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March 13, 1980

H-3-24

MEMORANDUM TO: G. F. Kemper
State Highway Engineer
Chairman, Research Committee

SUBJECT: "Effect of Interrupted Flow on Traffic Noise", Research Report 542, KYP-72-24; HPR-PL-1(15), Part III-B

This study is one of several which have dealt with the prediction of traffic noise. The first study (Report No. 379) involved on evaluation of the prediction procedure outlined in NCHRP Report 117. This study resulted in the development of a correction nomograph which was incorporated into Kentucky's noise prediction procedure. A recent study (Report No. 534) involved an evaluation of a new, traffic noise prediction procedure which was adopted for use in Kentucky beginning January 1, 1980. In another study (Report No. 417), we investigated the effect of pavement texture on traffic noise and recommended adjustment factors to be used for various pavement types. The objectives of this study were to investigate the effect of interrupted flow on traffic noise and to recommend an adjustment factor, if necessary. Interrupted flow occurs when traffic is stopped by a traffic control device such as a stop sign or traffic signal.

The data showed that no adjustment factor is necessary to account for interrupted flow of traffic. It was recommended that the current procedure used for interrupted-flow locations be continued. In this procedure, no adjustment factor is used, and the traffic speed used in the prediction is the free-flowing vehicle speed (speed limit).

Respectfully submitted,

Jas. H. Havens
Director of Research

KRA/gh
cc: Research Committee

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16. Abstract

The objectives of this study were to investigate the effect interrupted traffic flow has on traffic noise and to determine an applicable adjustment factor. No attempt was made to develop a specific equation to predict noise levels at interrupted flow locations.

The basic method of analysis consisted of comparing the field data taken at intersections to determine if the measured noise levels changed as a function of distance from the intersection. Results showed that interrupted flow conditions did not cause an increase in the L_{10} or L_{eq} noise levels. Data taken before and after the installation of traffic signals showed that the addition of traffic signals did not significantly affect the average noise level. A comparison of measured and predicted noise levels showed general agreement.

It was concluded that no adjustment factor is necessary to account for interrupted flow. It was recommended that the current procedure used for interrupted flow locations be continued. In this procedure, no adjustment factor is used, and the traffic speed used in the prediction is the free-flowing vehicle speed (speed limit).

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Research Report
542

EFFECT OF INTERRUPTED FLOW ON TRAFFIC NOISE

KYP-72-24; HPR-PL-1(15), Part III-B

by

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March 1980

INTRODUCTION

Specific traffic noise levels for highway design were first given in Policy and Procedure Memorandum 90-2 of the Federal Highway Administration *(1)*. To determine if noise levels of future highways would conform to these standards, it was necessary to predict noise levels. This presented many problems and has been the subject of several research studies resulting in methods to predict traffic noise level. The Kentucky Department of Transportation has been using the procedure outlined in NCHRP Report 117 *(2)*. Past research investigated the accuracy of the prediction model. A correction nomograph was developed and incorporated into Kentucky's noise prediction procedure *(3)*. Another study investigated the effect of pavement texture on traffic noise and recommended adjustment factors to be used for various pavement types *(4)*. Another area which has been the source of confusion concerns the effect of interrupted flow on traffic noise. Interrupted flow occurs when traffic is interrupted by a traffic control device such as a stop sign or traffic signal. The original design guide contained an adjustment for interrupted flow *(2)*; however, the adjustment was not considered accurate and was not usually used. The revised design guide outlined in NCHRP Report 174 did not contain any adjustment for interrupted flow *(5)*. A traffic noise prediction computer program based on this procedure has been adopted by the Kentucky Department of Transportation to replace the NCHRP 117 procedure. The objectives of this study were to investigate the effect of interrupted flow on noise and to recommend an adjustment factor. No attempt was made to develop a specific equation to predict noise levels at interrupted flow locations.

BACKGROUND

In the past, two prediction procedures have been used primarily in the United States. These procedures were referred to as the NCHRP Report 117 method *(2)* and Transportation Systems Center (TSC) Method *(6)*. The two methods were accepted by the Federal Highway Administration for use on federal-aid highway projects *(7)*. Recently, a revised design guide (RDG) has been developed which uses additional data to develop a traffic noise prediction procedure *(5)*. The NCHRP Report 117 method did contain an adjustment for interrupted flow; no such adjustment was present in the other methods. The NCHRP Report 117 adjustment of 2 dBA for cars and 4 dBA for trucks was added to the L_{10} noise level for the length of roadway affected by the interrupted flow. The L_{10} noise level is the level exceeded 10 percent of the time and is the level used in noise standards. A traffic control signal was assumed to have an influence on the operating noise of a vehicle over a distance of 1,000 feet (305 m) centered at the center of the signal area. However, this interrupted flow adjustment was not considered to be valid and was not generally used. Therefore, no adjustment is used for interrupted flow in the prediction methods accepted by the Federal Highway Administration.

Other prediction procedures have considered an adjustment for interrupted flow. The Ontario Highway Noise Prediction Method recommends that L_{10} levels, emitted by interrupted traffic flow containing at least 60 heavy trucks per hour, be increased by about 2 or 3 dBA *(8)*. The U. S. Department of Housing and Urban Development (HUD) Noise Assessment Guidelines also considers stop-and-go traffic *(9)*. The HUD guidelines state that, if there is a traffic signal or stop sign within 800 feet (244 m) of a site, the total number of trucks should be multiplied by a factor of 5. This adjustment is approximately equivalent to adding 3 to 5 dBA to the freely flowing traffic noise prediction *(10)*.

Measurements taken in New York City indicated that no adjustment should be made for freely flowing traffic to describe stop-and-go noise *(10)*. Although accelerating vehicles produce more noise than vehicles traveling at a uniform speed, only a fraction of the vehicles would be accelerating at a given moment. At an interrupted flow location such as a traffic signal, vehicles at any given time would either be idling, decelerating, continuing at a uniform speed, or accelerating.

A British study yielded an equation for predicting L_{10} levels on urban streets *(11)*. This model was specifically for use on typical urban streets where intersections, traffic signals, and other features influence the traffic and results in interrupted flow characteristics. The equation was derived as an alternate to the current equations available for predicting L_{10} noise for roads where traffic is freely flowing.

PROCEDURE

The procedure consisted of taking simultaneous recordings at various distances from the intersection under study. Normally, three recordings were taken. Each recording was of 10 minutes duration. Volumes, classified by type of vehicle, were determined for the mainline highway during each period. All the data were taken at a 5-foot (1.5-m) measurement height. An attempt was made to choose sites with zero grade, with the observer level with the roadway, and with no shielding in order to reduce the number of variables which might interfere. Sites were chosen so that there would be a large range in total traffic volume, percent trucks, and travel speeds. The method of traffic control at the intersections was either a signal or stop sign. The intersection approaches had to be a sufficient distance from another interrupted flow condition so that the vehicles were in a free-flowing condition as they approached the intersection. The intersections chosen were not in downtown areas where the noise levels would be affected by reflections off adjacent buildings.

The recordings were made using a precision sound-level meter and a strip-chart recorder. From the 10-minute recordings, noise levels at intervals slightly greater than one second were determined in the laboratory utilizing a digital data reduction system. The output was punched onto computer cards; and by means of a computer program, the L_{10} and L_{eq} (noise equivalent level) noise levels were determined.

The intersections studied are cited in Table 1. Data were taken at 15 intersections. The traffic control at 12 of the intersections was a traffic signal, and the remaining three were four-way-stop locations. The average volume (vehicles per hour) varied from 485 to 2,160 (average of 1,309). The average percentage trucks varied from 2.5 to 21.4. The speed limit of the locations varied from 35 mph (15.6 m/s) to 55 mph (24.6 m/s). A total of 169 data sets were taken -- resulting in 478 10-minute recordings.

The distance from the roadway was held constant for all data taken at a particular intersection. A sketch of a typical data collection setup is shown in Figure 1. The distance from the intersection was measured from the centerline of the cross street. At ten of the intersections (1 through 10 in Table 1), data were taken at 50 feet (15.2 m), 100 feet (30.5 m), and at 100-foot (30.5 m) intervals up to a maximum of 1,000 feet (305 m) from the intersections. The 1,000-foot (305-m) distance was chosen as the maximum distance the signal location might affect traffic noise. However, data were collected later at three additional intersections (11 through 13 in Table 1) where the distance from the intersection was substantially increased. The maximum distance was 4,000 feet (1,219 m) at two of the intersections and 2,500 feet (762 m) at the other.

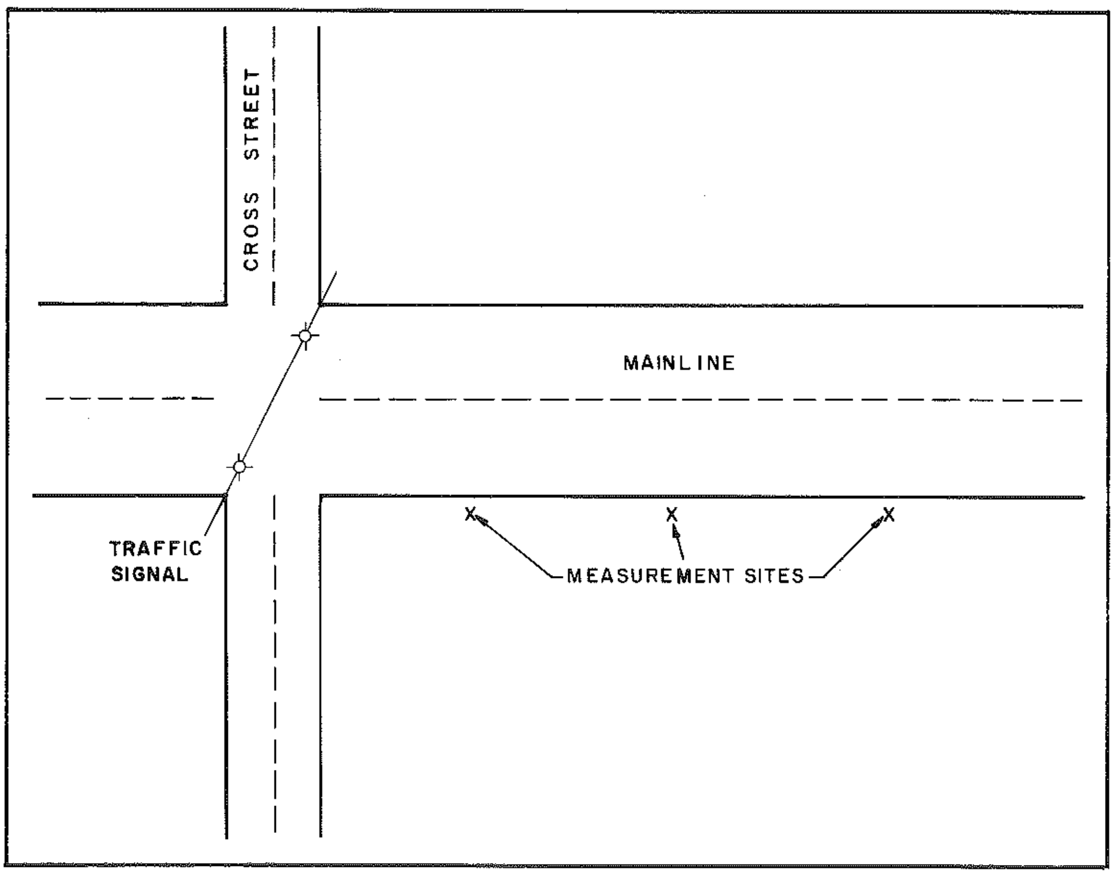

Figure 1. Typical Data Collection Setup.

Average L_{10} and L_{eq} noise levels were calculated at the various distances from the intersection. The noise levels were then compared to determine if any changes occurred at the measurement sites as a function of distance from the intersection.

One additional type of data collection was done. Data were taken at two intersections (14 and 15 in Table 1) before and after installation of traffic signals. A comparison was then made to determine if the addition of the traffic signal changed the traffic noise levels around the intersection.

The measured L_{10} noise level at each intersection was also compared to the predicted L_{10} noise level. The predicted noise level was determined by three methods: (1) the procedure outlined in NCHRP Report 117 and employing the Kentucky correction nomograph, (2) the procedure outlined in the revised design guide (NCHRP Report 174) (L_{10} nomograph), and (3) the FHWA level 1 Highway Traffic Noise Prediction Model *(12)*.

RESULTS

The basic analysis consisted of comparing the field data taken at the intersections to determine if the measured noise levels changed as a function of distance from the intersection. At ten of the intersections, data were taken at 100-foot (30.5-m) intervals along the mainline up to a maximum distance of 1,000 feet (305 m) from the interrupted flow location. The volumes remained fairly constant for all the data sets taken at any one site, and data were taken until a consistent average noise level was obtained at each distance. The results are shown in Tables 2 and 3.

While the noise levels at any one intersection varied several dBA, no trends were found to indicate that the interrupted flow influenced the noise levels. This was true for both the L_{10} and L_{eq} noise levels. The average noise level at each measurement distance for all 10 intersections was also determined and plotted (Figure 2). The range of noise levels at the various measurement distances was only 1.4 dBA for the L_{10} noise levels and 1.2 dBA for the L_{eq} noise levels.

Any influence that an interrupted flow condition had on noise levels should have been evident at the sites where data were taken up to 1,000 feet (305 m) from the cross street. However, as a further check, data were taken at three additional intersections. At these locations, data were taken at distances much farther from the cross street. The average noise level of the recordings taken 1,000 feet (305 m) or less from the cross street were compared to the average noise level at over 1,000 feet (305 m) (Table 4). The results of this comparison showed again that the interrupted flow did not cause an increase in the L_{10} or L_{eq} noise levels. In fact, the average noise levels at distances over 1,000 feet (305 m) from the intersection were slightly higher. The increase in noise levels caused by the higher speeds at distances farther from the intersection more than offset the added acceleration and deceleration noise near the intersection.

The final data collection involved taking traffic noise data before and after installation of a traffic signal. The average L_{10} and L_{eq} noise levels at the two test sites are given in Table 5. The results showed that the addition of traffic signals did not significantly affect the average noise level.

TABLE 1. DESCRIPTION OF DATA COLLECTION LOCATIONS

INTERSECTION LOCATION	INTERSECTION NUMBER	TYPE OF TRAFFIC CONTROL	AVERAGE VOLUME (VPH)[a]				AVERAGE PERCENT TRUCKS[d]	SPEED LIMIT		DISTANCE FROM MAINLINE[e]		NUMBER OF DATA SETS[f]	NUMBER OF 10-MINUTE RECORDINGS
			AUTO	MT[b]	HT[c]	TOTAL		mph	m/s	feet	m		
Nicholasville-Jesselin	1	Signal	1,722	36	12	1,770	2.7	40	17.9	45	13.7	10	26
Nicholasville-Arcadia Park	2	Signal	2,106	42	12	2,160	2.5	40	17.9	40	12.2	10	26
Nicholasville-Rosemont	3	Signal	1,927	48	11	1,986	3.0	40	17.9	40	12.2	9	25
Landsdowne-Malabu	4	Stop Sign	444	12	0	456	2.6	35	15.6	47	14.3	8	23
New Circle-Woodhill	5	Signal	1,776	90	42	1,903	6.9	45	20.1	78	23.8	14	42
Nicholasville-Zandale	6	Signal	2,088	54	12	2,154	3.1	45	20.1	75	22.9	9	26
Harrodsburg-Pasadena	7	Signal	748	36	14	998	5.0	55	24.6	78	23.8	12	36
Richmond-Chinoe	8	Signal	1,074	42	6	1,122	4.3	35	15.6	65	19.8	12	24
New Circle-Bryan Station	9	Signal	1,620	72	48	1,740	6.9	45	20.1	50	15.2	9	35
Lansdowne-Reynolds	10	Stop Sign	468	12	5	485	3.5	35	15.6	50	15.2	9	27
Harrodsburg-New Circle	11	Signal	666	36	18	720	7.5	55	24.6		0	13	37
Nicholasville-Wilson Downing	12	Signal	1,062	42	78	1,182	10.2	45	20.1	52	15.8	16	43
Danville Bypass - KY 34	13	Stop Sign	444	18	24	486	8.6	55	24.6	21	6.4	14	41
Newtown - Nandino	14	Signal	792	72	144	1,008	21.4	55	24.6	41	12.5	12	35
Tates Creek-Albany	15	Signal	1,398	54	12	1,464	4.5	45	20.1	58	17.7	11	32

[a]Volume on mainline, the street listed first.

[b]Medium trucks (MT) generally refer to gasoline-powered, two-axle, six-wheeled vehicles.

[c]Heavy trucks (HT) refer generally to diesel-powered, three-or-more-axle truck combinations.

[d]The percent of medium plus heavy trucks in the traffic stream.

[e]Distance from the centerline of the mainline highway.

[f]A data set was defined as one set of simultaneous recordings.

TABLE 2. AVERAGE L_{10} NOISE LEVELS AT DISTANCES UP TO 1,000 FEET (305 m) FROM AN INTERRUPTED FLOW SITE

INTERSECTION NUMBER	AVERAGE L_{10} NOISE LEVEL (dBA) DISTANCE (FEET) (m) FROM INTERSECTION[a]										
	50 (15.2)	100 (30.5)	200 (61.0)	300 (91.4)	400 (122)	500 (152)	600 (183)	700 (213)	800 (244)	900 (274)	1,000 (305)
1	73.0	74.9	75.6	73.4	74.3	76.8	74.4	76.9	76.4	76.9	75.9
2	77.6	77.4	77.2	76.9	77.1	77.1	75.2	77.1	76.5	77.2	76.4
3	74.0	77.4	76.0	74.3	75.0	76.0	76.2	77.2	75.3	80.3	80.3
4	65.0	63.6	65.6	70.2	70.3	65.8	68.9	70.9	71.8	69.0	71.6
5	74.2	72.7	74.3	73.6	73.7	73.7	73.8	73.6	74.2	73.7	71.0
6	70.1	71.1	67.6	69.3	66.8	71.0	72.3	70.5	72.3	70.8	70.3
7	66.6	67.8	67.3	68.3	67.4	65.3	65.4	66.9	64.2	66.9	64.2
8	72.3	70.9	70.0	69.8	69.4	70.7	71.9	72.6	72.1	71.8	70.4
9	77.5	78.2	78.7	77.6	74.8	75.0	76.1	76.8	75.4	75.7	76.8
10	66.6	65.8	66.2	66.2	66.6	63.8	66.1	66.8	64.1	62.6	65.6
Average	71.7	72.0	71.9	72.0	71.5	71.5	72.0	72.9	72.2	72.5	72.3

[a]Distance measured along the mainline from the centerline of the cross street.

TABLE 3. AVERAGE L_{eq} NOISE LEVELS AT DISTANCES UP TO 1,000 FEET (305 m) FROM AN INTERRUPTED FLOW SITE

INTERSECTION NUMBER	AVERAGE L_{eq} NOISE LEVEL (dBA) DISTANCE (FEET) (m) FROM INTERSECTION[a]										
	50 (15.2)	100 (30.5)	200 (61.0)	300 (91.4)	400 (122)	500 (152)	600 (183)	700 (213)	800 (244)	900 (274)	1,000 (305)
1	70.2	72.0	72.7	71.1	71.1	73.1	70.8	72.5	72.3	74.0	72.9
2	75.1	74.3	73.6	73.4	73.6	73.5	72.2	72.9	73.8	74.2	72.9
3	70.5	74.4	76.6	72.3	71.6	72.7	72.9	73.0	72.4	78.5	76.9
4	61.5	60.3	62.6	66.8	66.0	63.5	64.4	66.4	67.3	65.0	67.5
5	71.2	69.3	70.9	69.9	69.8	69.9	69.9	69.6	70.8	70.2	67.7
6	67.0	68.8	64.8	66.5	63.5	67.1	70.3	67.8	69.1	68.3	66.8
7	63.3	65.2	63.5	65.7	64.0	62.3	61.6	65.1	61.1	63.8	60.8
8	69.0	68.7	67.3	66.2	67.8	67.8	67.5	68.5	68.3	67.8	66.6
9	75.1	75.7	74.7	73.9	71.3	71.7	72.8	73.5	72.3	72.8	73.4
10	63.7	62.4	62.2	64.7	63.2	61.9	61.7	62.2	61.0	59.0	61.1
Average	68.7	69.1	68.9	69.0	68.2	68.4	68.4	69.2	68.8	69.4	68.7

[a]Distance measured along the mainline from the centerline of the cross street.

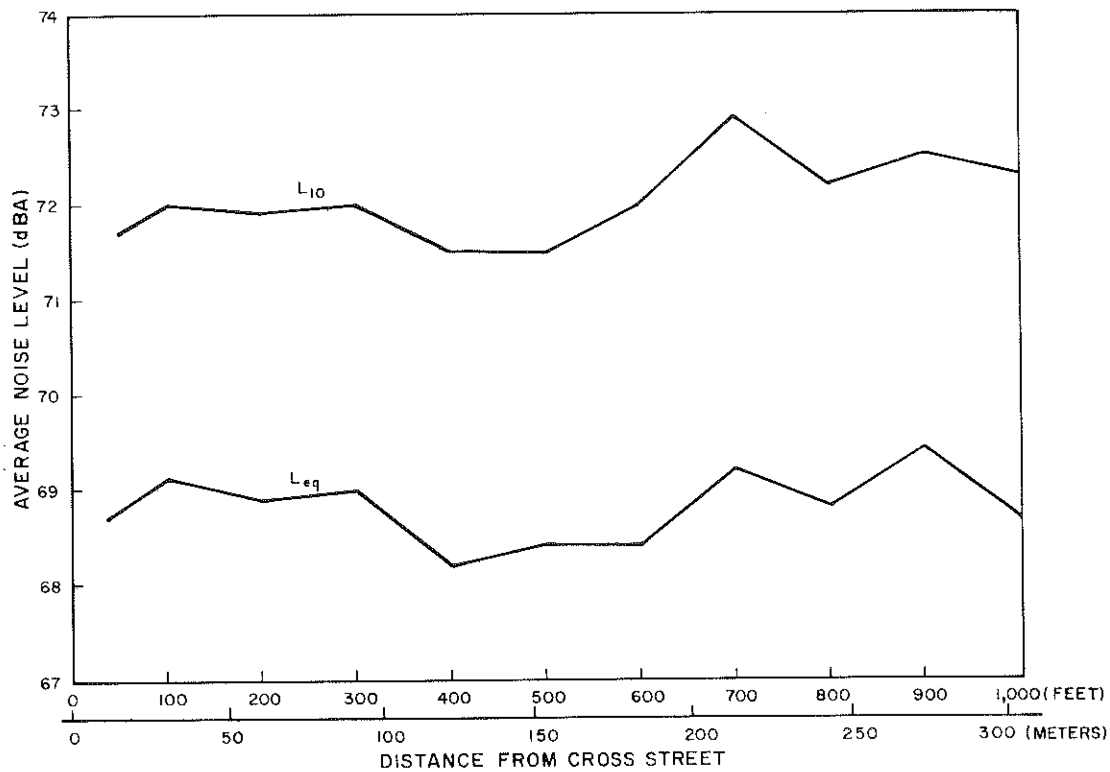

Figure 2. Variation in L_{10} and L_{eq} Noise Levels for Distances up to 1,000 feet (305 m) from the Cross Street.

TABLE 4. AVERAGE NOISE LEVEL AT VARIOUS DISTANCES FROM INTERSECTIONS

INTERSECTION NUMBER	AVERAGE NOISE LEVEL			
	L_{10} DISTANCE FROM INTERSECTION		L_{eq} DISTANCE FROM INTERSECTION	
	1,000 FEET (305 m) OR LESS	OVER 1,00 FEET (305 m)	1,000 FEET (305 m) OR LESS	OVER 1,00 FEET (305 m)
11	74.7	74.3	70.2	70.4
12	77.8	80.6	74.3	77.0
13	73.2	75.7	70.5	71.9
Average	75.2	76.9	71.7	73.1

TABLE 5. CHANGE IN NOISE LEVEL AFTER INSTALLATION OF A TRAFFIC SIGNAL

INTERSECTION NUMBER	AVERAGE L_{10} NOISE LEVEL		AVERAGE L_{eq} NOISE LEVEL	
	BEFORE	AFTER	BEFORE	AFTER
14[a]	81.5	80.9	76.5	77.8
15[b]	76.5	77.3	72.8	73.1

[a]Data were taken from 100 feet (30.5 m) to 2,500 feet (762 m) from the signal.

[b]Data were taken from 50 feet (15.2 m) to 2,000 feet (610 m) from the signal.

Another analysis compared the measured and predicted noise levels (Table 6). The data given in Table 1 were used to predict a noise level at each site. The noise contributed by the cross street was not a factor in the predicted values. Three methods of prediction were used. First, the method outlined in NCHRP Report 117 *(2)* and modified by the correction nomograph developed for Kentucky *(3)* was used. This has been the procedure used in Kentucky for the past several years. As currently used in Kentucky, the speed limit was used as the traffic speed in the predictions. Second, the revised design guide method as outlined in NCHRP Report 174 *(5)* was used. The short method was used. This involved use of an L_{10} nomograph. The short method was designed to overpredict expected noise levels because the short method includes many assumptions and simplifications. The amount of overprediction would depend on the complexity of the real highway situations. However, since the study locations were selected so that no adjustments would be necessary, the amount of overprediction should be a minimum. The third method was the FHWA Level I Highway Traffic Noise Prediction Model (SNAP 1) *(12)*. This is the recently adopted procedure used in Kentucky. A limitation of the computer program was that it does not predict noise for observer-to-roadway distances under 50 feet (15 m). Using this program, both L_{10} and L_{eq} noise levels were predicted and compared to measured values. The average noise values for all the intersections showed that there was an overall good agreement between measured and predicted values. There was a tendency for the "NCHRP Report-117-plus-correction-factor" and the SNAP 1 procedures to underpredict the measured L_{10} values. There was only an overall average underprediction of 2 dBA using the revised NCHRP Report 117 procedure. The very short distances used and the generally low truck volumes probably accounted for some of the differences. In fact, these predictions were obtained by manual calculations because of inaccuracies in computer procedures for the very short distances. The predicted L_{10} values using the SNAP 1 program under predicted the measured values. However, the average of the L_{eq} predicted values using this procedure was only 1 dBA lower than the average of the measured L_{eq} values.

RECOMMENDATION

The measured noise data showed that no adjustment factor is necessary to account for interrupted flow of traffic. It is recommended that the current procedure used in Kentucky for interrupted flow locations be continued. In this procedure, no adjustment factor is used, and the traffic speed used in the prediction is the free-flowing vehicle speed (speed limit).

TABLE 6. COMPARISON OF MEASURED AND PREDICTED NOISE LEVELS

INTERSECTION NUMBER	MEASURED NOISE LEVEL		PREDICTED L_{10} NOISE LEVEL			PREDICTED L_{eq} NOISE LEVEL (SNAP 1)
				REVISED DESIGN GUIDE (NCHRP Report 174)		
	L_{10}	L_{eq}	NCHRP REPORT 117 PLUS CORRECTION FACTOR	L_{10} NOMOGRAPH	SNAP 1[a]	
1	75	72	70	74	b	b
2	77	74	72	75	b	b
3	77	74	72	75	b	b
4	68	65	63	66	b	b
5	74	70	74	74	71	69
6	70	67	68	71	69	68
7	66	63	69	70	69	67
8	71	68	69	69	65	64
9	77	73	76	77	73	72
10	66	62	62	68	64	63
11	74	70	74	76	b	b
12	79	76	75	78	74	72
13	74	71	76	78	b	b
14	81	77	85	81	b	b
15	77	73	74	73	70	68

[a]Simplified Noise Analysis Program 1.0

[b]Program does not predict noise for observer-to-roadway distances under 50 feet (15 m)

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