Automated Light Rail Transit (ALRT) in Vancouver, Canada: Measured and Perceived Noise Impacts

V. SETTY PENDAKUR AND HUGH MCLEAN

This paper analyzes the wayside noise impact of the Automated Light Rail Transit (ALRT) in the Broadway Station and Nanaimo Station areas of Vancouver, Canada. The research objective was twofold: to establish a relationship between noise levels and the distance to the ALRT guideway, and to relate residents' noise perceptions to the measured noise. In April 1986, noise measurements and a survey of residents' perceptions were undertaken by the School of Community and Regional Planning, University of British Columbia. Using this base data, the 24-hr L_{eq} was calculated. The analysis indicates that the relationship between noise and distance is semilogarithmic. An L_{eq} of 55 dB or more, after adjustments to the 24-hr L_{eq} based on criteria for previous community exposure to ALRT noise and background noise in the neighborhood, defines the zone of high impact. The distance from the ALRT guideway at which noise levels are unacceptable ranges from 20 to 200 ft. The Vancouver ALRT system was planned and built on the basis that only those properties within the ALRT right of way were to be acquired and noise impacts were not important. The experience since 1986 and this research indicate that noise impacts are important and should be mitigated. It is possible to establish measured zones of high impact. Planning goals must necessarily include the preservation of environmental quality. Prevention and mitigation of negative impacts must be part of the system's planning.

Vancouver is Canada's third largest metropolitan area, with 14 municipalities and a total population of 1.4 million in 1986. As early as 1970, rapid transit was promoted as an effective solution to transportation problems (*1*). The Greater Vancouver Regional District (GVRD) and the City of Vancouver produced plans for rapid transit systems with appropriate technology over the following 12 years, but neither group had the legal authority, taxation powers, or the finances to build a regional rapid transit system (*2,3,4*).

The turning point was 1982, when the provincial government announced that Vancouver would be the host city for a 1986 World's Fair with "TRANSPORTATION" as its theme. The fair, at first called "Transpo '86," was later named "Expo '86." In conjunction with Expo '86, it was decided to build a fully automated and elevated light rail transit system (ALRT). The planning, design and construction of the ALRT system was subsequently taken out of the hands of local/regional authorities and became the sole responsibility of a provincial crown corporation/agency called B.C. Transit. This agency is now responsible for all public transit in British Columbia. The system, as built, is shown in Figure 1. It is underground within the central business district, and the remainder is generally on an elevated guideway, with some segments at ground level or in-cut.

University of British Columbia, Vancouver V6T 1W5, Canada.

STUDY AREA

The study covers the Broadway Station and the Nanaimo Station areas, as shown in Figure 2. In the vicinity of the Broadway Station is a mix of apartments, duplexes and single-family residences, with commercial activity along Broadway and Commercial Drive. South and east along the ALRT line toward the Nanaimo Station, the neighborhood consists primarily of single-family dwellings.

The decision by B.C. Transit, in 1982, to construct an elevated transit guideway parallel to Commercial Drive and through a residential neighborhood sparked local protest and controversy. B.C. Transit contended that this was the only practical route and that the suggested alternatives were uneconomical. Local residents and the city of Vancouver demanded that a cut-and-cover tunnel be constructed under Commercial Drive to avoid the demolition of homes and numerous other negative community impacts including noise (*5*). The additional $14 million required for a tunnel, however, was not acceptable to B.C. Transit, and construction began in early 1984 without local approval and amid much controversy. The ALRT system was in full operation by January 1986, in time for Expo '86, which opened in May 1986.

MEASURED AND PERCEIVED NOISE IMPACTS

Research Goals

The research goals were to calculate the 24-hr L_{eq} based on wayside ALRT noise and ambient background noise levels, to establish a relationship between ALRT noise and distance from the guideway, to delineate zones of high and low impact, and to analyze residents' perceptions of noise based on these zones of impact.

The zone of high impact is defined as the area in which ALRT outdoor noise levels are unacceptable. Canada Mortgage and Housing Corporation (CMHC) guidelines specify a

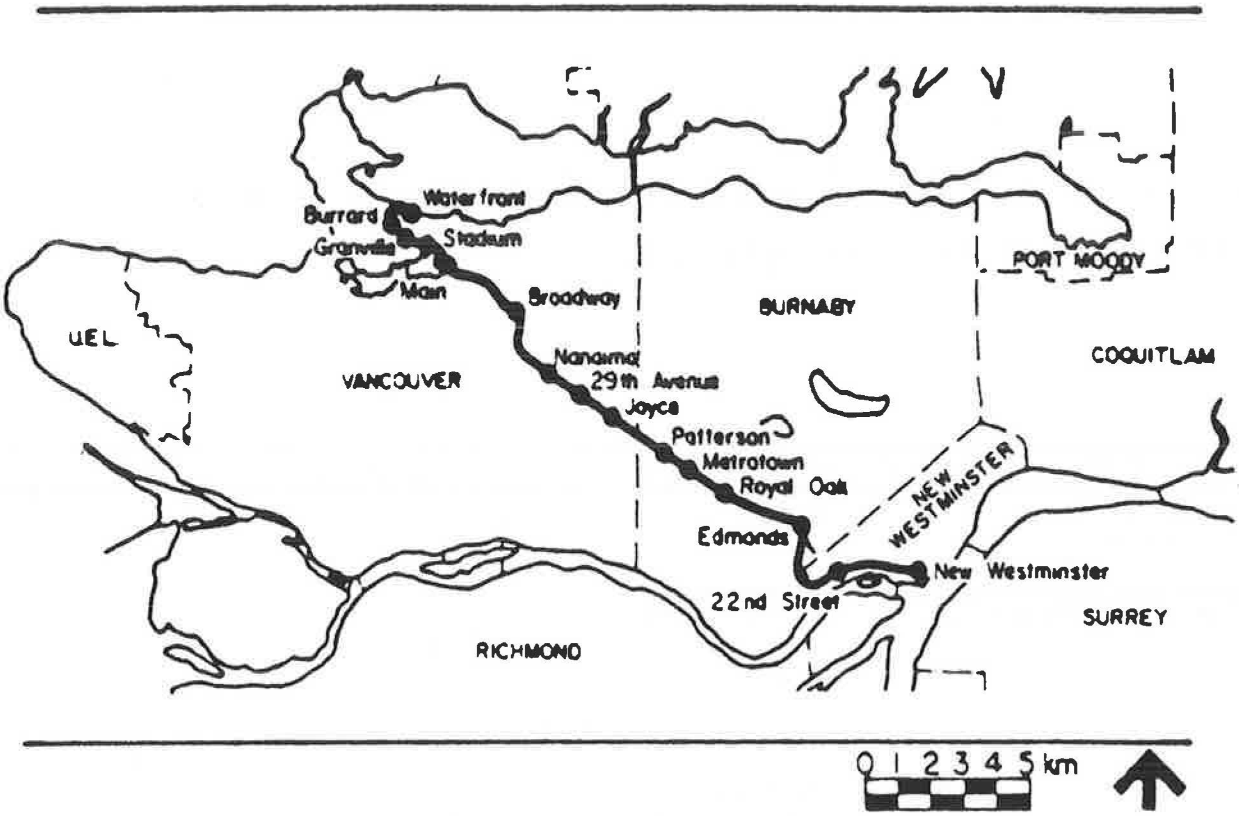


FIGURE 1 Regional ALRT route.

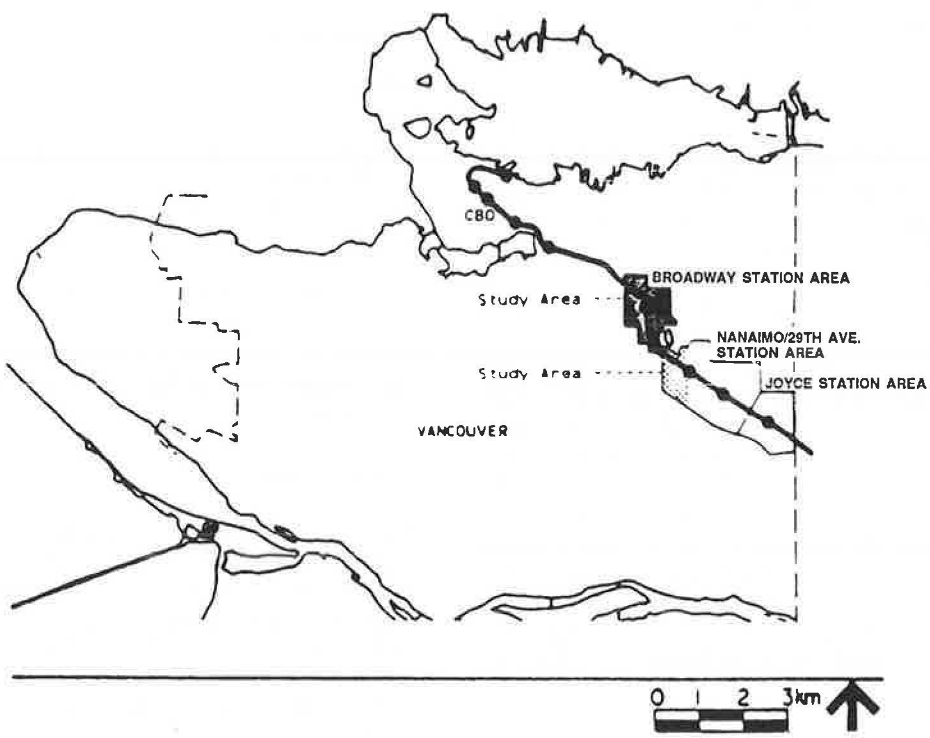


FIGURE 2 Study area: Broadway Station area and Nanaimo Station area west of Nanaimo Street.

24-hr L_{eq} of 55 dB or more as unacceptable in a residential area (6). The zone of low impact is the remainder of the study area, in which the 24-hr L_{eq} was less than 55 dB.

In order to relate noise levels to perceptions, an adjustment was made to the L_{eq} on the basis of U.S. Environmental Protection Agency (EPA) criteria for previous community exposure and noise levels measured in absence of the intruding noise (7). This adjustment applies only to relating the measured noise to perceptions. It was not used in the analysis of the relationship between noise and distance.

The EPA adjustments applicable to the study area were +5 dB for areas with no prior experience with intruding noise, and a correction for outdoor noise levels in the absence of intruding noise: zero dB for an urban residential community not adjacent to heavily traveled roads, or −5 dB for a noisy urban community near relatively busy roads (7). It is recognized that EPA adjustments apply to L_{dn} measurements. However, there is only a 3-dB difference between L_{eq} and L_{dn} if the ALRT system does not operate between 1.00 a.m. and 6.00 a.m., and at half the frequency between 6.00 a.m. and 7.00 a.m., and midnight and 1.00 a.m. (8).

Theoretical Aspects

Many factors contribute to the environmental quality of a neighborhood. Among the negative impacts of the ALRT, noise is the most easily identifiable and quantifiable. Often the benefits of improved accessibility on the regional scale take precedence over negative impacts imposed at the neighborhood level. The responsible authorities are all too often unaware of, or ignore, local impacts whether they be measured or perceived.

ALRT noise is generally produced by wheel-rail interaction and the electric motor. It can be intensified by wheel squeal around sharp curves and an elevated guideway, often the result of design constraints (8,9,10). Noise from elevated transit structures is also a function of train speed and length, distance from the track to the receiver, shielding, air and ground attenuation, structure type, and vehicle and track condition.

The perceived noise impact depends on whether residents consider the source as an intrusion, and whether their behavior is disrupted or enhanced (11). Responses to questions on rapid transit, in particular, depend on the noise magnitude as a function of frequency and time, socioeconomic conditions, the type of activity interfered with, past experiences and emotional associations with similar noises, individual sensitivity, and the type of question used in the survey (12,13,14,15).

Research Methods

The ALRT noise level forecasts for 1986 were obtained from a consultant's report and the municipality's expectations (16,17). The consultant study was done in 1983 and combined the measurements of ALRT pass-by noise taken at the ALRT Development Center in Kingston, Ontario; background noise was measured at three residential sites in the study area.

The East Vancouver Neighborhoods Study surveyed residents near the ALRT line during the ALRT construction, between May and August of 1984 (18). Residents were queried on the ALRT's influence on future neighborhood noise and neighborhood character. Socioeconomic characteristics were noted. No noise measurements, however, were taken in this study. The ALRT system was completed and became operational in January 1986.

In April 1986, noise measurements and a perception survey of residents were undertaken by the School of Community and Regional Planning at the University of British Columbia (V. S. Pendakur et al., "ALRT Noise Measurements in the Broadway Station Area," unpublished, 1987). Forty residential sites between the Broadway and Nanaimo Stations were chosen at random. The distance from the guideway for surveys and noise measurements varied from 20 to 320 ft (approximately one short block). The *A*-weighted noise measurements were divided into an indoor 15-min L_{eq}, peak indoor and outdoor levels, and ambient indoor and outdoor levels. For both the peak indoor and outdoor levels, four to six measurements were taken to obtain an average level.

Another set of measurements were taken on cross-streets at 50-ft intervals, up to 200 ft from the ALRT guideway. These measurements were of single-event maxima and ambient noise levels. They were taken at 76 sites. Together, outdoor noise measurements were performed at a total of 116 sites.

The L_{eq} values were measured with a Metrosonics Model 306/140 dB - 306 Metrologger, and single-event levels were measured with two Bruel and Kjaer Model 2206 Precision Sound Level Meters. Each device was calibrated to 92.5 dBA.

As a part of the perception survey, the residents were asked whether the ALRT noise could be heard indoors, and if so, in which rooms it could be heard. They were then asked if the noise affected their sleeping patterns. They were asked to rank ALRT noise with all other neighborhood noises, and to rate the overall noisiness of the neighborhood.

Analysis

All single-event noise measurements and the background noise were converted to 24-hr L_{eq} levels. This convention was based on the following formula (8):

$$L_{eq} = L_a + 10 \log (nl) - 49$$

where

n = number of trains per hour for the L_{eq} time period,
l = length of a train in meters, and
L_a = the maximum *A*-weighted sound level for train pass-by.

The background noise was converted to a 24-hr L_{eq} using a model developed by Barron and Associates (19). The model assumes that the noise levels are at maximum from 6 a.m. to 6 p.m., dropping from 6 p.m. to midnight and lowest from midnight to 6 a.m. Examples applicable to the study area are 60 dB, 54 dB and 48 dB for the three periods respectively.

The relationship of ALRT noise and distance from the guideway was computed by using regression analysis. Those sites where background noise contributes more to the 24-hr

L_{eq} than the ALRT pass-by noise are excluded, reducing the total number of sites from 116 to 93.

Environmental factors such as the height of the ALRT guideway, shielding and reflection of noise, and topography, each have an influence on the 24-hr L_{eq}. It is not within the scope of this study, however, to assess the relative significance of these factors. Similarly, other noise sources such as traffic are considered here as part of the background L_{eq}. The relative significance of each of these has not been studied here.

A zone of high impact is based on a 24-hr L_{eq} of 55 dBA or more. Adjustments were made to the 24-hr L_{eq} for previous community exposure and background noise for all 1986 noise measurements. The previous studies provide noise measurements and forecasts, but differ somewhat in the perception questionnaire. Therefore, they are analyzed separately and not combined with the 1986 measurements.

The two important perceptions from the 1984 East Vancouver Neighborhoods Study are the anticipated effect of the ALRT on neighborhood noise levels and neighborhood character. Residents were asked to rate the effect as better, no change or worse. These were analyzed together with a set of other perceptions, such as the factor liked best or least in the neighborhood, the anticipated changes in the area including traffic on local streets, and the quality of public transit service. The cross-tabulation procedure was used to obtain the association between nominal variables, and the nonparametric procedure calculated the Kendall Tau-b values for a bivariate analysis of ordinal variables.

Data from the 1986 Noise Perception Survey were coded on a weighted scale of 1 to 5 for statistical analysis. The three main categories were: Perceived Extent of ALRT Noise, Noisiness of the Neighbourhood, and Rank of ALRT Noise with Other Noise Sources. The coding system is shown in Table 1.

These perceptions were analyzed with the adjusted 24-hr L_{eq}. At 5 of the 40 residential sites, background noise was a greater contributor to the 24-hr L_{eq} than the ALRT pass-by. These sites were, therefore, excluded from the analysis of perceptions.

TABLE 1 PERCEPTION ANALYSIS: CODING SYSTEM

	Scale	
Category	Original	Recoded
Perceived extent of ALRT Noise		
Minimal/no impact	1	1
Noise heard only outside	2	
Heard in one room	3	2
Heard in > one room	4	3
Heard everywhere	5	4
Sleeping pattern affected	6	5
Noisiness of neighborhood		
Quiet	1	1
Fairly quiet	2	2
Moderately quiet	3	3
Noisy	4	4
Very Noisy	5	5
Rank of ALRT noise with other noise sources		
ALRT is noisiest	1	5
ALRT is second noisiest	2	4
ALRT is third noisiest	3	3
ALRT is fourth noisiest	4	2
ALRT is fifth noisiest	5	1

RESEARCH FINDINGS

The outdoor 24-hr L_{eq} at the 40 residential sites are shown in Table 2. Similar data for street level locations are shown in Table 2. The site locations in relation to the ALRT guideway are shown in Figures 3, 4, 5 and 6. Data in Tables 2 and 3, and in Figures 3 and 4 indicate that there are many sites in the study area where ALRT noise levels exceed acceptable CMHC standards.

Background noise, predominantly road traffic, contributes more to the 24-hr L_{eq} than the ALRT along three streets: East 11th Avenue, Victoria Drive and Nanaimo Street (see Figures 3 and 4). Virtually all the other figures show that noise decreases to varying degrees with greater distance from the ALRT guideway. The average L_{eq} at each of the 50-ft intervals are: 58 dB, 54 dB, 53 dB and 50 dB. This is similar to the 1983 forecasts (*16*).

Between the Broadway Station and Hull Street (Maps 3a and 3b) except for East 15th Avenue, the L_{eq} exceeds 55 dB up to 200 ft from the guideway. Along the west side of the guideway, the noise from and road traffic on Commercial Drive limits the impact of ALRT noise.

Between Hull Street and the Nanaimo Station, the impacts differ in intensity and distance. To the north of the guideway, ALRT noise exceeds 55 dB only at 50 ft, while at greater distances, the noise levels are acceptable. On this side, the topography drops significantly moving away from the guideway. To the south of the guideway, the noise levels exceed 55 dB up to 150 ft. This higher level may result from more open space and a gradual incline moving away from the guideway.

The regression analysis shows a marked correlation between noise and the log of distance ($r = -0.723$, $p < .0001$), with over half of the observed variance explained by the model ($r^2 = 0.523$). The 24-hr L_{eq} drops by 15 dB from 20 ft to 320 ft. The equation representing the complete study area is:

$$\text{Noise} = 79.99 - 12.45 \log(\text{Distance measured in ft}).$$

The scattergram is shown in Figure 5.

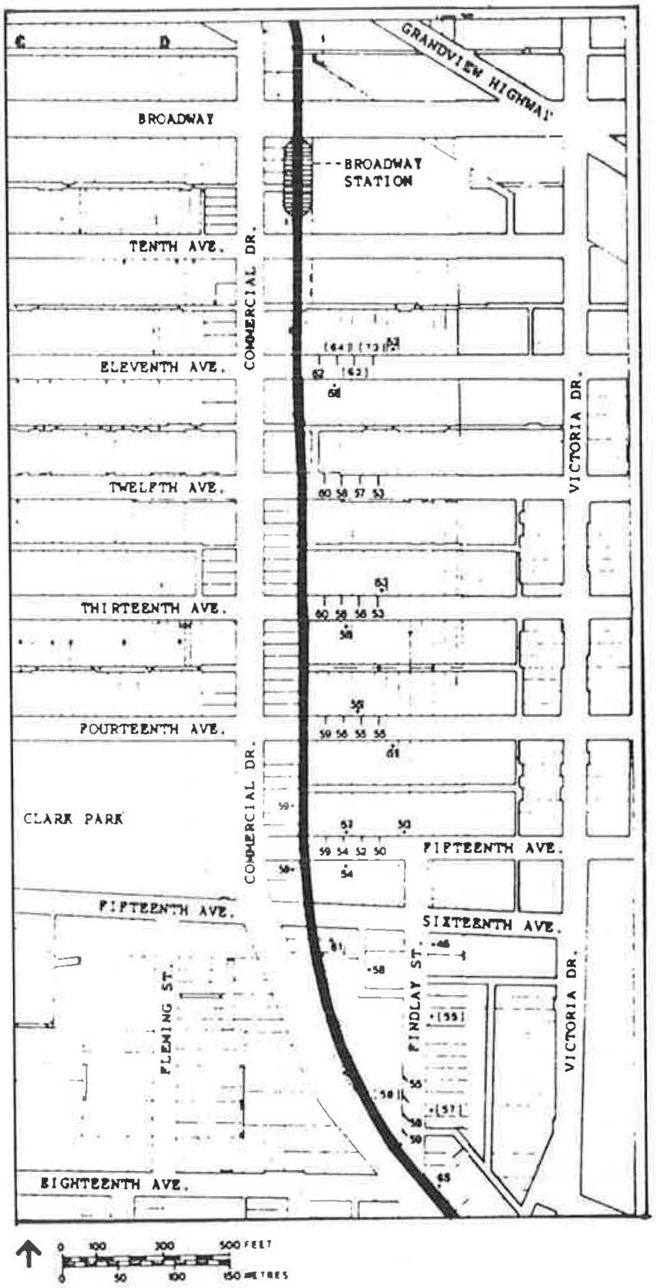
The distance from the guideway is divided into three segments, where the first segment is approximately less than two-thirds of the wheel track spacing, and the third segment is approximately more than two-thirds of the train length (*10*). This would divide the distance from the guideway at points of 26 ft and 92 ft. In the first and third segments, the noise represents a line source and in the middle segment, it resembles a point source (*10*).

The correlation and slope for the first segment is not computable because all the three points are at the same distance from the guideway. In the second segment, $r = -0.391$ with a significance of 0.02, and 15 percent of the variance is explained by the model ($r^2 = 0.152$). In the third segment, $r = -0.601$, with a significance of 0.0000, and 36 percent of the variance

TABLE 2 OUTDOOR 24-HOUR L_{eq} AT RESIDENTIAL SITES

	ALRT PASS-BY OUTDOOR dBA			BACKGROUND dBA		
SURVEY SITE	AVERAGE	PURE PASS-BY	24-HR L eq	SINGLE-EVENT	24-HOUR L eq	TOTAL 24-HOUR L eq
01	80.6	81	59	50.0	47	59
02	75.0	75	53	50.0	47	54
03	77.3	77	55	54.0	51	56
04	75.0	75	53	46.0	43	53
05	72.6	73	51	50.0	47	52
06	77.3	77	55	46.0	43	55
07	72.4	72	50	46.0	43	51
08	66.6	67	45	42.0	39	46
09	71.4	71	49	45.0	42	50
10	80.6	81	59	60.1	57	61
11	80.4	80	58	56.5	54	59
12	76.6	77	55	58.0	55	58
13	67.8	68	46	56.6	54	[55]
14	73.9	74	52	58.0	55	[57]
15	87.0	87	65	55.5	53	65
16	76.8	77	55	55.0	52	57
17	75.4	75	53	54.0	51	55
18	84.7	85	63	62.0	59	64
19	64.5	65	43	45.0	42	46
20	64.8	65	43	42.0	39	44
21	87.5	88	66	42.0	39	66
22	80.7	81	59	51.0	48	59
23	77.8	78	56	44.0	41	56
24	67.8	68	46	48.0	45	49
25	72.5	73	51	54.0	51	54
26	63.7	64	42	50.0	47	[48]
27	76.1	76	54	54.0	51	56
28	68.8	69	47	46.0	43	48
29	72.8	73	51	48.0	45	52
30	71.5	72	50	52.0	49	53
31	69.0	69	47	44.0	41	48
32	76.3	76	54	47.0	44	54
33	62.2	62	40	39.0	36	41
34	78.7	79	57	55.0	52	58
35	78.6	79	57	50.0	47	57
36	67.0	66	44	62.0	59	[59]
37	59.8	60	38	46.0	53	[44]
38	73.4	73	51	51.8	49	53
39	73.0	73	51	47.1	44	52
40	75.3	75	53	54.5	52	56

Source: Calculated from 1986 UBC Study
Note: Brackets [ ] indicate that the background noise level contributes more to the 24-hour L eq than the ALRT pass-by.



NOTE: 1. All noise levels are measured in dB(A). 2. Brackets indicate that background noise exceeds ALRT pass-by level. 3. *e* refers to noise measurements at residential sites.

FIGURE 3 Total 24-hr L_{eq}.

is explained ($r^2 = 0.361$). The null hypothesis of no difference between the two slopes (i.e., $B_1-B_2 = 0$) was tested. The 95 percent confidence interval was calculated as $0.904 < B_1-B_2 < 2.397$, resulting in rejection of the null hypothesis.

The study area is also divided into two sections: from the Broadway Station to Hull Street, and from Hull Street to the Nanaimo Station. For the former, there is a strong correlation ($r = -0.833, p <. 0001$), and over 69 percent of the observed variance is explained ($r^2 = 0.694$). For the latter, the correlation is significant ($r = -0.733$, $p < 0.0001$), but less of the observed variance is explained ($r^2 = 0.538$).

The adjusted 24-hr L_{eq} of 55 dB defines the zone of high impact (Figures 6 and 7). For calculating the adjusted 24-hr L_{eq} between the Broadway Station and Hull Street, no adjustment was made. The community had no prior experience with the noise, which justifies the addition of 5 dB to the L_{eq}; at the same time, this is a very noisy urban residential community which, under EPA criteria, would reduce the L_{eq} by 5 dB.

From Hull Street to the Nanaimo Station, 5 dB is added to the L_{eq}, because there was no prior exposure to the noise at that time; furthermore, it is an urban residential community not immediately adjacent to any arterial streets.

The nonparametric analysis of residents' perceptions shows that for the complete study area, as the ALRT noise increased, the residents tended to rate the neighborhood as noisy ($r = 0.3765$, Sig 0.002). Between these two variables, however, neither correlation was significant in the two zones. For the ALRT noise and the perceived extent of ALRT noise, none of the correlations was statistically significant. For the adjusted L_{eq} and ranking of ALRT noise with other sources, there is a pattern of ranking the ALRT as the first or second largest contributor to neighborhood noise, regardless of the adjusted 24-hr L_{eq}. This results in poor correlations for the study area as a whole, and in each zone of impact.

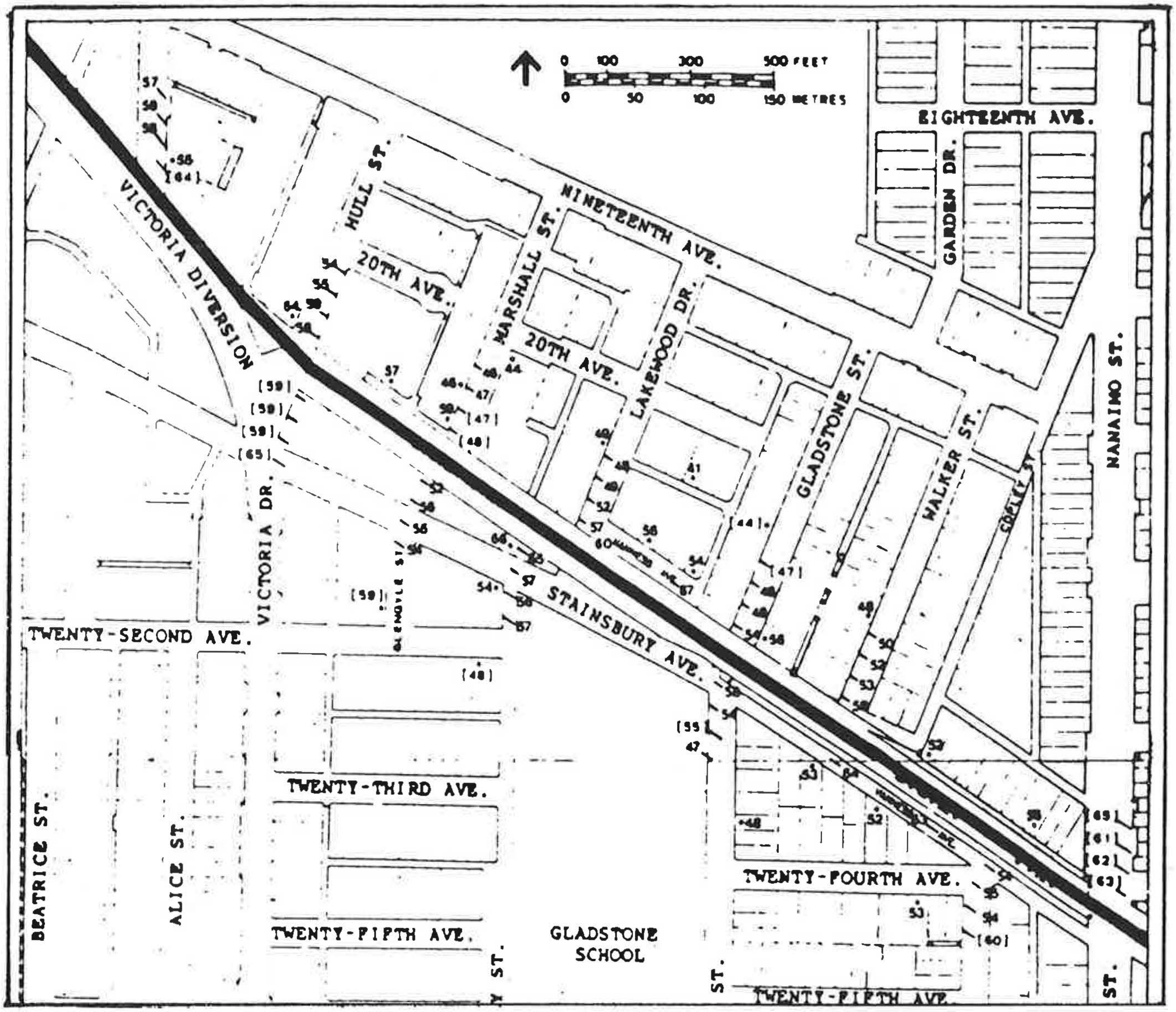
For the perceived extent of ALRT noise, in the zone of high impact, there is 1 case in 23 where the noise is heard only outside (58 dB), and 1 case where it is heard in only one room of the dwelling (56 dB). One case claimed that the noise was heard in more than one room at 71 dB. These three cases suggest a lack of emphasis on the impact. There are two cases at 55 dB where noise is claimed to affect sleeping patterns. Based on CMHC standards, these two cases suggest an exaggerated sensitivity on the part of the respondents. These responses are not consistent with measured noise impacts.

Of the 12 cases in the zone of low impact, 3 claim that the ALRT affects sleeping patterns at an L_{eq} of 50 dB, 51 dB, and 53 dB. One case at 51 dB, two cases at 53 dB and one case at 54 dB claim that the ALRT noise is heard everywhere in the residence. It appears that in this zone, these seven cases do not represent responses consistent with other studies. The location of these seven cases does not indicate that such a response is the result of a quiet location. Four of the seven cases are from the noisier area, between the Broadway Station and Hull Street.

For the analysis of the discrepancies between the two zones of impact, the variable "noisiness of the neighborhood" presents similar findings to those for the "perceived extent of ALRT noise." In the zone of high impact, the frequencies show that there are only 3 cases out of 23 where the noise impact is underrated by the respondent: at 57 dB there is one case claiming the neighborhood is "quiet," while at 58 dB and 61 dB, one case for each claims "some noises." The remainder of cases appear to be consistent with the measured noise impact based on CMHC standards.

In the zone of low impact, 5 cases out of 12 do not appear to be representative of the measured noise. At 46 dB and 49 dB, there is one case for each where the neighborhood is judged as "fairly noisy," and one case at 50 dB and two at 51 dB where the judgement is "noisy." These five cases may account for the poor Tau-b correlation in this zone.

The comparison between the two zones of impact indicates that there is a greater proportion of cases in the zone of low



NOTE: 1. All noise levels are measured in dB(A). 2. Brackets indicate that background noise exceeds ALRT pass-by level. 3. *e* refers to noise measurements at residential sites.

FIGURE 4 Total 24-hr L_{eq}.

impact where the perceptions are not representative of the adjusted 24-hr L_{eq}. The perceived noisiness of the neighborhood is a slightly more accurate indicator of the measured noise impact than the perceived extent of ALRT noise.

For the complete study area, those households with four or more occupants tend to claim that ALRT noise affects sleep. Also, those with four or more occupants and those having lived in the study area longer than 10 years rank the ALRT as one of the largest contributors of all sources. In the high-impact zone, those in single-family dwellings and those having resided in the area 2 years or more generally perceive that the ALRT noise affects sleep patterns. Those with four or more persons in the household tend to rank the ALRT as the greatest contributor. In the zone of low impact, those with a longer residency, at least 10 years, rank ALRT noise as the greatest contributor and evaluate the noisiness of the neighborhood as "noisy" or "very noisy."

The pre-ALRT perceptions measured in the 1984 East Vancouver Neighborhoods Study also reveal some variation between the two zones of impact. For the complete study area, 42.1 percent believed that the ALRT would have no effect on neighborhood noise levels, and 38.2 percent gave a negative outlook. In the zone of high impact, 48.5 percent were neutral, and 33.3 percent had a negative outlook. In the zone of low impact, 41.3 percent were neutral, 38.9 percent were negative, and 6.9 percent were positive in their outlook.

In the zone of high impact, there was no evident association between a negative outlook on the effect of the ALRT on

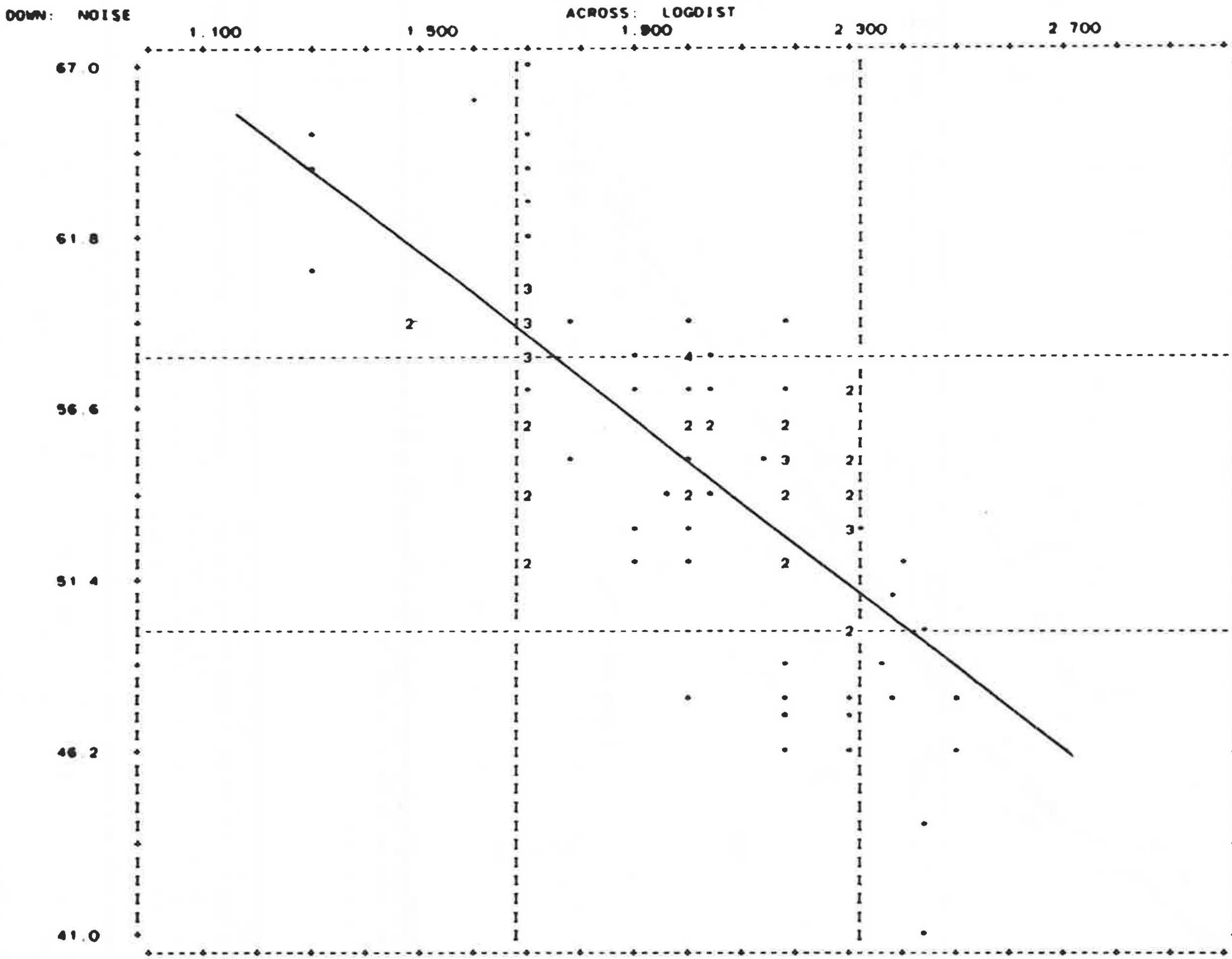


FIGURE 5 Scattergram: Noise (24-Hour L_{eq}) and log of distance.

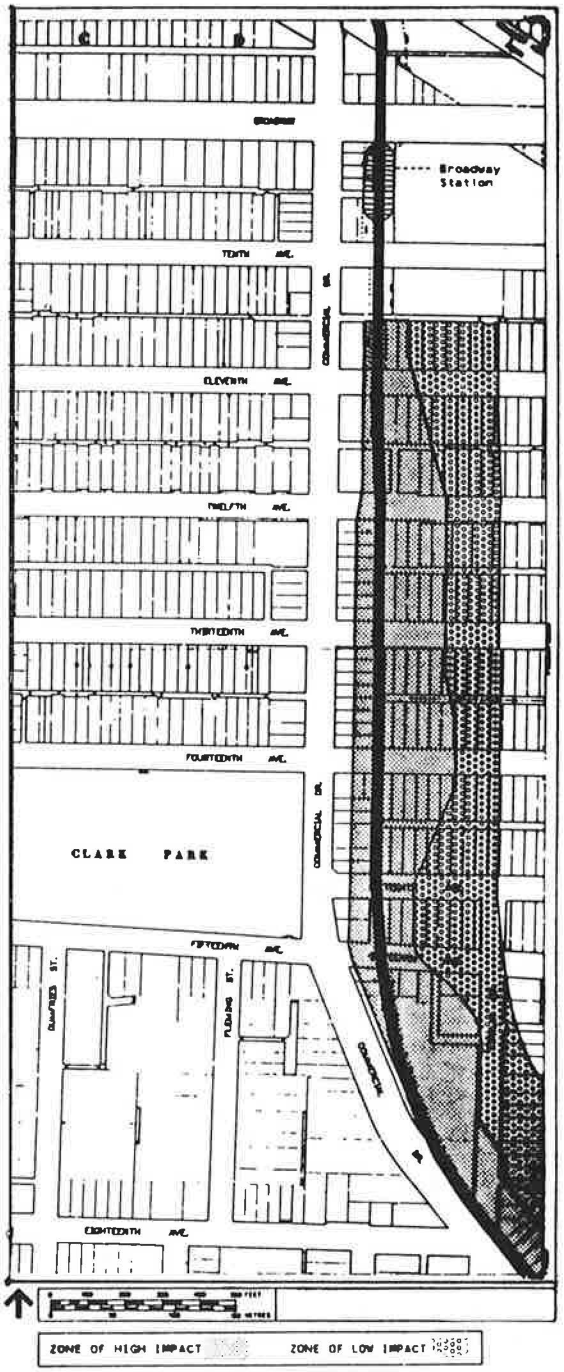


FIGURE 6 Zones of impact based on adjusted 24-hr L_{eq}.

neighborhood noise and one single factor liked or disliked in the neighborhood. In the zone of low impact, however, a negative attribute associated with a negative response to future ALRT noise was traffic noise (26 percent).

In the zone of low impact, those having a negative attitude toward the ALRT's effect on future neighborhood noise levels also had a negative outlook toward its effect on neighborhood character (0.2244, Sig .001). Furthermore, those anticipating higher noise levels noted a problem of noisy neighbours (0.1750, Sig .003).

For the complete study area, a neutral response tended to come from those frequently at home, such as homemakers, the retired and the unemployed, as well as from blue-collar workers. White-collar workers tended to have a negative response. A neutral response applied to age groups over 40 years, while a negative response was evident from the two youngest age groups, 16–29 and 30–40 years. In the zone of high impact, there was a tendency for those knowing more than five people on the block and those owning the residence to anticipate a negative effect from ALRT noise, while a neutral response was attributed to those not owning the residence. In the zone of low impact, those who have a white-collar job were more likely to anticipate higher noise levels, and those remaining at home tended to give a neutral response.

CONCLUSIONS

The research underlying this paper has been neither exhaustive nor covered all environmental factors. Nevertheless, the following conclusions can be drawn:

1. Vancouver's ALRT system produces noise levels that exceed the acceptable community environmental standards established by the CMHC (24-hr $L_{eq} > 55$ dBA).
2. In general, the ALRT noise levels decrease with distance from the ALRT guideway. The 24-hr L_{eq} decreases 15 dBA from 20 ft to 320 ft distance from the ALRT guideway.
3. Even though several factors influencing noise impact (guideway geometrics, housing structure differentials, socio-economic and demographic differentials of respondents) were not studied in detail, the analyses indicate that the relationship between ALRT noise and distance from the guideway in the study area is semilogarithmic. For this particular study, the relationship is:

$$\text{Noise} = 79.99 - 12.25 \log(\text{Distance in ft})$$

4. It is possible to define zones of high impact where the noise levels are expected to exceed community environmental standards.
5. Within the zones of high impact (24-hr $L_{eq} > 55$ dBA), the perceived noise levels are consistent with the measured noise levels.
6. Within the zones of low impact (24-hr $L_{eq} < 55$ dBA), the perceived noise levels are substantially higher than measured noise levels. This perception is more pronounced in larger households.

PLANNING IMPLICATIONS

Unlike the mandatory requirements in the United States regarding environmental impact statements, information dissemination and public participation, the transit authorities in British Columbia are not required to publish environmental impact statements. Furthermore, the B.C. Transit Act states that neither B.C. Transit nor the Province of British Columbia is legally obligated to compensate the residents, so long as their property was not acquired by expropriation or otherwise. In the case of Vancouver's ALRT, B.C. Transit decided that

TABLE 3 TOTAL 24-HOUR L_{eq} (DECIBELS)

STREET	DISTANCE FROM GUIDEWAY			
	50 FT. (15.5 M)	100 FT. (31.0 M)	150 FT. (46.5 M)	200 FT. (62.0 M)
E. 11th	62	[64]	[62]	[73]
E. 12th	60	58	57	53
E. 13th	60	58	56	53
E. 14th	59	56	55	55
E. 15th	59	54	52	50
FINDLAY	59	58	[58]	55
VICTORIA DR. N.	[64]	58	59	57
HULL	58	59	55	54
HULL-VICTORIA	[59]	[59]	[59]	[65]
MARSHALL	[48]	[47]	47	46
GLENGYLE	52	56	55	54
LAKEWOOD	57	52	49	48
SIDNEY	65	57	56	57
VANNESS East of Lakewood	60	--	--	--
VANNESS West of Gladstone	67	--	--	--
GLADSTONE N. of Guideway	54	48	48	[47]
GLADSTONE S. of Guideway	58	54	[55]	47
WALKER	58	53	52	50
VANNESS East of Gladstone	64	--	--	--
VANNESS West of Brant	63	--	--	--
BRANT	54	55	54	[60]
NANAIMO N. of Guideway	[63]	[62]	[61]	[65]

Source: Calculated from 1986 UBC Study
Note: Brackets [ ] indicate that background noise contributes more to the 24-hour L eq than the ALRT pass-by.

it will not acquire or expropriate any properties that are not within the right of way. Neither were any noise mitigation measures undertaken. Furthermore, "the B.C. Transit Act protects the government from claims of injurious affection arising from the transit systems" (*19*).

Some governmental agencies are recognizing the fact that negative environmental impacts have negative impacts on property values. The British Columbia Assessment Authority, which establishes the base values of real estate property for taxation purposes, decided in 1987 to reduce the property values within 300–600 feet of the elevated or at-grade guideway throughout the metropolitan area. These reductions ranged from 15 percent to 20 percent of the total value. The Ombudsman of British Columbia, appointed by the Legislature, is an independent guardian of the public trust. The ombudsman in a recent study of the negative environmental impacts of the ALRT has recommended that the government compensate affected property owners (*20*).

This research has established that there are zones of high impact adjacent to the ALRT guideway where noise levels exceed accepted community standards. Although further research is necessary to delineate clearly the extent of impact zones throughout the system area, proper mitigation measures appear to be warranted.

The extent of the high-impact zone depends upon geometrics, land use, community exposure to noise and the socioeconomic characteristics of the residents. In the low-impact zone where the noise perceptions are exaggerated, it is necessary to provide for an open transportation planning process in which citizens can learn, understand and appreciate the noise measurements and methods used.

These research findings can be used for forecasting the extent of the high-impact and low-impact noise zones. They must, of course, be modified by further research including a discriminant analysis of other geometric, operational, topographical factors and perception related variables. Successful

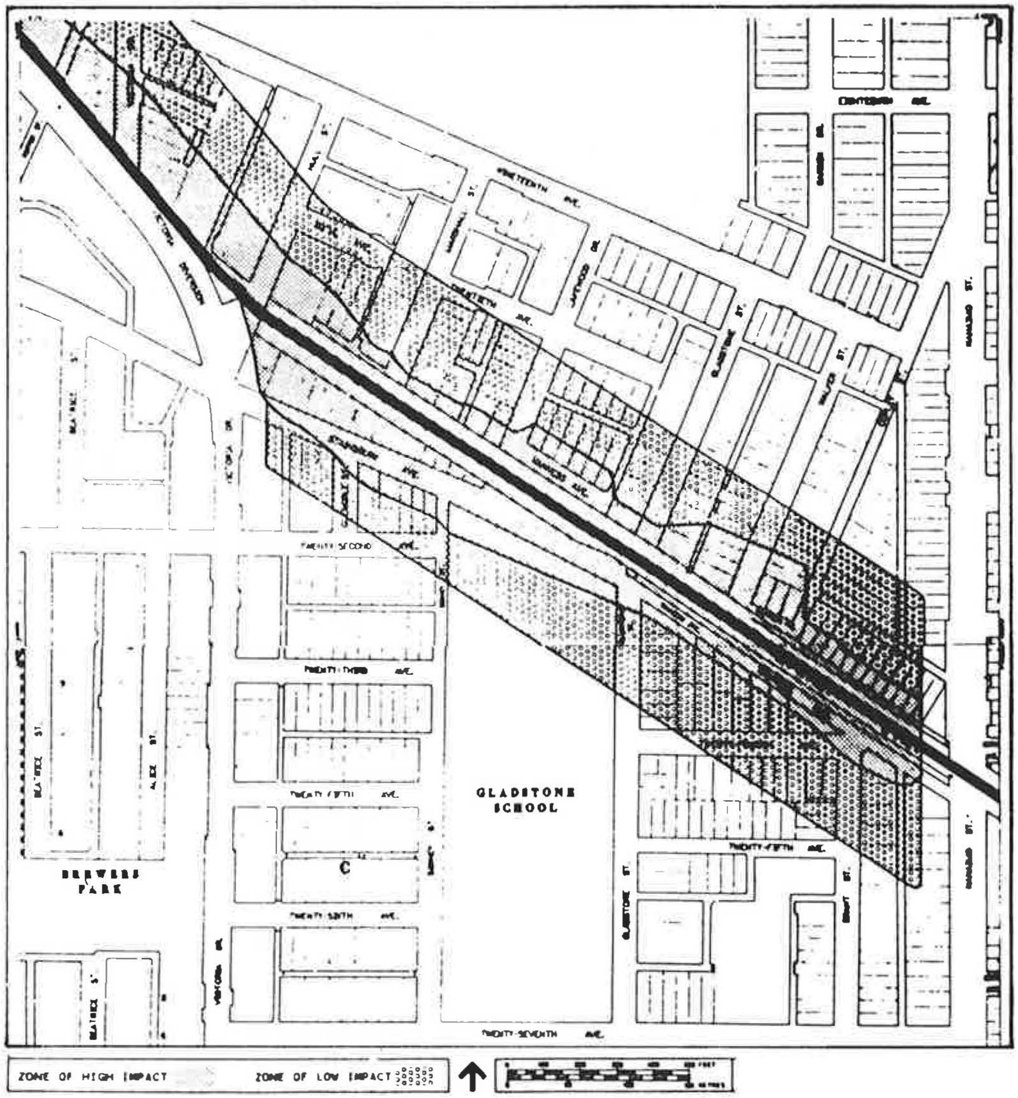


FIGURE 7 Zones of impact based on adjusted 24-hr L_{eq}.

transportation planning and implementation depend on the planner's understanding the citizens and their concerns, and respecting long-term environmental quality.

ACKNOWLEDGMENTS

Graduate students in urban transport planning at the University of British Columbia conducted the surveys and noise measurements in 1986; without their involvement this research would not have been undertaken. Assistance and valuable comments by Ken Barron of Barron and Associates, Nick Losito of the City of Vancouver, and Henry Hightower and Krishna Pendakur of the University of British Columbia are gratefully acknowledged.

REFERENCES

1. DeLeuw, Cather and Company. *Report on the Greater Vancouver Area Rapid Transit Study*. Greater Vancouver Regional District, Vancouver, B.C., Canada, 1978.
2. *Livable Region 1976–86*. Greater Vancouver Regional District, Vancouver, B.C., Canada, 1975.
3. *Rapid Transit Technical Report #1. Corridor Priorities*. Greater Vancouver Regional District, Vancouver, B.C., Canada, 1978.
4. Where's Rapid Transit Now? *Quarterly Review*, Vol. 8, No. 3, 1981, pp. 14–15.
5. S. Hasson. *Locational Conflict and Community Action: The Impact of Vancouver's ALRT System*. Center for Human Settlements, University of British Columbia, Vancouver, B.C., Canada, 1984.
6. *Road and Rail Noise: Effects on Housing*. Canada Mortgage and Housing Corporation, Ottawa, Canada, 1984.
7. *Community Noise*. U.S. Environmental Protection Agency, 1972.
8. D. N. May. Criteria and Limits for Wayside Noise from Trains. *Journal of Sound and Vibration*, 1976, pp. 537–550.
9. C. E. Hanson. Noise Characteristics of Alternative Urban Transit

Technologies. *Noise and Vibration Measurement: Prediction and Mitigation.* (W. A. Redl ed.). American Society of Civil Engineers, New York, N.Y., 1985.
10. D. A. Towers. *Noise Impact Inventory of Elevated Structures in U.S. Urban Rail Rapid Transit Systems.* U.S. Department of Transportation, Cambridge, Mass., Sept. 1980.
11. D. Appleyard. *Livable Streets.* University of California Press, Berkeley, Cal., 1981.
12. A. M. Voorhees and Associates. *Guidelines for Assessing the Environmental Impact of Public Mass Transportation Projects.* Notebooks 1–5. Office of Environment and Safety, U.S. Department of Transportation, 1979.
13. T. J. Schultz. *Community Noise Rating.* Applied Science Publishers, London, England, 1982.
14. J. Goldstein. Descriptors of Auditory Magnitude and Methods of Rating Community Noise. Special Technical Publication 692. *Community Noise.* American Society for Testing and Materials, Philadelphia, 1979.
15. J. M. Fields and J. G. Walker. Reactions to Railway Noise in Great Britain. *Inter-Noise* (W. W. Lang, ed.), Interpress, London, England, 1978.
16. H. K. Wakefield. *Noise Assessment of Vancouver ALRT Along the East Lane of Commercial Drive.* B.C. Transit, Vancouver, B.C., Canada, 1983.
17. *Impact Statement of ALRT Along the East Lane of Commercial Drive. Planning for the Community and Rapid Transit.* The City of Vancouver, Vancouver, B.C., Canada, Aug. 1983.
18. R. Coote and B. Thomson (eds.). *East Vancouver Neighborhoods Study.* The City of Vancouver, Vancouver, B.C., Canada, Sept. 1984.
19. Barron and Associates. *Background Noise Loads in the Broadway Station Area.* Unpublished mimeo. Ken Barron and Associates, Vancouver, B.C., Canada, 1987.
20. Ombudsman of British Columbia. *SkyTrain Report.* Public Report No. 8. Queen's Printer, Victoria, B.C., Canada, 1987.

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