# HIGHWAY NOISE AND PROPERTY VALUES

## *A Survey of Recent Evidence*

By Jon P. Nelson*

The concern of public officials over the environmental effects of highways is reflected in recent reports by the Organisation for Economic Co-Operation and Development (OECD, 1978, 1980), the U.S. Noise Control Act of 1972, and the U.S. Federal Aid Highway Act of 1972. The latter Act, for example, directs the Department of Transportation to develop and promulgate standards for highway noise levels compatible with different land uses. These standards are to include a thorough analysis and assessment of noise effects of federal highway projects. As a result, the Federal Highway Administration (FHWA) has sponsored several comprehensive studies of the effects of major interstate highways on residential property values. The Federal Aid Highway Act of 1973 authorises the FHWA to develop standards for the control of noise on previously constructed highways. Noise abatement projects are to be approved when abatement benefits outweigh the economic and environmental costs of the project (see "Procedures for Abatement of Highway Traffic Noise and Construction Noise", 41 *Federal Register* 16939, 23 April 1976).

This paper reviews the evidence on highway traffic noise and residential property values as a possible basis for benefit-cost analyses of noise abatement projects. Evidence is presented from nine empirical studies covering 14 different housing samples for Canada and the United States. The results are summarised in the form of a noise depreciation sensitivity index, which is the ratio of the price of quiet to the price of an average house and lot. The range of values for this index provides a means of evaluating the consistency of the studies and their results. In addition, evidence is reviewed on other possible disadvantages for real estate, such as extended time on the market for properties close to major highways.

We do not propose a definitive measure of total benefits from abatement of noise. Rather, we attempt to clarify the technique of benefit measurement that underlies studies of property values, and to survey the results systematically. With these objectives, the remainder of the paper is divided into five parts. First, we examine some of the more controversial assumptions that underlie the hedonic price model of property values. Second, some fundamentals of noise measurement are discussed as a prelude to specification of property value models. Third, we survey the empirical

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evidence from nine studies of property values as a basis for benefit-cost calculations. Fourth, we survey evidence from three highway studies that examine other possible adverse effects on real estate markets. The last part presents the main conclusions of the paper.

## ASSUMPTIONS OF THE HEDONIC PRICE MODEL

Highway noise, like other types of pollution, is a controversial and emotional issue, and there is a need for some degree of objectivity in dealing with it. The measure of environmental quality adopted here is the value placed on freedom from noise, or the implicit damage cost of noise, as revealed by residential property values. The fact that explicit market values for quiet are not recorded does not imply that people would not be willing to pay money (or expend time and effort) to obtain more quiet or to avoid increased exposure to noise. Even main highways have limited areas of exposure to noise. Thus, individuals should have an opportunity to vary their exposure to noise at the margin through their choice of a residential location. The total amount expended on quiet will vary, reflecting prices paid for comparable housing with different levels of noise exposure. That is, the premium paid for land and housing in a relatively peaceful neighbourhood measures the expenditure on quiet (price times quantity) for the households. Since future levels of quiet are uncertain and houses are durable goods, these premiums are expected discounted present values.

Suppose that housing prices initially did not reflect differential noise levels. Given that supplies of noisy and quiet land are relatively fixed, eventually people would attempt to purchase quiet housing (or alter their present houses) so as to avoid the deleterious effects of noise. Relocation would increase the demand for and price of quiet land, while simultaneously reducing the demand for and price of noisy land. A noise-price gradient for housing would develop, reflecting willingnesses to pay for land with lower levels of noise. Because noise from a highway will decrease by three to six decibels for each doubling of distance (Bolt Beranek and Newman, 1973, p. 9), the rental gradient will have a shape similar to that shown in Figure 1, all other things being the same. This gradient can be measured by hedonic price techniques.

Hedonic price models attempt to explain equilibrium willingness to pay in terms of a set of characteristics and attributes of the product.[1] The price a potential home buyer is willing to pay for real estate depends on location, attributes of the neighbourhood and community, local taxes, and locally provided services, as well as on physical characteristics of the structure and lot. Let

$$V = V(Q, Z) \tag{1}$$

represent the equilibrium relationship between price per house and characteristics, where $V$ is a vector of observations on housing prices, $Q$ a vector of neighbourhood environmental-quality characteristics, $Q_j$ the level of quiet, and $Z$ a vector

[1] See Freeman (1979a, 1979b), Nelson (1978a), Palmquist (1980) and Rosen (1974) for more extensive discussions of the hedonic price model. For critical evaluation of the model see, among others, Harris (1981), Maclennan (1977), Mäler (1977) and Pearce (1978).

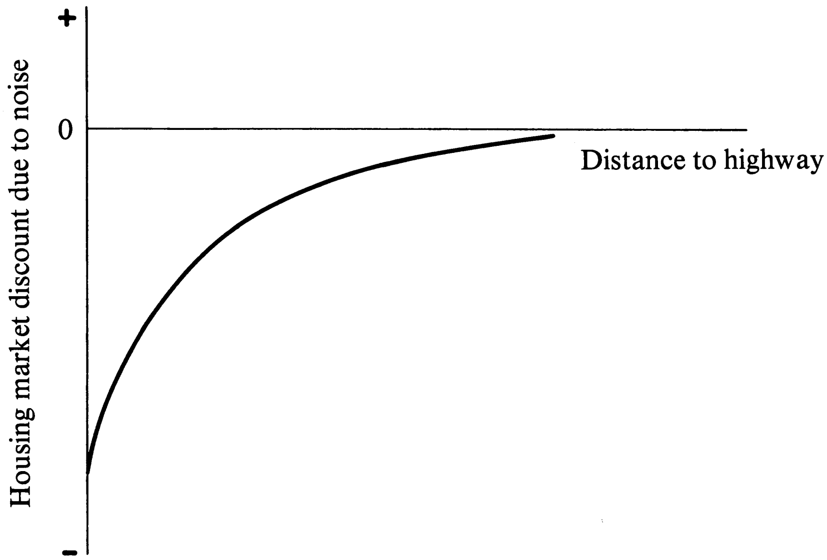


FIGURE 1

representing all other characteristics of housing. Then $\partial V/\partial Q_j$ is the marginal implicit price of quiet, or increase in expenditure on $V$ required to obtain a decibel reduction in the noise level, other things being equal. After equation (1) is estimated econometrically, $\partial V/\partial Q_j$ can then be evaluated at different values of $Q_j$ to produce an estimate of the price function facing buyers and sellers of real estate (Rosen, 1974, p. 44). This function is a locus of equilibrium willingnesses to pay, and individuals are assumed to locate themselves so that price differences between different "brands" of housing are equilising at the margin (i.e., hedonic prices represent compensating price differentials).

The assumptions that underlie the hedonic price model are the subject of some controversy. Three assumptions will be dealt with in this paper (see Pearce, 1978, p. 32).[2] First, residents are assumed to be "free to move" from one location to another to

[2] In addition, there is the important question of the underlying preference function of the consumers. This issue is especially critical if one attempts to estimate both a hedonic price function and the demand function for a characteristic (see Rosen, 1974). Mäler (1977, p. 359) notes that, unless all individuals are identical, the hedonic price function can be used to estimate aggregate marginal willingness to pay, but not total willingness to pay. Freeman (1979a, pp. 144–146) argues that total willingness to pay can be approximated using a hedonic price function, provided the data are ungrouped. All but one of the studies reviewed in the present paper used observations on individual houses. In addition, Freeman (1979b, pp. 166–167) concludes that it is necessary to assume similar preference structures in order to estimate demand functions, except for those variables which are controlled for in the demand function regression (e.g., income, family size, education, age). Nelson (1978b, pp. 365–366) notes that many taste variables are highly correlated with family income. None of the studies reviewed here attempts to estimate a demand function for residential quiet. Given this restriction, there is no claim that the empirical results reviewed are suitable under all conditions for estimation of noise abatement benefits.

increase their utility. Second, there must be sufficient variation in the environment for noise to be not a ubiquitous public bad, but a localised one. Third, it must be possible to measure noise in a quantitative fashion, and it must be possible to disentangle the effects of noise from the other determinants of housing prices.

**Freedom to move**

The degree of inter- and intra-urban mobility of the population is crucial to interpretation of the results from hedonic price models. Freedom of choice among alternatives does not, however, imply that choice itself is costless. Consider a change in the housing market that alters the relative rewards or "productivity" associated with various sites, such as a reduction in the noise level for some segment of the housing stock. Potential owners will bid up prices of relatively quiet houses in an attempt to capture the economic surplus associated with higher productivity, and will be willing to pay less for relatively noisy houses. With sufficient mobility, any differences in economic surpluses will be capitalised into the value of housing, so that the difference between prices for groups of homes reflects the amount people are willing to pay for different levels of quiet. However, the bidding process is not necessarily costless; this is shown by the existence of real estate agents, closing costs, advertising and other activities designed to disseminate information about bids and offers. But the costs of physical relocation of personal belongings, and psychic costs, would be incurred regardless of whether the location of the population was determined by market forces or by administrative fiat. Physical transfer and psychic costs fall logically under the heading of production costs, rather than exchange or transaction costs.

Are transactions costs in the housing market so large that residential mobility is constrained in a significant way and price differentials therefore understate the true social cost of noise?[3] Instantaneous adjustments are implausible, but an answer to this question depends partly on whether one adopts a short-run or long-run perspective, because it is always more costly to accomplish the same thing within a shorter time span (Alchian, 1977, p. 321). In general, the higher the costs of relocation, the less

[3] This issue has been debated theoretically in a number of papers, including Freeman (1979a, 1979b), Harris (1981), Maclennan (1977), Mäler (1977), and Mishan (1976). The basic point is that property value changes can be used as benefit measures only if all surpluses are eliminated. Transactions costs may prevent this, because households are assumed to relocate only to the extent that marginal gains exceed marginal costs, including various relocation costs. For example, Harris (1981, p. 37) concludes that "the housing market does not in general provide a good example of perfectly competitive equilibrium, and individuals are never free to move without constraint", while Maclennan (1977, p. 68) concludes that "imperfect information ... will generate an increased dispersion of prices for houses of identical quality". There are, of course, many biases that might be introduced by transactions costs, taxes, and other assorted market imperfections and constraints. For calculation of the extent of bias under various circumstances, see Freeman (1979a, pp. 133–137) and Harrison and Rubinfeld (1978). With regard to income level, it is sometimes argued that only the rich can "afford to move with comparative ease" (OECD, 1980, p. 40). Why there should be a strong correlation between ability to move and willingness to move is not made clear in the OECD report. It could be argued that the rich place a greater value on their time, and this increases costs of search and removal. The empirical evidence on income level and mobility is confused, and it may be that only positive income changes are a major determinant of increased mobility (Quigley and Weinberg, 1977, p. 54).

residential mobility one would expect to observe. For the United States, residential mobility is amply documented. Approximately 20% of all households change residence each year. Of these, two-thirds, or 13% of all households, move within the same metropolitan area. Fully 40% of U.S. households can be expected to relocate at least once within a four-year period (Quigley and Weinberg, 1977, pp. 43–46).[4] The empirical studies reviewed below use cross-sectional (i.e., long-run) data for highways constructed before the date of each study. Complete data are not available on highway opening dates, but most were constructed at least several years before the study date. This should allow sufficient time for the housing market to adjust to the disruptions associated with a new highway, as can be seen by examining evidence on mobility in areas subject to highway noise (see below).

**A localised pollutant**

The second objection to hedonic price studies is that noise must be a localised pollutant or public bad. There is little question that this condition will be met in the studies in question. First, noise is a continuous variable, and individuals can choose an optimal level of quiet at the margin. The range of noise levels in most of the empirical studies is about 25 decibels (55 to 80 decibels).

This point is not universally accepted. Mishan (1970, p. 229) argues there is an unavoidable asymmetry in the weighting of "imponderables"; that is, as noise increases over time, it is likely that differences in noise will diminish within a given area, resulting in a more or less ubiquitous level of noise. While I am unaware of any satisfactory time series data on this point, the following 1972 urban population distribution data are available from the U.S. Environmental Protection Agency (Nelson, 1978a, p. 185):

| *Noise Level (dBA)* | *Exposed Population ($10^6$)* | % |
|---|---|---|
| 55–59 | 36.3 | 36.7 |
| 60–64 | 36.0 | 36.4 |
| 65–69 | 18.4 | 18.6 |
| 70–74 | 6.1 | 6.0 |
| 75–79 | 1.7 | 1.7 |
| 80–84 | 0.4 | 0.4 |
| 85–90 | 0.1 | 0.1 |

It is generally agreed that above 75 decibels a significant fraction (close to one) of the exposed population will be "highly annoyed" by a given noise level. Hence, about 2.2% of the total exposed population is subject to "highly annoying" noise levels by this standard and these figures.

Second, the study areas used are for the most part quite small (see Appendix A). In general, this means that the demand schedule for quiet houses will be highly elastic, reflecting the abundance of alternatives available elsewhere (Walters, 1975, p. 48).

[4] For empirical evidence on the determinants of intra-urban mobility, see Goodman (1976), Seigel (1975), Speare, Goldstein and Frey (1975), and Weinberg (1979). For evidence on intermetropolitan stability of hedonic relationships see Butler (1980) and Nelson (1980, 1981).

**Measuring noise**

The third assumption dealing with measurement and specification of the empirical relationship will be discussed after a review of the principles and methods of traffic noise measurement.

## MEASUREMENT OF TRAFFIC NOISE

The empirical studies reviewed below employ a variety of traffic noise measures and model specifications. In order to interpret and evaluate the results, a brief review of some fundamentals of noise measurement is in order.[5] These fundamentals are applied in the next section to specification of relationships between property value and traffic noise.

All sound measurements are expressed in decibels (dB). Because the ear's pattern of response is more nearly logarithmic in nature, decibels are on a logarithmic rather than an arithmetic scale. A sound of 60 dB is thus ten times as intense as one of 50 dB, and so on. The human ear is sensitive to both the intensity of sounds and their frequency or pitch. Sensitivity is greatest in the middle range of frequencies, and weighting scales are available that selectively discriminate against sounds of very high and very low frequency. The most commonly used weighting scale is the A-scale, denoted by dBA. Also, the pyschological sensation of loudness roughly doubles with each 10 dB increase in the intensity level, other things being the same. Thus, there is a semi-logarithmic relationship between loudness of a noise and the measured level of sound intensity in decibels (Schultz, 1972, p. 19).

The subjetive annoyance produced by a stream of traffic on a highway or street is the result of the complex interaction of vehicle characteristics and mix, highway configuration, and time of day. The cumulative noise distribution resulting from these factors can be described as follows:

$L_{90}$—the background or residual noise level, the level in dBA that is exceeded 90% of the time;

$L_{50}$—the median or average noise level, the level in dBA that is exceeded 50% of the time;

$L_{10}$—the peak noise level, the level in dBA that is exceeded 10% of the time.

Daytime background noise levels for many residential neighbourhoods are in the 45–55 dBA range, with a 5 dB reduction at night time. A given noise is usually more annoying at night, partly because of the reduction in the reference noise level $L_{90}$. The traffic noise indexes described below, however, tend to be dominated by peak noises, reflecting the logarithmic nature of the decibel unit.[6]

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[5] For additional discussion, see Bolt Beranek and Newman (1973), Nelson (1978a), Schultz (1972), and US EPA (1974a).

[6] If two sounds, $L_1$ and $L_2$, are of unequal intensities, the overall level $L = 10 \log (10^{L_1/10} + 10^{L_2/10})$; e.g., if $L_1 = 60$ dB and $L_2 = 66$ dB, then $L = 67$ dB. If two sounds differ by 10 dB or more, the noise level will be about equal to the louder of the two sounds.

TABLE 1

*Description of Noise Indexes*

| *Noise Index* | *Description* | *Approximation*[a] |
|---|---|---|
| Energy mean sound level ($L_{eq}$) | Equal to the steady-state continuous sound level with the same energy content as the actual time-varying noise distribution. | $L_{10} - 3$ dB $\pm$ 2 dB |
| Day-night average sound level ($L_{dn}$) | $L_{eq}$ level during a 24-hour period with a 10 dB penalty for noises during the hours of 10 p.m. to 7 a.m. | $L_{eq} + 3$ dB |
| Noise-pollution level (NPL) | NPL equals $L_{eq}$ plus 2.56 times the standard deviation of the noise distribution. | $L_{eq} + (L_{10}–L_{90})$ |

[a] Assuming the distribution of roadside passby noise levels is normal and there is a steady stream of closely spaced passbys. Skewed distributions can result from truck traffic or unequal vehicular spacing.

A number of comprehensive indexes for traffic noise have been proposed, and each one attempts to capture in a single number the multivariate nature of highway-generated noise. Among the variables incorporated are components or correction factors for intensity, pitch, duration, variability, background noise, time of day, and frequency of occurrence. One simple means of describing the potential annoyance due to traffic noise is to calculate a measure of intrusiveness such as $L_{10}–L_{50}$ or $L_{10}–L_{90}$. Noises with large variations in level are generally considered more annoying, and there is evidence that people do judge intruding noise by reference to the existing background level (US Environmental Protection Agency, 1971, p. 96). An extension of this theme is the Traffic Noise Index (TNI), expressed as $(L_{10}–L_{90}) + 0.25\ L_{90}$.

Simple measures of intrusiveness discard information contained in the cumulative noise distribution. Three more comprehensive indexes are described in Table 1. In general, these measures attempt to account for the intensity and duration of all sounds occurring during a given time period (e.g., 24 hours), with possible correction factors for time of day and variability. For example, the noise pollution level (NPL) index implies that annoyance is determined by two factors, the sound level reaching the listener and the degree of variability of sound above background levels. Because the variability of sound tends to be greater during early morning hours, the NPL calculated for a 24-hour period indirectly includes a weighting factor for night-time noise (see Wesler, 1973, for instructive examples).

Because any index number selectively discards some information, there can be no single index that is best suited for all purposes. The NPL index is optimal under many circumstances, and it reduces to $L_{eq}$ if the variance is small. Thus Langdon (1976) concludes that, for freely flowing traffic, subjective annoyance is most highly correlated with $L_{10}$, $L_{eq}$, or the log of vehicle flow rate. But when traffic is disrupted, the NPL and TNI indexes yield superior correlations. Langdon's results suggest that in economic studies it might be preferable to break the NPL into components such as $L_{eq}$ and $L_{10}–L_{90}$. In this manner, one could determine whether intrusiveness is a separate variable from the mean noise level. To date, only the study by Allen (1980) provides extensive examination of several alternative noise measures as explanatory variables. He concludes that $L_{10}$ is preferable to $L_{eq}$, $L_{10}$–$L_{90}$, or TNI (Allen, 1980, p. 14). However, as a practical matter $L_{10}$ and $L_{eq}$ are usually highly correlated (US EPA, 1974b, p. 13). There is as yet no empirical study that gives careful consideration to the possible differences between $L_{eq}$, $L_{dn}$, and NPL.

## SURVEY OF STUDIES OF TRAFFIC NOISE AND PROPERTY VALUES

There have been at least eight studies of the relationship between traffic noise and property values that are consistent with, or rely explicitly on, the hedonic price model. These studies employ a cross-section or pooled cross-sections of residential property values along with information on characteristics of housing and one or more measures of exposure to traffic noise. One set of studies (Langley, 1976, 1980) applies time series analysis to changes in the value of houses (sale-repeat sale pairs) during the period 1962–78. Langley's results are based on the price index model suggested by Bailey, Muth and Nourse (B-M-N) (1963). In addition, Palmquist (1980, 1981) breaks new ground by combining and comparing hedonic and B-M-N models. Summaries of the nine studies are presented in Appendix A.

Three specification issues are dealt with here. First, there is the problem of selecting a homogeneous sample (study area and time period) within which there is sufficient co-variation between traffic noise levels and sale prices for real estate. Second, selecting an appropriate noise index and measuring traffic noise levels has posed various problems, including that of specifying a threshold below which there is no annoyance from traffic noise. Third, in order to derive an unbiased damage cost for noise, it is important to control for other adverse and beneficial effects of highways, such as air pollution and accessibility.

Traffic noise, especially that from highways bisecting suburban areas, is a localised form of pollution. That is, measured noise levels decline to background levels within roughly 1,000 feet of a highway (see Gamble *et al.*, 1974, for illustrative examples). Recognising this fact, most investigators use small residential areas as a basis for data collection, and then attempt to increase the sample size either by pooling several years of data (with adjustments for inflation) or by pooling data from several "comparable" residential areas. In general, too little attention has been given to the homogeneity of the resulting empirical relationships. For example, Allen (1980) pools three years of data for two Virginia suburbs near Washington, D.C. (sample size N = 206), Bailey (1977) pools nine years of data for North Springfield, Virginia (N = 90), and Hall *et al.* (1978) pool three years of data for two Toronto suburbs (N = 21). In the absence of more extensive statistical tests, the specific coefficient values may contain unknown biases due to inconsistent aggregation.

A related problem is the tendency for the samples to be dominated by sales of housing at or near background noise levels. This is a particular problem in the studies by Anderson and Wise (1977) and Gamble *et al.* (1974). For example, the former's sample of 25 housing sales for Bogota, New Jersey, has only five observations with noise levels that are above the background level (Anderson and Wise, 1977, p. 5–22). The coefficient of the noise variable is then being estimated with only four degrees of freedom. A similar problem arises in the study by Hall *et al.* (1978), where the sample is restricted to the first two or three rows of housing along the highways.

Two studies (Nelson, 1978c; Vaughan and Huckins, 1975) adopt a different approach to the sampling problem. They employ single cross-sections of housing data from the Washington, D.C., and Chicago urban areas, respectively, so that the results reflect all possible noise sources. However, problems then arise in measuring noise levels at widely dispersed sites as well as in controlling for many other factors that influence housing values in an urban area.

Given a representative sample of data, the next step is to select a noise index and specify the functional form. Two studies employ the NPL (Anderson and Wise, 1977; Gamble *et al.*, 1974); two employ $L_{eq}$ (Hall *et al.*, 1978; Vaughan and Huckins, 1975); two employ $L_{10}$ (Allen, 1980; Palmquist, 1980, 1981), and one employs $L_{dn}$ (Nelson, 1978a). Bailey (1977) employs the log of distance from the highway as a noise surrogate, while Langley (1976, 1980) divides properties into abutting, impact, and control zones. Most studies regress the noise index on the sales price of real estate or the log of the sales price, although several studies (Allen, 1980; Anderson and Wise, 1977; Palmquist, 1980; Vaughan and Huckins, 1975) report results for several functional forms.[7] In general, the best results are obtained by using a semi-log relationship between the dependent variable and the noise index.

The choice of functional form in studies of traffic noise and property values can be motivated by acoustical studies. Presumably, what matters in the residential environment is the loudness, or degree of subjective annoyance, associated with various noise levels.[8] The relationship between the relevant variables is semi-logarithmic:

$$A = c_0 e^{c_1 L} u_1 \qquad (2)$$

where $A$ is the subjective annoyance due to traffic noise, $L$ a noise index, $e$ the natural log base, and $u_1$ a stochastic error term. Suppose additionally that the hedonic price relationship is multiplicative:

$$V = b_0 Z^{b_1} A^{b_2} u_2$$

where $V$ is the property value, $Z$ a set of physical and locational characteristics, and $u_2$ an error term. Taking logs and substituting for $\ln A$, we obtain

$$\ln V = d_0 + d_1 \ln Z + d_2 L + u_3 \qquad (3)$$

where $d_2 = b_2 c_1$, etc. The implicit marginal damage cost is $\partial V/\partial L = d_z V$, which implies a damage cost that rises with the property value.[9]

[7] Anderson and Wise (1977, p. IV-3) argue that the housing structure is malleable (putty), while features of the land site are nonmalleable (clay). The resulting model is intrinsically nonlinear, but their econometric estimates were roughly comparable to those found with a log-linear model.

[8] Theoretically, loudness and annoyance are not equivalent if sounds differ in frequency or are impulsive or intermittent in nature. However, Schultz (1972, p. 32) notes that some empirical studies do not demonstrate that loudness and annoyance are independent attributes of a sound.

[9] This is not inconsistent with the view that environmental quality is a superior good. The price of a family's house is a good indicator of its level of permanent income.

Noise measurements have generally been obtained by field surveys (exceptions are Bailey, 1977; Langley, 1976; Nelson, 1978a). There are two problems associated with use of field data. First, these data cover only a short time period, ranging from a few days to only five minutes in one case. Too little is known about the representativeness of such data. Second, the field data are usually collected at the end of the study period and may not be representative of earlier years.[10] Distance measures, such as that used by Bailey, or dummy variables for noise levels are excellent alternatives to field surveys. Nelson uses data on population density and a US EPA study (1974b) to derive noise level estimates, thus avoiding the problem of field surveys. However, interpretation problems arise if the resulting indexes are correlated with other urban disamenities such as industrial noise, air pollution, congestion, and the like. This is also a problem with the field data.

Finally, there is likely to be some level below which traffic noise is no longer perceived as an intrusion in the residential environment. Although more extensive empirical tests would be desirable, most studies have selected 50–60 dBA as the ambient noise level, a level comparable to that of normal conservation.

The third specification problem is that of controlling for other influences that affect residential property values, including inflation and highway-related variables such as air pollution. Because of the relatively small size of most study areas, many locational and housing characteristics are effectively constant. However, two studies (Allen, 1980; Hall *et al.*, 1978) pool data from separate geographic areas without what would appear to be adequate tests for interurban differences in housing markets. In those studies using pooled cross-sections, deflating the dependent variable is probably sufficient if the time period is short. Studies covering longer periods (Bailey, 1977; Hall *et al.*, 1978; Palmquist, 1980) include a time trend, but if noise levels have risen over time some of the noise effect may be captured in the trend variable.[11]

Most studies include the noise index and a selection of housing characteristics as explanatory variables. The housing characteristics range from a few in some studies to over a dozen in the cases of Nelson (1978a), Palmquist (1980), and Vaughan and Huckins (1975). Several studies have also attempted to control for other environmental effects associated with highway traffic. Nelson includes variables for particulates and photochemical oxidant (smog) air pollution levels. High collinearity with the noise index was not a problem in his sample (Nelson, 1978a, pp. 95–96). Studies by Anderson and Wise (1977), Gamble *et al.* (1974), and Vaughan and Huckins (1975) include air pollution measures in the data sets, but final regressions omit these variables because of collinearity problems. Anderson and Wise include a dummy variable if the highway is visible from the house, but this variable is also collinear with NPL (Anderson and Wise, 1977, p. 5–17). In general, there is likely to be a downward bias in the regression coefficients for noise because of correlation with omitted variables for other highway disamenities. Some upward bias may also be

[10] For his Kingsgate sample, Palmquist (1980, p. 61) was able to obtain traffic count data for earlier time periods. He argues that the noise levels did not vary significantly for the period 1970 to 1976.

[11] Palmquist (1981) includes an interaction variable defined as the product of the time trend and the noise variable. Since the interaction variable was not statistically significant, he concludes that the assumption of a relatively constant noise level is justified for his North King County sample.

present if higher noise levels are associated with the omission of accessibility variables.[12]

The main findings of these studies can be summarised, with some adjustments, by means of a noise depreciation sensitivity index (Walters, 1975, pp. 102–105). For two residential properties that differ only in their level of exposure to noise, the absolute amount of housing depreciation per decibel (price of quiet) can be defined as

$$\mathrm{D} = \frac{\text{difference in total noise discount}}{\text{difference in noise exposure}} \tag{4}$$

Dividing D by the price of a basic house, the percentage rate of depreciation, or noise depreciation sensitivity index (NDSI), is defined as

$$\begin{aligned} \mathrm{NDSI} &= \frac{\mathrm{D}}{\text{property value}} \cdot 100 \\ &= \frac{\text{difference in total percentage depreciation}}{\text{difference in noise exposure}} \end{aligned} \tag{5}$$

Because the studies of traffic noise and property values cover different time periods, we assume that any differences in nominal price levels are fully accounted for when D is deflated in accordance with the average value of property in each study area.

Table 2 summarises the NDSIs for the nine studies. The unadjusted NDSIs are derived in the appendix. The adjusted NDSIs reflect the fact that the studies employ different noise measures and the estimates are adjusted to $L_{eq}$ using data contained in US EPA (1947b).[13] The range of adjusted NDSIs is 0.08 to 1.05% per decibel, with a weighted mean of about 0.4% per decibel. This means that a residence exposed to an $L_{eq}$ of 75 dB would sell for 8% less on average than the same house exposed to only 55 dB.

Three means and standard deviations are presented in Table 2. The simple mean based on seventeen estimates is 0.42, with a standard deviation of 0.26. As a practical matter, three estimates (Toronto, Washington, D.C., Spokane) lie outside the mean plus and minus one standard deviation. Excluding the highest and lowest values (1.05 and 0.08) yields a mean of 0.40, with a standard deviation of 0.20. Reducing the weight of Gamble's sample and of the North Springfield coefficients yields ten estimates. The weighted mean is 0.40, with a standard deviation of 0.23. Only one estimate (Washington, D.C.) lies outside the range 0.40 ± 0.23. The coefficient of variation is 0.58, which is twice the relative variability present in twelve estimates of the NDSI for aircraft noise (Nelson, 1980, p. 43). Given the diverse samples and measurement problems discussed above, this outcome is not too surprising. Whether or not the mean value is biased systematically can only be determined by additional careful studies of relationships between traffic noise and property values.

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[12] Most of the study areas are small enough that accessibility factors can be safely ignored; two exceptions are Nelson, and Vaughan and Huckins.

[13] These adjustments are approximate, based on the linear relationships estimated in US EPA (1974b).

TABLE 2

*Summary of Empirical Studies*

| *Study, Noise Index, and Area* | *Unadjusted* NDSI % | *Adjusted* NDSI – $L_{eq}$ % |
|---|---|---|
| Allen (1980)—$L_{10}$ | | |
| Northern Virginia | 0.15 | 0.15 |
| Tidewater | 0.14 | 0.14 |
| Anderson and Wise (1977)—NPL | | |
| North Springfield | 0.14 | 0.18 |
| Towson | 0.43 | 0.54 |
| Four areas | 0.25 | 0.31 |
| Bailey (1977) | | |
| North Springfield | 0.30 | 0.38 |
| Gamble *et al.* (1974)—NPL | | |
| North Springfield | 0.21 | 0.26 |
| Towson | 0.43 | 0.54 |
| Four areas | 0.26 | 0.32 |
| Hall *et al.* (1977)—$L_{eq}$ | | |
| Toronto suburbs | 1.05 | 1.05 |
| Langley (1976) | | |
| North Springfield | 0.32 | 0.40 |
| Langley (1980) | | |
| North Springfield | 0.40 | 0.50 |
| Nelson (1978)—$L_{dn}$ | | |
| Washington, D.C. | 0.87 | 0.88 |
| Palmquist (1980)—$L_{10}$ | | |
| Kingsgate | 0.48 | 0.48 |
| N. King County | 0.30 | 0.30 |
| Spokane | 0.08 | 0.08 |
| Vaughan and Huckins (1975)—$L_{eq}$ | | |
| Chicago | 0.65 | 0.65 |
| Average—all studies | — | 0.42 (0.26) |
| Average—excluding Spokane and Toronto | — | 0.40 (0.20) |
| Average—weighted[a] | — | 0.40 (0.23) |

[a] Includes an average of the NDSIs for Anderson and Wise (1977), and Gamble *et al.* (1974), and an average of the NDSIs for Bailey (1977), and Langley (1976); Spokane and Toronto are excluded. Standard deviations in parentheses.

## RESIDENTIAL MOBILITY AND HIGHWAY NOISE

Although the precise effect of highway noise on prices is still somewhat uncertain, the evidence establishes that there is some effect and suggests a mean value for the NDSI. It is possible that, in addition to the effect on price, proximity to a highway might increase the length of time real estate remains on the market. Increased time on the market would conflict with the mobility assumption of the hedonic price model. Whether or not there is such an effect has been examined in three studies, the results of which are summarised in Appendix B.

A theoretical model of selling time is developed by Palmquist (1980), who applies the work of Gordon and Hynes (1970) and others to optimal pricing of real estate. Palmquist shows that expected selling time for a house depends on the optimal expected price. If sellers of houses in close proximity to a highway are aware of the effect of noise, they will adjust their initial asking price accordingly, so the expected selling time should not vary with the noise level. However, if the variance of the distribution of potential offers increases as a result of highway noise, then the optimal selling time will rise (Palmquist, 1980, p. 140). Thus, selling time for houses close to the highway could be greater if noise levels influence the variance of potential offers, perhaps because of differences in noise tolerance among members of the population.

Palmquist presents several simple tests for the selling-time hypothesis. For example, he compares mean days on the market for two groups of houses, those close to the highway and those removed. The difference between the means (70 and 81 days, respectively) is not statistically significant. Similar results are obtained for reductions in the initial asking price, proportion of listings not sold, and terms of sale.

Testing a similar hypothesis, Anderson and Wise (1977) conclude that differences in vacancy rates in their study areas (a measure of the tightness of the housing markets) have no connection with the price depreciation caused by noise. The mean distances to the highway for sale properties and for a random sample of non-sale properties were also not statistically different. This suggests that turnover or frequency of sale is not affected by the noise level. Finally, Allen regresses days on market on the deflated sales price and the noise level. His results show that, for houses with identical sales prices, each additional 10 dBA adds about four days to the selling time. At most, houses abutting on highways would be on the market for two weeks more than houses with low noise exposures, other things being the same.

At present, there are too few studies of this issue to allow us to arrive at any firm conclusions. The three studies reviewed tentatively suggest that highway noise has no other adverse effects on real estate markets, or that it minimally increases the expected selling time. The evidence tends to support the mobility assumption of the hedonic price model.

## CONCLUSION

We have reviewed nine empirical studies covering fourteen different housing market samples for Canada and the United States. All the empirical studies conducted to date contain various shortcomings that may bias the results in generally unknown ways. The small number of empirical studies, repeated use of certain areas, and the inherent diversity and difficulties encountered lead to problems of variability and interpretation. However, the estimates are fairly consistent and they do have policy relevance. The weight of the evidence reviewed is consistent with the orthodox economic theory of land rents. The survey suggests noise discounts in the range 0.16 to 0.63% per decibel, with a mean of 0.40%. Noisy and quiet houses will differ by

20–25 decibels of noise exposure. Thus, a $40,000 house would sell for $36,000 to $36,800 if located adjacent to a major highway, or at a total discount of 8 to 10%. There is little point, however, in selecting one value as the measure of benefits from abatement of noise. Sensitivity analysis based on a range of estimates is preferable, and higher noise discount values should possibly be attributed to high income areas. Finally, the evidence reviewed suggests that highway noise does not lead to increased time on the market for real estate, and should not therefore reduce residential mobility.

# APPENDIX A

## Survey of Nine Property Value Studies

### Allen (1980)

*Areas studied:* The Northern Virgina sample includes residential areas contiguous to Interstate (I) Highway 495 near North Springfield and between I-66 and Telegraph Road in Alexandria. The Tidewater sample includes neighbourhoods contiguous to Denbigh Boulevard in Newport News and Great Neck Road in Virgina Beach, Virginia.

*Noise pollution measure:* Several alternative measures are used, including a dummy variable for the 70 dBA contour, $L_{10}$, $L_{10}$–$L_{90}$, $L_{eq}$, and the Traffic Noise Index. The best results are obtained using $L_{10}$ for peak traffic periods in the year 1979. The mean $L_{10}$ level in the Northern Virginia sample is 63 dBA; the Tidewater mean is 59 dBA.

*Type of data:* Individual housing sales prices for 1977–79 obtained from multiple listing sources, deflated to 1978, using housing price indexes for the urban areas in question. Sample sizes are 206 for Northern Virginia and 207 for Tidewater. The mean housing prices are $67,360 and $65,000, respectively. The dependent variable is the deflated sales price for each residence or its logarithm.

*Model characteristics:* Explanatory variables include square feet of floorspace, square feet of lot, no. of baths, no. of fireplaces, age of the house, and dummies for style, type of basement, and type of construction. The explanatory variables enter regressions in either linear or log forms.

*Main findings:* Allen (1980, pp. 14–17) concludes that a one-decibel increase in the $L_{10}$ level will reduce property values in the Northern Virginia sample by $94, if the linear functional form is used. The semi-log form has an NDSI of 0.15% per decibel. For the log-log form, the damage cost is $101 per decibel, evaluated at sample means. The damage cost for the Tidewater sample is $88 per decibel, although the estimate is statistically significant at only the 85% level. The $R^2$s are 0.71 and 0.69, respectively. NDSIs are 0.15 and 0.14% per decibel, respectively.

### Anderson and Wise (1977)

*Areas studied:* Four suburban residential areas near limited-access interstate highways: Bogota, New Jersey (I-80), Towson, Maryland (I-83 and I-695), Rosedale, Maryland (I-95), and North Springfield, Virginia (I-495). These areas are near New

York, Baltimore, and Washington, D.C. This study uses data collected by Gamble *et al.* (1974).

*Noise pollution measure:* The NPL index was calculated from traffic noise measurements (four days duration) taken during October–November 1971. Calculated NPL values range from ambient levels of 55 or 60 to a maximum of 80 dBA for properties located within 1,000 feet of the highways, except in Bogota where the ambient level was 70 dBA (the maximum was 77). The NPL or its logarithm are used in regressions.

*Type of data:* Individual housing sales data for 1969–71, deflated to 1970, using consumer price indexes for housing in the appropriate urban area. Sample sizes are 25, 50, 32, and 45, respectively. The dependent variable is log of the deflated sales price for each property. In addition, sales price data for 1965–71 were obtained by surveying residents in each study area. Sample sizes are 100, 137, 81, and 146, respectively.

*Model characteristics:* Explanatory variables include no of rooms, no. of bathrooms, age of house, dummy for design, dummy if highway is visible from house, and no. of years survey respondents had lived in the house in 1972. Most regressions use logs of the explanatory variables as regressors.

*Main findings:* Anderson and Wise (1977, pp. 5-22 and 5-23) conclude that damage costs for North Springfield and Towson are $42 and $129 per decibel, respectively, for a $30,000 house. For Bogota and Rosedale study areas, variation in log of NPL is so small that reliable estimates could not be obtained. When data from the four areas are pooled, each decibel increase in NPL reduces the value of a $30,000 property by $75 (p. 6-1). The corrected $R^2$ is 0.65 for the pooled regression, and 0.59 and 0.51 for North Springfield and Towson, respectively. The NDSIs are 0.14, 0.43, and 0.25% per decibel for North Springfield, Towson, and the pooled sample, respectively.

**Bailey (1977)**

*Area studied:* North Springfield, Virginia (I-495), a residential area near Washington, D.C.

*Noise pollution measure:* No explicit noise pollution measure is used; the regressor is the natural log of distance from highway up to 1,000 feet. (Noise levels are linear in the log of distance from a major point source.) This implies a noise level ranging from about 55 to 80 on the NPL scale (see Gamble *et al.*, 1974).

*Type of data:* Individual housing sales for 1968–76, obtained from a multiple-listing sources. Sample size of 90 observations. Dependent variable is the log of sales price.

*Model characteristics:* Because of the homogeneity of the North Springfield subdivision, explanatory variables are limited to dummies for house design, sales after 1973 (reflecting a sewer extension moratorium), financing by the Veteran's Administration, and a monthly time trend.

*Main findings:* Bailey (1977, p. 3) concludes that a house located 1,000 feet or more from the highway sold for 7.5% more than did the same house abutting on the highway. This implies that each decibel above 55 dB will reduce housing prices by 0.3%. The regression $R^2$ is 0.89 and the NDSI is 0.3% per decibel.

**Gamble *et al.* (1974)**

*Areas studied:* Four suburban residential areas near limited-access interstate highways: Bogota, New Jersey (I-80), Towson, Maryland (I-83 and I-695), Rosedale, Maryland (I -95), and North Springfield, Virginia (I-495). These areas are near New York, Baltimore, and Washington, D.C.

*Noise pollution measure:* The NPL index was calculated from traffic noise measurements (four-day duration) taken during October–November 1971. NPL values range from ambient levels of 55 or 60 to a maximum of 80 dBA for properties located within 1,000 feet of the highway, except in Bogota where the ambient level was 70 dBA (the maximum was 77).

*Type of data:* Individual housing sales for 1969–71, deflated to the second quarter of 1970 by the U.S. residential structures price index. Sample sizes are 32, 54, 39, and 75, respectively. Mean property values are $29,100, $33,100, $25,100, and $33,600, respectively. The overall sample mean is $31,100. The dependent variable is the deflated sales price for each property.

*Model characteristics:* Explanatory variables include no. of floors, no. of rooms, no. of bathrooms, age of house, and dummy variables for central air conditioning, corner lot, exterior construction, design, and finished basement. Air pollution variables are excluded because of high correlation with NPL. All explanatory variables are in linear form, but only a few are significant in the regressions for individual areas.

*Main findings:* Gamble *et al.* (1974, p. 6-11) conclude that the damage cost per decibel is $646 for Bogota, $141 for Towson, $60 for Rosedale, $69 for North Springfield, and $82 for the overall sample. The noise coefficients for North Springfield and Rosedale are not significant at conventional levels. Individual area regression $R^2$s range from 0.48 to 0.78, while the overall regression has an $R^2$ of 0.60. The NDSIs are 0.43, 0.21, and 0.26% per decibel for Towson, North Springfield, and overall sample, respectively (see Anderson and Wise, 1977, for comparisons).

**Hall *et al.* (1978)**

*Areas studied:* Housing in parallel rows adjacent to major highways near Mississauga, Burlington, and Ancaster, Ontario. There are six study areas, but a significant effect of noise is reported for only a pooled sample consisting of two areas near Mississauga and Burlington.

*Noise pollution measure:* The $L_{eq}$ index is computed from traffic noise data for a 24-hour weekday period. The difference in $L_{eq}$ for the first two rows of houses is 14 dBA for a Mississauga site (76 and 62 dBA) and 10 dBA for a Burlington site (73 and 63 dBA). Hall *et al.* (1977, p. 42) argue that the "noise level does not appear to affect housing prices significantly when the daytime $L_{eq}$ is below 70 dBA even where a 10-dBA difference exists between rows of housing".

*Type of data:* Individual housing sales data obtained from multiple listing sources for the period 1975 to June 1977. The data for two study areas are pooled, but because of missing observations the final sample size is only 21. No breakdown is given of observations between first and second rows of housing. The mean sales price is about $62,500. The dependent variable is the difference between the selling price of a house and mean selling price for all houses at that site (Mississauga or Burlington).

*Model characteristics:* Explanatory variables include no. of rooms, no. of bathrooms, garage size, a dummy for swimming pools, and an annual time trend. All variables are in linear form.

*Main findings:* Hall *et al.* (1978, p. 43) argue that the damage cost is $650 per decibel for the two-site pooled sample. At the remaining four sites the coefficient on the $L_{eq}$ variable is not statistically significant. The $R^2$ for the two-site regression is 0.94. The implied NDSI is 1.05% per decibel.

**Langley (1976, 1980)**

*Area studied:* North Springfield, Virginia (I-495), a residential area near Washington, D.C.

*Noise pollution measure:* The study area was divided into three zones: an impact zone consisting of all properties within 1,125 feet of the highway, an abutting zone consisting of all properties abutting on the highway, and a control zone that includes all other properties in the study area. There are 620 properties in the impact zone, 99 abutting properties, and 957 control zone properties.

*Type of data:* All valid property sales for the period 1962 to 1972, deflated to 1962 by the U.S. residential structures price index. The mean property value is $23,543. There were 1,966 property sale-resale pairs of values available for analysis. The price index model suggested by Bailey, Muth and Nourse (1963) is used to compute appreciation rates for the three zones.

*Model characteristics:* The price index for each year and zone is computed by regressing the logarithm of price relatives for sale-resale pairs on a transitional matrix, the entries of which are $-1$ in the $t$th column indicating the initial sale, $+1$ in the $t+n$th column indicating a resale and zero in each of the other $t = 1, \ldots, T$ columns. No other housing characteristics are included.

*Main findings:* Langley (1976, p. 63) concludes that impact zone properties sold for an average of $1,026 less in 1971 and $1,619 less in 1972 than did control zone properties. Differences between abutting and control zone properties were $1,650 in 1970 and $1,652 in 1972. The regression $R^2$s are 0.36, 0.30, and 0.45 for abutters, impact, and control zones. For 1970–72, the mean property value was $26,175 in 1968 dollars. Assuming abutting and control zones have noise levels that differ by 20 dB, the NDSI is 0.32% per decibel. In an update of his earlier work for the period 1962–78, Langley (1980, p. 10) found that properties in proximity to the highway sold for $3,000–$3,500 less than equivalent properties located further from the highway (1959 dollars). Relative to the end-of-period mean sales price for abutting properties ($29,830), this implies an NDSI of about 0.40% per decibel, using Gamble *et al.* (1974) noise levels.

**Nelson (1978a)**

*Area studied:* Washington, D.C., urban and suburban areas.

*Noise pollution measure:* The $L_{dn}$ measure is computed for each of 456 census tracts, using population density data and data obtained from U.S. Environmental Protection Agency (1974b). The mean $L_{dn}$ is 58.5 dB, with a standard deviation of 5.5 dB. The minimum $L_{dn}$ is 39 and the maximum is 70.

*Type of data:* Census tract median property values, owner estimates for April 1970. The mean property value is about $28,000. Sample sizes are 456 ($L_{dn} \geq 39$) and 420 ($L_{dn} \geq 50$). The dependent variable is log of the median property for each census tract.

*Model characteristics:* Explanatory variables include no. of rooms, lot area in square feet, age of house, plumbing facilities, central air conditioning, racial mix, dummy for riverside locations, accessibility index, land use in industrial and commercial categories, oxidant air pollution, and particulate air pollution. All variables are in logs, except dummies and $L_{dn}$.

*Main findings:* Nelson (1978a, p. 95) concludes that NDSIs are 0.60% ($L_{dn} \geq 39$) and 0.87% per decibel ($L_{dn} \geq 50$). The $R^2$ is 0.89.

**Palmquist (1980, 1981)**

*Areas studied:* The study includes the suburban communities of Kingsgate (I-405) and North King County (I-5) near Seattle, and an urban area just inside the east city limits of Spokane, Washington (I-90).

*Noise pollution measure:* The basic noise measure is $L_{10}$, but some results are reported for a variety of related measures, including linear distance from the highway. The $L_{10}$ level is obtained by monitoring traffic noise levels at 30, 57, and 41 locations, respectively, during 1976–1978. The readings were taken during peak traffic hours and were used to construct noise contours in 2.5 decibel increments. For Kingsgate, the range is 55–70 dBA. For North King County, the range is 55–75, with a mean of about 60 dBA. For Spokane, the range is 55–80, with a mean of about 65 dBA.

*Type of data:* All valid individual housing sales for the period 1962 to 1976 for Kingsgate, 1958 to 1976 for North King County, and 1950 to 1978 for Spokane. Dummy variables are used to capture inflationary effects in the study areas. Total sample sizes are 4,785, 2,823, and 745, respectively, including sales made both before and after opening of the highways. The highway opening dates are 1970, 1965, and 1959. Sample sizes after the openings are 1,574, 436, and 243, respectively. The mean property values for the total samples in 1976 dollars are $39,244, $29,834, and $14,617, respectively. Several functional forms were tried, and a semi-log form provided the best results (Palmquist, 1980, p. 69).

*Model characteristics:* Palmquist's work is a synthesis of the hedonic price model and a price index model suggested by Bailey, Muth and Nourse (1963). The hedonic regressions incorporate a number of structural and locational features of each area. For example, the Kingsgate regressions include variables for square feet of finished living space, square feet of lot area, square feet of attic area, square feet of basement area, square feet of garage area, no. of bathrooms, no. of built-in appliances, age of house, distance to nearest park, and dummies for fireplaces, trees, and membership in recreational associations. Regressions for other areas include variables for detached garages, underground utilities, type of heating, type of floor, and a quality rating measure. The information on building and neighbourhood characteristics is used to generate a quality-adjusted price index. This index is then compared with an index for an area which had been unaffected by highway changes.

Palmquist (1981) estimates the Bailey, Muth and Nourse model with adjustments for depreciation and highway noise effects. He concludes that the results are very similar to the estimates provided by hedonic regressions for the same area.

*Main findings:* Palmquist (1980, p. 230) reports damage costs in terms of the percentage reduction in average house price for each 2.5 dBA increase in noise levels above ambient (55 dBA). These percentages are 1.20, 0.75, and 0.20, respectively. The regression $R^2$s are 0.90, 0.86, and 0.68. NDSIs are 0.48, 0.30, and 0.08% per decibel, respectively. Palmquist (1980, p. 214) concludes that area differences are due to differences in the income levels of residents.

### Vaughan and Huckins (1975)

*Area studied:* Chicago urban and suburban areas.

*Noise pollution measure:* Two indexes, $L_{eq}$ and a sound pressure approximation to $L_{eq}$, are calculated from sound measurements (5 minutes duration) for 233 sites. The range is 46 to 70, with a mean of 54 dB.

*Type of data:* Individual housing sales for the period March 1971 to June 1972, obtained from a real estate appraisers' association. The mean property value is $22,550. The dependent variable is the sales price or its logarithm.

*Model characteristics:* Explanatory variables include square feet of living space, no. of garages, lot width, age of dwelling, and dummies for exterior construction and interior design, distance to the CBD, distance to Lake Michigan, total lots on the block (a crowding measure), no. of visible broken windows (a blight measure), available recreation land, and air pollution levels (a composite of sulfates and particulates). All explanatory variables are in linear form.

*Main findings:* Vaughan and Huckins (1975, p. 21) conclude that the best results are achieved with an ambient noise level of 50 dBA. Damage costs per decibel for the linear model range from $135 to $177, with a best estimate of $140. Damage costs for the semi-log model range from 0.41 to 0.80% per decibel, with a best estimate of 0.65%. The $R^2$ is about 0.55 for the semi-log model, and the NDSI is 0.65% per decibel.

## APPENDIX B

### Survey of Three Selling Time Studies

### Allen (1980)

*Areas studied:* The Northern Virginia sample includes residential areas contiguous to I-495 near North Springfield and between I-66 and Telegraph Road in Alexandria.

*Type of data:* Data were collected on number of days on market for 206 housing sales for the period 1977–79. The data source is a multiple listing agency.

*Tests conducted:* Linear regressions were estimated with days on market as the dependent variable. The regressors are deflated sales price and the noise level. The results show that, for houses with identical sales prices, those lying within the 70 dBA noise contour were on the market 11 days longer. Coefficient estimates for other noise measures show that each 10 dBA difference adds about 4 days to average selling time (Allen, 1980, p. 17).

### Anderson and Wise (1977)

*Areas studied:* Four suburban residential areas near limited-access interstate highways: Bogota, New Jersey (I-80), Towson, Maryland (I-83 and I-695), Rosedale, Maryland (I-95), and North Springfield, Virginia (I-495).

*Type of data:* Data obtained on mean distance to the highway and vacancy rates. The distance data are for 1969–71 and were obtained from various public sources. The vacancy data are for 1970 and were obtained from census sources.

*Tests conducted:* The mean distances to the highway for sale properties and for a random sample of non-sale properties were not statistically different. The vacancy rates for the four areas differ substantially, but there is no evidence that houses with high noise levels are discounted less heavily in the markets with the lower vacancy rates (Anderson and Wise, 1977, p. V-50).

### Palmquist (1980)

*Area studied:* Kingsgate (I-405), a residential area near Seattle, Washington.

*Type of data:* Data were collected on the initial listing price, selling price, number of days on the market, terms of sale, end date of the listing, and status of the property (sold, withdrawn, inactive, expired). There were 1,170 cases, of which 64 were houses within 600 feet of the highway. The data source was a multiple-listing agency. The time period is 1974 to June 1976.

*Tests conducted:* Properties sold close to the highway averaged 70 days on the market, while those removed from the highway averaged about 81 days. The different is not statistically significant. Properties not sold averaged 75 and 96 days on the market, respectively. The difference is not statistically significant. The mean reduction in the final selling price from the initial asking price was not statistically different for the two areas. Similar results were reached by correlation coefficients. The proportion of listings that were not sold was not statistically different for the two areas. The terms of sale were not statistically different for the two areas. Palmquist (1980, p. 182) concludes that reductions in housing prices appear to be the only adverse effect of highways.

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