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SUBJECTIVE RATING OF THE SOUND INSULATION OF PARTY WALLS

(A Pilot Study)

by

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I. INTRODUCTION

For many years the Division of Building Research has studied noise-related problems in buildings and the propagation of this noise through walls. The results of this work provide guidance to the construction industry and to government agencies such as Canada Mortgage and Housing, and are a major source of input to the National Building Code.

Our overall understanding of the physical acoustical aspects of sound isolation between dwellings has gradually improved. For about 20 years the sound insulating properties of party walls have been measured in terms of their sound transmission class (STC), and the National Building Code[1] now specifies that party walls should achieve a minimum sound insulation of STC 45.

Unfortunately, very little progress has been made concerning the human side of the problem. The lack of extensive studies and data on human reactions to various levels of party-wall sound insulation has made it difficult to verify the accuracy of STC in predicting such adverse reactions. For the same reason, it has not been possible to determine a satisfactory minimum value of party-wall sound insulation, or to understand the interaction of the many factors that influence the reaction of residents to noises caused by their neighbours. Since sound insulation of party walls is solely for the benefit of people, it is imperative that researchers improve their understanding of how people in multi-residence buildings react to noises from their neighbours.

A number of field surveys on the annoyance caused by various environmental noises such as road traffic noise have been carried out.[2] More recent studies using improved experimental techniques have found quite strong correlations between individual responses and acoustical measurements of traffic noise levels.[3-6] It was not clear however, whether the methods used in the traffic noise surveys were suitable for a survey concerning party-wall sound insulation, since comparable previous studies were not available. (Data from two very recent unpublished studies have been obtained and are discussed later in this report.) For example, it was not known whether annoyance-type responses could be related to physical measures of sound insulation in a statistically significant manner, or whether the situation would be confused by other intervening variables. This note describes the pilot study undertaken to test the suitability of one proposed experimental approach.

To make the physical measurements as complete as possible, it was decided to include both detailed 1/3 octave band measurements of sound insulation as well as at least one complete 24-hour record of background noise levels in each home. The physical measurements were to be carried out after the related interviews were completed. As in previous traffic noise surveys, the initial approach to each subject was designed to obtain the maximum cooperation, without possibly biasing responses by informing the subjects before the completion of the interview of the exact purpose of the study. The subjective responses were to be obtained with a structured questionnaire administered by a trained interviewer in each person's home. Results were obtained from pairs of adjacent homes. In all, the responses of 98 subjects were included in the analyses, together with measurements of the background noise levels in the 98 homes and the sound insulation of the 49 common walls.

For practical reasons, it was possible to consider only one neighbour of each subject, to measure only one common wall, and to measure background levels at only one point during only one day. As there was no previous information to indicate whether disturbance due to neighbours' noises was related to some properties of the wall, to noise levels in each home, or to a combination of these quantities, the procedure used should ideally have allowed the consideration of all possible variations. Unfortunately, it was not practical to make more extensive measurements, due to the extra research effort required, and to the difficulty of finding large numbers of subjects willing to permit such disruption of their homes.

II. SURVEY PROCEDURE

1. General

Since this was only a pilot study, it was limited to 100 subjects. To ensure that such a small sample would allow a reliable evaluation of the proposed techniques, it was essential to include the widest possible range of sound insulation values. To simplify administrative problems, only residents living in condominiums were approached. A local condominium management company assisted by suggesting sites that might have superior, average or inferior quality sound insulation. Subjects were selected randomly in pairs from 11 different sites. Generally, 10 subjects (5 pairs of adjacent dwellings) were interviewed at each site, but there were as few as 6 and as many as 12 interviews at some sites.

Subjects were first contacted by means of an introductory letter stating that they would be visited by an interviewer from the Division of Building Research at the National Research Council who was carrying out a "Building Satisfaction Survey". The interviews were carried out using a structured questionnaire that is described in the following section. Following a successful interview, the interviewer asked if the subject would permit sound insulation and background noise measurements to be made. If one of the adjacent neighbours was also successfully interviewed and also agreed to permit noise and sound insulation to be measured, then one complete pair of interviews from adjacent residences was obtained and sound insulation measurements were made within a month after the interviews.

The first interview of each pair was selected randomly from site plans. The person answering the door, if 18 years or older, was asked to answer the questionnaire. Interviews were carried out both in the daytime and the evening to ensure a reasonable balance between male and female respondents. Of the subjects, 84% lived in two-storey row housing, while the remainder lived in apartment blocks. This uneven spread between row housing and apartments was deliberate since the acoustically simpler case of row housing was expected to produce significant problems, while the more complex situation in apartment blocks was not considered suitable for an initial pilot survey. A few apartment condominium residents were included, however, to give some indication of the possible problems in that type of building.

In all, 120 successful interviews were obtained which resulted in 98 subjects for the final analyses. Of the other interviews, 20 were unmatched interviews; that is, a successful interview with an adjacent neighbour could not obtained. The 2 remaining interviews could not be used because one subject eventually withdrew permission for the sound insulation measurements. During the interviewing stage, 27 subjects declined to be interviewed and a further 6 subjects did not meet the requirements for subjects. If one considers the 27 refusals as a proportion of the 120 successful interviews, a response rate of 81% was obtained.

On completion of the field measurements, all subjects received a letter informing them of the average results for their condominium corporation, and thanking them for their assistance.

2. The Questionnaire

The questionnaire and coding information is included in Appendix A. The first section of the questionnaire (Questions 1 to 9) contains open-ended questions and some direct questions about the general desirability of the building in which the subject lives. Questions 10 and 11 assess the noisiness of his particular home and lifestyle, while Questions 12 to 19 assess directly elicited annoyance to various types of noises. The noises made by neighbours are considered separately for different spatial relationships within the building and for different times of day. Also included are questions to determine which noises are particularly annoying. Questions 20 and 21 concern the possibility of sleep disturbance due to noise and are followed by Question 22, which is an attempt to measure the perceived annoyance in terms of a readily understood objective cost. Questions 23 to 28 gather demographic and other data that may contribute to understanding annoyance responses. The last page of the questionnaire contains Speilberger's measure of trait anxiety[7] which in previous studies of annoyance due to noise[4-6,8] has been found to contribute to annoyance responses. Most responses were obtained using seven-point response scales with only the extremes and the mid-points labelled. These were labelled "not at all," "medium" and "extremely." This procedure had been found to be successful in the past in providing appropriate interval scale data, and was used again here with only a minor change to one of the labels to agree with the work of Levine.[9]

The questionnaire was pretested on subjects working in the Division of Building Research. To ensure a realistic test, pretest subjects were selected who lived in multiple-residence buildings and had no technical knowledge of any previous acoustical studies.

A total of 98 variables per subject were entered into the final data file of which 30 were noise or sound insulation measures. Survey responses were entered directly into a mini-computer using a program that prompted the user with questions from the questionnaire. Avoiding the intermediate step of coding sheets thus eliminated the possibility of errors in transcription.

3. Noise and Sound Insulation Measures

In each home one complete 24-hour record of normal background noise levels was obtained using a miniature device that stored an A-weighted L_{EQ} value (energy equivalent sound level) digitally for each three-minute period of a complete 24-hour day (Metrosonics Metrologger dB-301). From these 480 L_{EQ} values, a daytime (7:00 a.m. to 10:00 p.m.), a nighttime (10.00 p.m. to 7:00 a.m.) and a complete 24-hour L_{EQ} value were calculated. These are referred to as L_{EQ}^{D}, L_{EQ}^{N} and L_{EQ}^{24}, respectively, in this report. Each subject's data in the final data file contained the three L_{EQ} values for both his home and his neighbour's. Since the homes were all occupied and the occupants frequently included small children, the L_{EQ} measuring devices had to be positioned in locations where they were least likely to be disturbed rather than in acoustically optimum positions. Thus, they were usually placed on shelves or on top of cabinets in the living room of each home. The microphone was generally close to a wall or large reflecting piece of furniture.

To minimize the inconvenience to subjects, the test sounds were tape recorded in the homes and then analyzed in the laboratory with a computer. When perfected, this technique allowed the complete sound transmission loss measurements involving measurements in two adjacent homes to be completed in 20 minutes. In a number of cases a more time-consuming procedure simply would not have been tolerated.

Using a conventional pink noise source and a FM instrumentation tape recorder, sounds were recorded for three 16-second bursts in both the receiving and source rooms. A manually rotated microphone boom was used to average the sound levels for each room. In the side selected as the receiving room, background noise levels, as well as five sound decays, were also recorded, again using a pink noise source. When recording the receiving room levels, in which the spectrum was strongly influenced by the typical sound transmission loss properties of walls, the signal was first filtered to provide a flatter spectrum and thereby to optimize the use of the dynamic range of the tape recorder. An inverse filter was then used when playing back the sound. The tape recordings were processed using a mini-computer with an analogue to digital converter interfaced to the integrated (RMS) outputs of a parallel set of 1/3 octave filters. By averaging the sampled sound levels in each 1/3 octave band from 100 to 4000 Hz over the time required for the microphone to rotate, room-averaged sound levels were produced for the two cases that used the pink noise source, as well as for the background noise levels. The average of the sound decays in each 1/3 octave band was displayed on a computer graphics terminal. The operator then selected the portion of the curve to which a straight line was to be fitted for calculating the reverberation time in the receiving room. This avoided any possibility of including the effects of background noise levels in the calculation of reverberation times.

The sound transmission loss (TL) was calculated in each 1/3 octave band, from 100 to 4000 Hz, using the relationship:

$$TL = \overline{SPL_S} - \overline{SPL_R} + 10 \log(S/A_R), \tag{1}$$

where $\overline{SPL_S}$, $\overline{SPL_R}$ are the space-averaged sound pressure levels in the source and receiving rooms respectively, S is the area of the common wall and A_R is the total sound absorption in the receiving room calculated from the Sabine reverberation equation as

$$A_R = 0.161*V/T_{60},$$

where V is the room volume of the receiving room and T_{60}, the measured reverberation time.

From the information for each 1/3 octave, several single-number ratings of the airborne sound isolation were calculated. The sound transmission class (STC) was calculated from the 1/3 octave STL values from 125 to 4000 Hz according to the standard procedure ASTM E413.[10] The noise isolation class (NIC) was calculated as well using the ASTM E596 procedure.[11] In addition, several A-weighted single-number measures were calculated which, although not standardized quantities, are extremely similar to the ASTM E597 procedure.[12]

Since some of the A-weighted measures depend on the source spectrum, the source room levels were first corrected by establishing equal levels in each 1/3 octave band so that the source room spectrum was exactly pink in nature. The same corrections were then added to the corresponding 1/3 octave sound levels in the receiving room. Four of the five measures calculated were a form of A-weighted level difference and would therefore be influenced by the source spectrum. The exception was an A-weighted transmission loss sum given as follows:

$$STA = -10 \log \left\{ \frac{1}{17} \sum_{i=1}^{17} 10^{(-TL_i + W_i)/10} \right\}. \tag{2}$$

TL_i are the individual 1/3 octave sound transmission loss values obtained as in equation (1) above; W_i are the attenuations in decibels of the A-weighting curve at the 1/3 octave band centre frequencies. The STA values are positive and very similar in magnitude to the corresponding STC values.

Four A-weighted difference in levels-type measures were calculated and given the symbols DA, DAS, DAN, DANS. The first, DA, was simply the difference in overall A-weighted levels measured after the source was corrected to be perfectly pink. The second, DAS, was an A-weighted difference in overall levels between the source and receiving rooms after the source had been corrected to the source spectrum proposed by Schultz. This Schultz source spectrum is included in the ASTM E597 procedure.[12] Two other measures included a normalization that compensated for variations in common wall area and receiving room absorption. Thus, before the A-weighted differences for each 1/3 octave band were summed up, they were normalized by an addition of $-10 \log (S/A_i)$ (where A_i is the individual 1/3 octave band receiving room absorption). Normalized A-weighted differences calculated with a pink source spectrum were given the symbol DAN, and those calculated with the Schultz source spectrum were given the symbol DANS.

In the analysis of the results a further noise measure, the British aggregate adverse deviation (AAD), was also calculated (e.g., see Ref. 13). This measure is the sum of all deviations below a reference contour and thus ignores all bands where the measured performance is superior to the performance standard contour.

4. Analysis

Both the survey response data and the noise and sound insulation data were initially processed on a mini-computer. A final combined data file was created with 98 variables for each subject as detailed in Appendix A. The combined data file was then transferred to the NRC IBM 370 computer and statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS), Release 8.1.

III. RESULTS

1. Characteristics of the Survey Sample

Since the sample in this pilot study is quite small (98 subjects), survey responses should be considered with reference to the particular acoustical conditions to which they relate and not as generally representative of some larger population. In Table I, which summarizes measured noise levels and single-number sound insulation values, the mean value and standard deviation about the mean is given for each quantity. It is seen that the mean 24-hour L_{EQ} in the homes measured was 53.0 dBA with values ranging from 39 to 67 dBA. The mean measured sound transmission class (STC) is shown in Table I to be 51.2 dB. The complete distribution of measured STC values, illustrated in Figure 1, ranges from 39 to 60 dB. Figure 2 presents the mean values and standard deviation of the measured 1/3 octave sound transmission loss (TL) values.

It is seen that these data do represent a quite wide range of party-wall sound insulation values in terms of the STC. Since one would not expect to find significant numbers of walls with STC values outside the range included here, these data should thus be representative of most realistic party-wall sound insulation values. Unfortunately, there is a perhaps inevitable concentration of STC values in the range STC 46 - 54 which includes 69% of the data.

A summary of the basic demographic information for the 98 subjects of this study is found in Table II. The split between males and females was nearly equal and quite satisfactory for studying possible effects due to the respondents' sex. It would appear that most respondents were away from home during the day and probably worked full-time, while a smaller number worked in the evenings or at night and were usually home during the day. Since the residences were all condominiums, most subjects (91.8%) were also the owners of the home.

Table III summarizes the ownership and use of various potentially noise-producing devices. On average, radios and televisions were found to be used many more hours per week than stereo equipment. It should be noted that the range of these values as reflected by the standard deviations is quite large; there is thus considerable variability among the subjects in the use of these three types of devices. Table III also lists the percentages of subjects owning various noise-producing appliances.

Annoyance responses are frequently examined by considering the proportion of respondents who are very annoyed by various noises. Because there were only 98 subjects in all, the number of subjects falling into this extreme category was generally too small to provide reliable results. For this reason, the annoyance responses were first examined in terms of the percentage of subjects who were annoyed to any degree. Thus, Table IV shows the percentage of subjects scoring greater than 1 on various response scales. From Table IV it is seen that more than half of the subjects were annoyed by noises from neighbours on either side of them, by traffic noise and by other outdoor noises. Clearly, the problem of annoyance due to outdoor noises (including traffic noise) was at least as severe as the problem of disturbance or annoyance due to noises from their neighbours. Plumbing noises, building machinery noises, aircraft noises, neighbours' noises and doors slamming annoyed from 30 to 34% of the respondents. Of course, the percentage annoyed by aircraft noise would depend largely on the location of each home relative to aircraft flight paths. Annoyance due to floor vibrations, noises from tools and appliances, and telephone rings was somewhat less frequently expressed. Subjects had more difficulty falling asleep and were more often awakened by outdoor noises than by noises from their neighbours.

Subjects were asked whether there was any particular room in which they were more annoyed by noises from their neighbours. Of the 45 subjects who responded, 55.8% were more annoyed while in their bedrooms whereas 27.8% were more annoyed in their living rooms.

2. Differences Between Row Housing and Apartment Residents

Of the 98 subjects, 16 lived in apartment condominiums and 82 lived in two-storey row housing condominiums. Although the number of apartment residents was by design very small, some comparisons between the two types of dwellings can nevertheless be made. Table V compares data describing the two groups of residents. It is seen that the noise levels in the homes were quite similar for these types of homes. Row housing was on average slightly noisier in the daytime, perhaps because of the on average greater number of children in these homes. There were considerable differences in the STC values between the two housing types, the average STC for the apartments measured being considerably less than that for the row housing. While these observations certainly cannot be generalized, they must be borne in mind when comparing annoyance responses. From the other data in Table V, one can see that the row housing sample included more expensive homes, more children, but no other large differences when compared with the apartment housing sample.

Table VI compares annoyance responses for the two housing type groups. This table gives percentages of subjects who were "at all annoyed" on each response (i.e., scored greater than 1), and contains combined data similar to those in Table IV. A number of results indicate that apartment dwellers were much more disturbed than row housing residents. For example, although the percentage of residents annoyed by noises from neighbours on either side of them was only slightly less for those in apartments than for those in row housing, they were distinctly much more annoyed by: noises from neighbours above or below (81.2%), noises in halls and stairs (68.7%), traffic noises (81.2%), and the sounds of doors slamming. Most of these examples of greater annoyance for apartment dwellers are not readily attributed to the inferior average measured STC of their party walls. People living in apartments are subjected to a greater number of sources of annoying noises, some of which are more likely to be a more severe problem in apartment buildings. Only apartment dwellers can have neighbours above or below them, noises from halls and stairs, and footstep noises above them. In addition, because of the nature of their buildings, they are potentially exposed to more types of building machinery noises and doors slamming. This combination of more sources of annoying noise and greater exposure to some noise sources causes a more severe noise impact on them. A case in point is the fact that all four sleep response items indicated greater disturbance to apartment dwellers than to row housing residents. This may at least partly be due to the generally inferior party-wall sound insulation of apartments. Although the sound insulation of floors was not actually measured in this study, it appears to be a more critical problem in apartments than the insulation of party walls.

Despite the limitations caused by the small number of apartment residents surveyed, these comparisons confirm the expectation that the disturbance by neighbours' noises within apartment buildings is a much more complex problem to untangle than that for row housing. They also indicate the need for a detailed study of sound insulation problems in floor and ceiling assemblies and of footstep noise.

3. Composite Response Scales

Previous research[8] has shown composite response scales to be more reliable measures of disturbance than single-item responses and more highly correlated with objective acoustical measures. In this study a factor analysis was first carried out on 22 annoyance and sleep disturbance responses, using the principal components method of factor analysis. Any factors with eigenvalues greater than 1.0 were then rotated by varimax. Finally, composite response scales were formed by summing the responses to items that loaded strongly on the major factor. It was found to be difficult to create a composite response scale that correlated much more strongly with acoustical measures than did the individual item responses. By limiting the possible number of factors to three, and only summing items that had factor loadings ≥ 0.70 on the major factor, which explained 64% of the response variance, a composite response scale was formed. The composite scale included the following items: annoyance with neighbours' voices, annoyance with neighbours' music sounds, annoyance with noises from neighbours on either side in the daytime, annoyance with noises from neighbours on either side at night, and frequency of difficulty in falling asleep due to neighbours' noises. This composite annoyance scale, which resulted from a factor analysis of response scores, is referred to as response variable 101 in this report.

A second composite annoyance scale was formed by summing the four responses correlating most highly with measured STC values and is referred to as response variable 104. The four items were: perceived noise in subject's own home, annoyance with the sounds of neighbours' voices, annoyance with neighbours' music sounds, and frequency of difficulty in falling asleep due to neighbours' noises. This somewhat arbitrarily derived scale correlated more strongly with STC values than the scale derived by factor analysis, as will be seen in the following sections. Although both annoyance scales were used in subsequent analyses, one should be aware of the differences in their method of formation.

The fact that factor analysis failed to produce a composite response scale with much improved correlations with STC values may be an important discovery. It indicates a distinct difference between subjective responses to traffic noise,[3-6,8,14] and subjective responses to noises caused by neighbours in multi-family dwellings. It appears that traffic noise is a more homogeneous source of disturbance and many different responses related to a general sense of annoyance to traffic noise. Annoyance with neighbours' noises does not appear to exhibit the same homogeneity. As discussed in later sections, different types of noise caused annoyance in different ways. This would explain why they did not add together very successfully to form a composite response scale. This difference also indicates the importance of considering each response separately throughout all further analyses since these responses may relate quite differently with both acoustical and non-acoustical predictor variables.

4. Physical Variables as Response Predictors

Most of the questionnaire items designed to assess the impact of noises from neighbours using 7-point interval scale responses were forms of directly elicited annoyance. With such questions there is always the possibility that the nature of the question is somewhat suggestive and hence produces a biased, excessively negative response. To verify that this was not the case, initial open-ended questions were included to obtain a measure of spontaneous annoyance to the noise of neighbours. Response variables 009 and 010 listing the things subjects liked and disliked about their building respectively were used to obtain these spontaneous responses. The liking of quietness or the disliking of noise were coded as 2; other likes or dislikes were coded as 1 and no likes or dislikes were coded as 0. Cross tabulations were then performed between these two response variables and the STC values of the tested walls which were grouped into four STC ranges. In both cases a Chi square test indicated that there was a significant relationship between the variables ($p \leqslant 0.02$ for variable 009, and $p \leqslant 0.005$ for variable 10). In addition, the respondents' satisfaction with their building was significantly related to some measures of sound insulation (Table VII). Thus the spontaneous responses to questions that did not mention noise were significantly related to the measured STC of each subject's wall.

The relationships between the major annoyance responses and the physical measures of sound insulation were first evaluated by Pearson product-moment correlations between pairs of variables. In Table VII, which gives the correlation coefficients significant at $p \leqslant 0.05$ level or higher for seven single-number sound insulation measures, it is seen that there are a large number of significant correlations despite the small sample (98 subjects). Thus, this pilot survey has successfully demonstrated that significant relationships between sound insulation and annoyance measures can be obtained. The correlations between responses and STC values vary from insignificant to a correlation of -0.335. Correlations with the A-weighted transmission loss STA were slightly higher, reaching a maximum of -0.378. In a recent British study, Langdon[15] found correlations between subjective ratings and sound insulation measures ranging from 0.25 to 0.40 in a study involving 917 subjects. Thus, the magnitudes of the correlations shown in Table VII are very much in line with the only other comparable study. In both the present pilot study and Langdon's study, the least emotional response correlated most highly with the measured sound insulation. In the present study this was response variable 054, the amount of money subjects were prepared to pay monthly to eliminate annoying noises. In Langdon's study it was a subjective rating of the existing sound insulation. Table VII indicates that most other annoyance-type responses correlated with STC at about 0.20 or slightly higher. There are also a number of quite notable exceptions where response variables did not correlate significantly with sound insulation measures; hence, one must assume that the degree of the disturbance is largely independent of the sound insulation of the wall. These responses would include: overall annoyance with noises from their neighbours on either side (027), annoyance with speech sounds from their neighbours' radio or television (039), annoyance with the sounds of their neighbours' children (041), and daytime annoyance with noises from their neighbours on either side (046). In some of these cases, correlations which were marginally significant might be increased in a study with a larger number of subjects.

Preliminary comparisons of the suitability of various sound insulation measures can be obtained from Table VII, although in general there are only minute differences between the correlations with various sound insulation measures. The differences between DA and DAS and between DAN and DANS are so small that the differences between a pink source spectrum and the Schultz source spectrum are clearly unimportant in these data. Since STA and DAN are physically very similar, it is not surprising that Table VII shows them to produce virtually identical correlations with response measures. There does seem to be a trend, however, for the A-weighted transmission loss measures, such as STA or DAN, to produce slightly higher correlations with subjective responses. The simple A-weighted difference in levels, DA, produced slightly smaller correlations with responses in all but two cases. For the question on the degree of noise perceived by the occupant in his own home, and the annoyance to sounds of slamming doors, DA correlates slightly more highly than do STC or STA. The first of these responses is clearly different in nature from all the others in that it rates the subject's own home. The second response (slamming doors) probably has exaggerated correlations. Most subjects complaining about the noises of doors slamming lived in apartments which tended to have lower STC values than the other homes. Thus, the small number of subjects who were annoyed by doors slamming and who tended to live in apartments with relatively low STC values could lead to somewhat misleadingly high correlations with STC values. A larger sample of apartment dwellers is needed to properly evaluate this response.

Table VIII gives correlation coefficients obtained between response variables and various measures of background noise levels. Only one response correlated significantly with noise levels measured in the subject's own home (degree of noise perceived by occupant in his own home (026). A number of responses correlated significantly with the daytime or 24-hour L_{EQ} measured in the neighbour's apartment. There was a definite trend such that the responses not correlating significantly with sound insulation measures did correlate significantly with the noise level in the neighbour's home. These responses included: general annoyance with neighbours on either side (027), annoyance with noises of neighbours' children (041), and daytime annoyance with neighbours on either side (046). Table VIII also gives the results of correlations between responses and the difference between the subject's and the neighbour's 24-hour L_{EQ}. Although three of the responses did correlate significantly with this noise level difference, these correlation coefficients were always lower than the correlations with the neighbour's 24-hour L_{EQ}. Therefore, there is no evidence that the difference in noise levels between homes is the principal factor influencing responses. The noise level difference is just another variable that is correlated with the neighbour's L_{EQ}^{24} (074), ($R = 0.652$, $p < 0.001$). The present data consequently do not support the idea that noises in one's own home can act as masking noise and thus lead to reduced annoyance with the noises of neighbours.

The data do show that different sounds from neighbours cause annoyance by quite different mechanisms. Some noises seem to be annoying because the sound insulation of the party wall is not adequate, while other sounds are annoying quite independent of the properties of the wall, probably simply because they create high sound levels in the neighbour's home. The relatively high correlation between the measured sound insulation values of the party walls and the less emotional, more strictly factual responses concerning the number of dollars per month the subjects are prepared to pay to reduce annoying noise, clearly indicate that subjects can judge the quality of the sound insulation of their wall and are concerned enough to be willing to pay to improve it. However, when the subjects were asked how annoyed they were because of their neighbours' noises, the sound insulation of the wall was not the only factor that influenced their answer. Subjects apparently took the quality of the wall into account and tended to report greater annoyance with excessively noisy neighbours, as indicated by the significant correlations between annoyance (027, 046), and noise levels in the neighbours' homes.

One factor that would have reduced the correlation between annoyance responses and measured noise levels in the neighbours' homes was that probably about 50% of the time the most annoying neighbour was not measured. Each subject usually had two immediate neighbours, one on either side of his home. In this study, measurements were only made in one of the neighbouring homes, so that one could expect to pick the more annoying neighbour in only about 50% of the cases considered. This is a particularly obvious problem with regard to annoyance due to noises of neighbours' children. Approximately 62% of the homes had children under 18 years old. In some cases, reported annoyance due to children was correlated with the measured noise levels in homes without children. In other cases, the annoyance responses were correlated with noise levels in a neighbouring home with children, who were perhaps not as noisy as the children in the other neighbouring home. In spite of this problem, highly significant correlations were obtained between annoyance due to the sounds of neighbours' children (041) and the neighbours' daytime L_{EQ} value (072). One can probably conclude that the mere presence of children is sufficient to cause annoyance regardless of the level of noise they create.

As an initial step in considering the possibility of improved single-number measures of sound insulation, the principal subjective responses were correlated with the measured sound transmission loss in each 1/3 octave band. The statistically significant ($p \leq 0.05$) correlation coefficients that resulted are presented in Table IX. All the responses except one (annoyance due to sounds of neighbours' children (041)) were significantly related to the 1/3 octave transmission loss values in at least one 1/3 octave band. However, most responses were significantly related to the TL values in only a small number of bands. For most responses, correlation with the 125 Hz and 160 Hz 1/3 octave band TL values yielded the higher, if not the highest, correlation coefficients. In fact, all the correlation coefficients between responses and the 160 Hz TL values were higher than for those with STC values. The results given in Table IX appear to indicate that the lower 1/3 octave bands are most critical in determining the resulting disturbance to residents.

To better understand the relationship between the physical variables, prior to attempting to form improved composite sound insulation measures, all sound insulation measures were correlated with one another. The correlation coefficients are given in Table X. As was expected, many of these measures were very highly intercorrelated. Among the seven single-number overall sound insulation values (STC, NIC, STA, DA, DAS, DAN, DANS) intercorrelations were very high, ranging from 0.904 to 0.9998. These high correlation coefficients clearly demonstrated the very high similarity between STA and DAN values. The STC and STA values were also very similar with a correlation coefficient of 0.968. The simple A-weighted level difference, DA, differed the most from STC but, even so, correlated with STC values with a coefficient of 0.904. It is therefore not surprising that the results in Table VII indicate no large differences among these variables as predictors of the subjective responses.

The correlations between the 1/3 octave sound transmission loss values tended to decrease as the separation of the frequency increased. Correlation coefficients between adjacent 1/3 octave bands were generally approximately 0.8 to 0.9, but for bands separated by one intermediate band the intercorrelations were generally 0.7 to 0.8. The lowest correlations between 1/3 octave-band TL values were about the same as the highest correlations between subjective responses and sound insulation measures. This same table shows that the STC values correlated most highly with the 1/3 octave TL values for 1/3 octave bands between approximately 200 Hz and 630 Hz.

It was hoped that new combinations of 1/3 octave TL values could be found that would correlate more strongly with subjective response measures. In an attempt to obtain such new measures, multiple regression analyses were performed regressing each response on the various 1/3 octave TL values. The order of entry of the 1/3 octave TL predictors into the equation was determined according to which one accounted for the largest part of the unexplained variance at that step. No successful combination of even two 1/3 octave TL values was found. That is, in no case could even two 1/3 octave TL values be found that when taken together, added significantly to the prediction of a subjective response. This is perhaps not surprising in view of the high intercorrelations between the 1/3 octave TL values given in Table X.

In Britain, sound insulation is measured in terms of an Aggregate Adverse Deviation (AAD) below a reference contour.[13] This contour is flat from the 1600 Hz to 3150 Hz 1/3 octave bands, with a value of 56 dB TL in each 1/3 octave band. Below this plateau the contour drops at 4 dB per octave. It was desired to evaluate the AAD as a predictor of subjective responses. In addition, three other variations of the standard AAD were considered in which the 4 dB per octave slope was varied. Slopes of 2, 3, 4 and 5 dB per octave were considered. The correlations between the resulting AAD type measures and the responses are given in Table XI. Varying the slope of the reference contour within the range just mentioned had only very minor effects on the resulting correlation coefficients. By comparing Table XI with Table VII, it is seen that slightly higher correlations with responses were obtained with AAD values as the predictor than with STC values.

Since both sound insulation values and background noise levels were found to relate significantly to responses, it was hoped that compound predictors could be found that included both types of physical measures. Multiple regression analyses were performed in which the order of entry of the predictor variables was predetermined to allow easy comparison between various combinations of predictors and the subjective responses. Three sound insulation measures were considered in separate analyses: STC, STA and AAD. One of these sound insulation measures was the first predictor variable entered into the equation, followed by the neighbour's L_{EQ}^{24} and finally by the subject's L_{EQ}^{24}. The resulting multiple correlation coefficients after each step are given in Table XII. In a number of cases, as noted earlier, the simple correlations between the sound insulation measures and the response variables were not significant, and are included here only to complete the table. In many cases the second term, the neighbour's L_{EQ}^{24}, did not add significantly to the prediction. In all cases, the third term, the subject's own L_{EQ}^{24}, did not add to the prediction of these subjective responses. That is, although in some cases successful combinations of sound insulation measure and neighbour's L_{EQ}^{24} were found, no successful combinations were found that included the subject's own L_{EQ}^{24}. The simple correlations of Table VIII had implied that the simple difference between the subject's and the neighbours' L_{EQ}^{24} (response variable 099) was not a successful predictor of adverse subjective responses. The results of Table XII confirm this and suggest that none of the combinations of the subject's and the neighbour's L_{EQ}^{24} values were successful predictors of adverse subjective responses.

As a final consideration concerning the relationship between physical measurements and subjective responses, possible causes of the measured noise levels were investigated. It was reasoned that subjects who used televisions or radios for longer periods, or who were home more often, would have noisier homes. The following response variables were considered as predictors of the measured noise levels: hours of television use (015), hours of radio use (016), hours of stereo use (017), days home per week (057), evenings home per week (058), nights home per week (059), number of adult residents (063), number of children in the home (064), and a sum of the responses to variables (018) to (025), indicating whether the home contained various noise-producing appliances. The only clearly understandable significant correlation between these possible predictors and measured noise levels was the correlation between the number of children and the measured daytime and 24-hour noise measures ($R = 0.334$, $p < 0.001$ for L_{EQ}^{D}, and $R = 0.318$, $p < 0.001$, for L_{EQ}^{24}). Thus, the subjects' reported annoyance with the noises of their neighbours' children correlated quite strongly with the noise levels in their neighbour's home, and the number of children in the home correlated strongly with the measured noise levels in it. Presumably, annoyance with the sounds of children would also correlate strongly with the number of children living in the neighbouring home.

5. Non-Acoustical Predictors

The influence of various non-acoustical variables on the recorded annoyance responses was then considered. Multiple regression analyses were performed incorporating both acoustical and non-acoustical variables as independent variables and various annoyance responses as dependent variables. The acoustical variables were forced into the regression first in the following order: (1) STC; (2) neighbour's L_{EQ}^{24}; (3) subject's L_{EQ}^{24}. Non-acoustical variables were then entered according to which one accounted for the greatest portion of the remaining unexplained variance. In the first such regression, the following non-acoustical variables were included: length of occupancy (005), satisfaction with building (012), considerateness of neighbours (013), helpfulness of building officials (014), value of the home (056), days home per week (057), evenings home per week (058), nights home per week (059), education (060), family income (061), age (062), number of adult residents (063), number of children residents (064), sex (065), and stress (068). Table XIII summarizes the results of these regression analyses. The order of entry is given for the non-acoustical predictors that added significantly to the equation. Negative signs indicate that the regression coefficient was negative for that variable. The acoustical variables that were significant predictors at the final stage of the regression are also shown. In some cases, inclusion of various non-acoustical variables changed the significance of the acoustical variables. The final values of the multiple correlation coefficients are also given.

A comparison of the multiple correlation coefficients of Tables XII and XIII shows that adding the non-acoustical variables approximately doubled the multiple correlation coefficients. Thus, the non-acoustical variables generally added greatly to the prediction of annoyance responses. Table XIII shows that the neighbours' considerateness, as perceived by the subjects, was the most important non-acoustical variable. In fact it was entered first for 11 of the 13 regressions. One can somewhat arbitrarily select the more important predictors as those that contributed significantly to at least four annoyance responses. The resulting predictors in this survey were: length of occupancy (005), satisfaction with the building (012), considerateness of neighbours (013), helpfulness of building officials (014), value of the home (056), days home per week (057), and stress (068). One is thus led to the conclusion that the subjects' annoyance with noises from their neighbours increased with the length of occupancy, the value of the home, the number of daytime periods at home and subjects' stress score. On the other hand, the more the subjects were satisfied with their building and found their neighbours considerate and building officials helpful, the less annoyed they were by neighbours' noises.

Further exploration of the apparently most important predictor (considerateness of neighbours (013)) provided greater insight into this response. It was discovered that the perceived degree of considerateness of neighbours was significantly correlated with the STC of the wall ($R = 0.206$, $p < 0.02$). Thus, neighbours were thought to be more considerate when in fact it was the higher sound insulation of the wall that may have caused this perception . To add further evidence to this explanation, it was observed that the perceived level of considerateness of neighbours was not significantly correlated with the measured noise levels in the neighbours' homes. Logically, the neighbours perceived as more annoying because they were less considerate would have homes with higher noise levels. The fact that the rating of the neighbours' considerateness is significantly related to the measured sound insulation strongly suggests that poor sound insulation may constitute a serious cause of social conflict. Neighbours may be thought to be inconsiderate when it is really their wall that is to blame.

A second set of regression analyses was performed in the same manner as the first set. Acoustical predictors were forced into the regression first as described earlier. Three additional non-acoustical variables were included; namely, the hours per week spent listening to television (015), listening to radio (016), and listening to stereo (017). The results of these multiple regression analyses are summarized in Table XIV in the same format as Table XIII. The multiple correlation coefficients presented in Table XIV are generally a little larger than those in Table XIII, except for response variables 050, 052 and 054, for which the multiple correlations are the same or slightly smaller than those found in the previous analyses. Two of the three new variables added significantly in predicting seven different annoyance responses.

It appears that increased annoyance was associated with increased television watching, but that decreased annoyance was associated with increased listening to radio. Perhaps noises from neighbours interfered with listening to television and hence led to increased annoyance. However, subjects appear to have used radios as a masking sound in that the more they used them, the less annoyed they were with noises from their neighbours. As was previously mentioned, analysis of the noise levels measured in this study showed no evidence that higher noise levels in the subjects' own home acted as masking sound. Consequently, it is not possible to conclude that masking sound in general will reduce annoyance with neighbours' noises. There may be some aspect of radio sounds, other than the overall energy equivalent level, that does lead to reduced annoyance with noises from neighbours; however, is not clear from this study which physical attribute of the radio sound is responsible. It was also observed that reported hours of listening to television and radio were correlated with a number of other possible predictor variables. Hours of television watching were correlated with evenings home per week ($R = 0.293$, $p \leq 0.002$), education ($R = -0.301$, $p < 0.001$), and family income ($R = -0.226$, $p \leq 0.01$). Hours of radio listening were correlated with nights home per week ($R = -0.351$, $p \leq 0.001$), age ($R = 0.227$, $p \leq 0.01$), number of adult residents ($R = - 0.191$, $p < 0.01$), and the stress score ($R = -0.191$, $p < 0.03$). Thus, it is quite possible that one of these correlated variables could be the actual cause of the increased or decreased annoyance.

IV. DISCUSSION

1. The Present Results

The present study was intended as a pilot study to determine the feasibility of carrying out a larger study to investigate relationships between the physical measures of noise levels and the sound insulation of party walls and the associated adverse human reactions. This work has been a complete success in that the approach followed here has found statistically significant relationships between physical measures and adverse human responses. Furthermore, it is now clear that with some small changes, particularly to the questionnaire, a larger study could be carried out that would be expected to lead to a much better understanding of the relationship between the physical and human response variables. The goals of obtaining: (1) good dose response relationships between physical measures and adverse responses, (2) information concerning the physical measures most appropriate for predicting human responses, and (3) information from which minimum acceptable sound insulation values can be determined, now all seem readily achievable in a future larger and more complete study.

Although it cannot be assumed that the respondents in the present pilot study are broadly representative of other Canadian occupants of multiple-residence buildings, these results do represent a wide range of party-wall insulation values (STC 39-60). From these results it is clear that a large proportion of the sample was disturbed by noises from neighbours. Although it is not the main focus of this research, it would appear that disturbance by outdoor noises, including road traffic noise, was a severe problem requiring further investigation. From the limited sample of apartment building residents, it would appear that the impact of the disturbance caused by neighbours was greater for them than for residents of row housing sites. This seems to be due to both the greater number of annoying sources of noise and the greater disturbance caused by neighbours above or below than from those on either side. Again, the present evidence strongly suggests the need to thoroughly investigate the disturbance caused by various noises in apartment buildings. This would require the measurement of airborne and impact sound insulation of floors and ceilings. As there is currently disagreement as to the most appropriate method of measuring impact sound transmission loss, carrying out such a study presents many problems.

The present results show that annoyance responses do relate to measures of sound insulation. That is, the actual physical properties of the wall do determine the resulting disturbance to people. The human responses in this study, however, seem to be more complicated to interpret than those in somewhat similar studies of annoyance to traffic noise. In this study, each annoyance response tended to exhibit different characteristics, whereas for traffic noise studies, it was possible to more successfully group a number of responses into one fairly homogeneous measure of annoyance. Thus, some annoyance responses in the present study related best to measures of sound insulation, while others related best to noise levels measured in a neighbour's home. Factor analysis led to a composite annoyance scale that correlated only slightly more strongly with sound insulation measures than did single-item responses. However, the composite annoyance scale had greater success since it correlated more uniformly with sound insulation and noise measures. In addition, the interviewer reported many situations where subjects clearly indicated that they were exposed to noises from neighbours, but still would not say they were annoyed because of their personal relationships with the neighbours in question. It appears that with a less personal source of noise such as traffic noise, subjects more readily admit annoyance than with noises from a particular neighbour. Accordingly, less emotional questions such as "how many dollars per month would you spend to eliminated annoying noises" (054) correlated more highly with measured sound insulation. Future studies should obtain stronger correlations between human responses and physical measures from questions that are more objective and do not imply that the subject is complaining about his neighbour. Langdon's recent study[15] substantiates this idea in that he obtained the highest correlation with measured sound insulation by simply asking subjects to rate the sound insulation of their party wall.

Of the various measures of sound insulation considered, all were useful predictors of human responses. The simple A-weighted difference

(DA), although the least accurate predictor of adverse responses, was much easier to obtain and may consequently be useful in many practical situations. It is not possible to draw final conclusions as to the relative merits of the other sound insulation measures; however, both the A-weighted transmission loss and the British Aggregated Adverse Deviation appeared to be slightly superior to STC.

It was also clear that the actual noise levels in the neighbour's home were very important predictors of adverse responses. In fact, some annoyance responses correlated solely with noise levels in the neighbour's home and not with measures of the sound insulation. There was no evidence that noise levels in the respondent's own home influenced the subjective results; consequently it was inferred that higher noise levels in the respondent's own home did not mask the annoyance caused by neighbours.

The inclusion of several non-acoustical predictors considerably increased the multiple correlations with annoyance responses. A number of annoyance responses increased with increased length of occupancy, value of the home, number of daytime periods spent at home, and levels on the stress scale. The subjects' feelings that neighbours were considerate, that building officials were helpful, and that they were satisfied with their building related to decreased annoyance. It was observed, however, that although having inconsiderate neighbours appeared to increase annoyance, it was the poor sound insulation that seemed to lead people to believe that their neighbours were inconsiderate in the first place. Subjects watching television seemed to be particularly sensitive to disturbance by noise from neighbours and this led to increased annoyance. On the other hand, increased time spent listening to radio was linked with decreased annoyance. This might indicate a masking effect caused by the radio sounds, or it might be due to other parallel correlated measures.

2. Acceptable Limits and Comparisons with Other Work

One could consider setting acceptable minimum values for party wall sound insulation in terms of a cost-benefit analysis and calculate the costs of various types of construction with known STC values. The benefit could be assessed from the reported mean trend for the amount of dollars per month subjects were prepared to pay to reduce annoying noises. Presumably, increasing construction costs to this mean trend would be acceptable if they in turn led to acceptable sound insulation between dwellings. The costs of various types of construction are not considered in this report; however, the reported dollars per month for reduced annoying noises versus STC values are plotted in Fig. 3. The best fit regression line shown is given by

$$\$/\text{month} = -0.572 \times \text{STC} + 34.4, \quad (R = -0.355,\ p < 0.001)$$

where R is the correlation coefficient and p is the probability.

It is seen, for example, that at STC 45 subjects were generally prepared to pay $9.00 per month, while at STC 60 this decreased to zero. Of course the total value of this monthly payment would have to be accumulated over the expected life of the building.

It was noted that if the "dollars per month" responses were divided by either the value of the home or the total family income, new measures were created that correlated more highly with STC values ($R = -0.400$, $p \leqslant 0.001$, and $R = -0.393$, $p \leqslant 0.0001$, respectively).

To determine the variation in impact of different noises with reference to the wall STC value, one can plot the percentage of annoyed subjects versus STC value. Four categories of STC values were created with nearly equal numbers of respondents in each category. Subjects scoring 3 or greater on a response scale were considered to be moderately or more annoyed. To illustrate simply the general trend of these results, a regression line was fitted to each group of four points (see Figure 4). While it is difficult to obtain significant relationships with only four points, it is felt that these results are at least qualitatively useful until a larger data set is available. Figure 4 shows that the percentage of subjects annoyed with neighbours' voices (038), annoyed with neighbours' radio and television (039), and the percentage moderately or more annoyed on the composite annoyance scale from a factor analysis (101) produced quite similar results as a function of STC values. The percentage of subjects annoyed with children's sounds varied less with STC values. The percentage of subjects annoyed with neighbours' music sounds varied more as a function of STC values, and increased to approximately 44% moderately or more annoyed at STC 45. The other annoyance responses mentioned indicated that approximately 24 to 27% of the subjects were moderately or more annoyed at STC 45. Because of the apparent reluctance of subjects to report that they were annoyed by a particular neighbour, these percentages were probably conservative estimates of the disturbance that actually occurred.

Recently, the results of two other studies that can be compared with the present results have become available. Figure 5 compares subjects' reports of hearing the sounds of their neighbours as a function of sound insulation value. Data from a study in Britain carried out by Langdon[15] on 917 subjects are included in Figure 5. This study reported only AAD categories for sound insulation measures. For the purposes of this comparison, AAD values have been approximately converted to STC values by the following relationship:

$$STC = -0.113 \times AAD + 56.7.$$

This was obtained by regression analysis of the STC values onto the AAD of the present study. The other study considered involved interviews of 1209 subjects and was carried out in Holland.[16] In this Dutch study, sound insulation was reported in terms of airborne sound insulation index $I_{\ell u}$ (isolatie-index voor lucht-geluid). These values were converted to approximate STC values by adding 50 to each $I_{\ell u}$ value. The $I_{\ell u}$ value is essentially an aggregate deviation of octave band measurements from a reference contour which closely approximates to an STC 50 contour. Because of the necessarily approximate nature of the conversions from one sound insulation measure to another, precise comparisons between studies are not possible; nevertheless, Figure 5 suggests considerable similarities between the three investigations. From the present study the percentage of subjects prepared to pay greater than zero dollars per month is plotted versus STC values. The fact that it agrees quite well with the other studies suggests that it reflects the subjects' ability to hear noises from their neighbours.

Figure 6 compares the percentage of subjects who were annoyed versus STC. Again, the same problems of converting from other sound insulation values to STC limit the comparisons. "Annoyed" in Figure 6 signified "moderately or more annoyed" in the present study, "bothered quite a lot" and "very much" in Langdon's study, and "percentage bothered" (Hinder) in the Dutch study. As in the previous comparison, results were generally comparable and overlapped considerably. In addition, the present study and the Dutch study produced results that most closely agreed while the British study suggested more annoyance for lower sound insulation (lower STC values).

Since AAD values were also calculated in the present study, it was possible to compare it more precisely with Langdon's study in terms of percent annoyance versus AAD values (see Figure 7). Although Langdon's study suggests higher percentages of annoyed subjects for poorer sound insulations (higher AAD values), there now seems to be closer agreement between the two studies than in the comparison presented in Figure 6. It therefore appears that the approximate conversion of sound insulation measures in Figures 3 and 4 has limited the degree of agreement between the three studies.

5. CONCLUSIONS

This pilot study has demonstrated that the general research procedures used were successful in obtaining useful and statistically significant relationships between acoustical measures and related adverse human responses. A more complete study with a larger and more representative sample of respondents should therefore be considered. Such a study could produce dose response relationships between acoustical measures and various adverse human responses that would be more generally representative of Canadians living in multiple-residence buildings.

From the present results, it is clear that subjects are aware of the quality of the sound insulation of their party walls. They are annoyed and disturbed by the noises from their neighbours to the point where they are prepared to pay for improved sound insulation. Subjects with poorer sound insulation are more likely to be annoyed with noises from their neighbours, and report more frequent difficulty falling asleep as a result. Poor sound insulation even seems to lead to false accusations that neighbours of being inconsiderate.

Some measures of sound insulation were more successful predictors of disturbance than others. Some relatively simple measures were found to be only slightly inferior to more complex measures. Including a measurement of the noise levels in the neighbour's home generally increased one's ability to predict the resulting disturbance. On the whole, this study provided conclusive evidence of the need for a more complete comparison of sound insulation measurements, as well as compound acoustical measurements including noise levels, in the neighbour's home.

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APPENDIX A

The Questionnaire and the Response Variables

A copy of the questionnaire used in the survey is shown on the following pages. The response variable numbers which are given to the right of the questions are frequently mentioned in the report to clearly identify a particular response. The other response variable numbers are given below.

Response Variable	Explanation
001	Subject number
002	Neighbour's subject number
003	Condominium site number
004	Apartment (=1), or row house (=0)
005-068	See questionnaire
069	L_{EQ}^{D} subject's home
070	L_{EQ}^{N} subject's home
071	L_{EQ}^{24} subject's home
072	L_{EQ}^{D} neighbour's home
073	L_{EQ}^{N} neighbour's home
074	L_{EQ}^{24} neighbour's home
075	125 Hz 1/3 octave sound transmission loss (TL)
076	160 Hz
077	200 Hz
078	250 Hz
079	315 Hz
080	400 Hz
081	500 Hz
082	630 Hz
083	800 Hz

084	1000 Hz
085	1250 Hz
086	1600 Hz
087	2000 Hz
089	2500 Hz
090	3150 Hz
091	4000 Hz
092	STC sound transmission class
093	NIC noise isolation class
094	STA
095	DA
096	DAS } see Section 2.3 for explanation
097	DAN
098	DANS

BUILDING SATISFACTION QUESTIONNAIRE

Division of Building Research
National Research Council Canada

Hello, I'm from the Division of Building Research at the National Research Council. You should have received a letter asking if you would be willing to answer a few questions concerning the building in which you live. (Offer your letter of identification.) (If resident received your letter, continue.) Would it be convenient for me to interview you now? It will only take about 15 minutes, and of course your responses will be completely anonymous. (If not convenient, arrange a more suitable time, and return then, thanking resident for their willingness to help.)

BIN No.: TB/CT-REG B 21611

Subject No. ________ A-4

Date ______________

Time ______________

		Response Variable
1. a) How long have you lived here?	______________________	5
b) In what type of home did you live previously?		
(A) Apartment Block	________	
(B) Small Building with Apartments (3 floors or less)	________	6
(C) Row Housing	________	
(D) Single Housing Unit	________	

2. What things do you like most about your immediate neighbourhood?

____

____

________________________ 7

____

3. What things do you dislike most about your immediate neighbourhood?

____

________________________ 8

____

____

4. What things do you like most about the building that you live in?

____

____

________________________ 9

____

5. What things do you dislike most about the building that you live in?

____

________________________________ 10

____

____

6. Would you like to move? (YES/NO) ______________ 11

If yes, why? ____

7. In general, how satisfied are you with the building that you live in? (Show Card)

1	2	3	4	5	6	7	12
Not at all			Medium			Extremely	

8. In general, how considerate are your neighbours? (Show Card)

1	2	3	4	5	6	7	13

9. In general, how helpful are the people who look after your building? (Show Card)

1	2	3	4	5	6	7	14

10. On average, how many hours per week are each of the following used in your home?

(A) Television ___________ 15

(B) Radio ___________ 16

(C) Stereo (record player, tape recorder, etc.) ___________ 17

11. Do you use any of the following in your home? (YES/NO)

(A) Central Air Conditioner (summer only) ___________ 18

(B) Wall or Window Air Conditioner (summer only) ___________ 19

(C) Food Blender or Food Processor ___________ 20

(D) Hair Dryer ___________ 21

(E) Vacuum Cleaner ___________ 22

(F) Washing Machine (in your home) ________ 23

(G) Clothes Dryer (in your home) ________ 24

(H) Dish Washer ________ 25

12. On average, how noisy do you think it is in your own home? (Show Card)

1 2 3 4 5 6 7 26

13. How annoying are the noises made by your neighbours in your building <u>either side of you</u>? (i.e., on the same floor?) (Show Card)

NA 1 2 3 4 5 6 7 27

14. How annoying are the noises made by your neighbours in your building <u>above or below you</u>? (Show Card)

NA 1 2 3 4 5 6 7 28

15. How annoying are the noises made by people in the halls or stairs near your home? (Show Card)

NA 1 2 3 4 5 6 7 29

16. a) If annoyed by neighbours, are you more annoyed by noises made by your neighbours when you are in a particular room? If yes, which room? (Give only <u>one</u> worst case.)

Bedroom _____ Living Room _____ Dining Room _____ Bathroom _____

Kitchen _____ Family Room _____ Other (Specify) _____ 30

b) If 'yes', why is it more annoying in this room?

i) (subject requires quieter conditions in this room)

____

ii) (subject's quiet room is adjacent to neighbour's noisier room) 31

____

iii) (other)

____

17. When you are at home, how annoying are the following?

(A) Plumbing noises in your building? (toilets, taps, etc.) (Show Card)

1 2 3 4 5 6 7 32

(B) Building machinery noises? (e.g., garbage chutes, elevators, etc). (Show Card)

1 2 3 4 5 6 7 33

(C) Traffic noises? (Show Card)

1 2 3 4 5 6 7 34

(D) Aircraft noises? (Show Card)

1 2 3 4 5 6 7 35

(E) Other outdoor noises? (Show Card)

1 2 3 4 5 6 7 36

(F) Floor vibrations in your home? (Show Card)

1 2 3 4 5 6 7 37

(G) The sounds of your neighbours' voices? (Show Card)

1 2 3 4 5 6 7 38

(H) Speech sounds from your neighbours' radio or TV? (Show Card)

1 2 3 4 5 6 7 39

(I) Music related sounds from your neighbours? (Show Card)

1 2 3 4 5 6 7 40

(J) The sounds of your neighbours' children? (Show Card)

NA 1 2 3 4 5 6 7 41

(K) The sounds of footsteps above you? (Show Card)

NA 1 2 3 4 5 6 7 42

(L) i) The sounds of your neighbours' tools or appliances? (Show Card)

1 2 3 4 5 6 7 43

ii) Which tools or appliances are most annoying?

____

(M) The sounds of doors slamming? (Show Card)

1 2 3 4 5 6 7 44

(N) The sounds of telephones ringing? (Show Card)

1 2 3 4 5 6 7 45

18. Considering different times of day, how annoying are the noises made by your neighbours, either side of you?

(A) In the daytime hours 7 a.m. - 10 p.m.? (Show Card)

NA 1 2 3 4 5 6 7 46

(B) In the nighttime hours 10 p.m. - 7 a.m.? (Show Card)

NA 1 2 3 4 5 6 7 47

19. How annoying are the noises made by your neighbours above and below you?

(A) In the daytime hours 7 a.m. - 10 p.m.? (Show Card)

NA 1 2 3 4 5 6 7 48

(B) In the nighttime hours 10 p.m. - 7 a.m.? (Show Card)

NA 1 2 3 4 5 6 7 49

20. How often do you have difficulty falling asleep due to:

(A) Noise made by neighbours in your building? (Show Card)

1 2 3 4 5 6 7 50

(B) Outdoor noises? (Show Card)

1 2 3 4 5 6 7 51

21. How often are you awakened by:

(A) Noises made by neighbours? (Show Card)

1 2 3 4 5 6 7 52

(B) Outdoor noises? (Show Card)

1 2 3 4 5 6 7 53

22. How many dollars per month would you be prepared to pay to eliminate annoying noises?

none _____ $0-5 _____ $5-10 _____ $10-15 _____ $15-20 _____ more _____ 54

23. Do you own or rent you home? Rent _____ Own _____ 55

a) If rent, approximately what is your monthly rent? _____________

56

OR b) If owner, approximately what is the value of your home? ___________

24. On average, for a typical week:

a) How many days per week are you at home during most of the daytime hours 7 a.m. - 6 p.m.?

57

____

b) How many days per week are you at home during most of the evening hours 6 p.m. - 10 p.m.?

_____________ 58

c) How many days per week are you at home during most of the nighttime hours 10 p.m. - 7 a.m.?

59

____

25. How many years of formal education have you completed?

Part Elementary _____ Completed Elementary _____

Part High School _____ Completed High School _____ 60

1 or 2 years college or university _____ More _____

26. In which category would the total gross household income fit?

$ - 10,000 _____ $10,001 - 20,000 _____ $20,001 - 30,000 _____ 61

$30,001 - 40,000 _____ $40,0001 - _____

27. In which category would your age fit?

18 - 27 _____ 28 - 37 _____ 38 - 47 _____ 48 - 57 _____ 62

58 - 67 _____ 68 - 77 _____ 78 - _____

28. How many people live in this home?

who are 18 years or older _____ who are under 18 years of age _____ 63 64

DO NOT ASK THE FOLLOWING:

29. Is subject Male _____ OR Female _____ 65

30. Did the subject appear to have any hearing problems?

YES _____ NO _____ 66

31. Horizontal distance from dwelling to centre of street? ______________

32. Floor of building? (1 = floor at ground level) (0 = basement level) 67

33. Number of vehicles per hour on adjacent road?

a) Cars _____

b) Heavy trucks (> 10,000 lbs. GVW) _____

To better understand your responses to this questionnaire, it is often helpful to evaluate more general attitudes by the questions below. Again, please remember that your responses are completely anonymous.

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and circle the number to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
1) I feel pleasant	1	2	3	4
2) I tire quickly	1	2	3	4
3) I feel like crying	1	2	3	4
4) I wish I could be as happy as others seem to be	1	2	3	4
5) I am losing out on things because I cannot make up my mind soon enough	1	2	3	4
6) I feel rested	1	2	3	4
7) I am 'calm, cool, and collected'	1	2	3	4
8) I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
9) I worry too much over something that really does not matter	1	2	3	4
10) I am happy	1	2	3	4
11) I am inclined to take things hard	1	2	3	4
12) I lack self-confidence	1	2	3	4
13) I feel secure	1	2	3	4
14) I try to avoid facing a crisis or difficulty	1	2	3	4
15) I feel blue	1	2	3	4
16) I am content	1	2	3	4
17) Some unimportant thought runs through my mind and bothers me	1	2	3	4
18) I take disappointments so keenly that I cannot put them out of my mind	1	2	3	4
19) I am a steady person	1	2	3	4
20) I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

-- THANK YOU VERY MUCH FOR YOUR HELP --

As you have probably guessed from the questions that were asked, our study is concentrated on noise and, in particular, the noise that passes through your walls from your neighbours. If at all possible, with the consent of you and your neighbour, we would like to arrange to return and measure the degree of sound isolation provided by your walls. This would require noise measurements in two adjacent homes and would take about an hour. The results of these tests are very important to help us learn to design adequate walls between dwellings. If one of your neighbours also agrees, would you be willing to allow us to measure in your home? (If yes, could we have your telephone number so that we can arrange a suitable time? Telephone ___________)

Who should we ask for?

Name ______________________________ (full name not required)

We would also like to leave a small box (the size of a pocket calculator) in your home for one day. It is an automatic noise recorder that adds up the total noise over a 24-hour period. It does not record actual sounds, and so does not interfere with your privacy.

TABLE I Mean Noise and Sound Insulation Values

Response Variable	Explanation	Mean Score	Standard Deviation
069	L_{EQ}^{D}	55.2	6.4
070	L_{EQ}^{N}	45.2	6.5
071	L_{EQ}^{24}	53.0	6.0
092	STC	51.2	4.5
093	NIC	54.5	4.7
094	STA	51.3	4.3
095	DA	52.8	4.5
096	DAS	52.3	4.5
097	DAN	49.6	4.3
098	DANS	49.2	4.3

TABLE II Summary of Respondent Characteristics

Response Variable	Explanation	Mean Score	Standard Deviation
056	Value of the home	$41,433.	$ 9,840.
061	Household income	27,245.	10,481.
062	Respondent's age	37.4	11.8
060	Years of formal education	13.7	2.9
065	Percentage male subjects	42.9	-------
065	Percentage female subjects	57.1	-------
063	Number of occupants 18 years or older	2.0	.67
064	Number of occupants under 18 years old	1.1	1.1
055	Percentage owners	91.8	-------
055	Percentage renters	8.2	-------
005	Length of occupancy (in months)	45.6	33.6
057	Days home per week	3.3	2.4
058	Evenings home per week	5.1	1.7
059	Nights home per week	6.6	1.2

TABLE III Summary of Reported Use of Noise-Producing Devices

Response Variable	Explanation	Mean Score	Standard Deviation
	(a) hours per week use of the following:		
015	television	24.7	19.9
016	radio	27.6	26.9
017	stereo (record player, tape recorder)	8.9	12.5
	(b) percentages of subjects owning the following:		
018	central air conditioning	5.1	
019	wall or window air conditioner	32.7	
020	food blender or food processor	41.8	
021	hair dryer	82.7	
022	vacuum cleaner	100.0	
023	washing machine (in home)	84.7	
024	clothes dryer (in home)	83.7	
025	dishwasher	53.1	

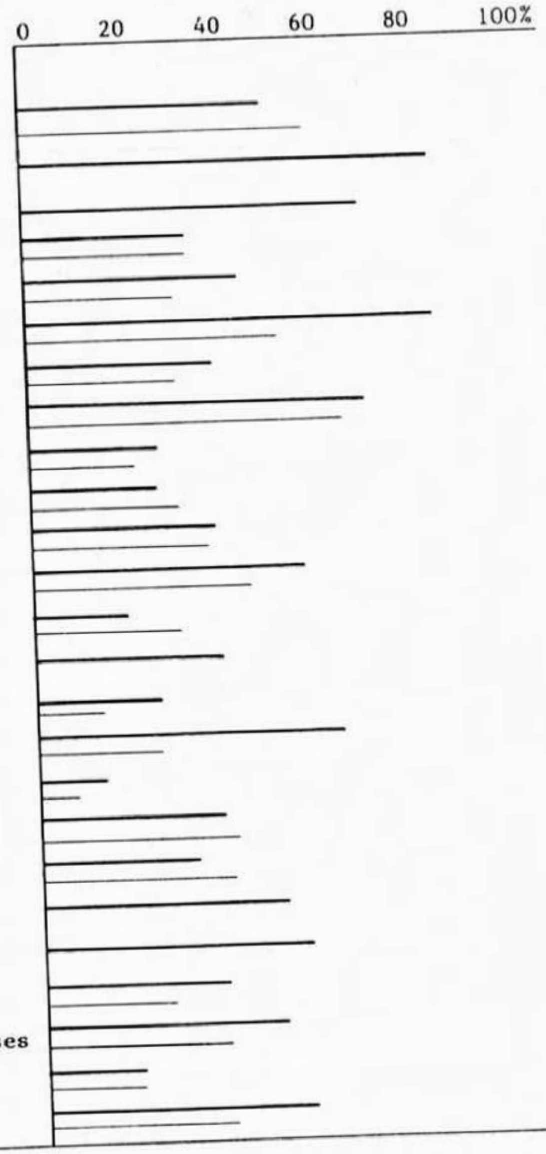
TABLE IV Summary of Percentages of Subjects at all Annoyed or Scoring Greater Than 1 on Response Scale

Response Variable	Explanation	Percentage of Subjects at all Annoyed (Scoring > 1)
		0 20 40 60 80 100%
	Annoyed with:	
027	neighbours either side	57.1
032	plumbing noises	33.7
033	building machinery noises	31.6
034	traffic noise	57.1
035	aircraft noise	31.6
036	other outdoor noises	65.3
037	floor vibrations	21.4
038	sounds of neighbours' voices	29.6
039	neighbours' radio or T.V.	36.7
040	neighbours' music sounds	46.9
041	neighbours' children sounds	36.3
043	sounds of neighbours' tools or appliances	15.3
044	sounds of doors slamming	31.6
045	sounds of telephones ringing	9.2
046	daytime: sounds from neighbours either side	39.8
047	nighttime: sounds from neighbours either side	37.8
050	difficulty falling asleep due to neighbours	27.6
051	difficulty falling asleep due to outdoor noises	39.8
052	awakened by neighbours	18.4
053	awakened by outdoor noises	40.8

TABLE V Comparison of Data for Apartment and Row Housing Residents

Variable	Explanation	Apartments	Row Housing
069	L_{EQ}^{D} (dBA)	53.2	55.5
070	L_{EQ}^{N} (dBA)	46.2	45.0
071	L_{EQ}^{24} (dBA)	51.2	53.4
092	STC (dB)	45.7	52.3
056	value of home	$30,500	$43,566
060	education (years)	12.9	13.8
061	household income	$26,250	$27,439
062	age	38.6	37.1
063	number occupants 18 or older	1.75	2.05
064	number occupants under 18	0.31	1.26
065	percent female	56.4	57.3
065	percent male	48.8	42.7
057	daytime, days home	3.2	3.3
058	evening, days home	5.3	5.1
059	night, days home	6.9	6.5

TABLE VI Comparison of "At All Annoyed" Responses for Apartment and Row Housing Residents



Response Variable	Explanation	Apartments	Row Housing
	Annoyed with:		
027	neighbours either side	50.0	58.5
028	neighbours above or below	81.2	--
029	noises in halls and stairs	68.7	--
032	plumbing noises	31.2	34.1
033	building machinery noises	43.7	29.3
034	traffic noises	81.2	52.4
035	aircraft noises	37.5	30.5
036	other outdoor noises	68.7	64.6
037	floor vibrations	25.0	20.7
038	neighbours' voices	25.0	30.5
039	neighbours' radio, T.V.	37.5	36.6
040	neighbours' music sounds	56.2	45.1
041	neighbours' children sounds	18.2	29.1
042	footstep sounds	37.3	--
043	neighbours' tools and appliances	25.0	13.4
044	sounds of doors slamming	62.5	26.6
045	sounds of telephones ringing	12.5	8.5
046	daytime: neighbours either side	37.5	40.2
047	nighttime: neighbours either side	31.2	39.0
048	daytime: neighbours above or below	50.0	--
049	nighttime: neighbours above or below	56.2	--
050	difficulty falling asleep due to neighbours	37.5	26.4
051	difficulty falling asleep due to outdoor noises	50.0	37.8
052	awakened due to neighbours	18.7	18.3
053	awakened due to outdoor noises	56.2	37.8

TABLE VII Correlation of Responses with Measures of TL

Response Variable	Explanation	Correlation Coefficients						
012	satisfied with building	-	-	.189	.200	.181	.191	.169
026	perceived degree of noise in home	-.207	-.211	-.215	-.230	-.228	-.216	-.216
027	annoyed by neighbours either side	-	-	-	-	-	-	-
038	annoyed by neighbours' voices	-.210	-	-.218	-.168	-	-.216	-.215
039	annoyed by neighbours' radio, T.V.	-	-	-	-	-	-	-.168
040	annoyed by neighbours' music	-.196	-.196	-.217	-.189	-.191	-.215	-.222
041	annoyed by sound of neighbours' children	-	-	-	-	-	-	-
043	annoyed by sounds of tools, appliances	-.223	-.198	-.182	-	-	-.178	-.185
044	annoyed by sounds of doors slamming	-.269	-.343	-.309	-.358	-.360	-.308	-.314
045	annoyed by sounds of telephones	-	-	-	-	-	-	-
046	daytime: annoyed by neighbours	-	-	-	-	-	-	-
047	nighttime: annoyed by neighbours	-.168	-	-.185	-	-	-.183	-.187
050	difficulty falling asleep due to neighbours	-.198	-.183	-.226	-.198	-.196	-.224	.229
052	awakened due to neighbours	-	-	-	-	-	-	-
054	dollars per month	-.355	-.339	-.378	-.360	-.359	-.374	-.373
101	annoyance (factor)	-.222	-.200	-.245	-.201	-.200	-.243	-.248
104	annoyance (correlation)	-.282	-.266	-.304	-.274	-.273	-.302	-.306
	Response Variable	092	093	094	095	096	097	098

LEGEND

092	STC	096	DAS
093	NIC	097	DAN
094	STA	098	DANS
095	DA		

Significance Levels

N = 98	R > 167	$p < .05$
	R > 235	$p < .01$
	R > 302	$p < .01$

TABLE VIII Correlation of Responses with Background Noise Measures

Response Variable	Explanation	Correlation Coefficients						
012	satisfied with building	-	-	-	-.206	-	-.208	-
026	perceived degree of noise in home	.197	-	.190	-	-	-	-
027	annoyed by neighbours either side	-	-	-	.251	-	.254	.242
038	annoyed by neighbours' voices	-	-	-	.195	-	.213	-
039	annoyed by neighbours' radio, T.V.	-	-	-	-	-	-	-
040	annoyed by neighbours' music	-	-	-	-	-	-	-
041	annoyed by sound of neighbours' children	-	-	-	.357	-	.331	.263
043	annoyed by sounds of tools, appliances	-	-	-	-.172	-	-	-
044	annoyed by sounds of doors slamming	-	-	-	-	-	-	-
045	annoyed by sounds of telelphones	-	-	-	-	-	-	-
046	daytime: annoyed by neighbours	-	-	-	.286	-	.288	.189
047	nighttime: annoyed by neighbours	-	-	-	-	-	-	-
050	difficulty falling asleep due to neighbours	-	-	-	-	-	-	-
052	awakened due to neighbours	-	-	-	-	-	.180	-
054	dollars per month	-	-	-	-	-	-	-
101	annoyance (factor)	-	-	-	.239	-	.245	-
104	annoyance (correlation)	-	-	-	-	-	.181	-
	Response Variable	069	070	071	072	073	074	099

LEGEND

	Subject	Neighbour
L_{EQ}^{D}	069	072
L_{EQ}^{N}	070	073
L_{EQ}^{24}	071	074

Significance Levels		
N = 98	$R > .167$	$p < .05$
	$R > .235$	$p < .01$
	$R > .303$	$p < .001$

TABLE IX Correlation of Major Responses with Individual 1/3 Octave TL Values

Response Variable	Explanation	1/3 Octave TL Response Variable Number 075	076	077	078	079	080	081	082	083	084	085	086	087	088	089	090	091
012	satisfied with building	.300	.306	-	-	-	-	-	-	-	-	-	-	-	-	-	.184	-
026	noisy home	-	-.227	-.210	-.170	-.174	-	-	-	-	-	-	-	-	-	-	-	-
027	annoy. neighbours' side	-	-.193	-.179	-	-	-	-	-	-	-	-	-	-	-	-	-	-
038	annoy. neighbours' voices	-	-	-.271	-.188	-.171	-	-	-	-	-.222	-.206	-.167	-	-	-.185	-.205	-.180
039	annoy. neighbours' radio, T.V.	-	-	-.204	-	-	-	-	-	-	-.178	-	-	-	-	-	-	-
040	annoy. neighbours' music			-.214	-.181	-.219	-.239	-.205	-	-	-.179	-.177	-	-	-	-	-	-
041	annoy. neighbours' children	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
046	day: annoy. neighbours	-	-	-.188	-	-	-	-	-	-	-	-	-	-	-	-	-	-
047	night: annoy. neighbours	-	-	-.183	-	-.186	-.186	-.219	-	-	-	-	-	-	-	-.174	-.196	-.167
050	difficulty falling asleep	-	-.184	-.200	-.171	-.242	-.247	-.217	-	-	-.195	-	-	-	-	-	-	-.174
052	awakened	-	-	-	-	-	-.187	-	-	-	-	-	-	-	-	-	-	-
054	$/month	-.246	-.284	-.406	-.371	-.350	-.238	-.292	-.230	-.278	-.271	-.210	-.219	-	-	-	-	-
101	annoyance (factor)	-	-	-.259	-.195	-.241	-.236	-.236	-	-	-.212	-.193	-	-	-	-	-	-.174
104	annoyance (correlation)	-	-.235	-.311	-.247	-.278	-.274	-.255	-	-.171	-.253	-.230	-.200	-	-	-	-	-
	1/3 Octave Centre Frequencies	100	125	160	200	250	315	400	500	800	800	1000	1250	1600	2000	2500	3150	4000

Significance Levels:

N = 98,	R > .167	p < .05
	R > .235	p < .01
	R > .302	p < .001

TABLE X Intercorrelation of Noise (TL) Measures

Variable	Details	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
075	100	1.0																							
076	125	.856	1.0																						
077	160	.701	.715	1.0																					
078	200	.510	.513	.871	1.0																				
079	250	.387	.409	.726	.839	1.0																			
080	315	.257	.271	.582	.693	.888	1.0																		
081	400	.263	.255	.551	.631	.831	.922	1.0																	
082	500	.259	.265	.590	.669	.750	.800	.862	1.0																
083	630	.268	.334	.532	.608	.674	.664	.738	.867	1.0															
084	800	.386	.497	.582	.560	.592	.575	.635	.729	.907	1.0														
085	1000	.326	.423	.482	.445	.510	.500	.576	.654	.852	.932	1.0													
086	1250	.442	.507	.516	.468	.529	.467	.479	.655	.841	.878	.899	1.0												
087	1600	.402	.470	.421	.371	.379	.320	.421	.540	.743	.765	.806	.924	1.0											
088	2000	.444	.479	.458	.406	.367	.283	.344	.514	.719	.729	.765	.868	.892	1.0										
089	2500	.447	.475	.426	.373	.331	.273	.357	.498	.642	.657	.653	.786	.798	.892	1.0									
090	3200	.401	.452	.409	.357	.436	.431	.522	.594	.703	.731	.708	.835	.776	.793	.893	1.0								
091	4000	.277	.392	.359	.300	.370	.367	.472	.587	.712	.732	.742	.847	.820	.804	.817	.867	1.0							
092	STC	.457	.515	.780	.841	.888	.856	.866	.846	.818	.769	.709	.723	.621	.583	.513	.596	.590	1.0						
093	NIC	.422	.472	.695	.729	.822	.784	.836	.793	.805	.752	.677	.716	.596	.570	.499	.613	.642	.937	1.0					
094	STA	.622	.647	.855	.866	.875	.809	.822	.812	.782	.760	.680	.732	.618	.614	.562	.617	.582	.968	.912	1.0				
095	DA	.589	.605	.765	.755	.802	.723	.776	.745	.769	.745	.651	.726	.600	.603	.555	.632	.634	.904	.969	.937	1.0			
096	DAS	.546	.566	.750	.756	.820	.753	.807	.773	.787	.750	.654	.718	.583	.579	.528	.617	.626	.915	.979	.937	.997	1.0		
097	DAN	.625	.650	.856	.866	.872	.807	.819	.810	.781	.761	.680	.731	.618	.615	.563	.617	.581	.966	.910	.999	.936	.936	1.0	
098	DANS	.519	.607	.838	.865	.891	.839	.852	.837	.797	.764	.683	.721	.601	.588	.534	.602	.573	.977	.920	.998	.932	.937	.997	1.0

Significance Levels:

$N = 49$, $R \geq .280$ $p \leq .05$

$R \geq .362$ $p \leq .01$

$R \geq .444$ $p \leq .001$

TABLE XI Correlation Between Responses and AAD Type Measures

Response Variable	Explanation	Correlation Coefficients			
026	perceived degree of noise in home	.171	.175	.183	.187
027	annoyed by neighbours either side	–	–	–	–
038	annoyed by neighbours' voices	.228	.223	.220	.217
039	annoyed by neighbours' radio, T.V.	.172	–	–	–
040	annoyed by neighbours' music	.211	.207	.212	.220
041	annoyed by sound of neighbours' children	–	–	–	–
046	daytime: annoyed by neighbours	–	–	–	–
047	nighttime: annoyed by neighbours	.211	.206	.205	.206
050	difficulty falling asleep due to neighbours	.239	.239	.242	.246
052	awakened due to neighbours			–	
054	dollars per month	.395	.394	.396	.400
101	annoyance (factor)	.255	.250	.252	.254
104	annoyance (correlation)	.291	.290	.295	.300
	Response Variable	106	107	108	109

LEGEND

Response Variable	Slope of AAD Type Contour
106	2 dB/oct.
107	3 dB/oct.
108	4 dB/oct. (British procedure)
109	5 dB/oct.

Significance Levels:

$N = 49$, $R > .280$ $p < .05$
$R > .362$ $p < .01$
$R \geq .444$ $p \leq .001$

TABLE XII Multiple Regressions of Responses on Sound Insulation and Noise Measures

Response Variable	Explanation	STC 1	STC 2	STC 3	STA 1	STA 2	STA 3	AAD 1	AAD 2	AAD 3
027	annoyance by neighbours either side	.099 (ns)	.283	.297	.152	.305	.318	.165 (ns)	.308	.322
038	annoyance by neighbours' voices	.210	.316	.327	.218	.316	.325	.220	.312	.319
039	annoyance by neighbours' radio, T.V.	.156 (ns)	.188	.199	.166 (ns)	.193	.203	.163 (ns)	.188	.196
040	annoyance by neighbours' music	.196	.246	.262	.217	.260	.276	.212	.252	.271
041	annoyance by neighbours' children's sounds	.002 (ns)	.333	.339	.023 (ns)	.334	.340	.015 (ns)	.332	.338
046	daytime: annoyance by neighbours	.134 (ns)	.332	.332	.155 (ns)	.336	.336	.151 (ns)	.330	.330
047	nighttime: annoyance by neighbours	.168	.296	.300	.184	.301	.303	.205	.310	.312
050	difficulty falling asleep due to neighbours	.198	.262	.265	.226	.281	.282	.242	.290	.291
052	awakened due to neighbours	.078 (ns)	.201	.203	.139 (ns)	.232	.233	.139 (ns)	.232	.233
054	dollars per month	.355	.355	.368	.378	.379	.388	.396	.396	.404
101	annoyance (factor)	.222	.350	.350	.245	.359	.359	.252	.358	.358
104	annoyance (correlation)	.282	.352	.362	.304	.365	.372	.295	.351	.357

LEGEND

1 simple correlation with single sound insulation measure

2 multiple correlation insulation measure + neighbour's L_{EQ}^{24}

3 multiple correlation insulation measure + neighbour's L_{EQ}^{24} + subject's L_{EQ}^{24}

(Underlined values indicate the new term added significantly to the prediction.)

TABLE XIII Factors Contributing to Multiple Correlations

Dependent Variable	092 STC	074 L_{EQ}^N	071 L_{EQ}^S	005	012	013	014	056	057	058	059	060	061	062	063	064	065	068	Multiple R
027		✓	✓	3		-1	-5		2		-7		6		-4				.646
038	✓	✓			-2	-1		3											.440
039				2	-7	-1	-4		5				6		-3				.525
040					-3	-1			2				5					4	.531
041		✓				-4		2				3						1	.530
046	✓	✓		2		-1		5						-3	-6	7		4	.605
047	✓	✓				-1		2											.419
050	✓	✓		2		-1	-3		4										.550
052						-1	-3		2		-4							5	.461
054	✓								1					-4			-2	3	.467
101	✓	✓		3		-1	-5		2					-4					.608
104	✓				-3	-1			2			4							.642

LEGEND:

005 length of occupancy
012 satisfaction with building
013 considerate neighbours
014 helpful building officials
056 value of home
057 days home per week
058 evenings home per week

059 nights home per week
060 education
061 income
062 age
063 no. of adults
064 no. of children
065 sex
068 stress

027 annoyed on neighbours' side
038 annoyed by neighbours' voices
039 annoyed by radio, T.V.
040 annoyed by music
041 annoyed by children's sounds
046 annoyed in daytime
047 annoyed at night
050 difficulty falling asleep due to neighbours

052 awakened due to neighbours
054 dollars per month
101 annoyance (factor)
104 annoyance (correlation)

✓ - indicates acoustical measure added significantly to prediction

TABLE XIV Factors Contributing to Multiple Correlations

Dependent Variable	092	074	071	005	012	013	014	015	016	017	055	056	057	058	059	060	061	062	063	064	065	068	Final Multiple R
027		✓	✓	3		-1	-5	6			8		2		-9		7		-4				.694
038	✓	✓			-2	-1			-3														.480
039				3	-4	-1		6	-2		8	5							-7				.577
040	✓		✓	4		-1	-7	3					2					-6				8	.573
041		✓						6	-1	-4		2				5						3	.577
046	✓	✓		3		-2			-1			6	5					-4				7	.621
047	✓	✓				-1		2			3												.438
050	✓	✓		2		-1	-3		-5				4										.550
052		✓				-1							2										.407
054	✓									2			1							-3			.453
101	✓	✓		4		-1	-7	6	-3		8		2			9		-5					.690
104	✓	✓			-3	-1		6	-2				4			7	5						.705

LEGEND:

005 length of occupancy
012 satisfaction with building
013 considerate neighbours
014 helpful building officials
015 hours watching T.V.
016 hours listening to radio
017 hours listening to stereo
055 own/rent
056 value of home
057 days home per week

058 evenings home per week
059 nights home per week
060 education
061 income
062 age
063 no. of adults
064 no. of children
065 sex
068 stress

027 annoyed on neighbours' side
038 annoyed by neighbours' voices
039 annoyed by radio, T.V.
040 annoyed by music
041 annoyed by children's sounds
046 annoyed in daytime
047 annoyed at night
050 difficulty falling asleep due to neighbours

052 awakened due to neighbours
054 dollars per month
101 annoyance (factor)
104 annoyance (correlation)

✓ - indicates acoustical measure added significantly to prediction

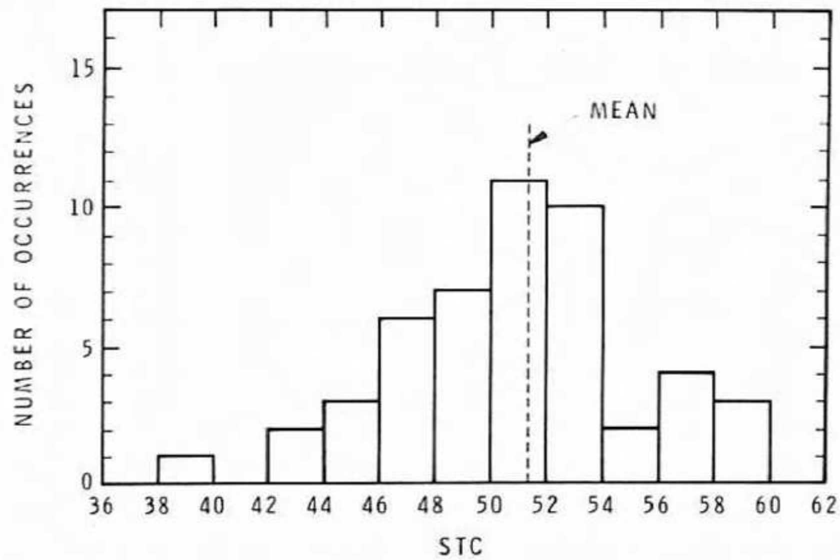


FIGURE 1

DISTRIBUTION OF MEASURED STC VALUES

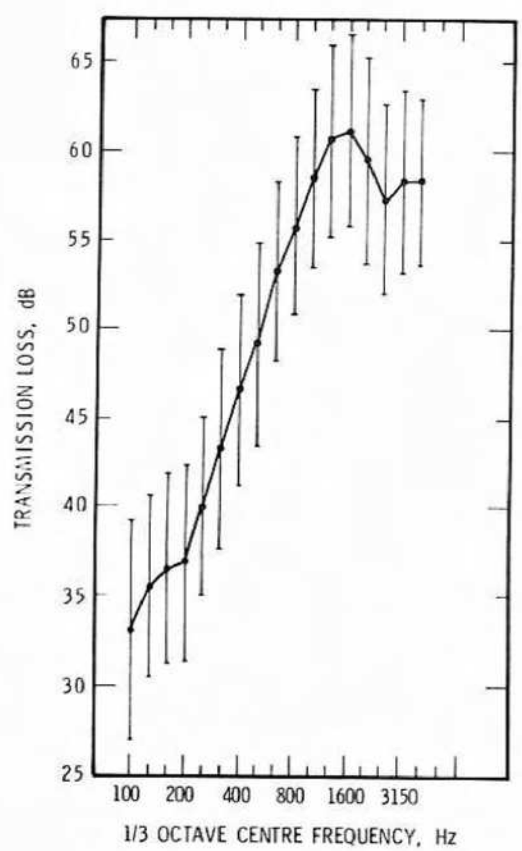


FIGURE 2

MEAN, ± STANDARD DEVIATION,
TRANSMISSION LOSS VS FREQUENCY

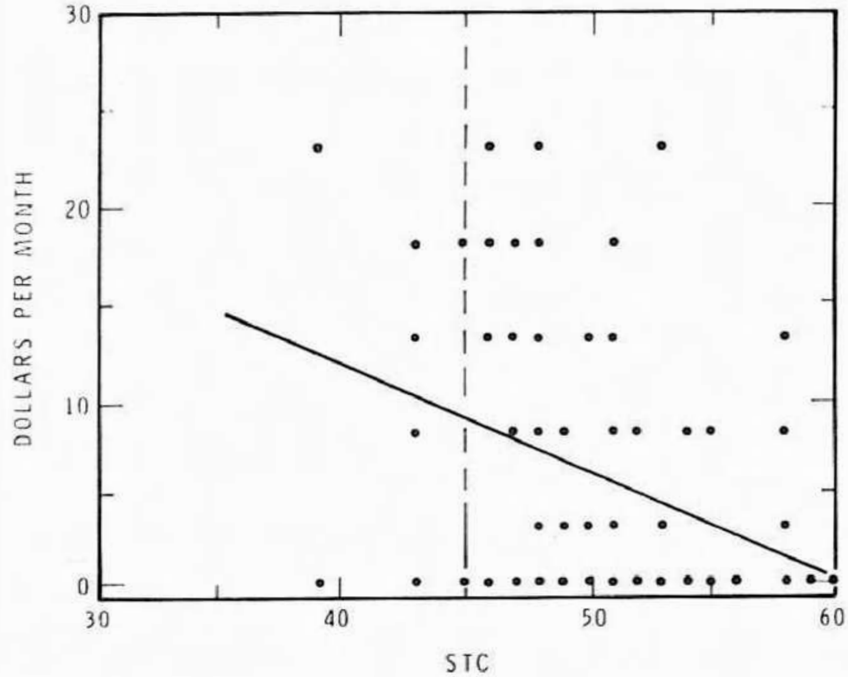


FIGURE 3

REGRESSION OF DOLLARS PER MONTH VS STC VALUES

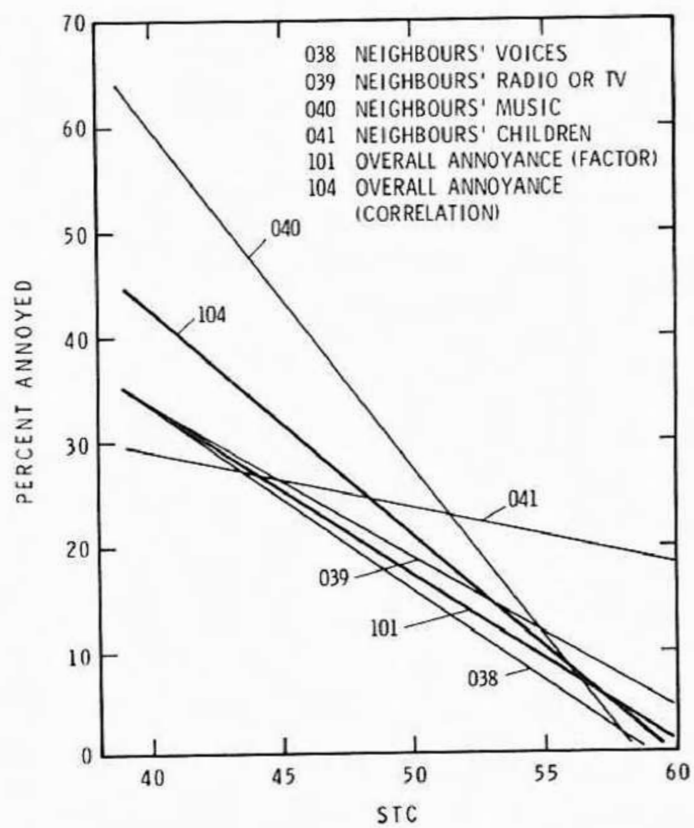


FIGURE 4

PERCENTAGE ANNOYED VS STC VALUE

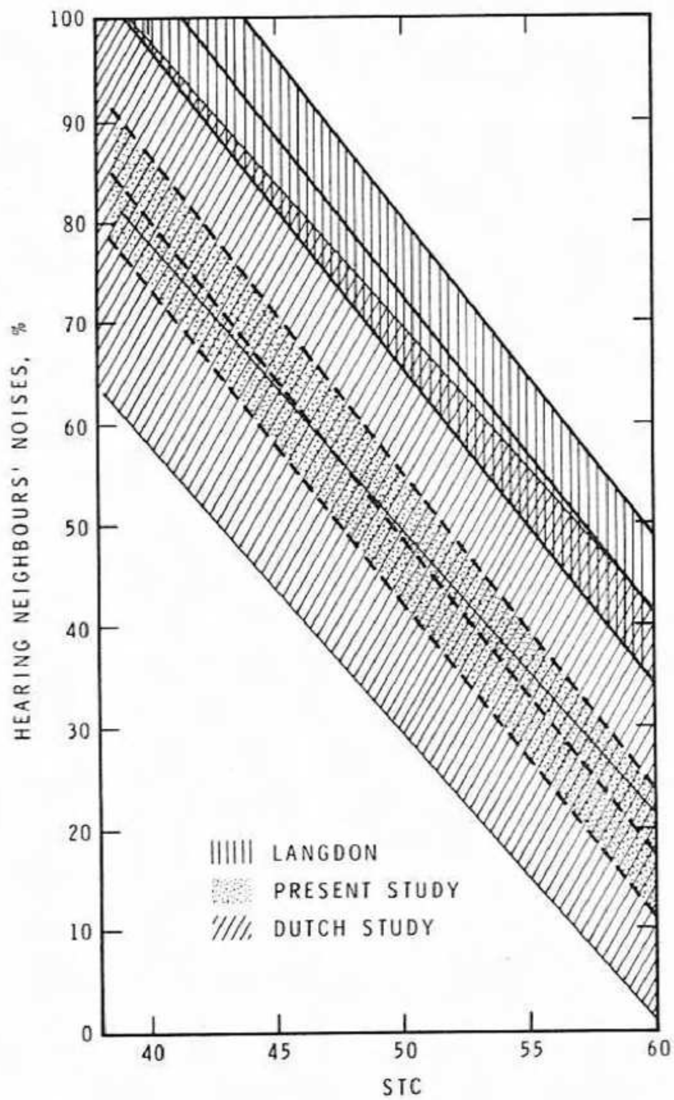


FIGURE 5

COMPARISON OF MEAN, ± STANDARD DEVIATION SCORES VS STC VALUES

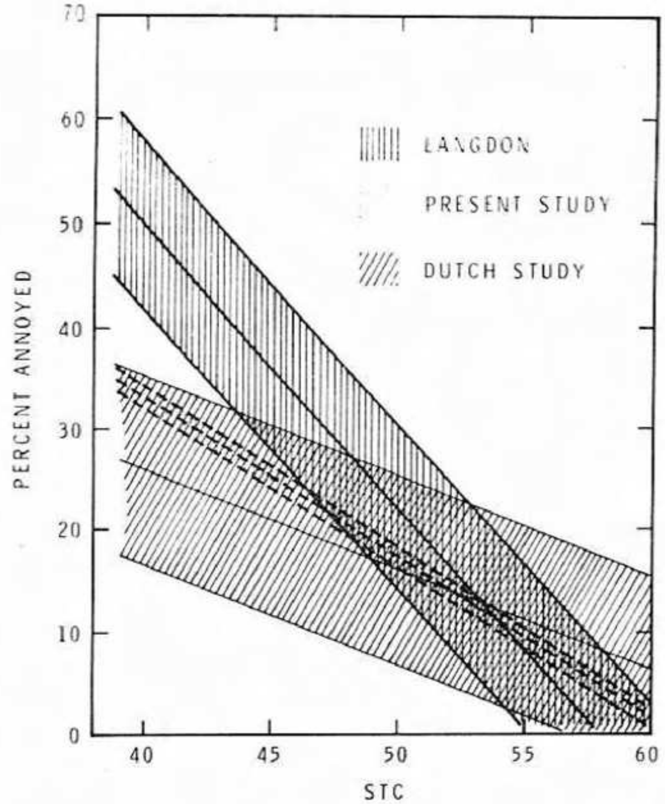


FIGURE 6

COMPARISON OF MEAN, ±STANDARD DEVIATION SCORES VS STC VALUES

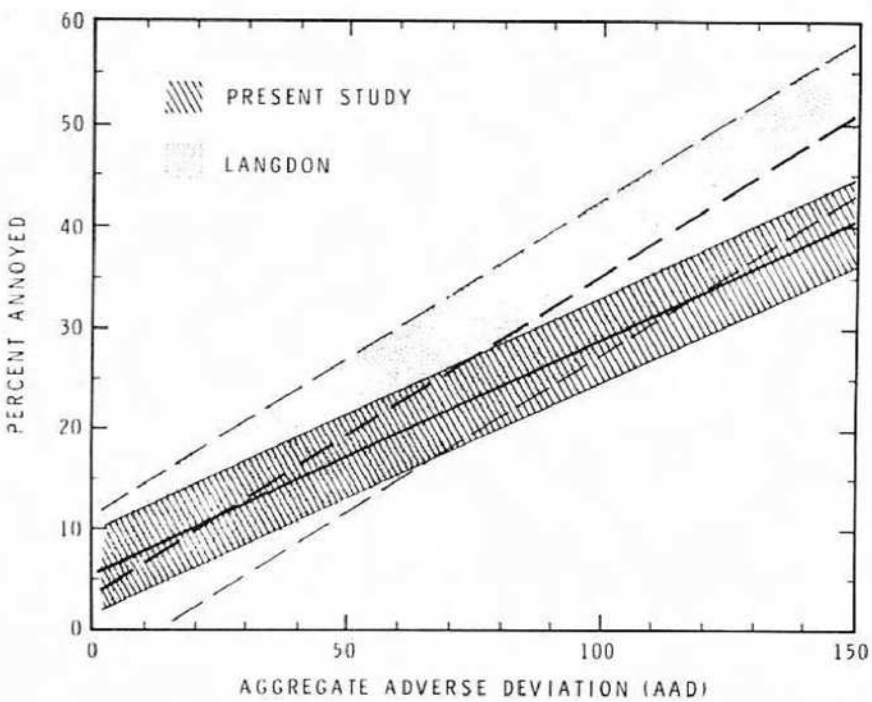


FIGURE 7

COMPARISON OF MEAN, ±STANDARD DEVIATION SCORES VS AAD VALUES