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PRELIMINARY ESTIMATES OF THE HEALTH AND WELFARE BENEFITS OF STATE AND LOCAL SURFACE TRANSPORTATION NOISE CONTROL PROGRAMS

TECHNICAL REPORT

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SUMMARY

The actual reduction in traffic noise exposure level for a given control measure can be conceptually considered a function of: the potential level reduction of the control, its applicability, the extent of its enforcement, and the effectiveness of its enforcement. A survey of the available literature yielded a reasonable amount of information regarding the potential level reductions of control measures, a limited amount of information regarding the observed exposure level reductions of control measures, and virtually no information regarding the applicability of controls, the extent of enforcement, or the effectivenss of enforcement. EPA's National Roadway Traffic Noise Exposure Model (NRTNEM) was used as a means of estimating the benefits of various state and local surface transportation noise control measures for the year 1985. Somewhat coarse simulations of the various controls gave the following results:

- Various low speed vehicle noise control measures, applied nationwide, roughly halved of the surface transportation noise impact.
- Upper estimates of high speed vehicle noise control measures (snow tire regulations and roadway surface treatment) yielded roughly a 2/5 reduction in impact.

- The exclusion of noisy vehicles from residential areas, applied to cities with greater than 50,000 people population, has a potential for the reduction of impact by about 1/4.
- Motorcycle enforcement resulting in the partial to total elimination of modified motorcycles has the potential for reducing impact between 1/5 to 1/4.
- Reducing local speed limits, in cities of greater than 50,000 people population, was estimated to yield a maximum impact reduction of 1/5.
- More stringent speed limit enforcement for highways, on a nationwide basis was estimated to have a maximum benefit of about 1/5 impact reduction.

Recommendations for future work include refining NRTNEM itself to more realistically describe vehicle behavior at intersections, refining the simulations themselves to yield more accurate estimates (e.g., considering snow tire controls only for "snow states" and their exclusion only for summer months), and the simulation of simultaneous multiple complementary controls. Finally, any estimates must be considered in the light of reasonable expectations for the applicability, effectiveness and the extent of enforcement of control measures. In the absence of a data base for these parameters, sensitivity tests should be conducted.

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I. INTRODUCTION

With the passage of the Quiet Communities Act of 1978, the Congress clearly indicated the desire that the objectives of the Noise Control Act be achieved primarily through programs implemented on the state and local levels. However, the benefit to the public health and welfare of state and local noise control programs has never been thoroughly studied or systematically assessed. Quantification of these benefits will be included in the Five Year Plan which is expected to be submitted to Congress in March 1980.

The purpose of this report is to document a preliminary assessment of the potential benefits to the public health and welfare of state and local surface transportation noise control programs. The objective of this effort is to preliminarily quantify the potential impact reduction benefits of a variety of noise abatement measures for vehicle traffic noise in the year 1985. The benefits will be quantified using output from the National Roadway Traffic Noise Exposure Model (NRTNEM) and will be described in terms of the reduction in Level Weighted Population (LWP) with respect to overall annoyance.

LWP is a measure of the severity of noise impact which considers both extent (the numbers of people exposed) and intensity (the level of exposure). As it is used here, it is based on the day-night sound level, L_{dn}. It is defined as:

$$LWP = \sum_i \frac{P_i}{20} \left(L_{dn_i} - 55\right)$$

where: P_i is the population exposed in level interval, L_{dn_i}, and 55 dB is the maximum day-night level identified by EPA as prerequisite to protecting the welfare of exposed persons with an adequate margin.

The noise control methods that are available to state and local enforcement officials fall into five general categories:

- Operational regulations
- Vehicle regulations
- Driver education
- Lane use control
- Roadway design.

Operational regulations restrict the operation of the vehicle to reduce its noise emissions. They may include requirements that vehicles be operated in such a way as not to exceed a given emission level primarily though lower vehicle acceleration rates or vehicle speed reductions. Operational controls may take the form of more stringent speed limit enforcement or lower speed limits in localities. Another operational control is the partial or complete exclusion of noisy vehicle types in certain localities.

Vehicle regulations obtain benefits by requiring the actual quieting of the vehicle itself. This may consist either maintenance of vehicles to their stock acoustical performance levels (such as by inspection/maintenance programs or muffler enforcement programs) or improvement of vehicle levels by the retrofit of quieter components (such as more effective mufflers). Vehicle regulations may also include prohibitions of snow tires during the summer months when they are not necessary.

Driver education consist of sensitizing vehicle operators to the noise emission characteristics of their vehicles. It is a voluntary form of noise control by encouraging drivers to effect lower noise emissions. Land use controls achieve reductions in impacts by the segregation of sensitive populations (i.e., residential areas) away from roadways. However, this control would be only beneficial with respect to new residential developments or new highway construction. Impacts may also be reduced by changes in roadway design such as the construction of barriers or the utilization of natural topography or greater right-of-way width to limit propagation to sensitive areas. Improved intersection design to yield more constant velocity traffic flows (such as separated grade crossings, improved traffic signal sequencing) will reduce the noise due to accelerating vehicles. Roadway surface treatments in conjunction with a standardized tire tread design may be applied which would yield reductions in tire/road interaction noise.

The actual noise exposure level reduction obtained from a control may be considered conceptually as a function of:

- Gross level reduction obtainable through the control -- the reduction in emission level obtained when a noise control is implemented to a vehicle, such as when a stock muffler is restored to a vehicle with a previously defective exhaust system
- Applicability of the control -- the percentage of vehicles for which a control will be relevant, for example, the percentage of vehicles with defective exhaust systems
- The extent of enforcement -- the percentage of states or localities which are implementing a control or the percentage of roadway mileage for which roadway design noise controls are constructed
- Effectiveness of Enforcement -- the degree to which offending vehicles are removed from the traffic mix by controls requiring active enforcement.

II. LITERATURE REVIEW

The primary focus of the literature review was to ascertain the potential source noise level reductions that various state and local surface transportation control measures may achieve. These gross decibel reductions are the basis for the development of the scenarios. NRTNEM is utilized to perform the actual calculations of the effectiveness of each control measure. Relatively little information was found which enables one to quantify the applicability or effectiveness of these various control measures. There are only a handful of localities which have well established programs where results are readily discernible. The following material briefly reports the relevant findings of the literature search for each control measure. Table 2.1 summarizes the literature search and review findings along with the decibel values utilized as input to the NRTNEM.

<u>New Product Noise Emission Limits</u>: The State of Florida, Department of Environmental Regulation found that a 3 dB truck noise source reduction yielded a 1 dB L_{eq} reduction along the highway. According to the Bureau of Motor Carrier Safety truck noise levels decreased by 3 dBA between 1970 and 1975.

<u>Operational Noise Emission Limits</u>: R.E. Burke after surveying seven states, reported that noise levels dropped 1.6 dB due to truck noise enforcement using a pass-by test. C.W. Dietrich, et alia, after reviewing

TABLE 2.1

SUMMARY OF POTENTIAL SOUND LEVEL REDUCTIONS RESULTING FROM STATE AND LOCAL SURFACE TRANSPORTATION CONTROLS

Control Measure	Reference (appearing at the end of this chapter)	Sound Level Reduction (dBA)	NRTNEM Input Sound Level Reduction (dBA)
New Product Noise Emission Limits			
trucks	State of Florida	1-3	1.25, 2.5
trucks	U.S. DOT, BMCS	3	
Operational Noise Emission Limits			
trucks	Burke	1.6	1.25, 2.5
autos	Dietrich	3-6	2,4
trucks	Dietrich	2-3	1.25, 2.5
motorcycles	Dietrich	4	2.5, 5.0
Operational Restrictions-Stringent Speed Limit	Wyle Lab	2-3	(a)
Operational Restrictions-Reduce Speed Limits	Hellweg	3	(a)
Operational Restrictions-Reduce Acceleration Rates			
autos	Hillquist	5-12	2,4
trucks	Hellweg	4	
autos	Hellweg	4	
autos	Plotkin	2.6-6.2	
trucks	Plotkin	1.8	
autos	Lenenan	8	

TABLE 2.1
(Continued)

Control Measure	Reference (appearing at the end of this chapter)	Sound Level Reduction (dBA)	NRTNEM Input Sound Level Reduction (dBA)
Time/Area Restrictions			
trucks	Schomer	4	(b)
trucks	BBN	2.6-6.9	
Vehicle Regulation-Retrofit			
trucks	BBN	1.6-3.4	1.25, 2.5
autos	Lenenan	1	2
Vehicle Regulation-Muffler Enforcement			
autos	BBN	1-6.5	
motorcycles	Olson	1-5	2.5, 5
Vehicle Regulation-Tires			
Tires	Rentz	3.5-5.0	2,5
	Thrasher	2-4	
Roadway Design-Barriers			
Barriers	BBN	7.5-13.9	-
Roadway Design-Surface Treatment			
Surface Treatment	Lawther	2-4	2,5
	Thrasher	1-1.7	
	Hillquist	3-10 — EPA	should emph. = [illegible]

(a) alter roadway traffic mileage data per vehicle speed and roadway type.
(b) alter the vehicle fleet mix percentages by urban place size and functional roadway type.

current information, found that vehicle in-use regulatory noise limits generally aim for a source noise reduction of 3-6 dBA for automobiles, 2-3 dBA for trucks, and 4 dBA for motorcycles.

Operational Restrictions -- Stringent Speed Limit Enforcement: According to the EPA Background Document for the bus regulation (Report No. 550/9-77-201), a majority of trucks exceed the national maximum speed limit of 55 mph (e.g., in California 72% of trucks in 1976). This indicates there is significant leeway for more stringent enforcement than there is currently. Wyle Labs found that motor vehicle sound levels can be characterized as increasing with vehicle speed according to a relationship given by:

$$L \propto 32 \log (S)$$

where S is the vehicle speed.

Operational Restrictions -- Reduced Speed Limits: The same relationship stated above would apply to reduced speed limits. Hellweg found that between 1973 and 1974, when speed limits were reduced from 70 to 55 mph, sound levels dropped 3 dBA along the highways.

Operational Restrictions -- Reduced Acceleration Rates: A 5 to 12 dB differential was observed between steady state cruise and wide-open-throttle acceleration sound levels for 1971 V-8 General Motors automobiles according to Hillquist. Hellweg found that, for trucks operating in Illinois, acceleration sound levels are 4 dB higher than low speed cruise on urban streets. Similarly, automobiles generate sound levels 4 dB louder when accelerating up a grade. Plotkin utilizes 4.5 dB sound level increase due to acceleration for automobiles (with a range of 2.6 to 6.2 decibel for high to low horsepower-to-weight ratios). For trucks Plotkin uses a 2.8 dB differential for the acceleration mode. Lenenan performed controlled noise monitoring tests on 20 automobiles and found approximately an 8 dBA differential between partial and full throttle acceleration from a stop to 30 mph.

Time-Area Restrictions: Schomer found approximately a 4 dB day-night sound level reduction on a rural section of an interstate highway in Illinois due to the absence of trucks. Bolt, Beranek, and Newman simulated the effect that a diversion of truck traffic might have on noise levels depending upon the percentage of trucks normally using the roadway. If 5 percent of the traffic consisted of trucks, a 2.6 dBA noise level reduction may be expected. If 10 or 20 percent of the traffic is trucks, a 4.3 or 6.9 dBA sound level reduction may be expected respectively by their exclusion.

Vehicle Regulation -- Retrofit: A 1.6, 2.5, or 3.4 dB traffic noise reduction is possible via retrofitting all existing heavy trucks for maximum noise reduction practical with current technology according to a simulation performed by BBN. The range depends upon the percentage of trucks along the roadway: 5, 10 or 20 percent. Lenenan outfitted several automobiles with a specially designed "super muffler" which reduced exhaust noise levels by 10 dBA, but only achieved 1 dBA reduction of total vehicle sound levels.

Vehicle Regulation -- Muffler Enforcement: Bolt, Beranek, and Newman found Eugene, Oregon's muffler enforcement program can achieve a 1-6.5 dBA reduction in automobile source noise levels for eight cylinder vehicles. Olson's measurements of two motorcycle types indicate that a 1-5 dB reduction may be achieved. According to data from the California Highway Patrol, operational enforcement will reduce by half the percent of vehicles in violation.

Vehicle Regulation: Snow tires are 3.5 to 5.0 dBA louder than straight rib tires according to Rentz. Thrasher cites a similar range of 2 to 4 dBA at one point and 3 dBA at another for the maximum observed difference between snow tires and conventional pattern tires (depending upon pavement texture). Old worn tires may be up to 4.5 dBA louder than new tires depending upon the roadway surface and tire type according to Rentz.

Roadway Design -- Barriers: The effectiveness of roadside barriers depends upon their construction, placement, height, distance and relative elevation of the receptor. Bolt, Beranek, and Newman simulated the noise level reduction that is possible for various highway configurations. They calculated that a 7.5 to 13.9 dBA reduction is possible with barriers ranging from 10-20 feet in height, 0-20 percent truck traffic and 100-500 feet distance from the traffic for the receptor. Plotkin and Kohli also estimated the potential effectiveness of barriers on Federal highways depending upon barrier height and traffic flow rates.

Roadway Design -- Surface Treatment: Surface treatment and tire design are the two sides of the "tire" noise generation. Lawther reports that certain surface textures can be a 2-4 dBA quieter for automobiles than other surfaces. Thrasher found that only 1-1.7 dBA can be gained for trucks. Hillquist notes a range of 3-10 dBA for different surface textures.

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III. NATIONAL ROADWAY TRAFFIC NOISE EXPOSURE MODEL

The National Roadway Traffic Noise Exposure Model (NRTNEM) is a simulation tool for estimating the noise exposure of the United States population from roadway traffic noise sources. NRTNEM's basic function is to estimate noise exposures and impacts given specified information such as motor vehicle noise emission levels, population information, and motor vehicle activity profiles. NRTNEM encompasses the noise source characteristics, source population, source activity and location, noise attentuation characteristics, and the receptors' location and density. The structure of the NRTNEM is such that several of these data elements are jointly rather than independently defined.

NRTNEM is structured primarily to estimate noise exposures from motor vehicle operations by assuming specified vehicle noise emission levels, vehicle growth rates, and population growth rates. The purpose of this study required a somewhat different set of independent variables. A brief description will follow explaining the structure of NRTNEM and some limitations encountered in its application to this purpose.

There are three basic sets of data bases which are manipulated by computational algorithms in order to calculate population and vehicle growth for future time periods and noise exposure from one or more roadways. The three fundamental data sets are:

TABLE 3.1

DISTRIBUTION OF POPULATION AND LAND AREA BY PLACE SIZE (INDEX J) AND POPULATION DENSITY CATEGORY (INDEX ID)

Population Place Size-Index J

Population Density Area-Index ID	PARAMETER	1 >2M	2 1M -2M	3 500k -1M	4 200k -500k	5 100k -200k	6 50k -100k	7 25k -50k	8 5k -25k	URBAN TOTAL	9 RURAL
1	Population	5.61	2.10	0.36	1.61	1.16	1.07	0.47	1.85	14.23	64.18
	Area	134.2	272	63	215	279	329	58	220	1570.2	3,476,938
	ρ^*	64,711	13,451	9,368	9,368	5,831	4,186	13,091	16,988	-	18.0
2	Population	22.28	4.08	2.04	10.43	2.93	2.12	2.98	4.97	51.83	0.0
	Area	3576	775	488	4558	1305	1115	896	1261	13970.0	0.0
	ρ^*	12,638	9.092	6,967	3697.0	3,384	2,863	8,506	10,681	-	
3	Population	21.59	11.13	8.40	6.75	6.84	4.53	3.51	8.46	71.20	0.0
	Area	8358	5080	4426	5790	5266	4195	2230	4527	29872.0	0.0
	ρ^*	6,107	5,014	3,842	2,264	2,011	1,612.0	4,698	6,271	-	
4	Population	0.0	5.35	5.30	0.0	0.0	0.0	1.92	2.70	15.27	0.0
	Area	0.0	4089	4584	0.0	0.0	0.0	2769	5820	17262.0	0.0
	ρ^*	-	2,505	2,336	-	-	-	2,147	1,673	-	
TOTAL POPULATION		49.43	22.66	16.09	18.78	10.93	7.71	8.88	17.98	152.52	64.18
TOTAL AREA		12064.2	10216.0	9561.0	10563.0	6850.0	5639.0	5953.0	11028.0	72674.2	3476938

Total Population = 216.70 million

Total Land Area = 3,549,612.2 square miles

ρ^*= Population/ (Area)(Area Factor) , Adjusted Population Density in People per Square Mile

- population data
- roadway and traffic data
- vehicle data.

The base year for the model's calculations is 1974. It is capable of calculating national noise exposures over a forty year time span to the year 2014.

POPULATION DATA

The baseline population in 1974 consists of 216.7 million people. There are 152.52 million which are categorized as residing within eight urban place size classes and 64.18 million people categorized as living in rural areas with an assumed uniform population density. The eight urban place sizes are each further subdivided into four population density categories. Using Federal Highway Administration (FHWA) data, the population was allocated to appropriate roadway traffic conditions. The FHWA data base was further parsed according to a functional roadway classification which incorporates the average population density adjacent to the roadway, the average travel speed by population place size, and the distribution of roadway mileage and travel. The population place sizes and density classifications are indicated in Table 3.1. The NRTNEM user has the option to specify various population growth rates based upon the Bureau of the Census projections. Population growth rates for particular population place sizes can be specified, but the total population growth rate must conform to the census projections.

ROADWAY AND TRAFFIC DATA

The roadway mileage, configuration, and travel data is structured around a functional roadway classification. The basis for this classification is the type of service performed by the roadway. The two basic characteristics of this roadway service are:

- Degree of vehicular access to adjoining land uses model
- Ease of vehicle passage.

Six classes of roadway types are utilized in the model:

- Interstates
- Highways
- Major arterials
- Minor arterials
- Collectors
- Local streets.

The nation's 3.586 million miles of roads are allocated according to this roadway classification and population place size. The quantity of Daily Vehicle Miles Traveled (DVMT) for each roadway type and population place size was also extracted from FHWA data. The Average Daily Traffic (ADT) is estimated by dividing the DVMT by the number of roadway miles per category. Table 3.2 displays the distribution of roadway mileage, ADT, and DVMT by population place size and roadway type. Five average travel speed ranges are also utilized to further subdivide the distribution of roadway mileage data by population place size and density. The average travel speed categories are indicated below.

Average Travel Speed Range	Average Speed	Index, L
Less than 25 mph	20 mph	1
25 to 35 mph	30 mph	2
35 mph to 45 mph	40 mph	3
45 mph to 50 mph	50 mph	4
Greater than 50 mph	60 mph	5

Table 3.3 is representative of the data contained in the highway mileage matrix. A "roadway factor" is included in order to account for the roadway mileage that passes through occupied land. This roadway factor is defined only to the level of aggregation of place size, regardless of population density or travel speeds. The fraction of roadway mileage through occupied land is shown in Table 3.4.

Further growth in ADT is assumed to be proportional to the growth in the vehicle population and distributed uniformly across all roadway types. Average travel speed is also assumed to remain constant despite increasing ADT over time.

TABLE 3.2

DISTRIBUTION OF ROADWAY MILEAGE, AVERAGE DAILY TRAFFIC (ADT) AND DAILY VEHICLE MILES TRAVELED (DVMT) BY PLACE SIZE (J) AND ROADWAY TYPE (K)

PLACE SIZE		ROADWAY TYPE: INTERSTATE	OTHER F'WAY & EXP'WAY	MAJOR ARTERIALS	MINOR ARTERIALS	COLLECTORS	LOCAL
>2M	Miles ADT DVMT	1,998 74,066 149,582,268	1,749 66,470 116,256,030	9,061 18,768 185,071,248	14,103 9,315 131,369,445	12,854 3,783 48,626,682	84,247 1,129 95,114,863
1M to 2M	Miles ADT DVMT	1,869 60,228 112,565,132	1,527 32,54[illegible] 49,700,796	5,156 17,397 89,698,932	10,219 6,898 70,490,662	10,308 3,496 36,036,768	64,678 656 42,428,768
500k to 1M	Miles ADT DVMT	1,477 46,997 69,414,569	739 34,036 25,152,604	4,034 16,359 65,992,206	6,320 8,045 50,844,400	7,190 3,760 27,034,400	47,465 672 31,897,152
200k to 500k	Miles ADT DVMT	1,743 40,367 70,359,681	1,076 28,812 31,001,712	5,566 16,029 89,217,414	8,569 8,470 75,579,430	7,897 3,812 30,103,364	58,252 839 48,873,428
100k to 200k	Miles ADT DVMT	854 32,190 27,490,260	803 22,984 18,456,152	3,051 14,984 57,352,943	5,502 7,301 40,170,102	5,714 3,287 18,781,918	36,697 649 23,815,353
50k to 100k	Miles ADT DVMT	512 21,913 11,219,456	600 19,971 11,[illegible]92,600	3,335 12,376 41,273,960	4,445 6,057 26,923,365	4,534 2,917 13,225,678	29,284 645 18,888,193
25k to 50k	Miles ADT DVMT	397 23,251 9,230,647	447 16,875 7,543,125	4,282 11,384 48,746,298	5,377 5,430 29,197,110	5,828 2,484 14,476,752	33,454 631 21,109,479
5k to 25k	Miles ADT DVMT	833 19,206 16,357,144	1,099 13,244 13,343,016	9,652 8,922 86,115,144	12,124 4,255 51,587,620	13,130 1,946 25,550,980	75,431 495 37,338,345
Rural	Miles ADT DVMT	31,744 13,700 434,892,800	85,716 4,623 396,265,068	155,547 2,523 392,445,081	435,517 899 387,174,613	307,917 370 113,929,290	1,942,733 98 190,387,834

NOTE: ADT=DVMT/MILES IS THE DERIVED QUANTITY

TABLE 3.3

ROADWAY MILEAGE DATA

ID = 1

HIGH POPULATION DENSITY AREAS

	K=1	2	3	4	5	6
J=1	13,	1,	6,	2,	1,	0,
2	29,	2,	7,	3,	3,	0,
3	6,	0,	1,	0,	0,	0,
4	21,	1,	6,	2,	2,	0,
5	20,	2,	8,	2,	2,	0,
6	17,	2,	10,	3,	3,	0,
7	2,	0,	2,	1,	1,	0,
8	10,	1,	9,	2,	2,	0,
9	26665,	40289,	73107,	73931,	52345,	0,

ID = 2

MEDIUM TO HIGH POPULATION DENSITY AREAS

	K=1	2	3	4	5	6
J=1	243,	26,	147,	42,	38,	0,
2	83,	6,	20,	8,	8,	0,
3	44,	2,	10,	3,	4,	0,
4	437,	23,	120,	37,	35,	0,
5	94,	7,	37,	10,	11,	0,
6	59,	6,	33,	9,	9,	0,
7	35,	3,	32,	8,	9,	0,
8	55,	5,	51,	13,	14,	0,
9	0,	0,	0,	0,	0,	0,

TABLE 3.4

FRACTION OF ROADWAY MILEAGE THROUGH OCCUPIED URBAN LAND

	Population Place Size, Index J								
K	1	2	3	4	5	6	7	8	9
1	0.764	0.764	0.764	0.764	0.764	0.764	0.656	0.656	1.000
2	0.738	0.738	0.738	0.738	0.738	0.738	0.679	0.679	1.000
3	0.866	0.866	0.866	0.866	0.866	0.866	0.843	0.843	1.000
4	0.845	0.845	0.845	0.845	0.845	0.845	0.849	0.849	1.000
5	0.852	0.852	0.852	0.852	0.852	0.852	0.867	0.867	1.000
6	0.852	0.852	0.852	0/852	0.852	0.852	0.867	0.867	1.000

J is Population Place Size Index

K is Roadway Type Index

The distribution of vehicle fleet mix by roadway type, place size, and vehicle type is defined in the NRTNEM data base by the matrix FLOMIX. A base year distribution for 1974 is already established as part of the model. This mix is shown in Table 3.5. The model adjusts this mix in future years based upon the sales forecast for each vehicle type for a particular future year. Roadway configurations are assumed to be homogeneous among types of roadways with a uniform 12 foot lane width.

Vehicle operating characteristics are defined by the percent of time each vehicle type is operating on a roadway type in a particular mode. There are four operational modes:

- Acceleration from idle
- Deceleration from cruise
- Cruise
- Idle.

Table 3.6 is a representative for the percent time per mode and roadway type for a particular vehicle type. Specific data only exists for four generalized vehicle types and two generalized roadway classes.

VEHICLE DATA

There are four overall categories of vehicles included in NRTNEM. These four categories are:

- Light vehicles (passenger cars and light trucks)
- Trucks (medium and heavy)
- Buses (intercity, transit and school buses)
- Motorcycles (unmodified and modified).

These overall categories are further subdivided along specific design characteristics into fourteen classes. The complete list of vehicle classes is shown in Table 3.7. The distribution of vehicle types, and survival patterns are derived from historical data. Future sales projections are supplied in the data base or can be altered by the model user.

Normally NRTNEM will incrementally implement a new product standard via the sales growth of new vehicles and the attrition of old vehicles over time. In this case it is assumed that state and local control

TABLE 3.5

PERCENTAGE VEHICLE MIX IN TRAFFIC FLOW
BY PLACE SIZE AND FUNCTIONAL ROADWAY CLASSIFICATION
BASELINE CONDITIONS

URBAN PLACE SIZES: Over 2M; 1M-2M; 500k-1M

VEHICLE TYPE	ROADWAY TYPE (INDEX K) 1	2	3	4	5	6
Light Vehicles	87.62	87.62	91.82	90.49	90.47	95.76
Medium Trucks	2.11	2.11	3.05	4.31	3.61	1.16
Heavy Trucks	9.17	9.17	4.03	3.11	3.82	0.99
Intercity Buses	0.00	0.00	0.00	0.00	0.00	0.00
Transit Buses	0.10	0.10	0.10	0.50	0.50	0.50
School Buses	0.00	0.00	0.00	0.10	0.10	0.10
Unmodified Motorcycles	0.88	0.88	0.88	1.32	1.32	1.32
Modified Motorcycles	0.12	0.12	0.12	0.18	0.18	0.18
	100.00	100.00	100.00	100.00	100.00	100.00

URBAN PLACE SIZES: 200k-500k; 100k-200k; 50k-100k

	ROADWAY TYPE (INDEX K) 1	2	3	4	5	6
Light Vehicles	87.64	87.64	91.84	90.69	90.67	95.96
Medium Trucks	2.11	2.11	3.05	4.31	3.61	1.16
Heavy Trucks	9.17	9.17	4.03	3.11	3.82	0.99
Intercity Buses	0.00	0.00	0.00	0.00	0.00	0.00
Transit Buses	0.04	0.04	0.04	0.30	0.30	0.30
School Buses	0.04	0.04	0.04	0.10	0.10	0.10
Unmodified Motorcycles	0.88	0.88	0.88	1.32	1.32	1.32
Modified Motorcycles	0.12	0.12	0.12	0.18	0.18	0.18
	100.00	100.00	100.00	100.00	100.00	100.00

NOTE: Some columns do not add up to exactly 100 because of rounding.

TABLE 3.5

PERCENTAGE VEHICLE MIX IN TRAFFIC FLOW BY PLACE
SIZE AND FUNCTIONAL ROADWAY CLASSIFICATION BASELINE CONDITIONS
(Continued)

URBAN PLACE SIZES: 25k-50k; 5k-25k

VEHICLE TYPE	ROADWAY TYPE (INDEX K) 1	2	3	4	5	6
Light Vehicles	87.72	87.72	91.92	90.39	90.37	95.66
Medium Trucks	2.11	2.11	3.05	4.31	3.61	1.16
Heavy Trucks	9.17	9.17	4.03	3.11	3.82	0.99
Intercity Buses	0.00	0.00	0.00	0.00	0.00	0.00
Transit Buses	0.00	0.00	0.00	0.20	0.20	0.20
School Buses	0.00	0.00	0.00	0.50	0.50	0.50
Unmodified Motorcycles	0.88	0.88	0.88	1.32	1.32	1.32
Modified Motorcycles	0.12	0.12	0.12	0.18	0.18	0.18
	100.00	100.00	100.00	100.00	100.00	100.00

RURAL AREAS

	ROADWAY TYPE (INDEX K) 1	2	3	4	5	6
Light Vehicles	79.71	79.71	85.81	88.26	93.32	96.75
Medium Trucks	2.74	2.74	3.80	4.39	0.56	0.41
Heavy Trucks	16.16	16.16	8.99	5.14	3.91	0.65
Intercity Buses	0.20	0.20	0.20	0.00	0.00	0.00
Transit Buses	0.00	0.00	0.00	0.00	0.00	0.00
School Buses	0.20	0.20	0.20	0.70	0.70	0.70
Unmodified Motorcycles	0.88	0.88	0.88	1.32	1.32	1.32
Modified Motorcycles	0.12	0.12	0.12	0.18	0.18	0.18
	100.00	100.00	100.00	100.00	100.00	100.00

NOTE: Some columns do not add up to exactly 100 because of rounding

TABLE 3.6

PERCENT OF TIME IN OPERATING MODE -- VEHICLE TYPE:
8 CYLINDER, GASOLINE-ENGINED, AUTOMATIC-TRANSMISSIONED, PASSENGER CAR

	OPERATING MODE			
ROADWAY TYPE	ACCELERATION N=1	DECELERATION N=2	CRUISE N=3	IDLE N=4
1	4.70	5.36	88.90	1.06
2	4.70	5.36	88.90	1.06
3	4.70	5.36	88.90	1.06
4	15.40	16.00	55.00	13.50
5	15.40	16.00	55.00	13.50
6	15.40	16.00	55.00	13.50

TABLE 3.7

CLASSIFICATION OF VEHICLE TYPES USED
BY THE NATIONAL ROADWAY TRAFFIC NOISE EXPOSURE MODEL

Index, I	Vehicle Type	Engineering Characteristics
1	Passenger Car	8 cyl. Gasoline Engine Automatic Transmission
2	Passenger Car	6 cyl. Gasoline Engine Automatic Transmission
3	Passenger Car	6 & 8 cyl. Gasoline Engine Manual Transmission
4	Passenger Car and Light Truck	4 cyl. Gasoline Engine Automatic Transmission
5	Passenger Car and Light Truck	4 cyl. Gasoline Engine Manual Transmission
6	Light Truck	6 & 8 cyl. Gasoline Engine
7	Passenger Car and Light Truck	Diesel Engine
8	Medium Truck	Two Axle (GVWR >10,000 lb)
9	Heavy Truck	Three or more Axles (GVWR >26,000 lb)
10	Intercity Buses	
11	Transit Buses	
12	School Buses	
13	Unmodified Motorcycles	
14	Modified Motorcycles	

measures will effectively have an immediate impact. In order to implement this effect with NRTNEM, the user has to invoke a sleight of hand. The method involved is to instruct NRTNEM to implement the control measure in 1957, the initialization date for the historical data base. The control measure will still be incrementally implemented but the vehicle fleet will have been nearly completely replaced by the critical year 1985. Table 3.8 illustrated the percentage of vehicles surviving as a function of age.

The baseline vehicle noise emission data are empirically defined from a sample of controlled field measurements. Vehicle noise levels are specified by vehicle type, operational mode, and vehicle speed. Each vehicle type has sixteen equivalent levels, L_{eq}, and standard deviations defining its noise emissions. Several sets of potential new source regulatory noise emission levels are exhibited in the NRTNEM documentation, but specific future noise emission levels are user defined. An example of the baseline vehicle noise emission data is shown in Table 3.9 and Figure 3.1 for an 8 cylinder, gasoline-engined, automatic-transmissioned passenger car. No tabulation or description of the standard deviation values used in the model was found in its documentation.

NRTNEM makes a number of simplifying assumptions to permit the computation of cumulative exposures on a nationwide basis:

- Traffic is uniformly distributed over all vehicle lanes.
- Cruise speed is the same for all vehicle lanes for any given segment of roadway.
- Headway (i.e., vehicle spacing) is constant.
- Roadways appear infinitely straight relative to the receiver.
- Daily traffic flow is constant (including weekends).
- Daytime (7 am to 10 pm) traffic always constitutes 87 percent of the total traffic flow.

SOUND PROPAGATION

The propagation of the roadway noise entails the final link in the calculation of the noise exposure to the population. The Generalized Adverse

TABLE 3.8

PERCENTAGE OF VEHICLES SURVIVING AFTER X YEARS

Vehicle X Years	Percentage of Passenger Cars Surviving	Percentage of Trucks Surviving
Less than 1	100.00	100.00
1 to 2	99.98	100.00
2 to 3	99.90	99.98
3 to 4	99.60	99.27
4 to 5	98.77	97.11
5 to 6	96.83	93.29
6 to 7	93.07	87.83
7 to 8	86.77	80.89
8 to 9	77.56	72.72
9 to 10	65.70	63.64
10 to 11	52.14	54.02
11 to 12	38.34	44.24
12 to 13	25.83	34.69
13 to 14	15.75	25.76
14 to 15	8.57	17.80
15 to 16	4.10	11.13
16 to 17	1.68	5.98
17 to 18	0.57	2.48
18 to 19	0.00	0.62
19 to 20	0.00	0.13
20 to 21	0.00	0.13
Greater than 21	0.00	0.00

TABLE 3.9

BASELINE VEHICLE NOISE EMISSION DATA
TYPE 1, PASSENGER CAR
8 CYLINDER GASOLINE ENGINE AUTOMATIC TRANSMISSION

ACCELERATION MODE					
YEARS>	1974				
0-20 MPH	59.30				
0-30	61.30				
0-40	63.00				
0-50	64.60				
0-60	66.70				
DECELERATION MODE					
YEARS>	1974				
20-0 MPH	53.50				
30-0	56.10				
40-0	60.10				
50-0	63.20				
60-0	[illegible]				
CRUISE MODE					
YEARS>	1974				
<25 MPH	59.80				
25-34	62.40				
35-44	66.40				
45-54	69.50				
≥55	72.00				
IDLE MODE					
YEARS>	1974				
	45.00				

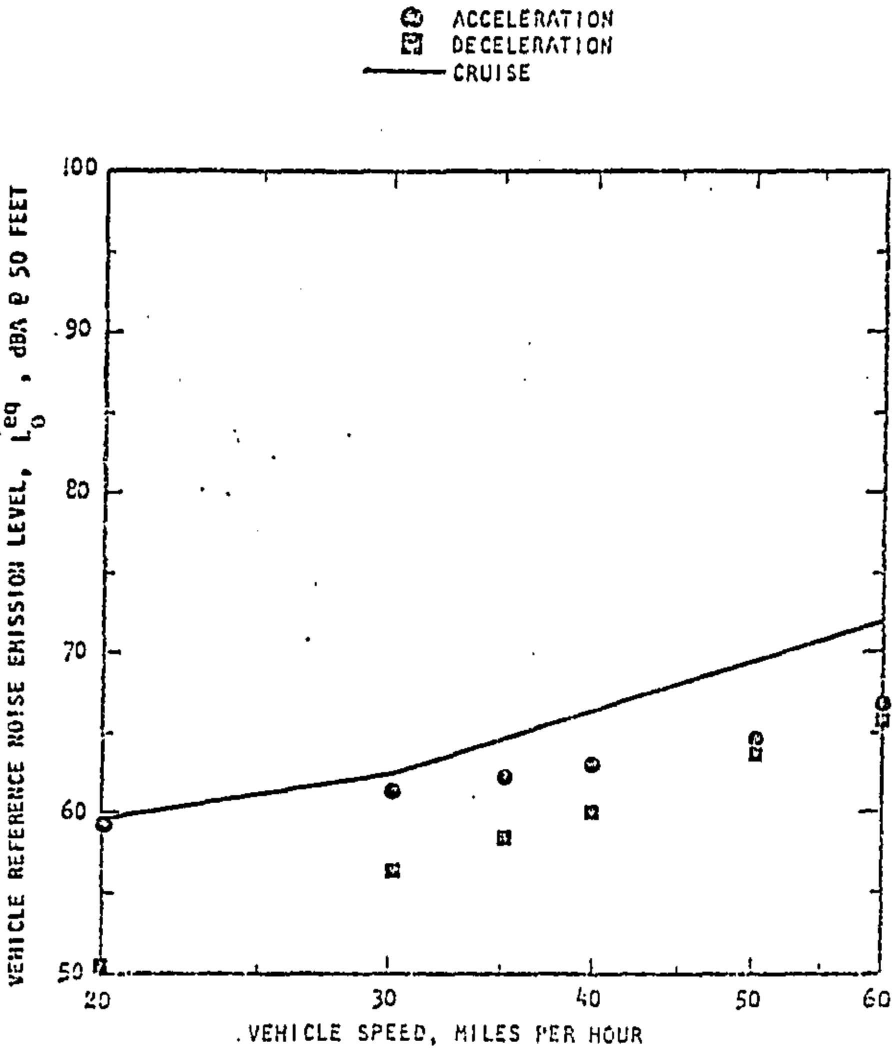

FIGURE 3.1. BASELINE VEHICLE NOISE EMISSIONS (1974): TYPE 1 VEHICLE

portion of NRTNEM uses different line source attenuation functions for high, medium, and low density population areas. Figure 3.2 presents these sound level attenuation curves. The distance from the roadway to the nearest receptors is defined by a matrix of "clear zones" as a function of roadway type and city size. The noise exposure from secondary roadways upon a receptor is also considered.

The output of the General Adverse Response portion of the NRTNEM is numbers of people and level-weighted people (LWP) exposure to roadway noise above a day-night level of 55 dBA for both the current or baseline period and future periods. Table 3.10 displays simple outputs from the model. The width of the decibel bands is specified by the user.

MODEL AND DATA LIMITATIONS

NRTNEM was not specifically designed to perform the analyses for which this task was undertaken. Nevertheless, the model is fairly readily applied to the problem of defining the benefits of state and local surface transportation controls. A major limitation is not inherently the model but the paucity of available information that is required for exercising the model's numerous data input specifications. Complementary data bases, that can utilize the full power of the model, which need to be developed are:

- Vehicle fleet noise deterioration
- Vehicle population and roadway data bases as a function of states and/or localities
- More refined data base for time in operational mode by vehicle type
- A vehicle noise data base which differentiates by vehicle component noise source emissions.

Operational changes to the NRTNEM codes which would enhance its usefulness are:

- Capability to model more accurately represent vehicle behavior at intersections (e.g., include variable vehicle spacing and exposure time effects)

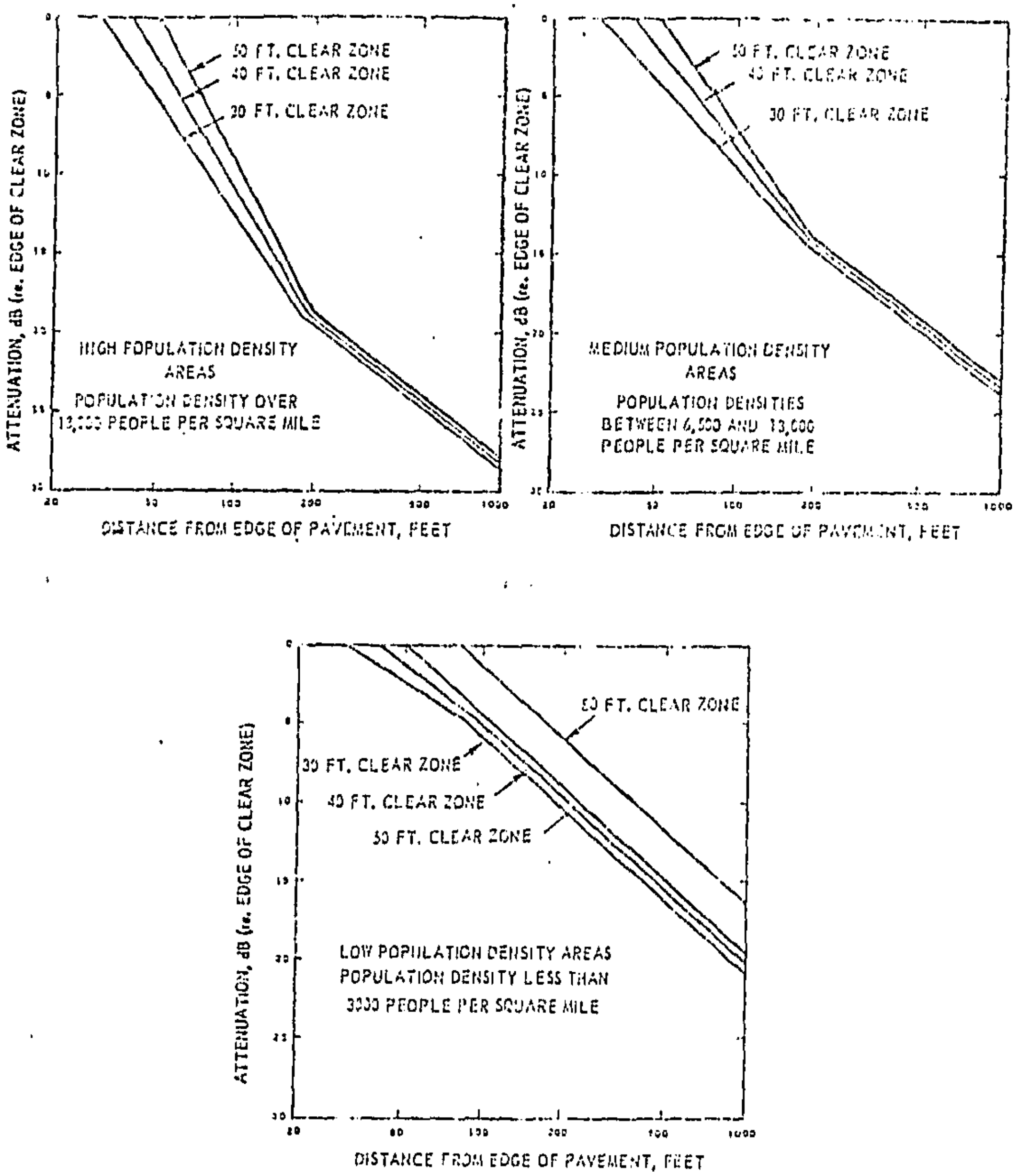

FIGURE 3.2. SOUND LEVEL ATTENUATION CURVES: LINE SOURCE

TABLE 3.10

NOISE IMPACT FOR EACH YEAR IN THE TIMESTREAM

[illegible]

	[illegible]	[illegible]	RELATIVE EXPOSURE [illegible]	POPULATION IMPACTED [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MILLIONS	PERCENT	MILLIONS	MILLIONS	[illegible]	MILLIONS	PERCENT
[illegible]	[illegible]	[illegible]	32.32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	32.79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

POPULATION EXPOSED IN DB BANDS ABOVE 55

[illegible]

[illegible]	[illegible]												
	[illegible]	[illegible]	[illegible]	5	[illegible]	7	[illegible]	[illegible]	10	[illegible]	12	[illegible]	TOTAL
[illegible]	[illegible]	[illegible]	[illegible]	82.-79.	79.-76.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]												
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.19	[illegible]	[illegible]	4.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

- Ability to incorporate additional vehicle categories
- A method for changing the level of service on roadways as ADT grows
- A data base for potential land use and population density changes
- Means to permit immediate and complete benefits due to an abatement strategy
- Tire/roadway texture noise generation algorithm
- Noise propagation functions which account for roadside barriers and street canyon effects.

IV. SIMULATION OF SCENARIOS

Seventeen potential state and local surface transportation noise control measures were identified. Three potential control measures were not analyzed. The national effectiveness of roadside barriers was previously analyzed and there is no suitable means of utilizing NRTNEM for this purpose at this time. The analysis of land use controls was foregone since the focus of this analysis is on the short run and land use controls would not be effective by 1985. NRTNEM is not currently amenable to the analysis of intersection design due to the definition of the vehicle noise levels for acceleration and cruise for automobiles.

EPA's goal of implementing noise control measures in the 400 largest localities and the 40 most populous states was considered in the development of the simulations. U.S. Census data indicate the 400 most populous cities essentially consist of all cities of population greater than 50,000 persons. Simulations involving roadway mileage and/or average daily traffic (ADT) were defined only for place sizes greater than 50,000 people since population (place size and population density), roadway mileage, and ADT are jointly defined in NRTNEM via a three-dimensional matrix. However, this joint definition precludes readily defining effects by states since each state, even the least populous or traveled, will include a mix of place sizes.

Eleven cases were formulated in order to analyze the remaining control measures. The first case established 1974 baseline conditions. The second case entitled "Baseline 1985", estimates the national noise exposure given current national trends including the implementation of the Interstate Motor Carrier noise regulation and the medium and heavy truck regulation but without any state or local controls. Cases one and two are designed to simulate the effect of state and local regulations implemented nationwide which involve:

- Vehicle noise emission limits
- Vehicle noise labeling
- Driver education
- Lower acceleration rates
- Retrofit and inspection.

Case one represents a reasonably achievable goal while case two is probably close to the maximum practical limit using these methods. The assumed noise source level reductions are as follows:

VEHICLE TYPES	LEVEL REDUCTION (dBA) CASE 1	CASE 2
Light Vehicles	2	4
Trucks and Buses	1.25	2.5
Motorcycles	2.5	5.0

Cases one and two are modeled by shifting the mean vehicle noise emission level for all vehicle speeds and operating modes less than 45 miles per hour. This method of portraying the noise emission change may cause a bias in the shape (kurtosis and skew) of the vehicle noise distribution rather than a shift of the central tendency.

Cases three and four perform a similar alteration to the vehicle emission levels but confine themselves to vehicle speeds of 45 miles per hour and greater. These cases are designed to reflect the potential noise reduction that may be achieved through snow tire or pavement treatments of a two and four decibel reduction respectively. The results of both these cases significantly overestimate the potential benefits. The sound level reductions were applied nationwide and for all seasons. Clearly snow tire regulations will only affect the northern portion of the country and only during about half of the year. Enforcement effectiveness will undoubtably be less than complete. Roadway surface treatments are not reasonably justified for all roadways with average vehicle speeds over 45 miles per hour. Therefore, the results from these two cases must be considered upper bounds.

NRTNEM's data base aggregates all fifty states. Given more time and resources, a more precise disaggregation could be performed in order to ascertain the effect on the forty most populous or traveled states. Reliable information on the percentage of vehicles or roadways that may reasonably be affected by such actions was not found in the literature search.

Case five is designed to reflect local area regulations restricting or prohibiting medium and heavy truck traffic along minor arterials, collectors and local streets. This control measure is applied only to localities with 50,000 population or larger. An arbitrary percentage decrease in truck traffic of fifty percent was chosen. An accurate assessment would need to assess the feasibility and impact of restricting truck traffic on local roads and rerouting it along other corridors.

Cases six and seven follow a similar modeling implementation as case five. The percentage of modified motorcycles in the vehicle fleet is arbitrarily reduced by fifty percent and one hundred percent for cases six and seven respectively. Presumably a stringent enforcement program could achieve the first goal and the second level would indicate an upper bound. These cases are also analyzed solely for cities greater than or equal to 50,000 people population.

Cases eight and nine are designed to assess the potential effectiveness of reducing local roadway speed limits and more stringently enforcing highway speed limits respectively. Case eight was implemented by arbitrarily reducing all the sixty and fifty miles per hour collector, minor arterial, and major arterial roadway mileage to fifty and forty miles per hour speed limits for cities greater than or equal to 50,000 people population. We also shifted one half of the roadway mileage from forty to thirty miles per hour for local roads and collectors for cities greater than or equal to 50,000 people population. (There were no sixty-mile-per-hour local roads.)
A realistic assessment of the effectiveness of reducing local roadway speed limits will require information on the effectiveness of posting and enforcing

the reduced speed limits and the feasibility of imposing such constraints upon the roadway network.

Case nine assumes no vehicle will operate at speeds in excess of fifty miles per hour on highways across the whole country. Past experience with the fifty-five mile per hour speed limit belies the likelihood of such an accomplishment. Case nine must be considered an upper bound reflecting the theoretical benefits that may be achieved given certain conditions are met.

Section V will summarize the findings of this study.

V. ESTIMATED BENEFITS OF CONTROLS

The reductions in Level Weighted Populations (LWP) were estimated for various state and local surface transportation noise control measures using the simulations described in Chapter IV. These simulations should be considered as preliminary estimates and/or maximum estimates of the potential benefits of the control due to limitations of:

- Data available with which to describe the control measures
- Limitations in NRTNEM in its existing form.

Data to quantify the applicability of the controls, the extent of enforcement, and the effectiveness of enforcement is not available. Consequently, no correction for these parameters is included for the simulations of noise emission limits, labeling, retrofit, inspection/maintenance, muffler enforcement, driver education, and the more stringent highway speed limit enforcement control measures. These factors are given effective assumed values for area restrictions, motorcycle enforcement, and reduced local road speed limits.

NRTNEM assumes the vehicle emission levels are normally distributed. Non-stock or defective vehicles are not explicitly addressed in the standard data base emission levels but are included in the vehicle type/operating mode distributions except for modified motorcycles. In cases 1 through 4, involving changes in vehicle noise emissions levels, the changes are represented as shifts in the mean of the distribution. This representation is inaccurate for controls which address defectives within the vehicle traffic mix (noise emission limits, labeling, inspection/maintenance, and muffler enforcement). Where defectives occur in the traffic mix, the correct representation consists of two distributions, one for the nondefective vehicles of that type and one for the defective vehicles of that type. The effect of the control would then be to reduce the population of the defective vehicle population with a resulting decrease in the numbers of vehicles at high sound levels but with the majority of vehicles at moderate and low sound levels unaffected.

The prohibition of snow tires during summer months will have benefits as a function of seasonal lengths and geographic location. NRTNEM does not readily allow the modeling of these effects, consequently the effects of snow tire regulation are substantiallly overestimated.

In modeling the benefits of area restrictions, medium and heavy trucks are excluded from minor roadways (local roads and streets, collectors, and minor arterials) and added to major roadways (major arterials, freeways and expressways, and interstate highways). This change effects both the traffic mix on the roads as well as the average daily traffic (ADT). NRTNEM does not readily allow the adjustment of ADT selectively by place size. Consequently, no correction was made for incrementing the traffic on major roadways by the added traffic received from minor roadways. This effect, however, is very small since the number of medium and heavy truck vehicle miles on the minor roadways will be much less than that of the major roadways.

Each of the state and local noise control measures was simulated for an analysis year of 1985 and compared to the baseline exposures for that year. In all scenarios and simulations, the effects of the existing Interstate Motor Carrier Regulations and medium and heavy truck new product regulation were included. The results of these simulations are summarized in Table 5.1 and are discussed briefly in the following paragraphs.

<u>Low Speed Vehicle Noise Emission Controls</u>. These controls are essentially engine noise controls, i.e., primarily controls to exhaust system and, to a lesser extent, to the intake, cooling fan, and bare engine. They include:

TABLE 5.1

ESTIMATES OF BENEFITS OF STATE & LOCAL TRANSPORTATION CONTROLS (ANALYSIS YEAR: 1985)

mulation No.	Control Measure	Overall Impact LWP =	Net Benefit $LWP_B - LWP_i$	Relative Change In Impact RCI = $\frac{LWP_B - LWP_i}{LWP_B}$	Demographic Application of Simulation	Notes
Baseline	None	29.8	-	-	Nationwide	1
1	Noise Emission Limits Labeling Inspection/Maintenance Muffler Enforcement Retrofit Driver Education	14.3	15.5	52%	Nationwide	1,2
2	Same as Simulation 1 but more stringent	12.2	17.6	59%	Nationwide	Upper estimates, 1,2
3	Snow Tire Regulation	16.9	12.9	43%	Nationwide	Upper estimate, 1,3
4	Roadway Surface Treatment	16.4	13.4	45%	Nationwide	Upper estimate, 1,4
5	Area Restriction	22.2	7.6	26%	Cities with >50K population	1,5
6	Motorcycle Enforcement	23.2	6.6	22%	Cities with >50K population	1,6
7	Same as Simulation 6 but more stringent	22.3	7.5	25%	Cities with >50K population	Upper estimate, 1,6
8	Reduced Speed Limits Local Roads	23.3	6.6	22%	Cities with >50K population	Upper estimate, 1,7
9	More Stringent Speed Limit Enforcement Highway	23.6	6.2	21%	Nationwide	Upper estimate, 1,8

TABLE 5.1. (Continued)

NOTES

1) The benefits of existing regulations covering Interstate Motor Carriers and medium and heavy trucks are incorproated.

2) Cases 1 and 2 assume a nationwide reduction of mean vehicle emission levels through one or more of several means including level street standards, retrofits, inspection/maintenance and muffler enforcement and driver education. Case 1 represents a reasonably achievable goal while Case 2 is probably close to the maximum achievable. The assumed level reductions are as follows for all operating conditions 45 mph.

Vehicle Types	Level Reduction (dBA)	
	Case 1	Case 2
Light Vehicles	2	4
Trucks and Buses	1.25	2.5
Motorcycles	2.5	5.0

3) Snow tire regulations would only apply to the northern half of the nation during the non-winter months. Case 3 modeled a snow tire regulation as a 2 dB level reduction for vehicles operating above 45 mph without taking the geographical, seasonal, and enforcement effectiveness into account. Therefore, these results significantly overstate the potential benefits.

4) Roadway surface treatments are only justified economically on a small proportion of roadways. Case 4 modeled the control measure by assuming all roadways with traffic speeds of 45 mph or more would receive treatment and exhibit a 5 dB level reduction. Therefore Case 4 overstates the realizable benefit of such an action, but it does define an upper bound for the maximum benefit.

5) Area restrictions were modeled by reducing the percentage of the medium and heavy trucks operating on all local roads for cities larger than 50,000 population. An arbitrary percentage decrease of fifty percent was utilized. An accurate estimate would need to assess the feasibility of restricting truck traffic on local roads.

6) A motorcycle muffler enforcement program is modeled by assuming a reduction by one half and a total elimination of modified motorcycle for cases six and seven respectively. These enforcement compliance percentages were chosen arbitrarily and do not necessarily reflect a realistic goal, but were applied only to cities larger than 50,000 population.

TABLE 5.1. (Continued)

7) This control measure was modeled by arbitrarily reducing the amount of roadways with 60, 50 and 40 mph traffic to the next lower speed category. A realistic evaluation of this control measure would require a feasibility assessment of taking such action on particular raodways.

8) Stringent speed limit enforcement on the nation's interstates and highways could reduce noise exposures by the amount indicated if complete compliance is achieved. This effect is modeled by the shifting of all vehicle operating at >55 mph to the 45 to 54 mph category. These results indicate the maximum potential benefit achievable with traffic speeds at <55 mph.

- Controls addressing the degradation of vehicle acoustical performance (noise emission limits, labeling, inspection/maintenance, and muffler enforcement)
- Controls which affect reductions in the stock vehicle emission levels (retrofit -- inasmuch as the distribution of vehicle emission levels includes both defectives and nondefectives the modeling of both retrofit and anti-degradation type noise controls is effectively the same)
- Controls which reduce vehicle emissions by changes in vehicle operation (driver education).

Application of these controls on a nationwide basis results in reductions of impact ranging from 52 to a maximum of 59 percent. (The small incremental benefit achieved in the maximum benefit case, which constituted a doubling of the decibel level reduction, indicates impact reductions are limited by high speed vehicle exposures).

High Speed Vehicle Noise Control Measures. High speed vehicle noise controls address the tire/roadway interaction noise emissions. The prohibition of the use of snow tires during non-snow months is estimated at a 43% reduction. However, this is a gross overestimate which does not consider the geographic and temporal (seasonal) applicability of such a regulation. Effects of roadway surface treatments in conjunction with appropriate tire tread designs results in quieter tire noise emissions to a maximum 45% impact reduction when universally applied to all high speed roadways. The small difference between the snow tire regulation effects (assumed as a 2 dB reduction at high speed vehicle operation) and the roadway surface treatment effects (assumed as a 5 dB reduction in high speed vehicle operation) indicates impact reductions are limited by low speed vehicle operation noise emissions.

Area Restrictions. The redirection of 50% of the medium and heavy truck traffic on minor roadways (local roads and streets, collectors, and minor arterials) to major roadways (major arterials, freeways and expressways, and interstate highways) was simulated for all cities with greater than 50,000 people population or approximately the 400 largest cities. The benefit of this control was approximately a 26% reduction in impact.

The Elmination of Modified Motorcycles. Modified motorcycles constitute between 12 and 14 percent of all motorcycles in the NRTNEM vehicle type data base depending on roadway type. Local enforcement activities in cities above 50,000 people population halving the incidence of modified motorcycles result in a 22 percent reduction in impact. Total elimination of all modified motorcycles results in a 25 percent reduction in impact. The relatively small incremental benefit from total elimination of modified motorcycles indicates impact reductions are limited by exposures to other vehicle types.

Speed Limit Controls. The reduction of speed limits on major and minor arterial and collector type roadways should cause a downward shift in vehicle speed distributions. Implementation of this measure for population place sizes of 50,000 people or greater will result in approximately a 22 percent reduction in impact. More stringent enforcement of the 55 mph speed limit on a nationwide basis for freeways and expressways, and interstate highways will result in approximately a 21 percent reduction in impact due to high speed vehicle noise.

VI. RECOMMENDATIONS

In this section, recommendations for improved benefits estimates will be discussed. These recommendations will take the form of general improvements to the NRTNEM codes, more detailed and accurate simulation inputs, and simulations describing compound controls (i.e., the simultaneous implementation of more than one noise control measure).

The NRTNEM documentation does not indicate any special accommodation for the behavior of vehicles around intersections is made in the model. A fundamental assumption of the model is that vehicle spacing remains constant for all vehicle operating modes. This is not representative of the behavior of vehicles at intersections since when the flow is stopped the vehicles will become concentrated. The model also describes acceleration sound levels in terms of the equivalent sound level over the period of acceleration. Consequently, for light vehicles--which are typically accelerated in part throttle -- the equivalent sound levels during acceleration are lower than those used in the model for constant speed cruise, as shown in Table 6.1. Apparently no accommodation is made for the longer exposure time past an observer from an accelerating vehicle versus that from a vehicle operating at constant speed. (It can be shown that a vehicle accelerating at a constant rate from rest to a given speed will require twice as much time to cover its distance-to-speed than a vehicle cruising steadily at that given speed covering the same distance. As a result, the noise exposure due to the accelerating vehicle will

TABLE 6.1

COMPARISON OF NRTNEM ACCELERATION AND CRUISE NOISE EMISSION LEVELS

dist?

#	Vehicle Type	Engine Type	Number Cylinders	Transmission Type	Baseline (1974) Vehicle Emission Levels (dB)	
					0-40 mph ACCELERATION	35-44 mph CRUISE
1	Passenger Car	Gasoline	8	Automatic	63.0	66.4
2	Passenger Car	Gasoline	6	Automatic	63.7	66.4
3	Passenger Car	Gasoline	6&8	Manual	63.9	66.4
4	Passenger Car & Light Truck	Gasoline	4	Automatic	65.1	66.4
5	Passenger Car & Light Truck	Gasoline	4	Manual	65.6	66.0
6	Light Truck	Gasoline	6&8		67.6	69.3
7	Passenger Car & Light Truck	Diesel			67.5	68.2
8	Medium Truck				76.5	76.4
9	Heavy Truck				82.8	82.1
10	Intercity Bus				82.3	78.4
11	Transit Bus				81.1	75.8
12	School Bus				78.4	75.8
13	Stock Motorcycle				75.4	74.4
14	Modified Motorcycle				89.6	88.6

be 3 dB higher by virtue of the doubled time for equal emission levels and ignoring other factors such as source directivity). Accommodation of these considerations is absolutely necessary if intersection design noise controls are to be simulated. In addition, estimates of all simulations will be more accurate with this improvement, although the sensitivity of this effect is not known at this time.

Refinement of the simulations themselves include more detailed geographic segregation of the data to allow the description of programs for limited numbers of states. This refinement would affect all those simulations which do not have any applicability limits in the results reported herein. (These include both the low speed and high speed vehicle noise control measures and the speed limit effects). This capability of adjusting on a basis of states must exist for both vehicle emission levels and vehicle speed data.

The differentiation of the distributions of defective vehicles by vehicle types is recommended to allow the more precise modeling of the low speed vehicle noise controls (for noise emission limits, labeling, inspection/maintenance, and muffler enforcement). These control measures address only defective vehicles in the mix while not affecting the emissions of those in nominally stock condition. Consequently, the simulations used in this study underestimated the effects on the noisiest vehicles while attributing level reductions to many vehicles which are not expected to experience change. The sensitivity to this consideration is also not known.

As was implied in the discussions in Section V, the simulations only addressed individual generic types of control measures implemented singlely. The estimated benefits of these measures in many instances were limited by noise exposure to vehicle operations or types beyond the scope of the particular control measure being considered. A balanced enforcement program would likely address as many of the vehicle types and operating modes as feasible to maximize the derived benefits. The following compound control measures should be considered:

- Low speed vehicle controls in conjunction with high speed vehicle controls
- Motorcycle enforcement controls in conjunction with area restrictions and/or reduced speed limits on local roads
- State-implemented controls in conjunction with locally-implemented controls.

A final note in closing: Even with the implementation of the recommendations above, the ability to predict the effects of controls will be limited by the data base. This is particularly true with respect to the parameters of applicability, extent, and effectiveness. Not only has information regarding these parameters been virtually unavailable, but also substantial danger exists in being excessively optimistic in assuming their values. For a control measure requiring active enforcement to be effective, it must be vigorously and continuously enforced. Instances of this to date have been rare. As a final recommendation, sensitivity analyses should be performed for ranges of these parameters -- applicability, extent, and effectiveness.