sors that meet U.S. Environmental Protection Agency standards would be ineffective because they contribute little to the total level that is dominated by the drills. Instead, the model might show that a temporary noise barrier of a certain height along the right-of-way line would provide adequate noise reduction. In another situation, for example, the model might show that a temporary barrier would be ineffective but that a strategy such as shifting the location of the haul road to take advantage of terrain shielding would provide significant noise reduction.

SUMMARY

A model and interactive computer program for predicting highway construction noise levels, called HICNOM, has been developed for FHWA. The model addresses noise sources as points, lines, and areas and also calculates noise-barrier insertion loss. A data base for 53 types of equipment and models has been developed from extensive field measurements and a literature review. The final product of the computer program is a list of $L_{eq(8h)}$ at each noise receptor as well as the contribution from each noise source.

Although use of the model is not required by FHWA, HICNOM can serve as a useful tool for identifying potentially impacted areas, quantifying that impact, designing abatement measures, and evaluating their potential effectiveness. Vanderbilt University has developed a manual calculation method and a series of programs for a handheld programmable calculator (Texas Instruments TI-59) based on the HICNOM model.

ACKNOWLEDGMENT

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Noise Control Through Land Use Planning: The Calgary Case

D.L. PARSONS

Noise attenuation measures are not often seen as an integral part of roadways. The need for attenuation, however, is determined by the adjacent land use and its noise sensitivity. Calgary, Alberta, Canada, uses land use planning and land use development as a major way of providing attenuation for surface transportation noise sources. Through enabling provincial legislation, the city has the mandate to negotiate attenuation measures as a condition of residential developments. Three scenarios provide opportunities to attain the design noise level objective of 60 dB (A) $L_{eq}(24)$: (a) construction or upgrading of a roadway adjacent to existing development, (b) development or redevelopment adjacent to an existing transportation corridor, and (c) development or redevelopment adjacent to a future transportation corridor. To take advantage of these three opportunities, the concept of potential noise impact zones was developed and is being integrated into the normal planning process to assist in flagging potential noise problems. The procedures and practices have been in place on an informal basis for several years and have proved successful in obtaining livable residential noise environments.

Calgary is becoming the economic center of Alberta's oil-based prosperity and a major financial center in western Canada. Located on the eastern edge of the Canadian Rockies, it is similar to Denver, Colorado, in terms of location, prosperity, and growth. Alberta's tremendous oil resources and resultant booming petroleum industry liken it to Houston and Dallas, Texas.

Calgary typifies growth and economic opportunity, perhaps better than does any other major center in Canada. The oil industry and a prosperous agricultural community provide both a strong regional economy and a vibrant local economy. The favorable employment market has created a growth rate of roughly 5 percent/year; some 2000 people take up residence in Calgary each month.

To provide the necessary services, utilities, and urban amenities for a rapidly growing population of 600 000 is both a challenge and a nightmare for planners, engineers, politicians, and citizens. The demand for housing has made the Calgary area a desirable place for land developers. During the 1970s, Calgary's total area grew to approximately 195 miles^2 through annexation, primarily initiated by the development industry. This reserve of developable land was needed to provide Calgarians with housing and associated urban amenities. One of these amenities is the provision of a good transportation network.

CALGARY: WESTERN UNI-CITY

Control of development and its integration with the existing built-up area and existing utilities could be a horrendous task. Calgary, along with other major cities in Alberta, is fortunate in that it operates as a uni-city with almost total jurisdiction over all municipal matters within its boundaries.

The system of government and constitution does not provide for control and funding from the federal level of government. In the Canadian system of government, the constitution delegates and defines jurisdictions between the federal government and the provinces. Each province in turn can then allocate responsibilities to the municipal level. In the context of provision of transportation services and land use planning and control in Alberta, there is little interplay between the federal government and the municipality. The primary relation on these matters is between the province and the individual city or other urban or rural municipality.

Provincial legislation, like the Alberta Planning Act of 1977 and the Alberta Municipal Government Act of 1968, provides a framework within which local municipalities can operate with considerable latitude. Procedures with respect to subdivision approval and routes of appeal, for example, are laid out at the provincial level but the actual decision-making power on particular proposals is municipal.

Funding of transportation facilities usually implies that some form of control lies with the funding agency. Within Alberta, the provincial government may share costs with the municipality on particular capital projects. For example, of the transportation capital expenditures during 1979 through 1981, the provincial government contributed between 27 and 31 percent of the total. Contributions to operating costs constitute a much smaller proportion of the total, and range between 4 and 7 percent. The application of these funds to particular transportation projects is at the discretion of the municipality.

With the exception of adherence to international design standards and practices, the planning, design, construction, and maintenance of our road and transit network is a municipal matter. Combined with total control over land use planning, Calgary has far-reaching powers that enable it to control and direct the development of our city.

CONTROL OF SURFACE TRANSPORTATION NOISE

Working within the kind of jurisdictional framework described, Calgary is in an excellent position to control surface transportation noise. Approval of a formal policy, Surface Transportation Noise Policy for the City of Calgary, provides consistency in the efforts to obtain our maximum design noise level of 60 dB(A) equivalent noise level for 24 h [$L_{eq(24)}$] for residential land uses.

With the magnitude of downtown development and associated transportation improvements needed to service development, three opportunities exist for control of surface transportation noise within Calgary:

Case 1--Construction or upgrading of a roadway adjacent to existing development,

Case 2--Development or redevelopment adjacent to existing transportation corridors, and

Case 3--Development or redevelopment adjacent to a future transportation corridor.

Case 1 employs the standard use of barriers, berms, and combinations thereof to effect noise control. The city is clearly responsible for funding any noise attenuation in this instance. Calgary continues to benefit from the design, construction, and maintenance experience of the American states and of large Canadian metropolises like Toronto.

Cases 2 and 3 can be described as noise control through joint negotiations between the city and the development industry. The benefit of negotiating the form of attenuation is the flexibility that is afforded to both the city and to the developer. Provided that the development adjacent to the noise source meets the acoustical requirements established by the city, the range of options for achieving the design noise level of 60 dB(A) $L_{eq(24)}$ is significant. From the perspective of the land developer, marketing of lots, for example, can be considered in the negotiation process and may be reflected in the site design and aesthetic treatment of any barriers.

Where a residential subdivision or development is proposed adjacent to an existing noise source, the developer is required to provide any necessary attenuation facilities, whatever their form. In numerous examples of case 2 situations, the developer has employed setbacks, frontage roads, grade change, or barriers to effect noise mitigation. Less conventional approaches have also been used successfully.

The residential subdivision of Ranchlands is a good example. The subdivision was planned adjacent to a six-lane expressway that was in the detailed design stages at the time of subdivision approval. The roadway was depressed to obtain both reasonable grades as well as some noise attenuation. In addressing the noise issue, the developer and the city negotiated a solution that incorporated a berm and barrier combination. The matter of negotiation was the placement of the property line. By placing the property line at the top of the berm, right-of-way acquisition costs to the city were minimized, the amount of developable land in the subdivision was maximized, and sufficient attenuation was achieved. The lots back onto the right-of-way such that maintenance of the community side of the berm and any landscaping is at the discretion of the homeowner. Maintenance of the roadway face of the berm and barrier is the city's responsibility.

Case 3 recognizes that development is occurring in areas where the final roadway, and hence, the ultimate noise problem, may not be constructed for many years. In this instance the developer is required to design and construct the project so as to either achieve the design noise level or provide the opportunity to do so at some future date. Completion of attenuation becomes the responsibility of the city and would occur at the time of construction of the transportation facility.

The city recognizes that not all residential developments adjacent to transportation corridors will experience traffic noise problems. To assist in processing case 2 and 3 development applications, a methodology has been developed that allows for the identification of potential surface transportation-related noise problems. If the potential is identified by some criterion, more detailed analysis is required to determine the extent of the noise problem and possible solutions for it.

The criterion most appropriate to Calgary was found to be related to the standard of roadway. Traffic noise is a function of traffic volumes, speed, and type of vehicle--factors that are also used in determining the standard of roadway design. By using the maximum expected values for volume, speed, and traffic mix for each roadway category, the distance at which the day-night sound level (DNL) of 60 dB(A) $L_{eq(24)}$ occurs can be deter-

Table 1. Determination of PNIZs.

Road Classification	Maximum Expected Volume (vehicles/day)	Posted Speed (km/h)	Distance from Centerline (m)	$L_{eq}(24)$ [dB(A)]	Recommended PNIZ (m)
Freeway	120 000	100	51[a]	68.4	135
			100	62.5	
			120	60.7	
			135	60.0	
			140	59.0	
Expressway	100 000	70	30[a]	70.1	100
			70	62.4	
			90	60.3	
			100	59.9	
Major	40 000	60	24[a]	68.7	60
			40	63.2	
			60	59.5	
Primary collector	10 000	50	17[a]	57.1	NA
Collector	5 000	50	17[a]	54.1	NA
Residential	1 000	50	14[a]	49.0	NA

[a]Property line plus a standard 6-m building setback.

Figure 1. PNIZ noise data sheet.

Submitted by _____
(company name)
Contact person _____
Phone number _____

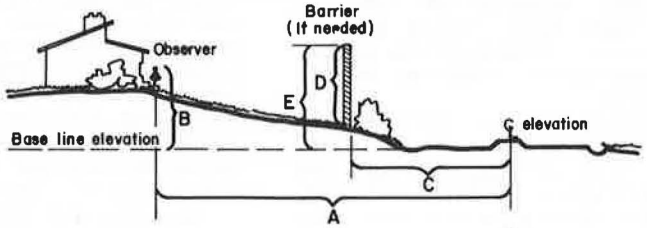
FOR OFFICE USE ONLY
Meets DNL as is ☐
Meets DNL with attenuation as shown ☐
Does not meet DNL ☐
Reason: _____
Checked by _____
Date: _____

TRAFFIC DATA

Category of road: _____
Average daily traffic: _____
(as obtained from Transportation Dept.)
Assumed percent of truck traffic: _____
Assumed road speed: _____
Assumed road grade: _____
(Note: Reference source of cross section) _____

SITE INFORMATION

Attach plan view of site (scale to be indicated). Attach cross-section similar to example below, showing distance A, ℄, of elevation and height B. Where barrier is required show C, D and E as well.



Centreline elevation _____
Observer distance (A) _____
Observer height above base line (B) _____

Where Applicable
Barrier distance (C) _____
Barrier height (D) _____
Barrier height above base line (E) _____

NOISE ANALYSIS

Noise level at observer without barrier _____ db (A) $Leq_{(24)}$

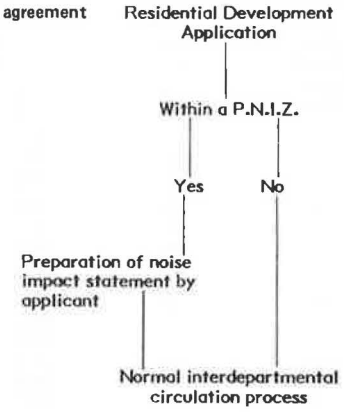
If this exceeds Design Noise Level of 60 db (A) $Leq_{(24)}$, specify proposed method of noise attenuation. (attach seperate sheet or plans if necessary)

Resultant noise level at observer _____ db (A) $Leq_{(24)}$

NOISE ANALYSIS METHOD USED

☐ Alberta Surface Transportation Noise and Attenuation Study
☐ Central Mortgage and Housing "Road and Rail Noise"
☐ Other (please specify) _____

Figure 2. Flow chart of development agreement for a project.



mined. These in turn are used to define potential noise impact zones.

An analysis of various roadway standards in the city was undertaken. These standards are reflected in several policy documents as well as in the standard development agreements negotiated between the city and the development industry. In reviewing the six recognized road classifications, three categories were found to have the potential to create noise problems for adjacent residential developments. The analysis summarized in Table 1 formed the basis for establishing recommended potential noise impact zones (PNIZs).

In establishing the PNIZ, consideration of rail noise was important in that Calgary has two national lines that pass through the city as well as a developing light rail transit (LRT) system. The potential for heavy and light rail oriented noise problems exists.

In the case of both heavy rail and light rail facilities, PNIZs are much more difficult to define. The variability in the composition, speed, and frequency of heavy rail trains implies that a standard PNIZ is not appropriate. Rather, each development proposal adjacent to a rail line is reviewed on its own merits. Although LRT vehicles generate substantially lower noise levels than do heavy rail trains, individual investigation of all proposed residential developments adjacent to LRT lines ensures compatibility.

The design noise guideline and the PNIZ concept or way to identify or flag potential noise problems are in the process of being incorporated into the normal development application approval process. The requirement of a simplified potential noise impact sheet achieves this goal without significantly effecting the processing of development applications.

Development or redevelopment proposals for PNIZs and adjacent to both heavy and light rail lines require that a noise impact statement be submitted with the proposal. By specifying the type and format of data required to adequately assess the noise environment and the analysis methodologies acceptable to the city transportation department, the use of the simple summary sheet shown in Figure 1 enables the development industry to address noise issues rapidly.

The flow chart in Figure 2 illustrates the simplicity of the approach. Any forms of noise attenuation that may be necessary and their funding are negotiated and finalized in the development agreement for the project.

DOES NOISE CONTROL THROUGH NEGOTIATIONS WORK?

The procedures and concepts described in this paper have been largely in place on an informal basis for the past few years. The PNIZ concept is to be implemented in early 1982. Amicable relations between the city and the development industry and its representative organizations, the Urban Development Institute (UDI) and the Housing and Urban Development Association of Canada (HUDAC), are critical in attaining controlled growth and good quality developments. Considerable discussions were held with UDI and HUDAC on the philosophy, procedures, and practices associated with surface transportation noise control. Although agreement was reached on the need for such control and the options available to achieve a recognized design noise level, the underlying philosophies differed.

The city's philosophy is that land use determines the need for noise protection and that the proponent of a noise-sensitive use is largely responsible for providing attenuation. For a hypothetical piece of roadway, only those adjacent uses that are noise sensitive need protection. For a roadway like Barlow Trail in Calgary, residential development on the west side needs some form of noise attenuation, but the light industrial uses on the east side are not noise sensitive. The development industry's position, however, is that the roadway is the source of the problem and that the responsibility for attenuation lies with the city as the developer of the road.

Notwithstanding the fundamental difference in philosophy and the implications for responsibility for funding, the development industry, in practice, has displayed considerable cooperation and enthusiasm for ensuring that their residential subdivisions provide good noise environments. A sensitivity to potential noise sources is exhibited very early in the planning stages, such that most developments are designed accordingly.

The aesthetic nature of barrier materials available in Calgary has led to more resistance than the concept of attenuation. The fledgling barrier industry in Calgary is beginning to address this concern. They recognize that attractive barriers facilitate marketing. The issue of noise attenuation through architectural acoustics has not been extensively addressed in Calgary. The existing provincial building code does not allow the city to require additional construction standards. The city recognizes that there are areas where desirable exterior noise levels cannot be obtained. Although acceptable interior levels are attainable through architectural design and acoustical insulation, enabling legislation is not in place to make this a requirement of development.

The city can only encourage attenuation through architectural design. Redevelopment in our inner-city areas is extensive; therefore, the need for incorporating this alternative form of noise attenuation has been recognized and is under investigation at this time.

CONCLUSION

Calgary has been progressive in its approach to noise control through land use planning and development. It has benefited from the technical work developed in the United States by adapting it to our own needs. Although the magnitude of our transportation noise problems is not comparable, fortunately, with the problems in cities like Los Angeles or Toronto, the average Calgarian perceives a noise problem that must be acknowledged and dealt with. The procedures and methodology described in this paper have proved to be successful.