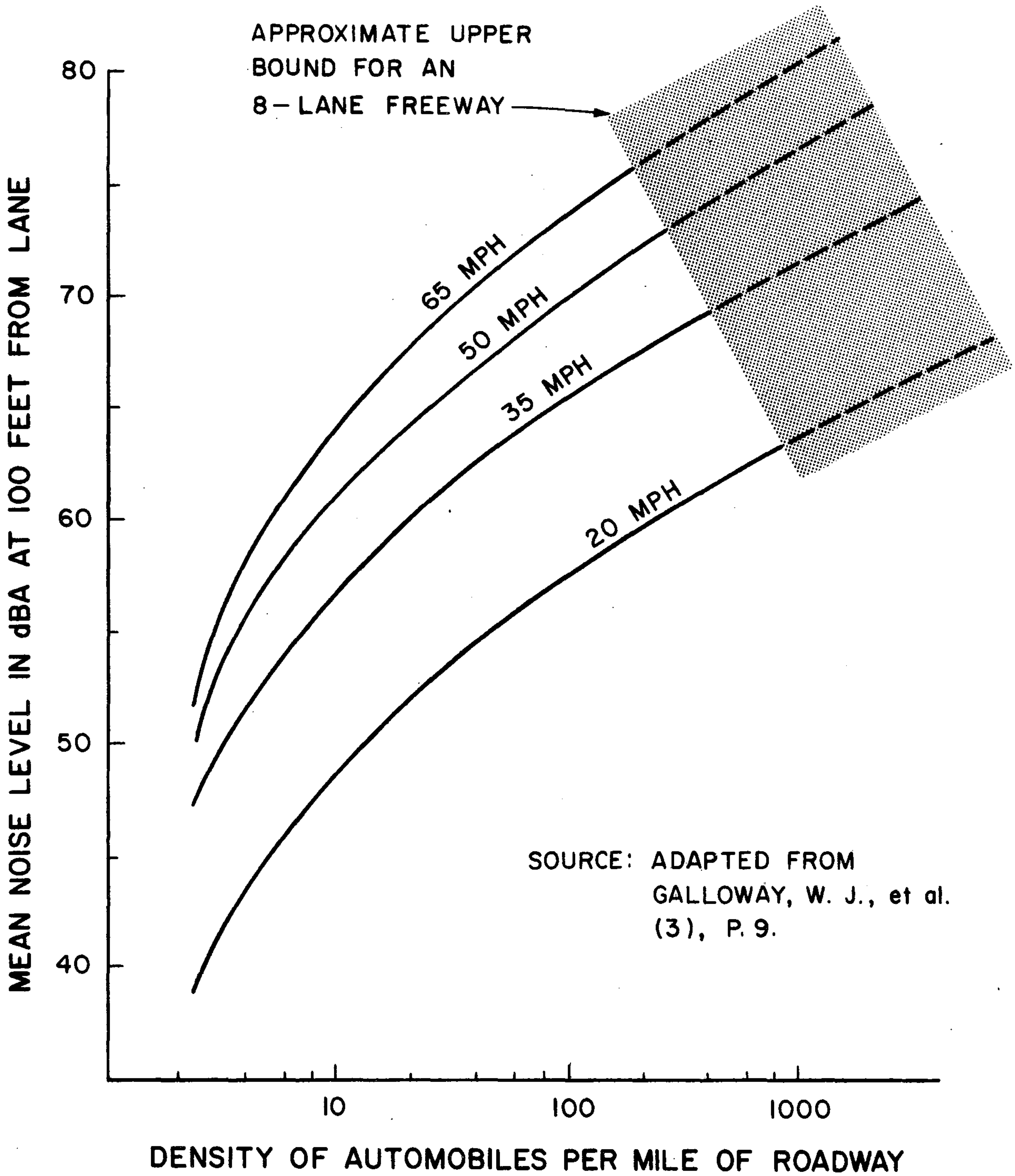

APPROXIMATE UPPER
BOUND FOR AN
8-LANE FREEWAY
80
70
60
50
40
MEAN NOISE LEVEL IN dBA AT 100 FEET FROM LANE
65 MPH
50 MPH
35 MPH
20 MPH
SOURCE: ADAPTED FROM
GALLOWAY, W. J., et al.
(3), P. 9.
10
100
1000
DENSITY OF AUTOMOBILES PER MILE OF ROADWAY

Figure 2

A good example of increased density causing increased noise was given by Galloway[3]; two automobiles per mile at 50 miles per hour gave less than a 40 dBA reading at 100 feet, but as the density increased, the noise increased to about 65 dBA, i.e., a four-fold increase in noisiness (note that dBA is not directly proportional to noisiness).

Truck noise increases with increasing engine speed, due to highway grades, and increased truck densities in the traffic stream. Figure 2 shows the relationship between noise and vehicle speed, while Figure 3 is a plot of the increase in noise level with increased truck volumes and density of traffic.

Colony[10] found that the majority of people living near a freeway considered trucks the main cause of noise. Further evidence comes from Thiessen[11] who showed the statistical distribution of sound pressure levels of automobiles, motorcycles and trucks. Figure 4 shows that although heavy trucks represent perhaps only 5 percent of the total traffic, they contribute more noise than the remaining 95 percent of the vehicles in the traffic stream. Decreased noise levels on Sundays in Ontario have been attributed to legislation which bans truck travel on that day.[11]

3. Who Is Affected by Highway Noise

An urban freeway passing through several neighborhoods, creating similar noise conditions, might be considered objectionable by one community but tolerable by another. It appears that the psychological impact of a freeway is far more dramatic for higher socio-economic groups. Galloway et al.[3] found that these groups appeared to have a

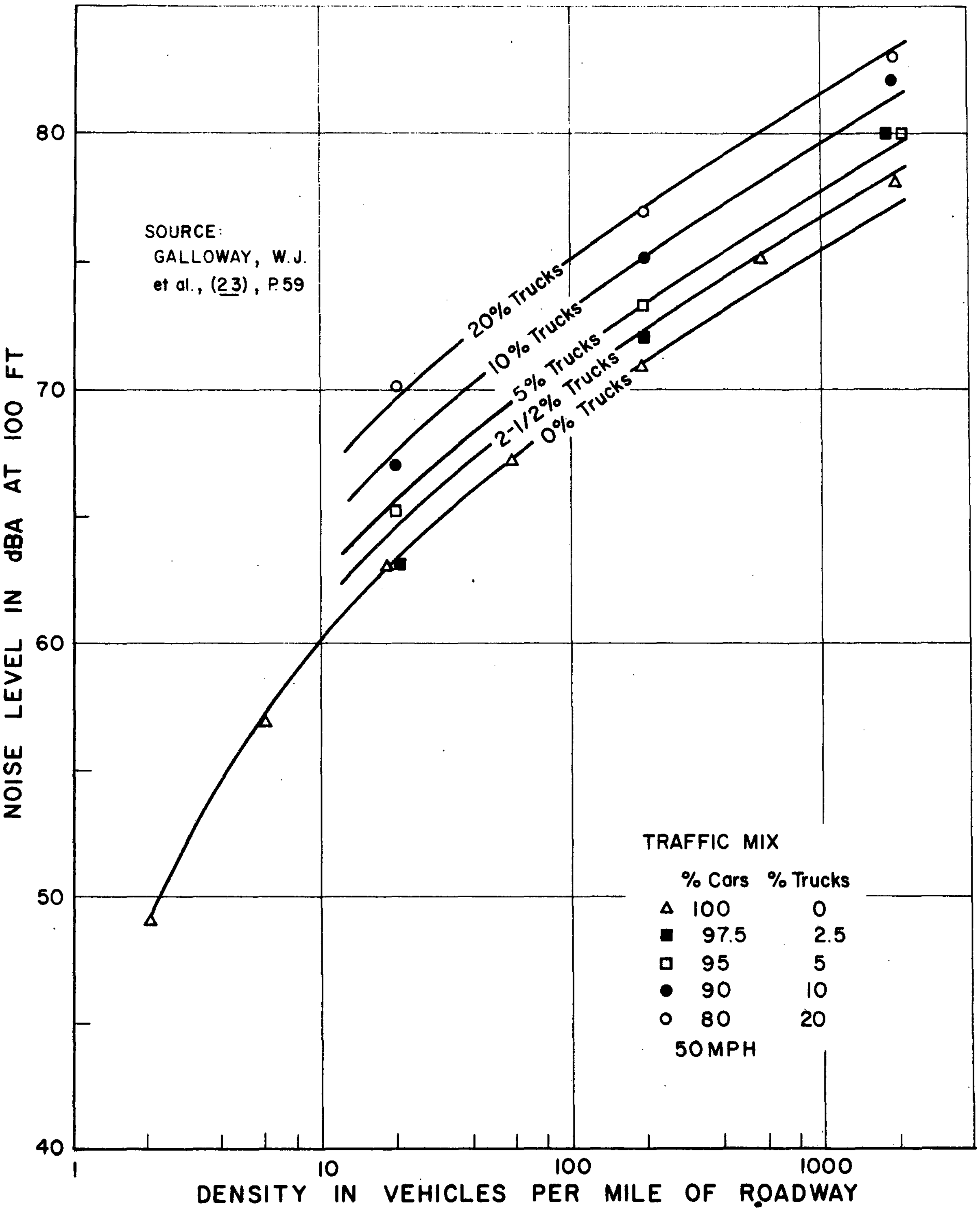


Figure 3. Curves for estimation of mean noise level in dBA at 100 ft distance from a lane (or single-lane-equivalent) of mixed car and Diesel truck traffic.

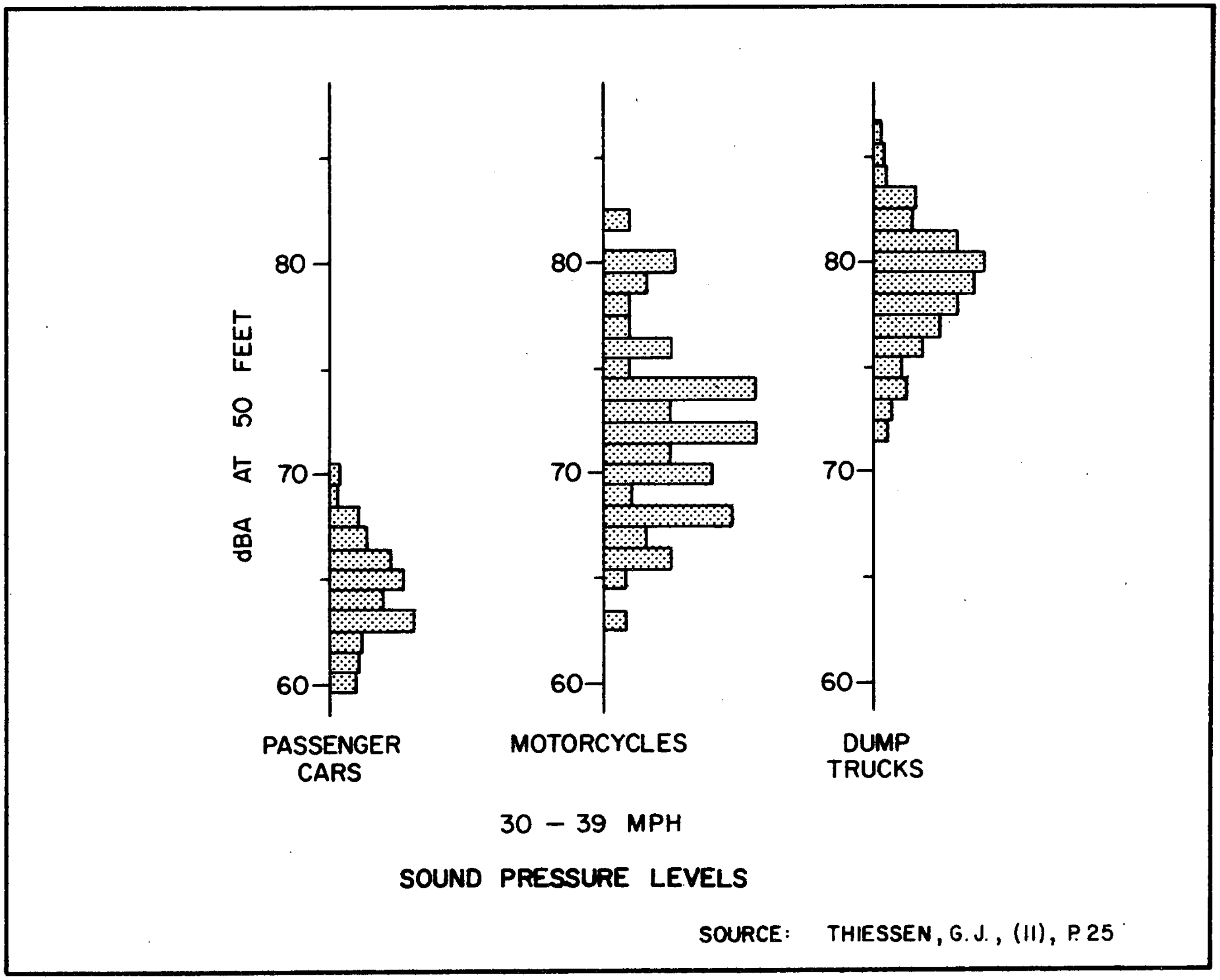

dBA AT 50 FEET
80
70
60
PASSENGER CARS
MOTORCYCLES
DUMP TRUCKS
30 – 39 MPH
SOUND PRESSURE LEVELS
SOURCE: THIESSEN, G.J., (11), P. 25

Figure 4

lower noise tolerance level than other groups. The annoyance expressed by these vocal groups was reflected in their attitudes toward freeways in general. Colony[(10)] found that nearly 66 percent of his survey respondents found highway noise irritating, etc., and would not live near a freeway again. This survey was conducted in an area of 80-85 decibel range of sound pressure. Colony also developed an acceptability index for various sound pressure levels. This relationship is presented in Figure 5.

The higher socio-economic groups not only complained of the noise from the freeway, but considered noise as part of the general lack of freeway aesthetics. These groups felt that the lack of landscaping was the major cause of freeway intrusiveness.[(3)] Further studies are needed to determine the relationship of the psychological effect of noise reduction by landscaping.

It should be noted that the frequently heard allegations that noise exerts ill effects on the mental health of residents adjacent to freeways remains difficult to confirm or disprove. This question is important, since it is a widely held belief. However, apart from the actual hearing mechanism, little evidence has come to light to relate noise to identifiable and attributable physical disease.[(12)]

No data are available to determine the traffic noise levels that must exist before hearing impairment occurs. However, studies from industrial noise suggest that hearing impairment from highway noise is unlikely. Botsford[(13)] considers 90 dBA to be the beginning of dangerous

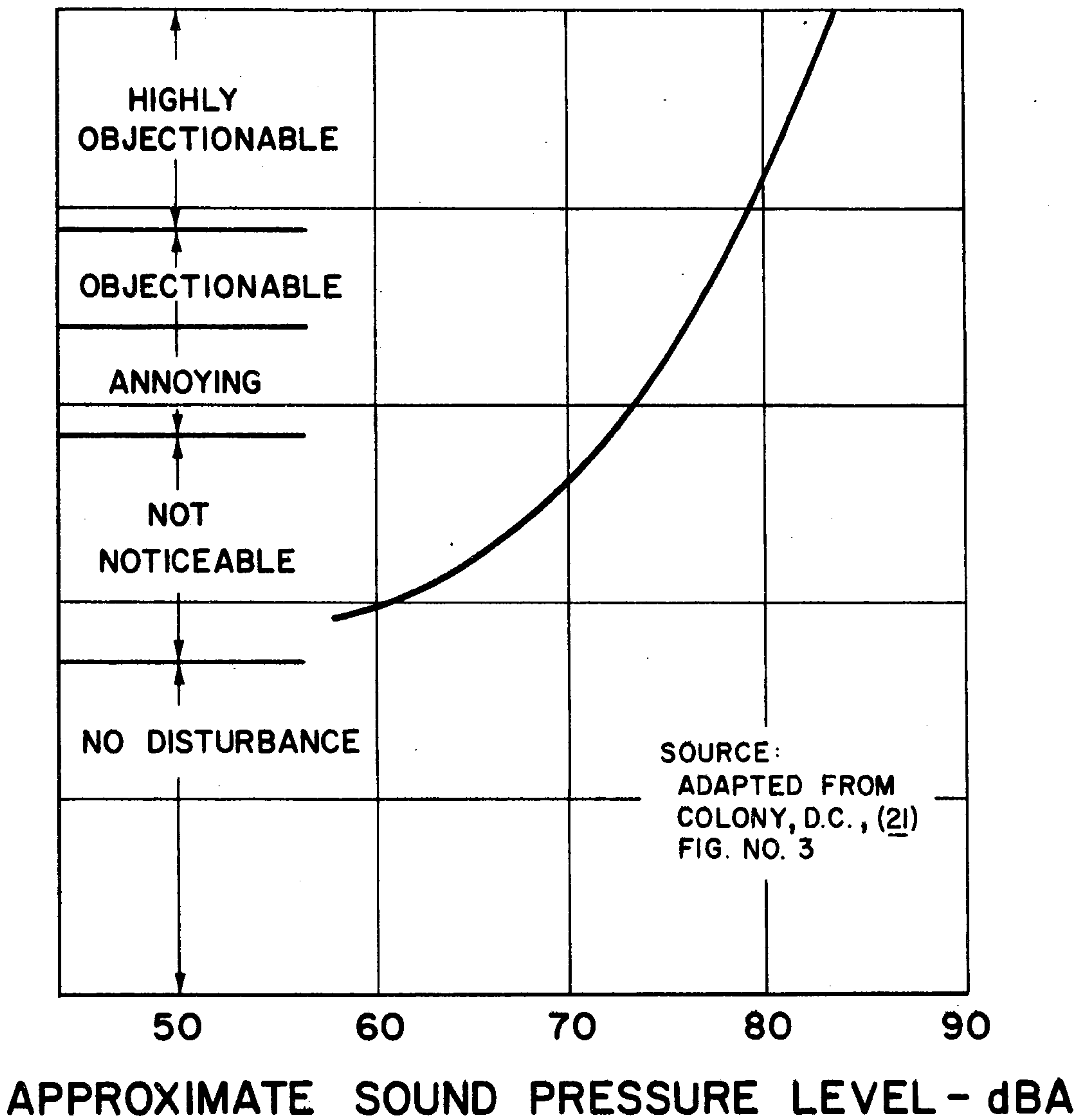


Figure 5. Acceptability index for residential property.

noise, but the value depends heavily on the exposure time. The International Organization for Standardization (I.S.O.) prepared a table[14] listing the percentage of people expected to experience a noise-induced hearing impairment for extended noise during a 40-hour work week (Table A). This table shows that a level of 85 dBA, for 40 hours per week, would cause 6 percent of the exposed people to suffer hearing impairment after 20 years. This level for such an extended period of time is virtually unknown in highway noise. Consequently, the noise problem is rarely a physical one, but rather a psychological one. This is reinforced by Borsky[15] who notes that a small percentage of the population is hypersensitive to almost all noise and that psychological factors, such as attitude toward the necessity of the noise, importance of noise source, fear associated with noise and the belief that noise will affect health, are important in the psychological hostility toward the noise source.

AMBIENT NOISE LEVELS

Ambient noise levels can be described as background noise and, consequently, vary from location to location. This factor must be considered when recommending maximum noise levels.

Table B[23] shows the recommended values for noise levels in various land use areas. These values appear to be rather low, since some are even less than the ambient noise levels. That is to say, the recommended noise level of 50 dBA is likely to be less than the existing background noise in most communities today.

TABLE A

PERCENTAGE OF PEOPLE EXPECTED TO EXPERIENCE
A NOISE INDUCED HEARING IMPAIRMENT

Due solely to extended exposure to noise during a 40-hour work week, for the years listed.

Equivalent Continuous Sound Level A in Decibels	Composite-Noise-Exposure Index	Percentage people Years exposure, 40 hr/wk 5	10	15	20	30
70	1					
75	3					
80	10	0	0	0	0	0
85	30	1	3	5	6	8
90	100	4	10	14	16	18
95	315	7	17	24	28	31
100	1000	12	29	37	42	44
105	3150	18	42	53	58	62
110	10000	26	55	71	78	77
115	31500	36	71	83	87	81

Source: Young, R. W., (14), P 146.

TABLE B

DESIGN NOISE LEVELS RECOMMENDED
BY GALLOWAY (23)

Observer Category	STRUCTURE			L_{50} **		L_{10}***	
				DAY	NIGHT	DAY	NIGHT
1	Residences		Inside *	45	40	51	46
2			Outside *	50	45	56	51
3	Schools		Inside *	40	40	46	46
4			Outside *	55	-	61	-
5	Churches		Inside	35	35	41	41
6	Hospitals		Inside	40	35	46	41
7	Convalescent Homes		Outside	50	45	56	51
8	Offices	Inside	a) Stenograph	50	50	56	56
			b) Private	40	40	46	46
9	Theaters		a) Movies	40	40	46	46
			b) Legitimate	30	30	36	51
10	Hotels, Motels		Inside	50	45	56	51

* Either inside or outside design criteria can be used depending on the utility being evaluated.

Note: All levels measured in dBA.

**L_{50} - Mean sound pressure level.
***L_{10} - 90th percentile sound pressure level.

Table B refers to L_{50} and L_{10} values. These are the 50 percent or median level (that which is exceeded for 50 percent of the time), and the 10 percent level (that which is exceeded for 10 percent of the time). Galloway's research[(23)] indicated that a 6-dBA difference exists between the L_{10} and L_{50} levels. This difference is rather dramatic, as a 10-dBA decrease in the noise level would reduce the noise by about one half.

Thiessen[(11)] calculated that the average daytime background noise of a city two miles in diameter was about 60 dBA, while at night it would be about 50 dBA. A city of this diameter is rather small. He used the example of Ottawa, with a population of about 300,000 and radius 4.5 miles, giving a background noise level of about 63 dBA during the day and 53 dBA at night (Figure 6).

Little[(24)] investigated ambient noise levels in Los Angeles and found that values were about 57 dBA in the quiet residential areas, about 62 dBA in the residential La Brea area, about 70 dBA in residential areas near heavy traffic and 76 dBA downtown. All of these values are above Galloway's[(23)] maximum values, and there appears to be no point in recommending highway noise levels that are less than the existing background noise. Little's study also found that the ambient noise level has been steadily increasing with time, a factor which will tend to make the objectionable peaks less noticeable.

It is also important to note that permitting noise levels substantially greater than the existing ambient levels is undesirable. Traffic noise is one of the primary contributors to the ambient noise

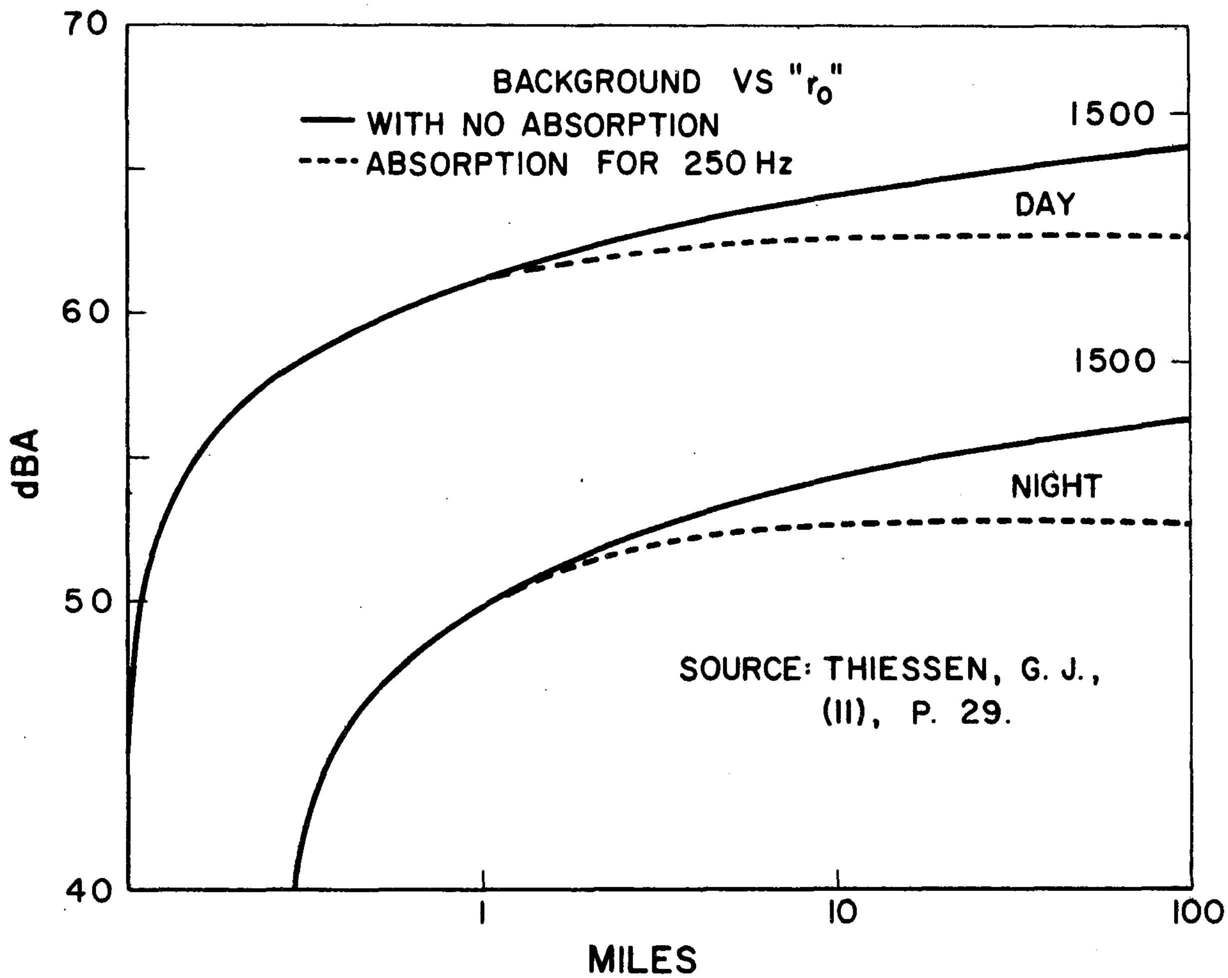


Figure 6. Change in background noise level with increasing size of the city. The curves with no absorption are theoretical while the dotted curves represent a modification of these curves by the experimental absorption data of Harris.[3]

level, and failure to place limits on both the maximum noise from an individual vehicle, and of the traffic stream as a whole, will result in a continued rise in the ambient noise level.

THRESHOLD NOISE LEVELS

The problem of assigning maximum noise levels for various land use activities is complicated by the fact that virtually every study that has been undertaken on this subject has recommended different maximum noise levels. Some studies suggested an overall maximum level, others suggested separate levels for trucks and automobiles, while still others recommended lower acceptable noise levels during night hours. To compound the complexity of selecting the maximum noise level values, the distance from the source varied from study to study.

Most studies suggest the use of the dBA scale at a distance of 50 feet from the source to measure highway noise levels. This is essentially the SAE and California sound-level criteria.[16] These criteria were also used by the U. S. Bureau of Public Roads[1] and Galloway et al.[2]

A summary of recommended maximum noise levels from several different sources is presented in Figure 7. The range of the recommended maximum values is from 70 dBA to 90 dBA, which represents a quadrupling of the "loudness" associated with noise. Beaton[1] indicates that complaints from traffic noise are infrequent when the sound pressure level remains below 70 dBA. Galloway, et al.[3] indicate that the expected noise levels for an automobile traffic stream for the conditions shown are as follows:

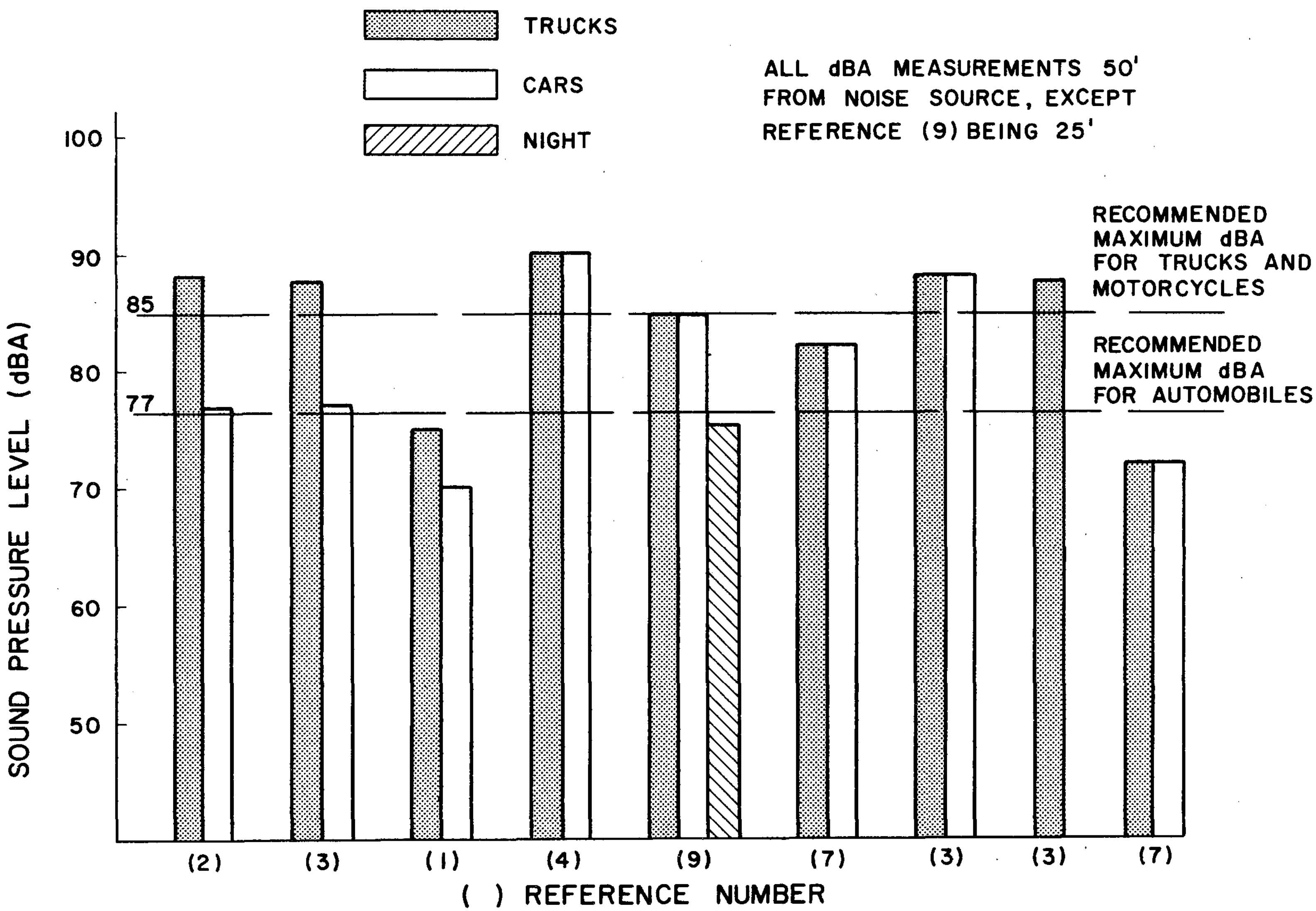
TABLE C

EXPECTED NOISE LEVEL FOR AUTOMOBILE TRAFFIC

Number of Lanes	Per Lane Volume (VPH)	Assumed Density of Traffic (VPM)	Assumed Operating Speed (MPH)	Noise Level (dBA)
4	1950	260	30	64
	1300	80	65	72
8	1950	520	30	67
	1300	160	65	74

From the values in Table C, it is apparent that automobile traffic streams will not produce a noise level sufficient to create a significant number of complaints. In fact, to reach the 75 dBA level would require about 300 vehicles per mile at an operating speed of 65 miles per hour. This condition represents a flow of 19,500 vehicles per hour. Referring to Figure 3, a 10 percent truck mix is required at 50 miles per hour with a total density of 200 vehicles per mile, to reach the 75 dBA level. This condition represents a flow of 10,000 vehicles per hour. It is interesting to note that if the noise level is increased to 80 dBA, the associated volumes required are increased to levels well beyond any observed flow rates.

The previous discussion eludes the fact that the problem of traffic noise control is primarily one of controlling the peak noise levels which



SUMMARY OF RECOMMENDED MAXIMUM NOISE LEVELS FOR INDIVIDUAL VEHICLES

FIGURE 7

in turn requires the establishment of maximum permissible noise levels for a particular combination of vehicle, roadway and adjacent land use.

In light of the previous discussion and due consideration to Table B, it is recommended that the following values be adopted as the maximum permissible noise levels for individual vehicles, measured 50 feet from the source, under a heavy acceleration condition:

TABLE D

RECOMMENDED MAXIMUM SOUND PRESSURE LEVELS FOR INDIVIDUAL VEHICLES (HEAVY ACCELERATION CONDITION)

Trucks & Motorcycles	85 dBA
Automobiles	77 dBA

Figure 7 shows these values compared with other suggested maximum values from previous studies. Preliminary investigations show that nighttime values of maximum noise level should be about 77 dBA for both trucks and cars, measured 50 feet from the source. The decreased night value in urban areas may require the exclusion of some trucks to ensure that these levels will not be exceeded. Studies have shown that a value of about 40 dBA inside a room is acceptable during sleeping hours.[9, 23] It can be assumed that the majority of houses are farther than 100 feet from the noise source, hence decreasing the noise level by about 6 dBA. This decrease with distance would reduce the noise level outside houses 100 feet from the source to 71 dBA at night, and about 79 dBA during the day. Double glazed windows or sound reducing barriers would be necessary to reduce these nighttime values to 40 dBA for residents near the freeways. The Bureau of Public Roads Task Force on Noise and Air Pollution[2] suggested that well designed buildings with double glazing can reduce noise up to 40 dBA. Figure 8[1] shows the decrease in truck noise with distance from the source. When threshold noise level is considered in commercial and industrial areas, the ambient noise level is an important factor to be considered. There are usually few complaints about freeway noise from adjacent commercial and industrial areas.[1] This is due to the ambient noise already within the buildings and the fact that these land use activities are not affected by nighttime noise.

The City of Dallas has zoning ordinances which give maximum permissible values of 65 dBA for planned industrial districts (measured at the property line) and 63 dBA for retail and commercial districts (daytime - measured at or within the boundary of the district). When the noise is infrequent, e.g., 5 minutes on and 60 minutes off, 10 decibels can be added to the maximum levels.

It is interesting to note that relatively few residents take action to reduce noise levels in their homes.[17,21] In a recent noise survey around Bradley International Airport, Connecticut, it was found that although adjacent residents complained of aircraft noise, little attempt was made to reduce the noise in their homes, even though partial monetary assistance was available.[17] Further study is needed to determine the psychological reasons for inaction to outside noise. Studies[2, 23] have shown that noise inside schools, hospitals and rest homes should be

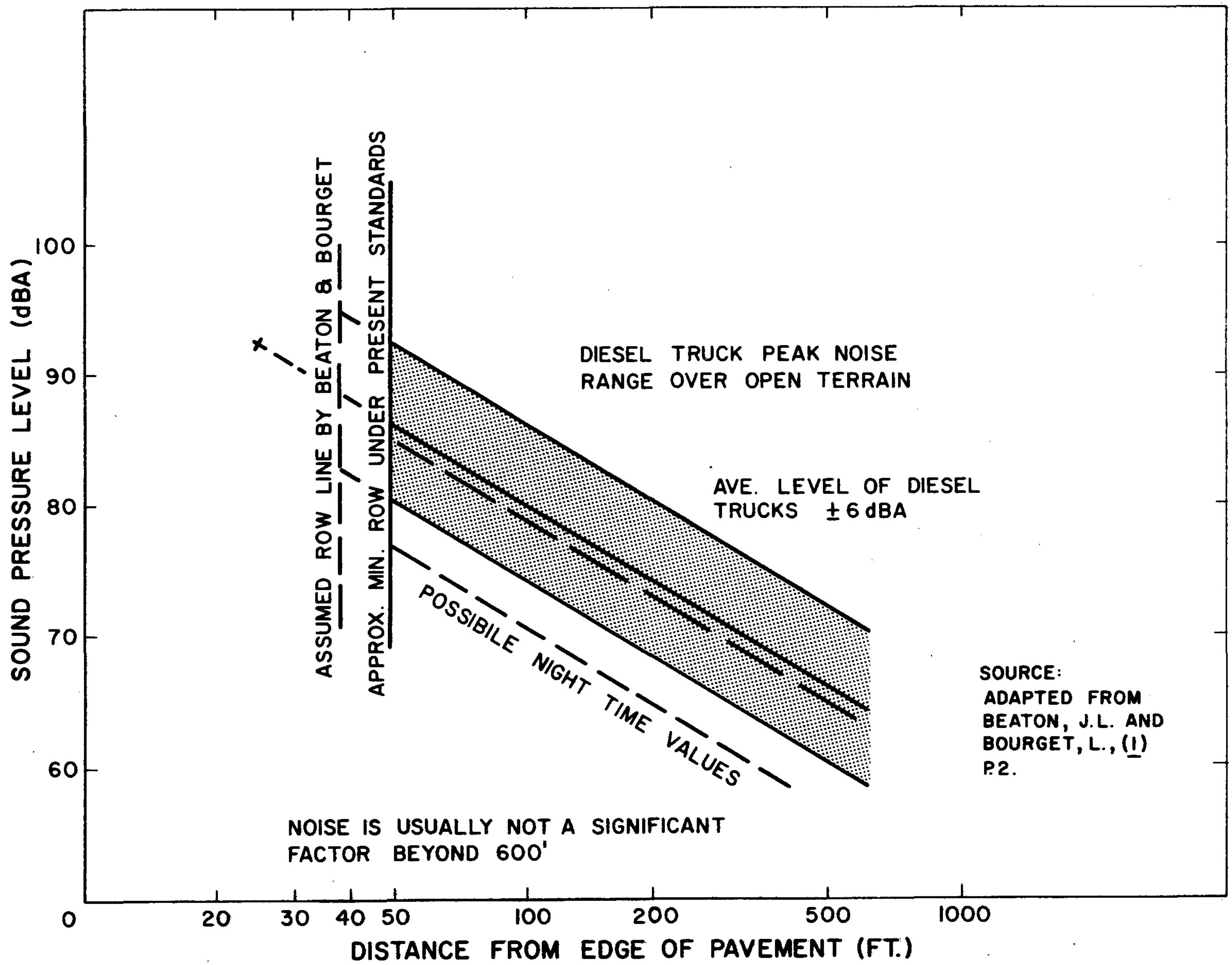

SOUND PRESSURE LEVEL (dBA)
100
90
80
70
60
0
20
30
40
50
100
200
500
1000
DISTANCE FROM EDGE OF PAVEMENT (FT.)
ASSUMED ROW LINE BY BEATON & BOURGET
APPROX. MIN. ROW UNDER PRESENT STANDARDS
DIESEL TRUCK PEAK NOISE RANGE OVER OPEN TERRAIN
AVE. LEVEL OF DIESEL TRUCKS ± 6 dBA
POSSIBILE NIGHT TIME VALUES
NOISE IS USUALLY NOT A SIGNIFICANT FACTOR BEYOND 600'
SOURCE:
ADAPTED FROM BEATON, J.L. AND BOURGET, L., (1) P.2.

Figure 8

about 45-50 dBA, and the effects of a highway adjacent to such land use areas should be carefully studied.

While the above maximum permissible noise levels are recommended, it must be realized that a vehicle could be below this limit for the majority of the time, but for peaks caused by open throttles, these values could be exceeded. Venema[16] noted that for 20 automobiles with road load levels showing a range of 6 dBA, at open-throttle levels this range became 16 dBA. Thus, an automobile at 60 miles per hour, with a normal sound level of 68 dBA, could increase this value to over 90 dBA during hard acceleration. While rapid acceleration of vehicles on freeways cannot be controlled, it is such peaks that often cause annoyance to adjacent residents.

The suggested maximum permissible values should be acceptable to most adjacent residents, but some soundproofing may be needed in selected areas to lower peak sound levels. Consideration of landscaping should also be given in residential areas, although dense trees with a 200-foot right-of-way only reduce sound by 2 to 4 dBA[18] more than the reduction due to distance alone. However, the psychological effect of "hiding" the highway reduces complaints.

The effect of highway noise on adjacent farm properties was studied[18] in Pennsylvania. Although farmers are bothered by the same noise problem facing urban dwellers, it is less severe due to the increased distance between the farmhouse and noise source. However, although the noise levels from the highway were lower, so too is the background noise on the farm when compared to a suburban area.

The problem of highway disturbance to high-rise apartment buildings is not common, but does exist.[(18)] The upper floors are never out of the direct path of the sound source, and only modifications to the structure are likely to reduce this noise.

Beranek[(20)] sums up noise pollution control in the following way:

> "We can mitigate the road of traffic - on the ground and in the air - by instituting and enforcing noise codes, by improving the design and operation of vehicles, interposing buffer zones to separate residential areas from airports and superhighways (through zoning and condemnation) and by sealing buildings against the noise where proximity of noise is unavoidable. With the willingness to pay the extra price in construction costs we can also have quieter homes. It appears that we shall have to pay these costs if we are to make a tolerable adaptation to the noises of civilization."

Considering the previous discussion, the practical working noise levels for use in highway design have been recommended in this study and are presented in Table E.

TABLE E

SUMMARY OF RECOMMENDED NOISE LEVELS
FOR VARIOUS LAND USES

Land Use Activity	Time of Day	Recommended Maximum Mean Sound Pressure Level (dBA)	
		At Property Line	Inside a Structure
Residential (single and multiple family)	Day	70	65
	Night	65	55*
Business, Commercial and Industrial	All	75	65
Educational Institutions	All	70	60
Hospitals and Rest Homes	Day	60**	55
	Night	50**	45
Public Parks	All	70	55

*Air conditioning systems commonly operate at 55 dBA. For non-air-conditioned residential structures it may be desirable to reduce this value by 5 dBA.

**Expected ambient noise level.

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