Community response to noise in Vietnam: Exposure-response relationships based on the community tolerance level

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Social surveys on noise annoyance have been conducted in five different cities in Vietnam. The surveys included both aircraft noise (three airports) and road traffic noise (five cities). The main objective for these studies was to establish dose-response functions that were representative for Vietnam. The results have been compared with results from similar surveys from other regions. Dose-response functions for aircraft noise in Vietnam showing the percentage of highly annoyed people versus the noise level are nearly identical to those presented in the European Noise Directive [European Commission (**2002**). http://ec.europa.eu/environment/noise/directive.htm]. For road traffic noise, however, the results indicate that people in Vietnam are more tolerant. The noise levels can be increased by 5–10 dB in order to have a response similar to the curve recommended by the European Commission. © *2015 Acoustical Society of America*.
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I. INTRODUCTION

Numerous attempts have been made to combine the results from different noise surveys to establish more general dose-response functions. The first serious attempt was done by Schultz (1978). He concluded that the annoyance response was independent of the source (aircraft or road traffic) and he also introduced the concept of "highly annoyed" (HA). He defined the annoyance response as a continuum ranging from "not annoyed" to "extremely annoyed," and people belonging to the upper 28% of this scale were considered HA.

Later, new surveys were added to the list and refined dose-response functions were proposed by Finegold *et al.* (1994), Miedema and Vos (1998), and Fidell and Silvati (2004), among others. The common approach for the meta-analysis done by these authors was to find a statistical "best fit curve" to the existing data given certain boundary conditions. All of the new functions were source specific meaning there were separate dose-response functions for aircraft, road, and rail noise.

A majority of the noise surveys, especially more recent ones, have been conducted for reasons associated with a change: expansion of operations, building of new roads and runways, etc. It is a well known fact that during a transient period with major changes, the annoyance response will be different from what can be found after some years of stable operations (Fidell and Pearsons, 1985; Horonjeff and Robert, 1997). The sites that were chosen for the Vietnam study represent stable conditions. A stable condition response is considered most appropriate to use for regulatory purposes.

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II. SURVEYS

A. Survey sites

Social surveys on aircraft noise annoyance were conducted in the vicinity of three airports and surveys on road traffic noise annoyance were conducted in five different cities.

Tan Son Nhat Airport in Ho Chi Minh City [International Air Transport Association (IATA) code SGN] is located in a crowded residential district and surrounded by busy commercial streets. The airport is situated just 6 km north of the city center. It handles about $15–17 \times 10^6$ passengers per year. At the time of the survey the traffic volume was about 225 movements per day (sum arrivals and departures).

The respondents were selected from ten areas; eight of them located directly under the flight paths at different distances from the airport and two to the side. The interviews were conducted from August to September 2008.

Noi Bai Airport in Hanoi (IATA code HAN) is located in a rural area about 45 km away from the city center. At the time of the survey the traffic volume was about 160 movements per day. Annual number of passengers was about 12.5×10^6.

The respondents were selected from nine areas; seven of them located directly under the flight paths at different distances from the airport and two to the side. The interviews were conducted from August to September 2009.

Da Nang Airport (IATA code DAD) is located about 3 km from the city center. It has a capacity of about $4–6 \times 10^6$ passengers per year. At the time of the survey the traffic volume was about 80 movements per day.

The respondents were selected from six areas located directly under the flight paths at different distances from

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TABLE I. Overview of the surveys.

Noise source	City	Number of sites	Number of responses	Response rate (%)	Noise range (L_{den}, dB)
Road	Hanoi	8	1503	50	73–81
traffic noise	Ho Chi Minh	8	1471	61	77–83
	Da Nang	6	492	82	66–76
	Hue	7	688	98	61–80
	Thai Nguyen	10	813	81	61–78
Aircraft noise	Ho Chi Minh	10	880	87	53–71
	Hanoi	9	824	85	48–61
	Da Nang	6	528	84	52–64

the airport. Unlike for the two other airports, SGN and HAN, successful land use planning in Da Nang has limited the number of residences in the most noise exposed areas. Most of the survey sites were therefore relatively sparsely populated. The interviews were conducted in September 2011.

Separate surveys on annoyance from road traffic noise were conducted in the same three cities; Ho Chi Minh City in 2007, Da Nang in 2011, and Hanoi in 2005. The survey areas were selected away from the airports where aircraft noise could not be heard. In addition, surveys on road traffic noise were also conducted in the cities of Hue in 2012 and Thai Nguyen in 2013.

B. Survey method

The surveys were conducted as face-to-face interviews during the daytime on weekends. The interviewers brought the questionnaire to each house of the selected survey sites, read the questions aloud to the respondents, and filled in the answers. One member of each household was selected. Only people 18 years or older were eligible. The respondents were selected in a sequential order to get an even distribution: House #1: father of the family, house #2: mother of the family, house #3: other member of the family (other than father/mother). Then the sequence was repeated. If the selected respondent was not available (or refused to participate) the interviewer moved on to the next house.

The design of the questionnaire followed Technical Specification ISO/TS 15666, and the survey was presented as "A survey on living environment" with no specific reference to the noise situation. The Vietnamese version (Yano and Ma, 2004) of the two standardized survey questions recommended by International Commission on Biological Effects of Noise (ICBEN) (Fields *et al.*, 2001) were included in the questionnaire. One question asks for a characterization of the noise situation the past 12 months using a 5-point verbal scale with modifiers like "not annoyed at all," "a little annoyed," etc., and the other question refers to an 11-point numerical category scale ranging from "0-zero" (not annoyed at all) to "11-eleven" (extremely annoyed). This report focuses on the response to these two questions.

The questionnaire on aircraft noise was almost identical to the one on road traffic noise, except for the reference to the specific noise source. The questionnaire included 32 questions and the interview lasted for about 30 min.

III. NOISE LEVELS

The noise levels at the respondents' residences were determined by measurements. The aircraft noise level was logged every second for seven consecutive days in a position that was considered representative for the whole survey site. Flight data was obtained from the official airport website and compared with the yearly average traffic to ascertain that the measurement period was representative for the noise situation.

Road traffic noise was measured curbside outside the residences for a 24-h period. Measurements were made for each section of the road (between two intersections), and this noise level was used for all the residences on that block.

The measurements were made using a calibrated class 1 sound level meter (RION NL-21/22) fitted with a rain protection windscreen (RION WS-16). The microphone was positioned on a tripod 1.5 m above ground/roof.

An overview of the surveys is shown in Table I. Detailed information on these surveys has been published by Nguyen and co-workers (Nguyen *et al.*, 2011; Nguyen *et al.*, 2012a; Nguyen *et al.*, 2012b; Nguyen *et al.*, 2013).

A. Highly annoyed

Schultz (1978) used the phrase "highly annoyed" to characterize the upper part of the annoyance scale. For convenience sake when converting existing survey data based on different scales to a common annoyance scale he defined the upper 28% of the scale HA.

The numeric ICBEN scale consists of 11 steps, 0–10. A response equal to the upper three steps: 8, 9, and 10 is scored as HA. This represents three eleventh, or 27.3%, of the total scale.

The verbal scale is more complicated. By taking only the top category: "extremely annoyed" (Vietnamese: *cuc on*) one would only include the upper 20% of the scale, and the two top categories: "extremely and very annoyed" (*cuc on, rat on*) would include 40% of the total scale. We have chosen to count the upper category plus 0.4 of the next category as HA. This represents exactly 28% of the total scale.

B. The CTL approach

Data from social surveys have traditionally been processed with standard statistical methods. A "best-fit" curve has been fitted to the existing data observing some chosen boundary conditions. Fidell *et al.* (2011) have described an alternative to such regression analysis for establishing dose-

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TABLE II. Ho Chi Minh City, % highly annoyed by aircraft noise.

L_{den} [dB]	5-point	11-point	Responses
53.2	1.4	0	86
55.1	6.0	6.9	90
57.2	3.7	8.8	90
59.3	6.7	5.1	85
60.0	1.4	1.1	89
61.7	23.9	3.4	89
62.3	16.1	10.6	88
64.2	26.9	48.8	83
65.6	27.6	34.4	90
70.6	41.6	51.6	90

response functions. On the basis of forty-three studies of the annoyance of aviation noise these authors found that the rate of change of annoyance with day-night average sound level due to aircraft noise, DNL or DENL, closely resembled the rate of change of loudness with sound level. For each set of survey results the effective loudness function gave a good fit to the existing data but still there were large differences between surveys. Thus they claimed that the annoyance response function could be described by a single decibel-like parameter anchoring the common effective loudness function to the exposure axis (x axis).

The annoyance prevalence rates according to Fidell *et al.* (2011) can be predicted as

$$p(\mathrm{HA}) = e^{-A/m},$$

where A is a scalar, non-acoustic decision criterion and m is an estimated noise dose given by

$$m = (10^{(\mathrm{DNL}/10)})^{0.3}.$$

The value of A in a given community is that which minimizes the root-mean-square error between the predicted and the empirically measured annoyance prevalence rates.

An arbitrary point on the effective loudness function could be used to anchor the prediction function to the x axis. The authors have chosen the mid-point corresponding to a 50% annoyance prevalence rate. The noise level corresponding to this point has been named the "community tolerance level" (CTL). It denotes the noise level at which 50% of the population of that particular community consider themselves HA. The CTL is calculated from A as follows:

$$\mathrm{CTL} = 33.3 \log A + 5.32.$$

CTL values were calculated for 43 aircraft noise surveys. The mean CTL value for these data sets was 73.3 dB. The

TABLE III. Da Nang, % highly annoyed by aircraft noise.

L_{den} [dB]	5-point	11-point	Responses
51.7	5.7	3.0	85
54.2	10.8	1.5	78
59.8	46.9	32.6	90
60.2	8.1	1.5	77
61.5	8.9	12.1	99
63.5	21.2	8.3	99

TABLE IV. Hanoi, % highly annoyed by aircraft noise.

L_{den} [dB]	5-point	11-point	Responses
48.0	17.4	18.4	76
49.2	3.2	4.4	99
52.4	17.2	4.7	87
54.7	10.2	6.4	96
56.2	11.6	11.2	89
56.3	46.6	67.0	99
56.8	6.2	8.0	88
60.9	47.4	57.0	100
61.1	16.7	20.5	90

best fit to the dose-response function recommended in the European Noise Directive (END) has also been found for a CTL value of 73.3 dB.

This recommended reference curve for aircraft noise annoyance in the END, often referred to as the "Miedema curve" is based on about twenty studies of aircraft noise annoyance. Similar reference curves have also been presented for road traffic and rail noise. The CTL parameter is community specific. By comparing the CTL value for a certain survey site with the CTL value corresponding to the END reference curve it is possible to express differences in the response by a single number. A CTL value for aircraft noise greater than 73.3 dB indicates that this community is more tolerant to noise than the reference, and values smaller than 73.3 dB indicates a less tolerant community. The actual difference between the CTL values show how many decibels the noise can be increased (or decreased) in the relevant community in order to have an annoyance response similar to the reference.

Schomer *et al.* (2012) have performed an analysis of available data sets on road noise similar to that reported for aircraft noise by Fidell *et al.* (2011). These authors calculated the CTL values for 35 studies on road traffic noise. The mean CTL value for these data sets was 78.3 dB. This value also represents the best fit to the END reference curve for road traffic noise.

CTL values for specific road traffic noise studies greater or smaller than 78.3 dB indicate thus more or less tolerance to this type of noise than what is predicted by the END reference curve.

C. Survey results

The survey results from each study site are shown in Tables II–IX. These tables show the percentage of HA people according to the verbal ICBEN scale and the numerical ICBEN

TABLE V. Ho Chi Minh City, % highly annoyed by road traffic noise.

L_{den} [dB]	5-point	11-point	Responses
74.9	31.3	15.3	170
77.7	26.8	34.0	179
79.4	24.0	35.9	189
79.7	63.8	69.2	200
79.8	42.0	44.4	184
81.5	42.7	36.6	169
82.6	52.9	64.0	194
83.1	25.9	20.4	186

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TABLE VI. Da Nang, % highly annoyed by road traffic noise.

L_{den} [dB]	5-point	11-point	Responses
66.4	1.7	0	93
68.9	3.7	0	49
70.2	8.5	2.7	75
70.9	6.6	6.8	90
75.7	40.0	24.5	98
75.8	23.0	22.1	87

scale and also the number of respondents (valid interviews) for each exposure level. More information on the Vietnamese noise studies have been presented at two Inter Noise conferences (Shimoyama *et al.*, 2014; Nguyen *et al.*, 2012a,b).

IV. DISCUSSION

A. Aircraft noise

All of the aircraft noise responses, Tables II–IV, have been plotted in Figs. 1 and 2. Figure 1 gives the response using the 5-point verbal scale, and Fig. 2 gives the response according to the 11-point numerical scale. In each figure a dose-response function has been fitted according to the CTL method.

The response to both ICBEN questions yields the same CTL value, 73.0 dB, which is very close to the mean CTL found by Fidell *et al.* (2011), 73.3 dB. The dose-response curve corresponding to this CTL value has been shown to be very similar to the END reference curve for aircraft noise. It can thus be concluded that the average annoyance response to aircraft noise in Vietnam is nearly equal to the average response that has previously been found in similar studies in Europe and North America.

A relative wide spread of the data points can be observed, which is also the case for other such meta-analyses. However, if each airport is considered separately, the data spread is much smaller. Figure 3 shows the annoyance response at the airport of Ho Chi Minh City only.

Similar analysis of the airports in Hanoi and Da Nang yields the CTL values listed in Table IX.

Table X shows that the prevalence of high annoyance among people living near the airports of Da Nang and Ho Chi Minh City is slightly *lower* than what can be predicted by the END reference curve. These residents tolerate about 2 dB higher noise levels in order to express the same annoyance as the average.

The prevalence of high annoyance among people living near the airport in Hanoi, however, is *higher* than the average. These residents tolerate about 5 dB less noise in order to express the same annoyance as the average.

TABLE VII. Hanoi, % highly annoyed by road traffic noise.

L_{den} [dB]	5-point	11-point	Responses
69.5	28.4	29.0	31
73.0	22.0	21.3	15
74.6	22.4	21.8	61
74.6	34.4	27.8	48
74.6	31.4	22.4	114
76.0	54.8	73.9	25
76.2	46.8	47.6	315
76.9	40.0	26.7	15
77.3	49.3	41.6	150
79.0	50.5	45.2	324
79.9	45.6	58.5	82
81.2	50.8	54.2	322

TABLE VIII. Hue, % highly annoyed by road traffic noise.

L_{den} [dB]	5-point	11-point	Responses
60.9	1.62	2.1	99
69.7	4.2	3.0	99
71.4	9.2	7.1	98
72.0	22.0	8.1	99
73.9	8.0	4.0	100
74.6	23.9	15.1	93
79.6	23.4	17.2	99

B. Road traffic noise

All of the road traffic noise responses, Tables V–IX, have been plotted in Figs. 4 and 5. Figure 4 gives the response using the ICBEN 5-point verbal scale, and Fig. 5 gives the response according to the ICBEN 11-point numerical scale. The data points have been weighted according to the number of respondents at each site. In each figure a dose-response function has been fitted according to the CTL method.

The response to the two ICBEN questions yields about the same CTL value, 84.0 and 84.6 dB, which is 6 dB higher than the mean calculated by Schomer *et al.* (2012), 78.3 dB. It can thus be concluded that the average citizen in Vietnam is less annoyed by a given level of road traffic noise than people in Europe and North America.

A relative wide spread of the data points can be observed, which is also the case for other such meta-analyses. However, if the survey results from each city are considered separately, the data spread is much smaller. Figure 6 shows the annoyance response due to road traffic noise in Tai Nguyen only.

Similar analysis of the results from the other cities yields the CTL values listed in Table XI. This table shows that the prevalence of high annoyance among people living in these five Vietnamese cities is *lower* than what can be predicted by using the END dose-response curves, corresponding to CTL

TABLE IX. Thai Nguyen, % highly annoyed by road traffic noise.

L_{den} [dB]	5-point	11-point	Responses
60.9	2.4	1.5	66
64.0	2.2	0	92
73.0	16.5	8.1	62
73.1	15.0	12.6	95
73.8	19.2	6.5	71
73.9	26.1	10.5	86
74.9	31.8	38.6	77
75.5	30.3	34.2	76
76.9	34.9	26.7	75
77.9	38.5	45.2	93

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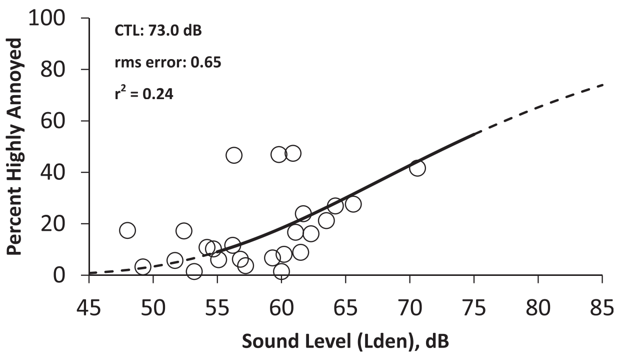

FIG. 1. Response to noise around three Vietnamese airports (ICBEN 5-point scale).

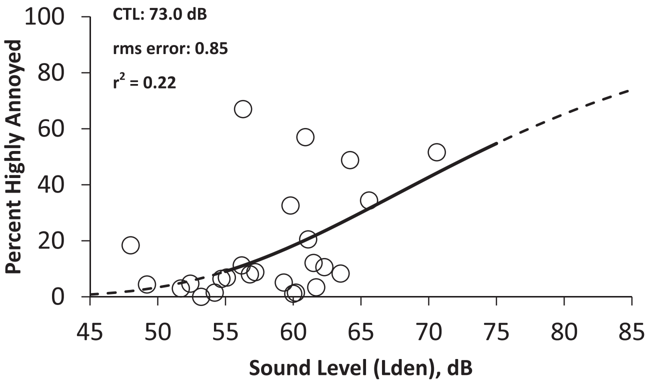

FIG. 2. Response to noise around three Vietnamese airports (ICBEN 11-point scale).

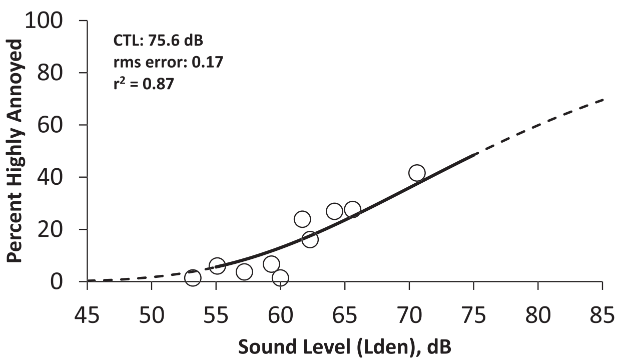

FIG. 3. Response to noise around HCM airport (ICBEN 5-point scale).

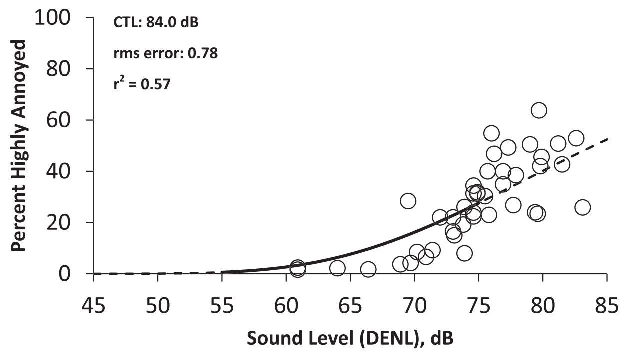

FIG. 4. Response to road traffic noise in five Vietnamese cities (ICBEN 5-point scale).

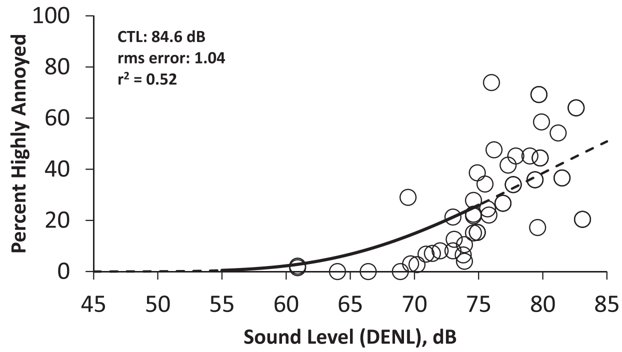

FIG. 5. Response to road traffic noise in five Vietnamese cities (ICBEN 11-point scale).

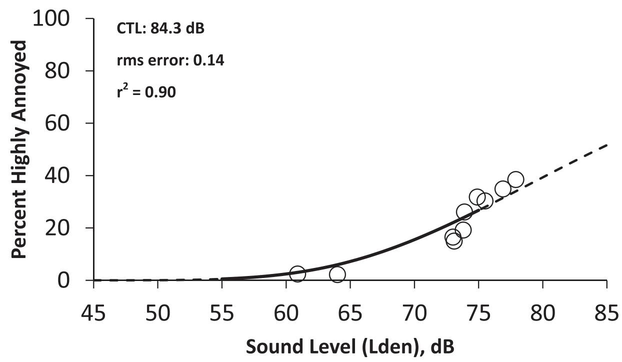

FIG. 6. Response to road traffic noise in Thai Nguyen (ICBEN 5-point scale).

TABLE X. CTL values for aircraft noise annoyance at three Vietnamese airports.

	5-point	11-point	Average
Ho Chi Minh City	75.6	75.3	75.45
Da Nang	73.0	77.0	75.0
Hanoi	68.0	68.3	68.15

TABLE XI. CTL values for road traffic noise in five Vietnamese cities.

	5-point	11-point	Average
Ho Chi Minh City	84.3	84.0	84.15
Da Nang	86.3	89.0	87.65
Hanoi	80.3	80.3	80.3
Hue	88.3	92.0	90.15
Thai Nguyen	84.3	86.0	85.15

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values 80–90 dB. The mean CTL value for road traffic noise calculated by Schomer *et al*. (2012) is 78.3 dB. The two standardized annoyance questions give similar results for the Vietnamese surveys. People in Hanoi seem to be less tolerant to road traffic noise than the Vietnamese average. This was also the case for aircraft noise in that city.

V. CONCLUSIONS

People's response to aircraft noise and road traffic noise has been studied at three airports and in five cities in Vietnam. All study areas represent stable noise conditions where there has been no major changes in the traffic situation over the years prior to the survey. The authors assume that the annoyance response functions that can be derived from these study areas are representative for the noise situation in Vietnam.

Several papers on possible changes in the annoyance response to noise have recently been published (van Kempen and van Kamp, 2005; Janssen *et al.,* 2011). In a new report from the European Commission (Stansfeld *et al.,* 2015), Janssen and Guski present a summary of aircraft noise studies conducted over the past 30–40 years. They claim that the percentage of HA people at an exposure level of L_{den} 55 dB has increased from about 10% in 1970 to about 30% in 2000.

The Vietnamese survey results presented in this paper contradict that conclusion. Similar results from Norway that show no increase in the annoyance response have been presented by Gelderblom *et al*. (2014).

Both the Norwegian surveys and the Vietnamese surveys were conducted in areas where there were stable noise situations and no on-going noise conflicts. However, since many recent aircraft noise annoyance studies have been conducted in the context of a change in the noise situation such as introduction of new aircraft, changes in the traffic volume, building of a new runway, etc., it is likely that the increased prevalence of annoyance as reported by Janssen and Guski (Stansfeld *et al*., 2015) is mainly caused by an abrupt change in the noise situation, and thus represents a transient response. Fidell *et al.* (2002) reached the same conclusion when studying the community response to a step change in aircraft noise exposure. They concluded that the "excess" annoyance was attributable to the influence of non-acoustical factors.

We conclude that the existing dose response curves for aircraft noise annoyance presented by Miedema and Vos (1998) and recommended by the European Commission (2002) are well suited to be used for regulatory purposes in Vietnam. These curves give a very good prediction of the expected annoyance response.

Similar curves for the response to road traffic noise seem to overestimate the prevalence of annoyance in Vietnam. People in Vietnam tolerate 5–10 dB higher noise levels from road traffic in order to give a response similar to the dose response curve recommended in the END.

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