Cost of Noise Barrier Construction in the United States

LOUIS F. COHN AND ROSWELL A. HARRIS

The results of a study of noise barrier costs in the United States are presented. A survey was made of each state highway agency and the FHWA to codify all barriers constructed through 1987. Costs associated with the construction of the barriers were then made current through the fourth quarter of 1988 using the FHWA quarterly price trends for federal-aid highway construction. New curves correlating cost per linear foot were then developed using standard statistical techniques. The new curves have been incorporated into the OPTIMA code. In addition, other changes to OPTIMA have been made and are described.

In 1982 FHWA distributed the companion computer programs STAMINA 2.0 and OPTIMA (*1*). Together, STAMINA 2.0 and OPTIMA constitute the barrier cost reduction (BCR) technique, which was developed in 1977 by Bolt, Beranek, and Newman (*2*).

OPTIMA contains cost data (Table 1) for noise barriers, allowing the OPTIMA user to develop cost-effective barrier designs based on an effectiveness/cost ratio (*E*/*C* table). The cost information included in OPTIMA has not been updated since the model was originally distributed and in fact is based on a very limited number of barriers constructed primarily in California in the early to mid-1970s.

Because the cost data currently in OPTIMA are quite old and are based on a limited number of constructed barriers, most users have been unwilling to rely on them for other than purely qualitative comparisons between barrier material types. The unreliability of the cost data has also diminished the use of OPTIMA as a design tool, because users cannot depend on even the relative accuracy of the *E*/*C* table numbers. Consequently, many barrier designers today use the OPTIMA *E*/*C* table only as a starting point, and then rely heavily on heuristic judgment to develop final designs.

EXTENT OF THE U.S. BARRIER PROGRAM

To address the problems, a study was undertaken to determine the extent and cost of the barrier construction program in the United States, to develop current base-year cost information for the barriers constructed, and to revise the cost-per-linear-foot curves contained within OPTIMA. Data for this study were received from the states and FHWA in response to a comprehensive survey. Concurrent with this study, another effort was undertaken to improve the usefulness of OPTIMA from a user interface standpoint. Results from both of these studies are discussed in the remainder of this paper.

As mentioned earlier, the costs presented in Table 1 are based on a limited number of barriers constructed in the early to mid-1970s. Since that time, many states have conducted extensive barrier programs; most other states have built at least one barrier. As presented in Table 2, more than 466 linear mi of barriers had been built through 1987 (*3*). This number is in contrast to 189 linear mi of barriers constructed in the United States through 1980 (*4*).

Most of the barriers presented in Table 2 were included in the data supplied by the states in response to the survey mentioned earlier. Distribution of height by material is presented in Table 3; the average height for all the barriers reported in the survey is 11.65 ft.

In summary, several conclusions can be drawn about the extent of the U.S. barrier program to date. Among these are the following:

1. The magnitude of the program has nearly tripled since 1980,
2. Concrete- and masonry-based materials are the most commonly used, and
3. Only a very small percentage of barriers exceed 20 ft in height, with the average barrier being about as tall as a heavy-truck exhaust stack.

COST OF THE U.S. BARRIER PROGRAM

The FHWA quarterly publication *Price Trends for Federal-Aid Highway Construction—1977 Base* (*5*) was used to account for geographic and time differences in construction costs for the barriers presented in Table 2. Factors based on the year of construction and the construction price index for the particular state in which the barrier is located were used to bring all barrier costs to constant 1988 dollars. For example, the cost of a concrete barrier constructed in 1977 in California was brought to 1988 by a factor of 2.26; a concrete barrier constructed in Florida in 1977 was brought to 1988 by a factor of 1.99; last, a concrete barrier constructed in Michigan in 1977 was brought to 1988 by a factor of 1.91. These factors are based on state-by-state cost indices for six indicator items that reflect price trends for all roadway excavation, surfacing, and structures.

This updated cost information was combined with the other information gathered from the state highway agencies in the survey to produce a data base for more than 700 barrier proj-

Department of Civil Engineering, University of Louisville, Louisville, Ky. 40292.

TABLE 1 ORIGINAL BARRIER COSTS IN THE OPTIMA CODE

Barrier Height (ft)	Cost per Linear Foot($)				
	Berm	Concrete	Masonry	Steel	Wood
1	2.40	9.80	5.60	11.20	6.40
5	7.80	41.50	23.90	52.60	28.70
10	23.90	81.50	52.60	124.50	57.50
15	49.50	139.00	95.80	204.40	102.20
20	95.80	183.70	111.80	354.70	175.70
25	142.10	228.30	127.80	505.00	249.20
30	188.40	273.00	143.70	655.20	322.70
35	234.10	311.20	159.70	805.50	396.20

TABLE 2 BARRIERS CONSTRUCTED IN THE UNITED STATES (*3*)

Material Type	Total Length (mi)	Percent
Block/brick	148.1	32
Concrete	91.2	20
Wood	68.9	15
Berm	47.4	10
Metal	22.6	5
Berm/concrete	18.0	4
Berm/wood	9.8	2
Berm/metal	6.7	1
Other	54.2	11
Total	466.9	

TABLE 3 DISTRIBUTION OF BARRIER HEIGHTS BY MATERIAL TYPE

Material Type	Percent Distribution by Height Group (ft)						
	1–5	5–10	10–15	15–20	20–25	25–30	30–35
Concrete	—	32	47	20	1	—	—
Masonry	—	72	18	10	—	—	—
Wood	—	49	18	34	—	—	—
Berm	3	65	17	10	5	—	—
Metal	9	32	31	25	—	3	—
Berm/concrete	—	46	10	32	8	4	—
Berm/wood	—	33	45	22	—	—	—
Berm/metal	—	41	31	28	—	—	—
Other	—	23	26	47	2	2	—
Total	1	42	32	22	1	1	1

ects in 37 states. The data base was prepared for analysis using dBase III Plus, and included the following fields:

State
City
Route
Year of construction
Cost update factor
Length (ft)
Height class (ft)
Actual height (ft)
Material class
Actual material
1988 cost ($/lf)

As Table 1 indicated, the OPTIMA code classifies barrier costs in five material categories: berm, concrete, masonry, steel, and wood. From the more than 700 barrier projects in the data base, 520 were selected for statistical analysis. These 520 were deemed to fit cleanly into one of the five categories. Linear regression was performed on the data in each material category. Cost coordinates were assigned to each of the 520 barriers, with the x-coordinate being height and the y-coordinate being (updated) cost per linear foot. Linear regression fits a straight line in the slope intercept form to produce regression lines. The regression lines developed for the five material categories were then tested for significance using correlation coefficient, t-test, and confidence intervals.

Correlation coefficients (r-values) measure the variation of one variable with respect to the variation of the other. Their values ranged as follows: berm, 0.315; concrete, 0.484; masonry, 0.386; steel, 0.666; wood, 0.524. These r-values indicate a relatively inconsistent relationship between cost per linear foot and height. This is to be expected, given the variety of ways in which the costs of barriers are determined in the construction environment.

In the t-test, the mean of the samples and the standard deviation estimated from the samples are used to make probability statements about the values of observations in the population from which the samples were drawn. A 95 percent level of significance was selected as acceptable for the barrier cost data. The tabulated value of the normal distribution for the 95 percent level of significance is $t = 1.96$. If the calculated t-value for the given material category is greater in absolute value than 1.96, then the null hypothesis is rejected, and the conclusion may be made that the regression line calculated from the actual data is significant. The calculated t-values (absolute values) for the material categories ranged as follows: berm, 3.22; concrete, 7.06; masonry, 4.18; steel, 7.02; wood, 5.88. These values confirm significance.

Table 4 presents the new cost data resulting from this study.

Figures 1 through 5 are plots of the updated cost data, as well as the original cost data found in the OPTIMA code. The figures also indicate the degree of scatter of the actual data for the updated costs.

The data presented in Table 4 may be easily incorporated into the OPTIMA Fortran code. Users with executable microcomputer versions of OPTIMA can seek modification to the cost data section of the Fortran code. Such requests naturally must be made to those with access to the Fortran code.

OTHER IMPROVEMENTS TO OPTIMA

In addition to the updated barrier costs, several improvements have been made to the microcomputer version of OPTIMA that is made available in the short course. Although many of

TABLE 4 UPDATED (1988) BARRIER COSTS FOR USE IN OPTIMA

Barrier Height (ft)	Cost Per Linear Foot ($)				
	Berm	Concrete	Masonry	Steel	Wood
1	25.95	56.42	47.46	14.98	1.00
5	42.19	103.10	84.53	72.95	50.24
10	62.49	161.45	130.86	145.41	117.81
15	82.81	219.79	177.19	217.87	185.38
20	103.11	278.14	223.52	290.32	252.94
25	123.42	336.49	269.86	362.78	320.51
30	143.72	394.83	316.19	434.16	388.07
35	164.00	453.00	363.00	508.00	456.00

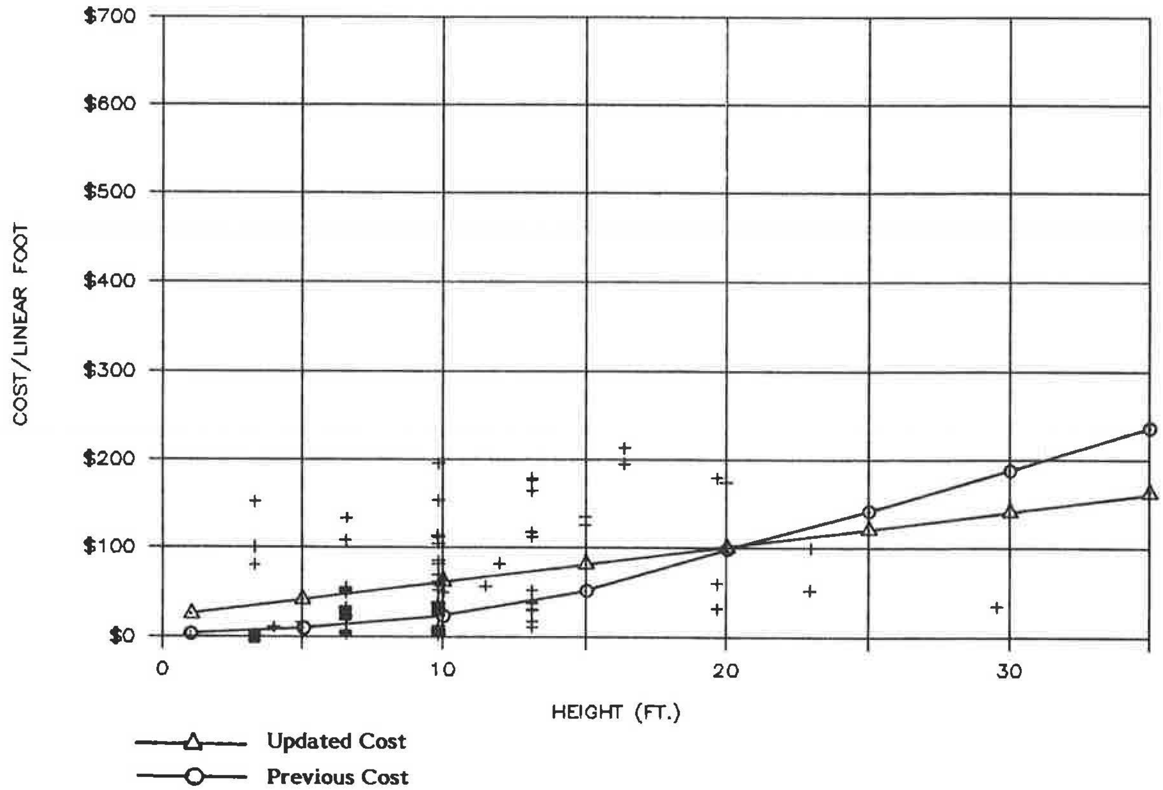

FIGURE 1 Noise barrier cost—berm.

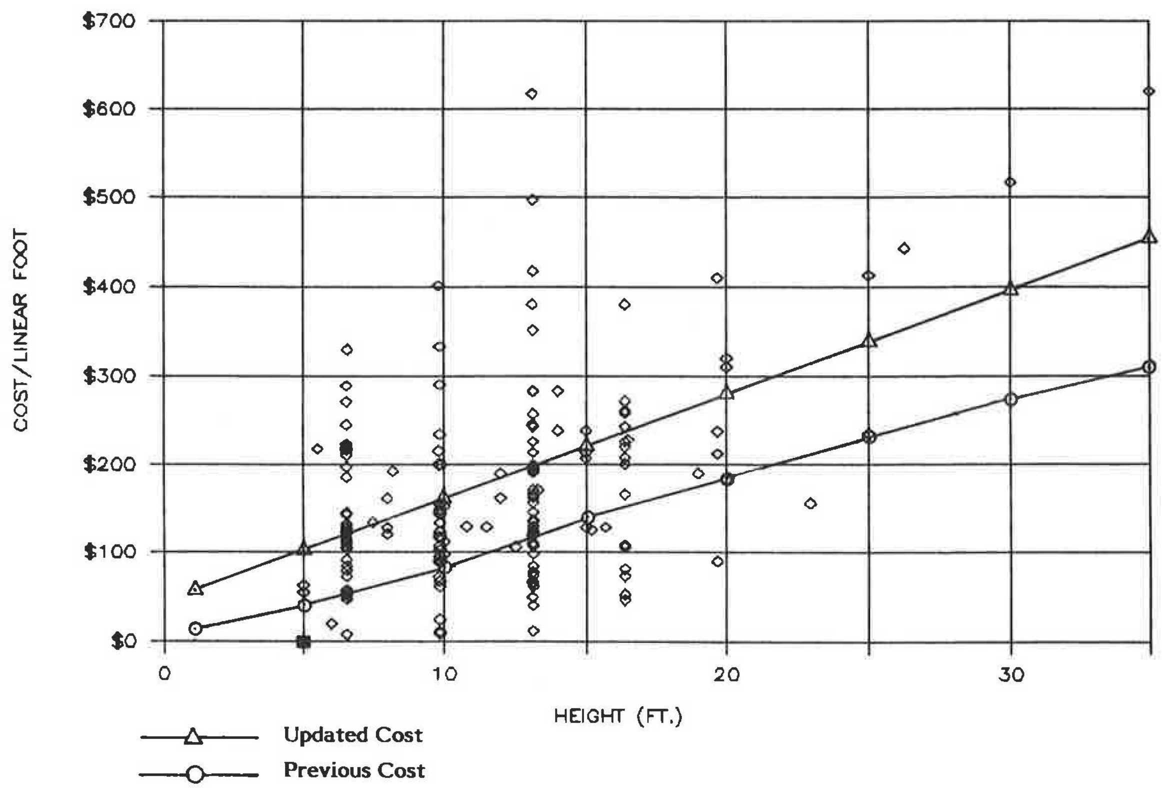

FIGURE 2 Noise barrier cost—concrete.

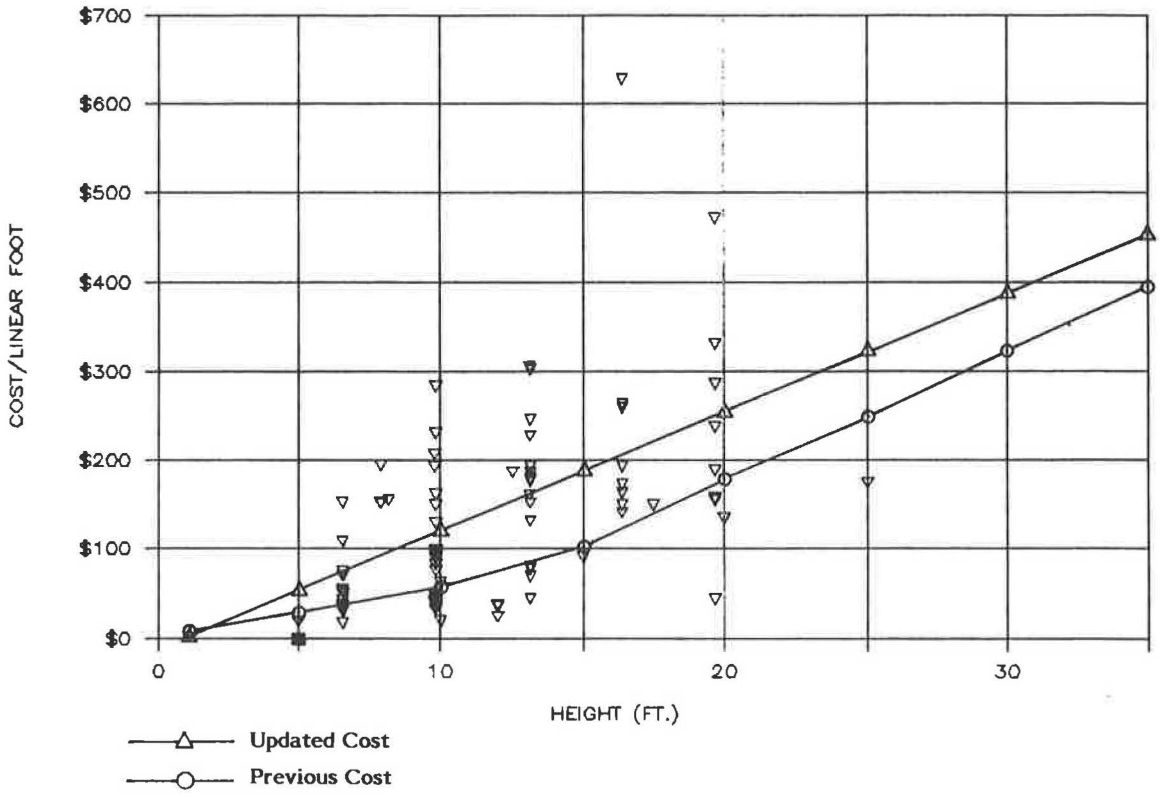

FIGURE 5 Noise barrier cost—wood.

RESULTS

REC	REC ID	LEQ	LEQ(Z(0))	IL
1	R10	61.5	68.7	7.2
2	R11	60.3	67.8	7.5
3	R12	59.6	67.3	7.7
4	R13	59.8	67.7	7.9
5	R14	59.9	68.0	8.1
6	R15	60.3	68.6	8.2

BARRIER TYPE	COST	AREA (SF)
FH-BERM	35200.	5184.
FH-MASON	118421.	9708.
FH-WOOD	80981.	6731.
FH-CONC	156631.	10743.
FH-STEEL	124985.	8601.
BARRIER COST = $	516218.	TOTAL AREA = 40967.

AREA BREAKDOWN

MATERIAL TYPE	BARRIER HEIGHT (FT.) <5	5-10	10-15	15-20	>20
FH-BERM	308.6	2304.6	2571.0	0.0	0.0
FH-MASON	0.0	800.9	3800.9	5105.8	0.0
FH-WOOD	0.0	812.8	4411.8	1506.9	0.0
FH-CONC	0.0	0.0	3641.4	5159.2	0.0
FH-STEEL	0.0	1599.5	3599.2	3402.1	0.0

FIGURE 6 OPTIMA output showing area information.

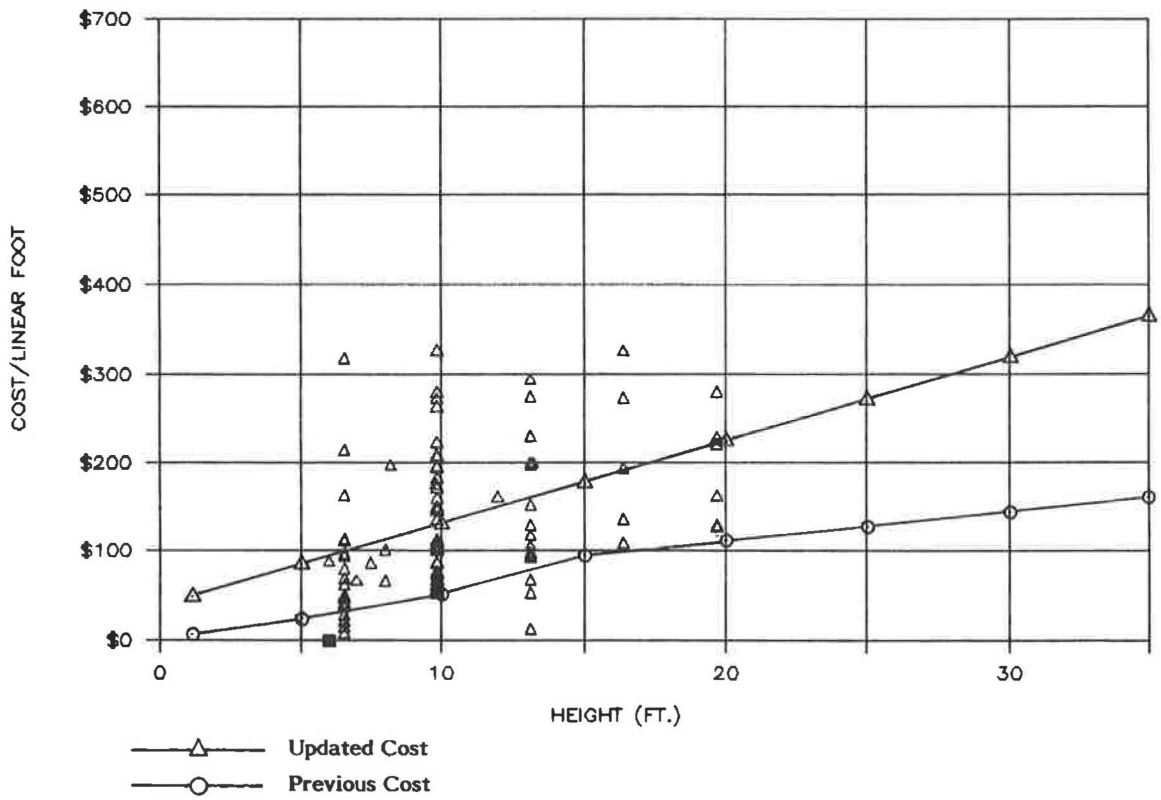

FIGURE 3 Noise barrier cost—masonry.

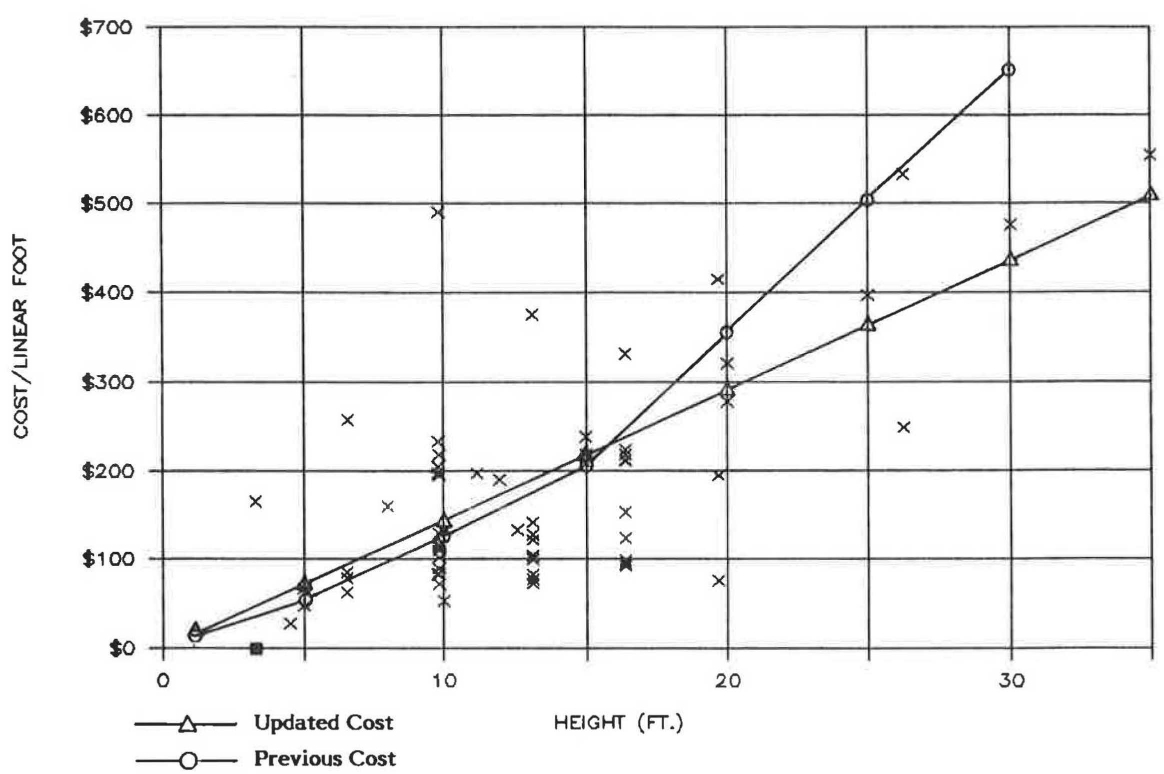

FIGURE 4 Noise barrier cost—steel.

these improvements relate to wording changes in the user interface, two are worth noting. First, it is now possible to reopen an existing OPTIMA output file (.OPT file). Before this change was made, it was necessary to reenter all the initialization information concerning material type for each barrier segment, and population and design noise level for each receiver, each time that OPTIMA was run for a given acoustics output file (.ACO file).

The second change results in the display of area information corresponding to a given set of height indices. This information is in addition to the L_{eq}, insertion loss, cost, and segment contribution data normally associated with OPTIMA output. Figure 6 shows the results portion of a typical OPTIMA output file for a barrier with mixed material types and various heights.

CONCLUSION

The barrier cost reduction (BCR) procedure is of some value in noise barrier design. The usefulness of the procedure has been severely limited by the incomplete and inaccurate nature of the cost data contained within the OPTIMA code for construction cost per linear foot for the various barrier material categories. This study has updated these cost data to 1988 through a comprehensive assessment of actual construction cost information for more than 700 barrier projects around the country.

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