Predicting Stop-and-Go Traffic Noise With STAMINA 2.0

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The STAMINA 2.0 computer program is the most commonly used method for prediction of traffic noise levels for impact analysis and noise barrier design. However, the program was based on theory for freely flowing vehicles at a constant speed. The work presented in this paper represents development of a methodology to use STAMINA 2.0 in nonconstant speed situations, such as signalized intersections, intersections with Stop signs, tollbooths, and highway loop and slip ramps. Through a review of literature and collection of new emission levels on accelerating, decelerating, and cruising heavy trucks, a data base was established for the methodology. The concept of zone of influence (ZOI) was used to represent stretches of road on which acceleration or deceleration occurs and on which sound levels may vary from cruise condition levels. Two series of equivalent constant speeds (one for acceleration, one for deceleration) were developed, permitting STAMINA 2.0 to calculate the desired difference in noise level relative to cruise on the basis of the findings of the literature review and field data analysis. Validation at two sites containing intersections produced results within 1 dB of predictions at all measurement points after refinement of the preliminary ZOI lengths and after calibration of the cruise predictions.

This paper presents the results of a study for the National Cooperative Highway Research Program (NCHRP) on predicting stop-and-go traffic noise with the STAMINA 2.0 traffic noise prediction computer program. The purpose of the study was to develop a method for using the STAMINA 2.0 program for nonconstant speed situations. There were two major tasks: (a) to study the existing literature and (b) to collect additional data as needed. The scope did not include development of any new computer programs. Also, the method had to be easy to use by the typical noise analyst.

APPLICABLE SITUATIONS

The first task was to define the universe of changing-speed situations and then to narrow that universe down to an acceptable subset for this research. The changing-speed situations can be categorized in six ways:

1. Areas in which there is congestion or unstable flow, such as level-of-service (LOS) F on highways, or LOS E or F for intersections;
2. Urban city street networks in which there are a large number of traffic signals in a highly reverberant area;
3. Highway entrance, exit, and transition ramps;
4. Suburban situations in which there are signalized arterials but no highly reverberant sound fields because of closely spaced buildings;
5. Areas with stop signs, but again no highly reverberant field; and
6. Highway toll booths, at which traffic decelerates to a stop and then accelerates back to cruising speed, similar to the case of the Stop sign.

The first two situations were not within the scope of this work. The first, congested or unstable flow, was not a condition toward which a designer would work. The second, urban street networks with highly reverberant sound fields, was a situation with which the STAMINA 2.0 program is not designed to deal. The last four situations, however, were all appropriate to be included in the scope of this study. After an examination of these four situations, the scope of study focused on three areas: (a) unsignalized (but signed) intersections, (b) signalized intersections, and (c) loop or slip transition ramps. The case of the unsignalized or signalized intersection could include the beginning or end of a ramp between a local highway or street and an arterial highway.

CURRENT FHWA RECOMMENDATIONS

The current FHWA recommendations for dealing with changing-speed or low-speed situations are contained in Appendix I of the *FHWA Highway Traffic Noise Prediction Model* (*1*). When speeds are below 30 mph, FHWA recommends that the analyst use a constant automobile noise emission level equal to the level at 30 mph. However, the FHWA model includes speed in a negative logarithmic function for the traffic flow adjustment calculation as well as in a positive logarithmic function for the noise emission level calculation. The result is that use of a constant noise emission level and these adjustments will actually cause the 1-hr equivalent sound level [L_{eq}(1h)] to increase as the average operating speed decreases.

For medium trucks, FHWA recommends the same strategy—to use the noise emission level at 30 mph. This procedure results in the same effect as for automobiles—an increasing L_{eq}(1h) as speed drops below 30 mph. For heavy trucks, FHWA recommends using the 87-dB emission level at approximately 62 mph when speeds drop below 30 mph. In terms of the effects on L_{eq}(1h) this use represents a 7-dB stepped increase in the levels as the speed drops below 30 mph and then a further increase in the hourly L_{eq}(1h) as the speeds drop lower. The result of the recommendation is that the L_{eq}(1h) for trucks below 30 mph is higher than the L_{eq}(1h) for trucks traveling 60 mph.

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RELEVANT LITERATURE

The first task in this work was to study existing literature. Most U.S. literature has focused on constant speed situations (2). Several useful European studies were found, including work by Lewis and James in 1980 (3). These researchers measured individual vehicle sound level changes at various distances from a traffic circle (roundabout) along the approach (deceleration) and departure (acceleration) roads. Three sites were studied with data for both trucks and cars. For the approach situation, the authors found that in all cases the levels dropped off smoothly as the distance to the roundabout decreased. However, for the departure cases, they found a fluctuation in the levels with increasing distance away from the roundabout. Generally, the levels first decreased and then increased, and finally either decreased or continued to increase, depending on the final speed.

Work in foreign countries has also focused on simulating traffic flow toward and away from a signal. In 1978, Favre (4) published the results of a simulation study of the effect on L_1 and L_{eq} for a mix of traffic approaching a signal, stopping, and then accelerating away from the signal. His results showed that the noise levels decreased during deceleration to a low point at about 160 ft behind the signal, which accounted for the queuing of vehicles waiting for the signal to change. He also found that the noise levels then increased as traffic accelerated away from the traffic signal, and then finally decreased before settling out to a constant level. Limited field data supported these simulation results.

As noted, most of the U.S. data focused on constant speed situations. However, a good data base for this study was developed for the U.S. Environmental Protection Agency (EPA) for its National Traffic Noise Exposure Model (5). Data were presented for a number of vehicle types for four operating modes: cruise, acceleration, deceleration, and idle. However, the noise emission levels were presented as average levels over the entire acceleration or deceleration event for an observer moving alongside the vehicle at a reference offset distance of 50 ft. This assumption greatly simplified the EPA model for predicting national exposure to traffic noise, but posed complications for a site-specific analysis such as those done with STAMINA 2.0.

Nevertheless, the data were still able to be used in this study after some manipulation and additional analysis. The EPA report presented emission levels averaged separately for events with the following speed ranges: 0 to 20, 0 to 30, 0 to 40, 0 to 50, and 0 to 60 mph. However, noise emission levels averaged over entire events would not be as useful for this work as noise emission levels that were more related to specific speeds. Using standard AASHTO vehicle acceleration rates (6), the times for a vehicle to go from 0 mph to various final speeds could be computed. Given these times and the average levels for acceleration from stopped to two different final speeds, average levels for the intermediate speed range between those two final speeds could be approximated as follows:

$$L_{(x-y)} = 10 \log \{[1/(t_y - t_x)] [(t_y)(10^{0.1L_y}) - (t_x)(10^{0.1L_x})]\} \quad (1)$$

where

$L_{(x-y)}$ = averaged level while the vehicle accelerates from x to y mph,
L_x = averaged level while the vehicle accelerates from 0 to x mph,
L_y = averaged level while the vehicle accelerates from 0 to y mph,
t_x = time to accelerate from 0 to x mph, and
t_y = time to accelerate from 0 to y mph.

For example, the average automobile noise emission level for a 0- to 40-mph acceleration event, according to EPA, was 64.1 dB. The average level for a 0- to 60-mph event was 67.4 dB. The time to accelerate from a stop may be computed as 18 sec for a final speed of 40 mph and 27 sec for a final speed of 60 mph. By Equation 1, the average level during the 30- to 60-mph acceleration is 70.5 dB. Similarly, the average levels can be computed for speed changes of 20 to 30 mph, 30 to 40 mph, 40 to 50 mph, and 50 to 60 mph, giving a stepwise speed profile for automobile acceleration. The EPA deceleration data were analyzed in a similar manner.

STUDYING THE ACCELERATION PHENOMENON

The next step was to gain a better understanding of the effect of the acceleration phenomenon on traffic noise levels. A small-timestep simulator was devised (using conventional spreadsheet software) for computation of the sound level at any given second during a vehicle passby event and subsequent plotting of the results.

Shown in Figure 1 are plots for an automobile cruise event at 60 mph and for an acceleration event (from 0 to 30 mph) for a receiver located 100 ft downstream from a Stop sign. In both cases, the receiver is located at an offset distance of 50 ft from the centerline of travel. For the cruise event, the vehicle is assumed to pass the receiver at time $t = 0$ sec. Note the symmetrical shape of the sound level profile time history. The computed sound exposure level (SEL) for this event was 76 dB. For the acceleration event, note the asymmetrical time history. The event begins at an arbitrarily assigned time of $t = -20$ sec and passes the receiver at a time of $t = -11$ sec; in other words, it takes 9 sec for the vehicle to accelerate from a stopped position to a position 100 ft downstream. The SEL value for this acceleration event was 70 dB, or 6 dB below the 60-mph cruise event.

Use of the simulator allowed the distance downstream for the receiver position to be varied to gain a better understanding of the effects. In general, as the receiver moved further downstream from the starting point, the sound level profile became more symmetrical.

Through use of the automatic calculation features of the spreadsheet, the SEL could be generated at a sequence of distances from the start for a particular event and then plotted. Figure 2 shows such an event for an automobile accelerating to 30 mph (open boxes on the graph), compared with the SEL from an automobile traveling at a constant 30 mph (solid boxes). Note the similarity in shape to the measured data shown earlier by Lewis and James (3)—a decrease in the levels, then an increase, and finally another decrease. Through

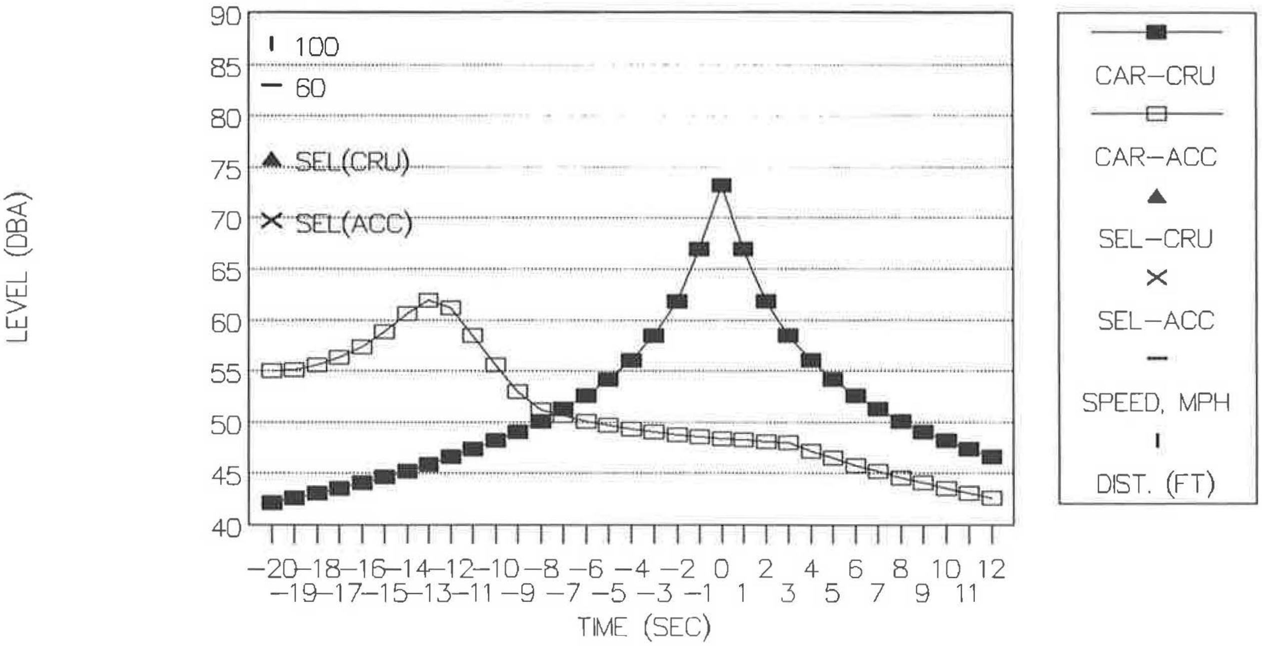

FIGURE 1 Predicted sound level time histories at a 50-ft offset distance for an individual car (a) cruising at 60 mph and (b) accelerating to 60 mph at a longitudinal distance of 100 ft from the start of acceleration.

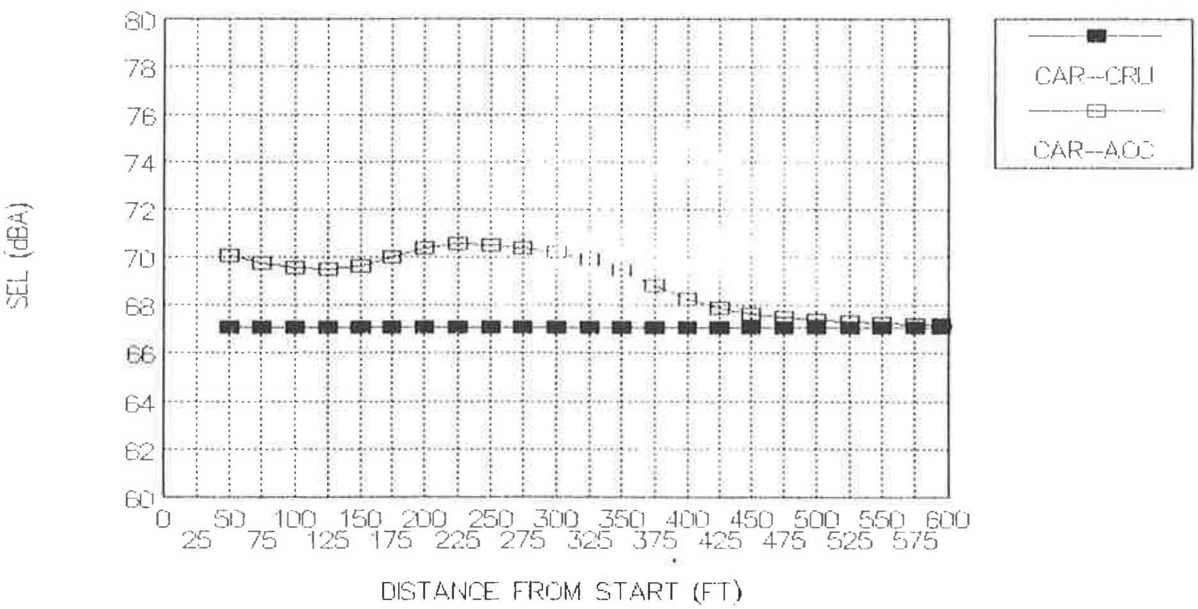

FIGURE 2 Predicted SEL at a 50-ft offset distance (a) at various distances from start for a car accelerating to 30 mph per EPA data and (b) cruising at 30 mph.

the use of the timestep simulation programs, tests could be run on the effects of the FHWA model assumptions, the EPA data base, and this study's measured data for heavy trucks.

FIELD-MEASURED DATA

Although some medium truck and automobile levels were measured, most of the data collection for this study focused on heavy trucks because of the importance of their contribution to overall received sound levels. The measurement sites were at two truck weigh stations on I-65 north of Nashville, Tenn. These sites were relatively flat and level, allowing analyzers to be set at a series of distances along the acceleration and deceleration lanes as well as downstream where the trucks were cruising at full speed. Trucks were measured simultaneously, three or four points at a time, allowing individual events at the different sites to be paired for analysis.

Care was taken to collect clean passbys, unaffected by other trucks at the weigh station or by automobile noise on the highway.

Time-Averaged Noise Levels

One of the first steps was to simply measure the L_{eq} for a series of 4-min periods simultaneously, at the cruise site, on the acceleration ramp, and on the deceleration ramp of one of the weigh stations, at an offset distance of 50 ft from the center of the travel lane. These data, shown in Figure 3, gave information on the effects of the various operating modes on the time-averaged level. The deceleration data were typically 6 to 9 dB below the cruise data at 60 mph, whereas the acceleration data were 0 to 4 dB below the cruise data. Note that these samples do not precisely represent the same vehicle populations because several minutes was required for a truck to decelerate, be weighed, accelerate, and finally pass the cruise site. Nonetheless, the trends are apparent. A similar series of 10-min L_{eq} measurements (not shown) at the cruise site and at three points along the acceleration ramp indicated that the L_{eq} values increased with increasing distance from the stopline. In all cases, the acceleration levels were less than the cruise levels when the vehicles were traveling at about 60 mph.

Noise Emission Level Data

With this better understanding of the anticipated effects, the noise emission level measurements were conducted. Both maximum level (L_{max}) and SEL data were collected on individual trucks. Figure 4 shows histograms of the sampled cruise events for both parameters. There is a fairly broad distribution and slight skew to the L_{max} data. However, the SEL data are more narrowly distributed, and in more of a Gaussian-shaped curve, with a mean of approximately 88 dB.

Figure 5 shows the aggregate results at the acceleration sites. The downstream distances range from 75 to 875 ft, all at a 50-ft offset distance. The mean SEL value was about 85 dB, or 2 to 3 dB below that of the trucks cruising at 60 mph. The tightness of the distribution suggests that a constant-acceleration SEL could be used, at least over the measured distance ranges (with a standard deviation very similar to that for the cruise data).

Figure 6 shows the deceleration data, aggregated over distances ranging from 175 to 475 ft before the stopline. Again, there is a broader, more skewed distribution for L_{max} values and a tighter, more symmetrical distribution for SEL values. The mean SEL value is about 79 dB or about 8 to 9 dB below that for the cruise condition.

The next step was to try to disaggregate the data by distance from the stopline. The distance dependence of both SEL and L_{max} is shown in Figure 7, but the relatively small variation for SEL is less than 2 dB between 75 and 875 ft. Figure 8 shows similar data for the deceleration sites. Again, the variation in mean SEL, at least to the 255-ft site, is only about 2 dB. The mean SEL at 175 ft, however, is 3 dB below that at 255 ft. This sharp decrease in the final stages of deceleration matches other results in the literature. The deceleration data are far below the data values for the cruise site.

ZONES OF INFLUENCES

On the basis of the findings from data collection and the literature review, it was decided to adopt the concept of zone of influence (ZOI) for modeling purposes. A ZOI is defined as an area in which the sound level changes because of acceleration or deceleration events. To create a methodology for

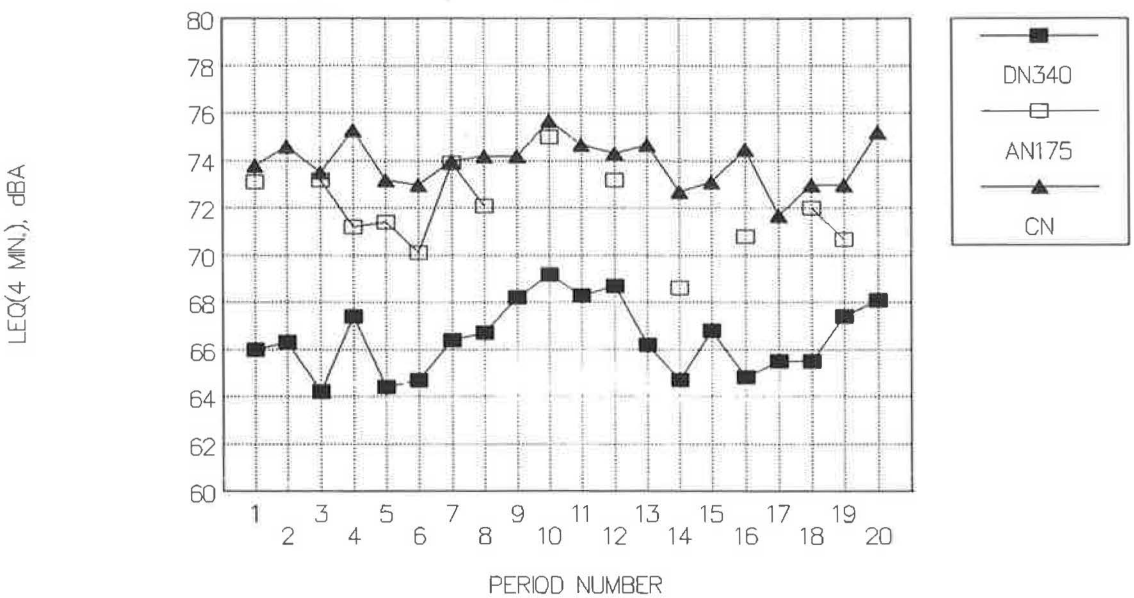

FIGURE 3 **L_{eq}(4-min) samples at I-65NB weigh station at deceleration (DN340), acceleration (AN175), and cruise (CN) sites, June 1, 1988.**

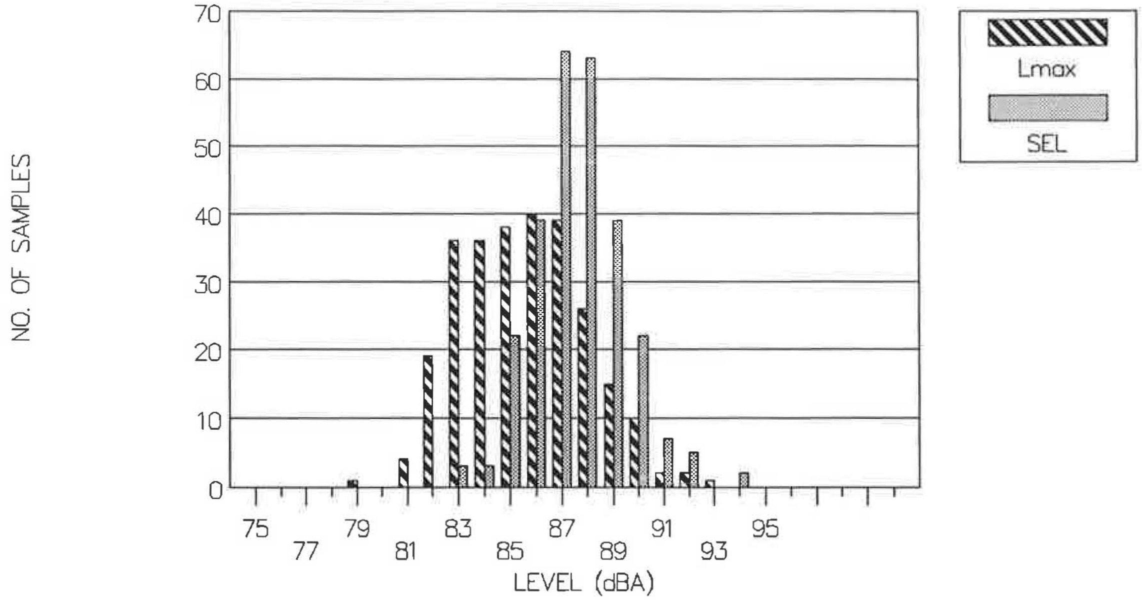

FIGURE 4 Distribution of sampled heavy truck emission level data for cruise site (55 to 65 mph, 50-ft offset).

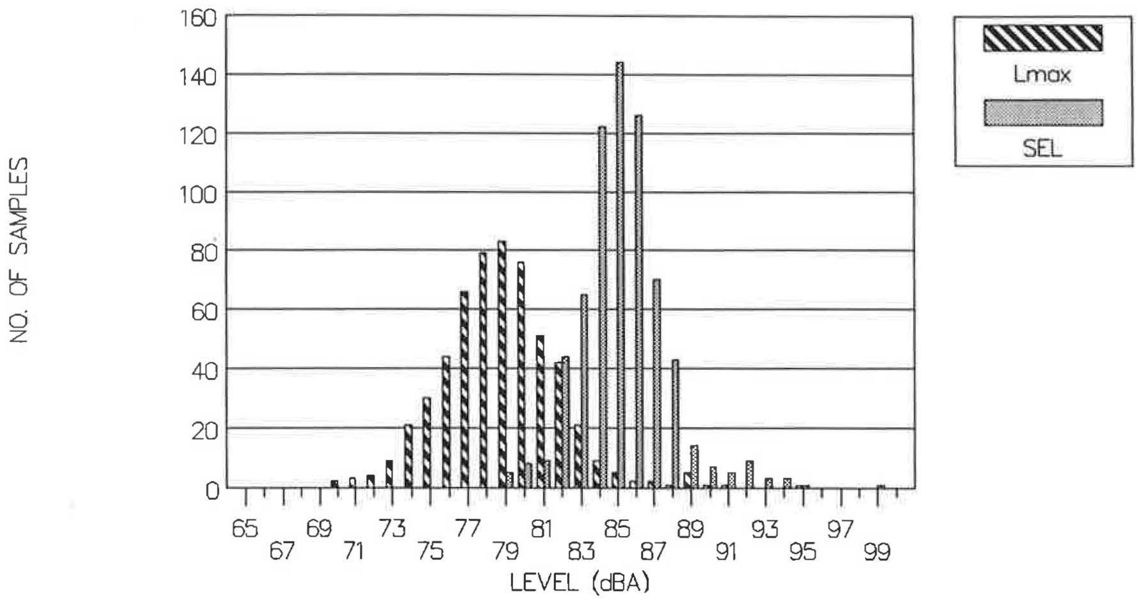

FIGURE 5 Distribution of sampled heavy truck emission level data along acceleration lane at 75 to 875 ft from stopline (50-ft offset).

the STAMINA 2.0 program, it was important to minimize the number of ZOIs that an analyst would be required to code as roadways for STAMINA 2.0. The data suggested that the number of ZOIs could be limited to two each for acceleration and deceleration with little loss in accuracy. Figure 9 shows these ZOIs.

After substantial analysis and validation, with the goal of minimizing predicted error, two tables, one for acceleration and one for deceleration, were developed that gave the recommended lengths for ZOIs. If the effects on SEL values observed in the field data were simulated, then the same effect on the predicted L_{eq} would be predicted, on the basis of the definitions for SEL and L_{eq}.

Tables 1 and 2 present a series of acceleration or deceleration ranges in terms of initial and final speeds and the recommended lengths for the first and second ZOI for each operating mode. In some cases, only one ZOI was needed to approximate a particular speed range. By using these tables as part of a step-by-step design guide presented in the final report for the project, an analyst could model signalized inter-

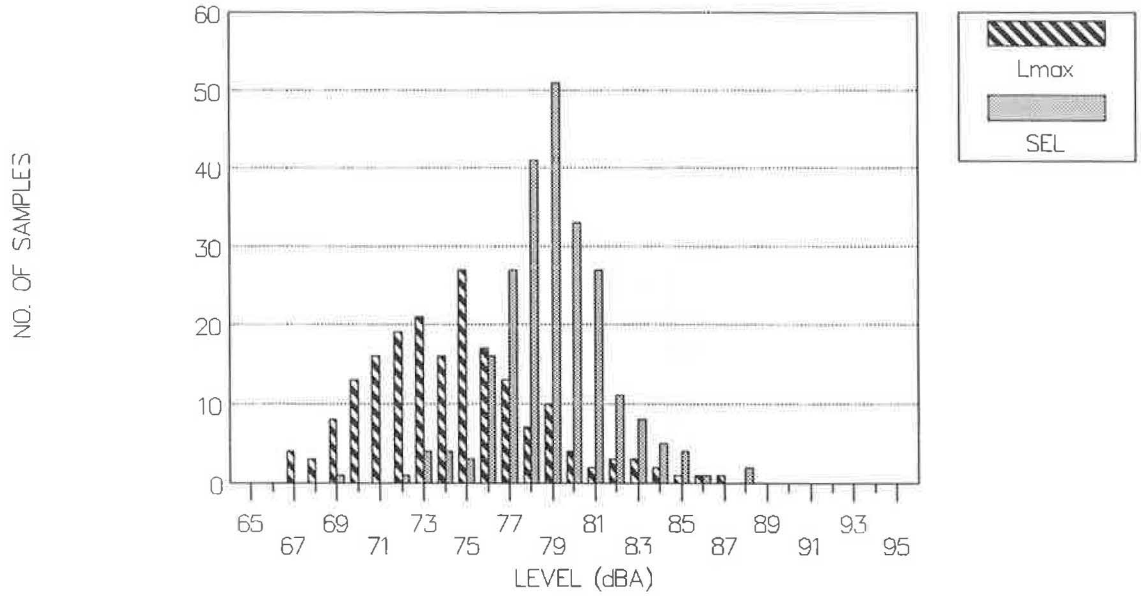

FIGURE 6 Distribution of sampled heavy truck emission level data along deceleration lane at 175 to 475 ft before stopline (50-ft offset).

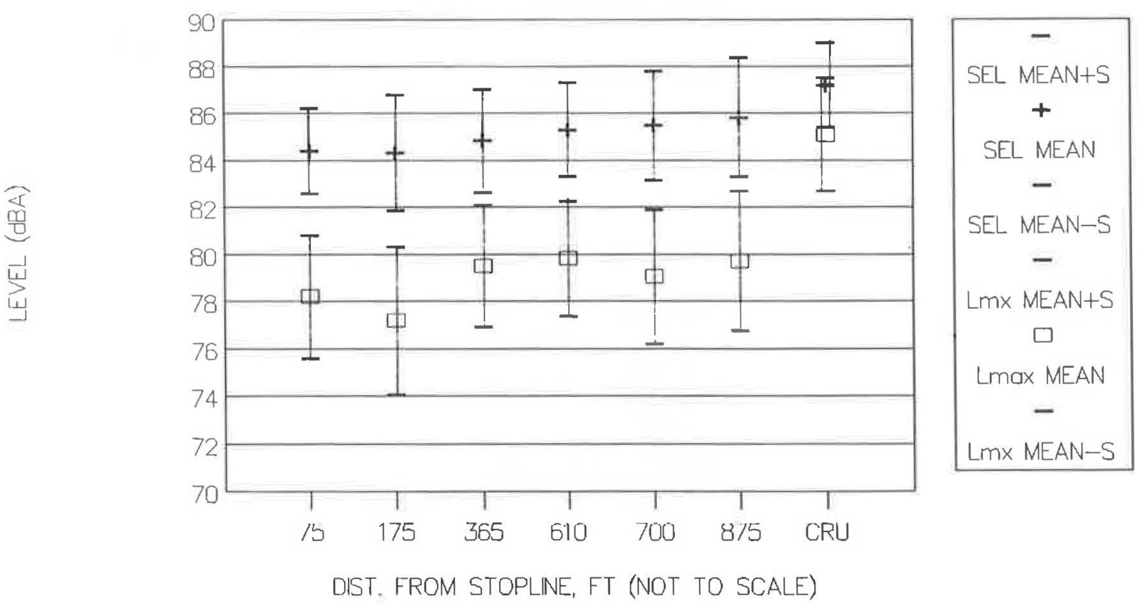

FIGURE 7 Mean and standard error of heavy truck emission level data for acceleration as function of distance from the stopline.

sections, unsignalized intersections, and highway ramps as a series of STAMINA 2.0 roadways.

The speeds given in these tables are not average operating speeds, but equivalent speeds that would produce the desired effect on the SEL values and hence the L_{eq} values at incremental distances on either side of a stopping point.

SENSITIVITY ANALYSIS

As part of the methodology development, a sensitivity analysis of parameters such as speed, distance, and percent of interrupted flow was performed. Figure 10 shows an example of L_{eq} profiles for a flow of 1,000 automobiles, 50 medium trucks, and 100 heavy trucks with a cruise speed before and after the stopping zone of 60 mph (flow is from left to right with the stopping point at 0 ft). Total L_{eq} values as well as the L_{eq} values for each vehicle type are shown. A decrease in L_{eq} of up to 6 dB relative to cruise occurs at a point somewhat behind the stopping line (which is located in the second of the deceleration zones).

Shown in Figure 11 is the same type of acoustical profile (L_{eq} as a function of receiver distance upstream or downstream) for cruise speeds of 30, 40, 50, and 60 mph. For all

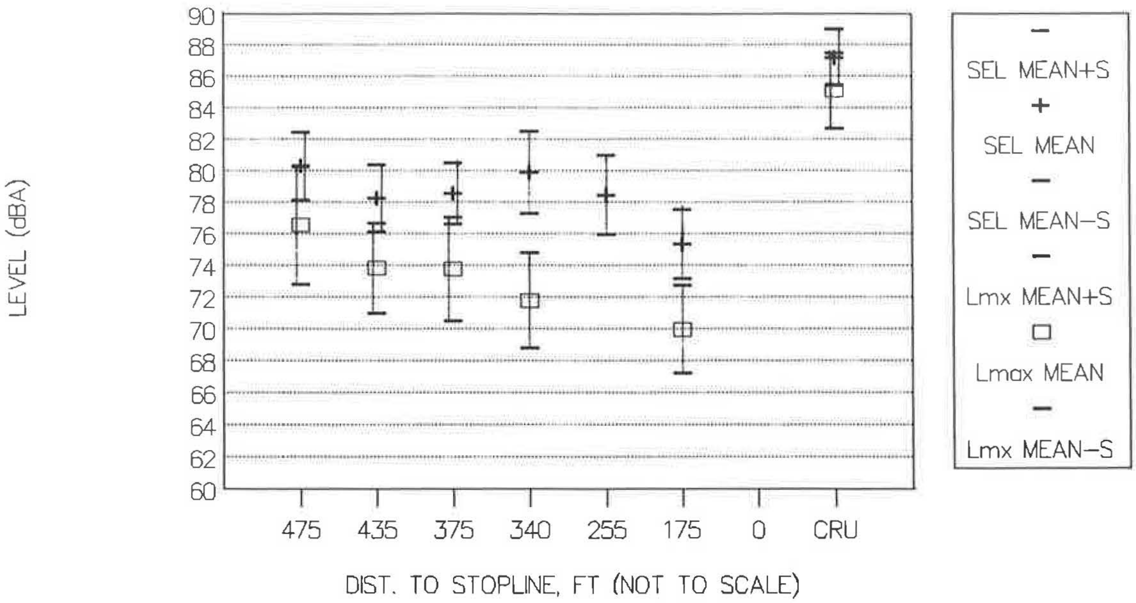

FIGURE 8 Mean and standard error of heavy truck emission level data for deceleration as function of distance from stopline.

cases, the deceleration levels are less than the cruise levels, but the acceleration levels are either greater or less than the cruise levels, depending on the final cruise speed.

Figure 12 shows the effects of introducing a percentage of nonslowing traffic through the stopline, as might happen at a signalized intersection. Once the proportion of cruise-through traffic exceeds 50 percent, the difference in levels relative to 100 percent cruise-through is less than 2 dB.

Finally, the sensitivity analysis examined the effect of increasing the receiver distance away from the modeled roadways. In Figure 13, the effect, which exceeds 6 dB for an offset distance of 50 ft, decreases to less than 2 dB by the time the receiver is offset 1,600 ft from the center of the travel lane. Also, the effect tends to broaden (while decreasing in magnitude) because of contributions from adjoining cruise speed roadway segments.

VALIDATION

As part of the method development, a limited validation was called for in the project scope. Two signalized intersection sites were chosen, one in a suburban area with two intersecting two-lane roads, and one in a slightly more urbanized area where a four-lane arterial with turning lanes intersected a two-lane local street.

Site 1

At the first site, monitors were set at two points on the deceleration side of the southbound lane and at five points on the acceleration side, as well as at a cruise speed position. Measurements were made for different periods over a 2-day span, with not all points being monitored at the same time. However, there were common points between sets of measurements, allowing comparison of all of these points.

Figure 14 shows a comparison of the measured and predicted levels for one of the measured hourly periods at Site 1. The lower curve (solid boxes) showed the measured hourly L_{eq} at each site. Notable were the lower levels in the deceleration range, the effects of the cross-street traffic near the intersection, and the increased level during acceleration.

The first attempt to predict the levels at this site used a 55-45 percent split between the stopping and the cruise-through traffic based on the observed signal cycle splits. The initial predicted results were 2.5 to 4 dB higher than measured. A return visit to the site and detailed observation of the actual number of vehicles stopping showed that fewer than 25 percent were able to cruise through at the posted speed of 50 mph on the north side of the intersection and 55 mph on the south side of the site.

When all traffic was modeled as stopping, the agreement between the measured and predicted levels was very good in the acceleration sites but still about 1.5 dB high in the deceleration sites. The original technique for modeling the ZOIs was then examined, using a detailed five-zone representation to model the changing deceleration levels more precisely. The results showed that by increasing the length of the deceleration zone nearest the signal by an additional 100 ft, the predicted levels at all points were within 1 dB of the measured levels and within 0.5 dB for the acceleration sites.

Site 2

Data were collected at the second validation site at one deceleration point, three acceleration points, and a cruise site. Figure 15 shows the measured (open boxes) and predicted levels at those points. An increased level occurred at the site that was 360 ft from the stopline. A closer examination in the field revealed that a solid wooden fence was located on the opposite side of the road from this microphone and that a reflection of the traffic noise was observable.

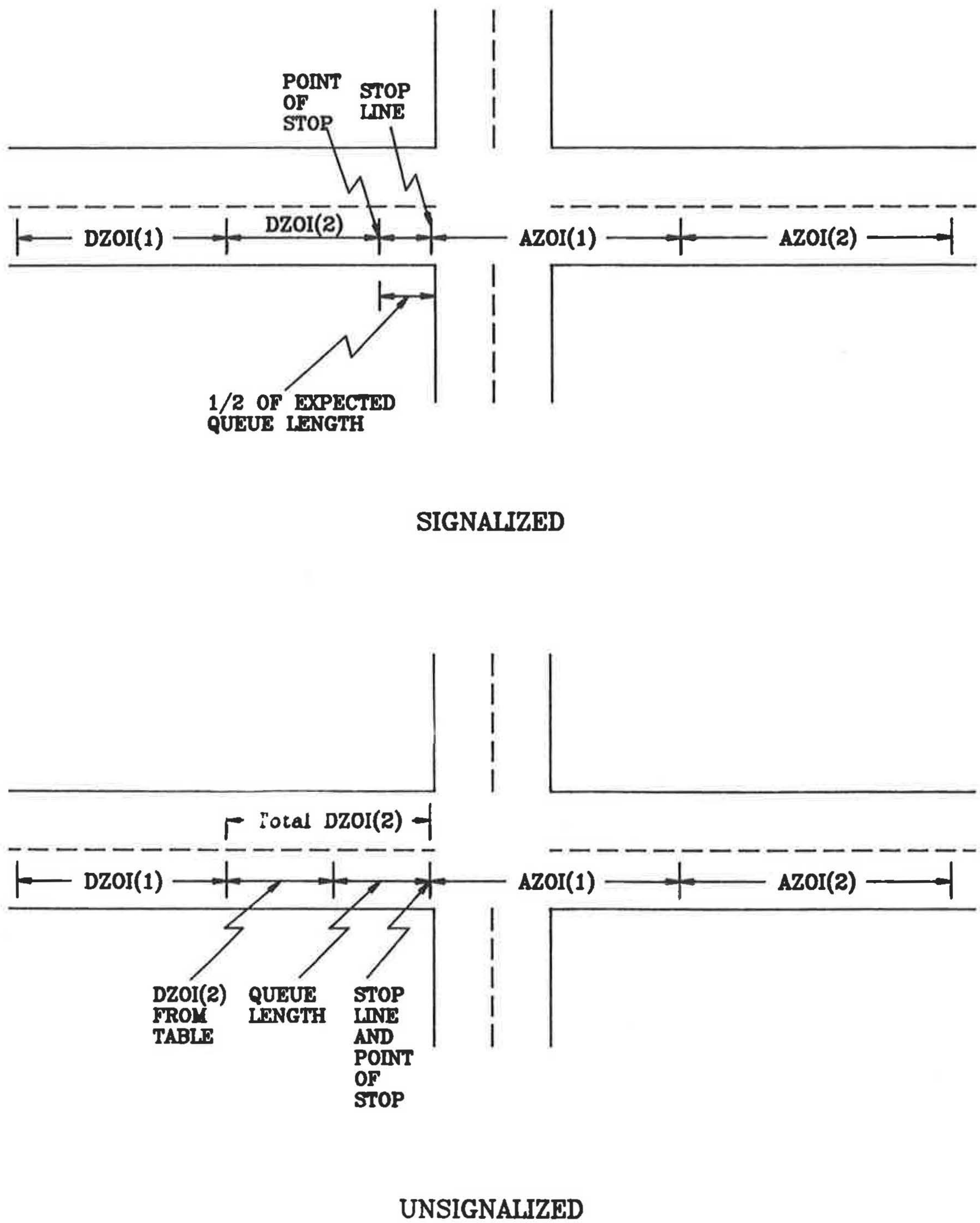

FIGURE 9 Definitions of zones of influence for signalized and unsignalized intersections.

TABLE 1 COMBINED ACCELERATION ZOIs AND CORRESPONDING EQUIVALENT SPEEDS FOR THREE VEHICLE TYPES

Accel. Range (mph)		Length(ft)		Speed, ZOI(1)(mph)			Speed, ZOI(2)(mph)		
$S_{INITIAL}$	S_{FINAL}	ZOI(1)[a]	ZOI(2)[b]	Autos	MT	HT	Autos	MT	HT
0	30	500	300	38	43	43	30	43	43
0	35	600	650	39	43	43	35	43	43
0	40	1000	none	40	43	43	n/a[c]	n/a	n/a
0	45	1000	none	42	43	43	n/a	n/a	n/a
0	50	1000	800	42	43	43	50	47	47
0	55	1000	800	42	43	43	50	40	49
0	60	1000	800	42	43	43	50	52	52
30	40	400	none	40	43	43	n/a	n/a	n/a
30	50	1000	none	42	43	43	n/a	n/a	n/a
30	60	1900	none	51	52	53	n/a	n/a	n/a
40	50	600	none	45	43	43	n/a	n/a	n/a
40	60	1500	none	50	52	53	n/a	n/a	n/a
50	60	any	none	60	60	60	n/a	n/a	n/a

[a] Starting from point of stop (or the end of queue for unsignalized intersections) and proceeding in direction of flow (see Figure 9).

[b] Starting from end of ZOI(1) (see Figure 9).

[c] n/a = not applicable

TABLE 2 COMBINED DECELERATION ZOIs AND CORRESPONDING EQUIVALENT SPEEDS FOR THREE VEHICLE TYPES

Decel. Range (mph)		Length(ft)		Speed, ZOI(1)(mph)			Speed, ZOI(2)(mph)		
$S_{INITIAL}$	S_{FINAL}	ZOI(1)[a]	ZOI(2)[b]	Autos	MT	HT	Autos	MT	HT
30	0	150	100	29	26	24	18	13	10
40	0	250	100	34	30	28	18	13	10
50	0	200	200	38	34	31	18	13	10
60	0	300	200	41	36	33	18	13	10
40	30	220	none	37	32	30	n/a[c]	n/a	n/a
50	30	375	none	42	37	36	n/a	n/a	n/a
50	40	270	none	46	41	42	n/a	n/a	n/a
60	30	530	none	46	41	42	n/a	n/a	n/a
60	40	430	none	51	46	47	n/a	n/a	n/a

[a] Starting from point of stop (or the end of queue for unsignalized intersections) and proceeding in direction of flow (see Figure 9).

[b] Starting from end of ZOI(1) (see Figure 9).

[c] n/a = not applicable

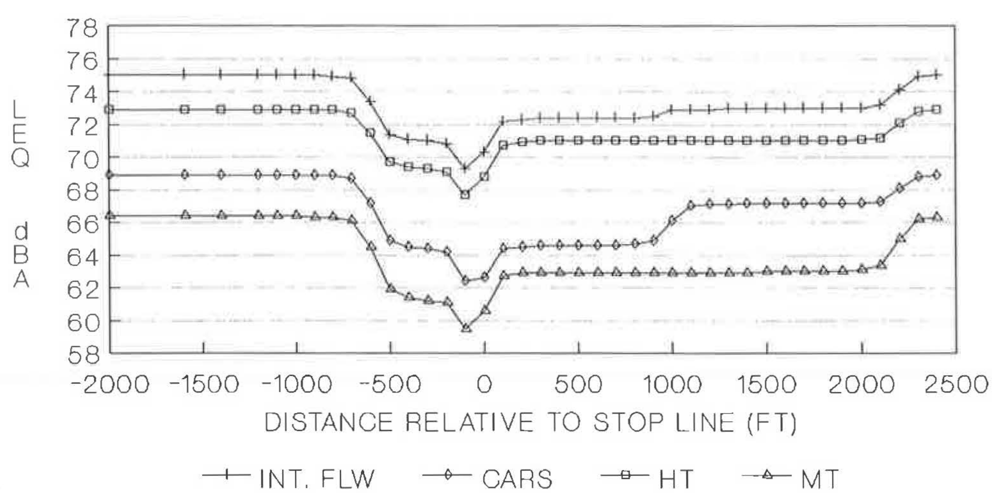

FIGURE 10 Predicted L_{eq}(1h) sound level contributions by vehicle type at a 50-ft offset distance for one-way traffic with 100 percent interrupted flow (hourly flow of 1,000 automobiles, 50 medium trucks, and 100 heavy trucks; cruise speed of 60 mph).

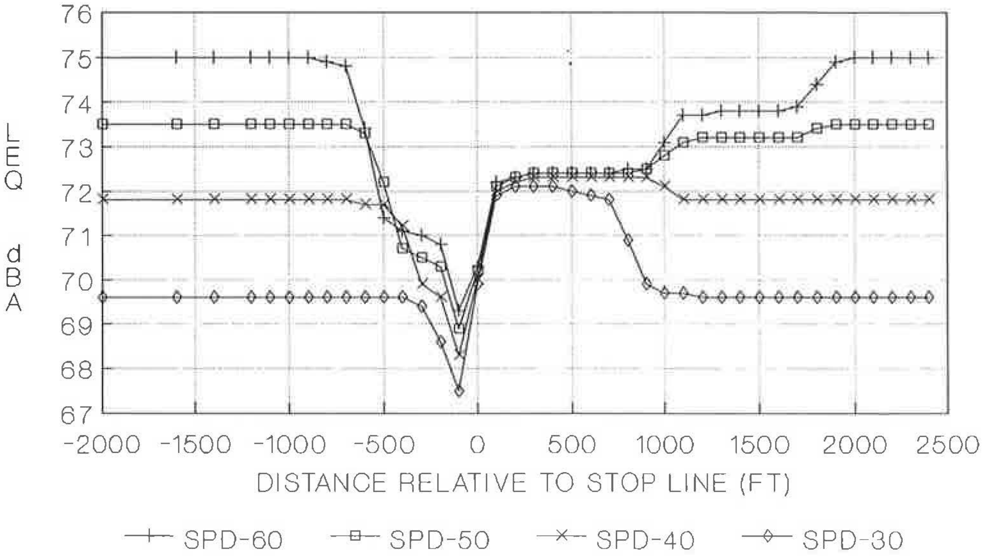

FIGURE 11 Predicted L_{eq}(1h) based on initial speeds of 30 to 60 mph for one-way traffic with 100 percent interrupted flow at a 50-ft offset distance (hourly flow of 1,000 automobiles, 50 medium trucks, and 100 heavy trucks).

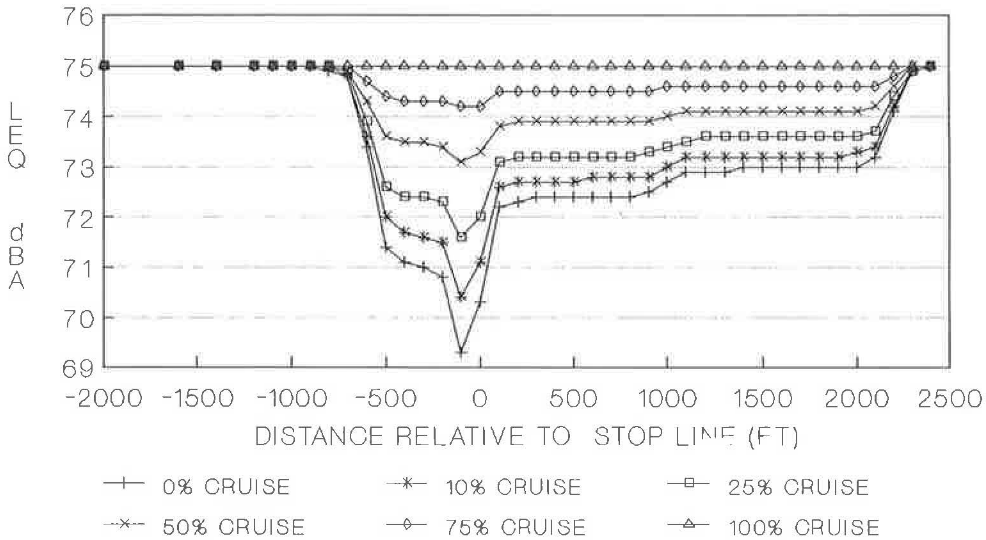

FIGURE 12 Predicted L_{eq}(1h) as a function of percentage of cruise traffic based on a cruise speed of 60 mph and a 50-ft offset distance (hourly flow of 1,000 automobiles, 50 medium trucks, and 100 heavy trucks).

In the first attempt to model this site, a pattern very similar to the measurements was achieved, with the exception of a point near the reflecting wall. However, all of the other predicted levels were about 2 dB higher than measured, including those at the cruise site. The differences were attributed to the vehicle noise emission levels, because the measured cruise site levels were also 2 dB lower than predicted. By calibrating the predictions with the measurements, excellent agreement was achieved (within 0.5 dB at all points except the point opposite the wooden wall).

GENERALIZED EXPRESSION

The data in Tables 1 and 2 are based on the use of the national reference energy mean noise emission levels (*1*). Several state departments of transportation have determined their own noise emission levels. In these cases, an agency must develop its own set of equivalent speeds to produce the needed difference between cruise levels and acceleration or deceleration levels. The generalized equation for computing those speeds is

$$S_{\text{equiv}} = \{\text{antilog}\,[(L_0)_{E,60} - 19.82 - a - \Delta_c]/(b - 10)\} \qquad (2)$$

where

S_{equiv} = equivalent speed (km/hr),
$(L_0)_{E,60}$ = state reference energy mean noise emission level $[(L_0)_E]$ at 60 mph,
a = Y-intercept from state $(L_0)_E$ equation,

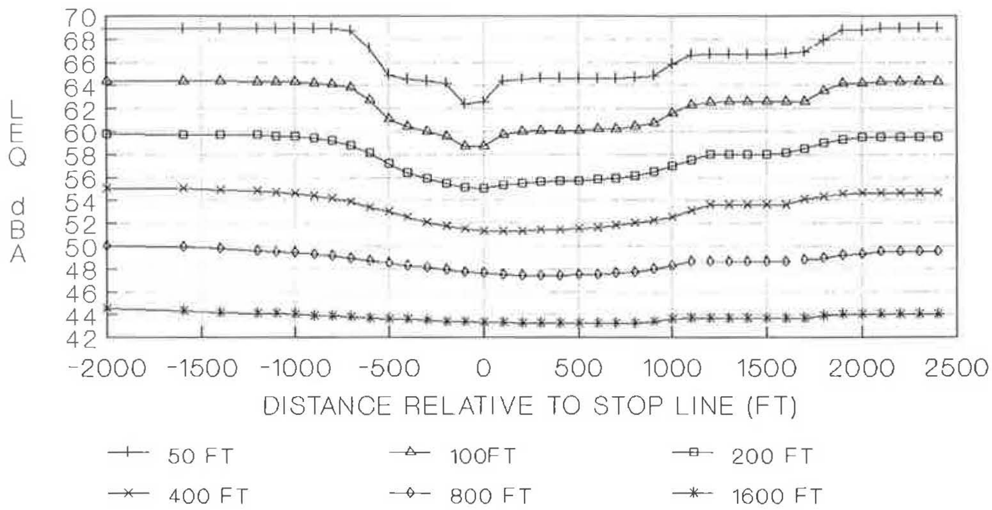

FIGURE 13 Predicted $L_{eq}(1h)$ as function of receiver offset distance based on one-way hourly flow of 1,000 cars (100 percent interrupted flow; cruise speed of 60 mph).

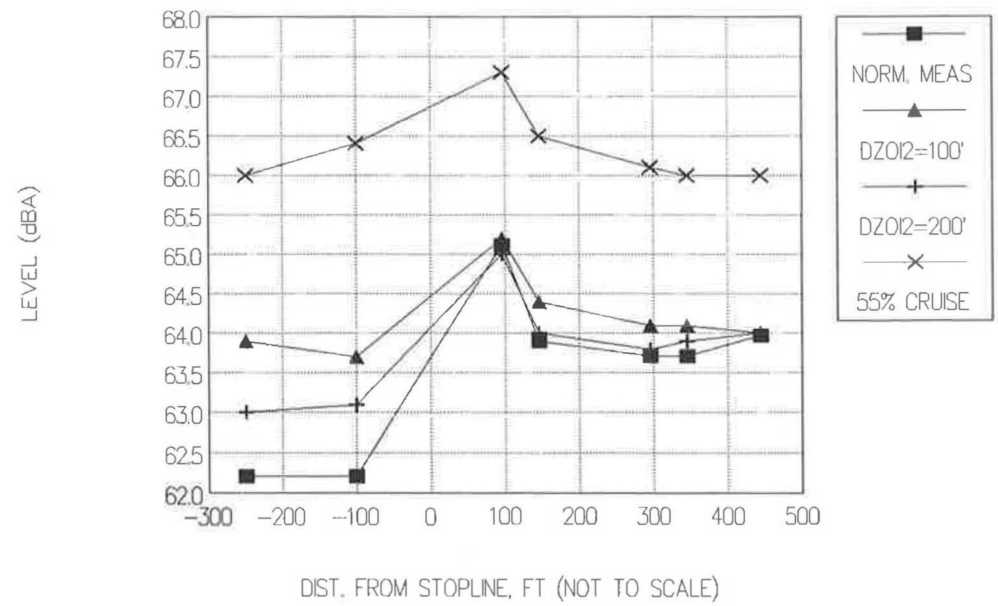

FIGURE 14 Validation results at Site 1 (Hillsboro Road), based on measurements normalized to the October 12, 1988, data, 1:00 to 2:00 p.m.

Δ_c = desired change in SEL value for cruise at 60 mph, and

b = slope from state $(L_0)_E$ equation.

Values for Δ_c are presented in Tables 3 and 4.

SUMMARY

To summarize, a detailed analysis of the levels associated with accelerating and decelerating vehicles was performed for three major situations: the signalized arterial or end of a highway ramp; the unsignalized, but signed, intersection such as a Stop sign on an arterial highway or at the end of a highway ramp, or at a toll booth; and the loop or slip transition ramp on a freeway. Two tables (one for acceleration and one for deceleration) were developed as part of a design guide. The tables presented the lengths to be used to model the site as STAMINA 2.0 roadways, and the equivalent speeds to be used for each vehicle type on these roadways. Levels in a deceleration zone decreased below cruise levels by 2 to 6 dB, depending on the initial cruise speed. In the acceleration zones, levels increased over the deceleration levels, but whether or not these increases exceeded the cruise levels depended on the final cruise speed. For example, if the final speed was 30 mph, the acceleration noise level was about 2 dB higher than the cruise level. However, if the final speed was 60 mph, the

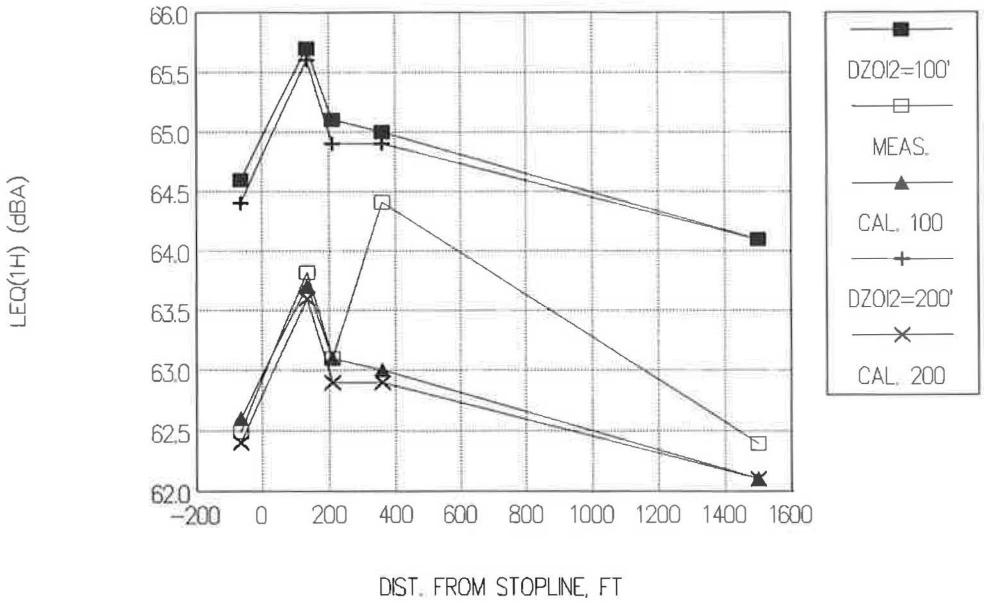

FIGURE 15 Validation results at Site 2 (Blakemore Avenue), based on measurements normalized to the October 14, 1988, data, 2:00 to 3:00 p.m.

TABLE 3 CHANGE IN SEL VALUES IN ACCELERATION ZOIs FOR THREE VEHICLE TYPES

Accel. Range (mph)		Change in SEL for ZOI(1) (dBA)			Change in SEL for ZOI(2) (dBA)		
$S_{INITIAL}$	S_{FINAL}	Autos	MT	HT	Autos	MT	HT
0	30	5.6	3.5	2.1	8.5	3.5	2.1
0	35	5.3	3.5	2.1	6.6	3.5	2.1
0	40	4.9	3.5	2.1	n/a[a]	n/a	n/a
0	45	4.4	3.5	2.1	n/a	n/a	n/a
0	50	4.4	3.5	2.1	2.2	2.5	1.5
0	55	4.4	3.5	2.1	2.2	2.1	1.3
0	60	4.4	3.5	2.1	2.2	1.5	0.9
30	40	4.9	3.5	2.1	n/a	n/a	n/a
30	50	4.4	3.5	2.1	n/a	n/a	n/a
30	60	2.0	1.3	0.8	n/a	n/a	n/a
40	50	3.5	3.5	2.1	n/a	n/a	n/a
40	60	2.2	1.5	0.8	n/a	n/a	n/a
50	60	0.0	0.0	0.0	n/a	n/a	n/a

[a]n/a = not applicable

TABLE 4 CHANGE IN SEL VALUES IN DECELERATION ZOIs FOR THREE VEHICLE TYPES

Decel. Range (mph)		Change in SEL for ZOI(1) (dBA)			Change in SEL for ZOI(2) (dBA)		
$S_{INITIAL}$	S_{FINAL}	Autos	MT	HT	Autos	MT	HT
30	0	8.9	8.7	5.8	14.7	15.9	11.4
40	0	6.9	7.2	4.8	14.7	15.9	11.4
50	0	5.6	5.9	4.2	14.7	15.9	11.4
60	0	4.6	5.3	3.8	14.7	15.9	11.4
40	30	5.9	6.5	4.4	n/a[a]	n/a	n/a
50	30	4.4	5.0	3.2	n/a	n/a	n/a
50	40	3.2	4.0	2.3	n/a	n/a	n/a
60	30	3.2	4.0	2.3	n/a	n/a	n/a
60	40	2.0	2.8	1.5	n/a	n/a	n/a

[a]n/a = not applicable

acceleration time-averaged noise level was about 2 dB lower than the cruise level.

CONCLUSION

There is certainly a need for more validation of the technique and for collection of more car and medium truck noise emission level data. It may also be desirable to build these results into the STAMINA 2.0 code or to modify the way in which STAMINA 2.0 computes the noise emission levels for its various roadway subsections. For now, however, the developed procedure will allow the STAMINA 2.0 model to be used with relative ease in changing speed situations with an improved level of accuracy relative to previously recommended methods.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the National Cooperative Highway Research Program (NCHRP), which funded this work. Special thanks go to the members of Project Panel 25–2 and NCHRP program staff. The work has been published as *NCHRP Report 311* (*2*).

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Publication of this paper sponsored by Committee on Transportation-Related Noise and Vibration.