Client Report :

The National Noise Incidence Study 2000 (England and Wales)

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Executive Summary

In 1990 BRE carried out a national study of environmental noise levels for the Department of the Environment. The study generated objective estimates of the pattern of the noise exposure of the population of England and Wales, based on 24 hour measurements outside 1000 dwellings.

During the year 2000, BRE conducted a similar study, supported by the Department for the Environment, Food and Rural Affairs and the Devolved Administrations, which involved new measurements and has produced new estimates of the pattern of population exposure. This report sets out the year 2000 estimates, and compares them with those obtained in 1990. All figures presented are estimates of the exposure of the entire population of England and Wales, extrapolated from the measurements of a sample of this population.

The current study was based on 24 hour measurements obtained outside 1020 dwellings in England and Wales. Of the 1020 measurement sites, 680 were chosen as repeats of the sites measured in 1990, being either the same dwelling, or one chosen to be as near an exact repeat as possible (i.e. a dwelling with a similar acoustical environment in a similar location). These repeat sites allowed an analysis of paired sites to be undertaken, thus increasing the sensitivity of the study to changes. The remaining 320 sites were newly selected sites. The purpose of these new selections was to allow the sample to dynamically change following any long-term changes in population density over the country. For similar reasons, the new selections involved the inclusion of an additional twenty sites in the south-east of the country.

Overall, the results obtained from the current study indicate that there have been statistically significant changes in the mean noise level since the previous study in 1990. These changes are small in magnitude, at most just over 1 dB(A). Indices measuring noise levels exceeded for a small proportion of the time (such as L_{A01} and L_{A10}) during day-time periods, have been shown to have decreased, whilst indices describing background noise levels (such as L_{A90}) at night have increased. This pattern is compatible with a model for noise source changes where the number of noise producing items or events (such as vehicles on roads) has increased, whilst the noise output of individual events has decreased; these two effects approximately balancing each other.

The cause of the increase in night-time background levels cannot be uniquely identified due to the 1-hour time resolution of the data available from the 1990 study. The indications are that the change could be due to either a general increase in level throughout the night, or a shortening of the quieter night-time period. The most likely explanation for this increase is a combination of these two effects.

Cumulative distributions of the estimated proportion of the population of England and Wales exposed to noise levels exceeding certain values indicate the same trend in the overall changes expressed above. In general the shift is seen to be fairly uniform across all levels. However, the L_{A10} index, during day-time periods, has generally shown a greater decrease at higher levels, whilst many indices show a slight reduction in width of the distribution, indicating less dwellings falling into the extreme high and low exposure bands. This last effect is very slight, and falls into a region of the distributions, where, due to the number of sites concerned, the uncertainties in the distributions, and hence the statistical significance of any changes seen cannot be accurately calculated.

The World Health Organisation (WHO)[1] states that ‘to protect the majority of people from being seriously annoyed during the day-time, the sound pressure level on balconies, terraces and outdoor living areas should not exceed 55 dB L_{Aeq} for a steady continuous noise.’… ‘At night, sound pressure levels at the outside façades of the living spaces should not exceed 45 dB L_{Aeq} and 60 dB L_{Amax}, so that people may sleep with bedroom windows open.’

In order to compare our results with these WHO levels we have defined the day as 0700 – 2300 and night as 2300 – 0700, and assumed that all the values represent noise levels measured at the façade of dwellings.

The National Noise Incidence Study 2000 has found that 55±3%[2] of the population of England and Wales live in dwellings exposed to day-time noise levels above the WHO level of 55 dB $L_{Aeq,day}$. In 1990 we now estimate that 60±3%[3] of the population were exposed above the level of 55 dB $L_{Aeq,day}$. This change represents a statistically significant decrease in the proportion of the population exposed above this level in 2000 when compared to the results of the 1990 study.

The National Noise Incidence Study 2000 has found that 68±3% of the population of England and Wales live in dwellings exposed to night-time noise levels above the WHO level of 45 dB $L_{Aeq,night}$. In 1990 we now estimate that 66±3%[3] of the population were exposed above the level of 45 dB $L_{Aeq,night}$. This change represents a statistically non-significant increase in the proportion of the population exposed above this level in 2000 when compared to the results of the 1990 study. It should be noted that this is the only of the established guideline values where we have detected an increase in population exposure in 2000 when compared to the 1990 study.

The percentage of the population of England and Wales exposed to noise levels exceeding 68 dB $L_{A10,18hr}$, (the qualifying level for insulation under the Noise Insulation Regulations for new roads[4]), is calculated as 8±1%, numerically equal to that found when the results from the 1990 study are extended in the same way to estimate the exposure of the whole of England and Wales.

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[1] Guidelines for Community Noise, World Health Organisation, 2000.

[2] For this and all subsequent figures in this format, the errors quoted represent the 95% confidence interval.

[3] These figures differ slightly from those quoted in BRE IP 21/93 following the study in 1990, for two reasons:

i. The figures are estimates of the national exposure, rather than proportions of the dwellings sampled,
ii. Corrections have been applied to the data measured in 1990 to produce the best estimates of the levels that would have been recorded had the instrumentation used for the current study been available.

[4] Noise Insulation Regulations, 1975 (as amended).

Contents

1 Introduction

In 1990 BRE carried out a national study of environmental noise levels for the Department of the Environment[5]. The study generated objective estimates of the pattern of the noise exposure of the population of England and Wales, based on 24 hour measurements outside 1000 dwellings.

During the year 2000, BRE conducted a similar study, supported by the Department for the Environment, Food and Rural Affairs and the Devolved Administrations, which involved new measurements and has produced new estimates of the pattern of population exposure. This report sets out the year 2000 estimates, and compares them with those obtained in 1990. Further measurements are to be conducted in Scotland and Northern Ireland in the summer of 2001. These will be discussed in a future supplement to this report.

1.1 Objective measures of environmental noise

It is appropriate briefly to consider the meaning of objective measures of environmental noise - expressed in terms of decibels - of the kind discussed in this report. First of all it is necessary to comment on the use of the term “noise” itself. This study is concerned with levels of noise measured 1 m from the front façade of dwellings (and at a height of 1.2 m). Since noise is often (simplistically) defined as “unwanted sound”, it might appear that an assumption has been made that all sounds detectable at such a measurement position are “unwanted” from the point of view of the dwelling’s occupants. On such a basis it is reasonable to conceive of an environmental noise level determined collectively by all the sounds present, as is the case in this study. However, in the context of this report “noise” should be read, if possible, as an entirely anodyne term without any implication of unwantedness or other negative connotation. The more neutral term environmental or external “sound” could equally have been used, but the term “environmental noise” has been preferred because of its familiarity and the precedent set by the 1990 study.

It is also worth considering briefly the choice of the standard fixed measurement position and its implications. Establishing a fixed standard position is practically expedient, it reduces variability (which is useful for statistical purposes), and it allows comparisons to be made. But its representativeness of individuals’ actual environmental noise exposure (the environmental noise at their ears) is likely to be highly variable from one person to the next. Therefore, the term “population exposure” as used in this report should not be taken literally. The data generated from this study provide an estimate of the pattern of the noise exposure 1 m from the front façades of the dwellings of each person in England and Wales, as a reasonable proxy for “true” population exposure.

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[5] Sargent J W, Fothergill L C, The noise climate around our homes, BRE Information Paper IP21/93.

In any case, it is the likely *effects* on the population of its noise exposure, rather than the exposure in itself, which is of most interest, and some remarks about the effects of noise are necessary at this point. Noise in the external environment rarely reaches the very high levels that may cause hearing loss. There are, however, many potential adverse effects from noise in the external environment such as emotional upset, interference with certain activities, and possible health effects in the long-term[6]. There are also potential benefits, such as comfort from the noise of other human activity, warning of danger, and masking of intrusive noise by relatively unobtrusive noise.

To a large extent, the degree to which any particular noise causes any adverse effects or provides any benefit depends on the context in which the noise is heard[7]. This means that objective measures, however formulated, can only ever give a partial indication of likely consequences. Nevertheless, in any situation in which there is a risk of adverse effects, a higher level of noise is generally associated with a higher risk than a lower level, whatever the actual risk.

In summary, the principal benefit of objective measures of environmental noise such as those reported here, is that they provide the basis for comparisons to be made between the noise environments in different places or at different times. Inferences about the implications of particular noise levels for a particular population, however, can only be drawn with a good deal of circumspection. For this reason the Department also commissioned BRE to carry out a national survey of attitudes to environmental noise, following a similar survey carried out by BRE in 1991. The findings of the attitude survey are presented in a separate report.

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[6] Guidelines for Community Noise, World Health Organisation, 2000.

[7] Wright, P., A context-response paradigm for environmental noise, Proceedings of Internoise 2000.

2 Method

The year 2000 study followed closely the approach used in 1990. As before, a multi-stage, clustered sample of addresses with stratification was used, to reduce survey costs.

2.1 The sample

The flow-diagram in Figure 1[8] shows the method by which the samples were chosen for both the 1990 and year 2000 studies.

2.1.1 The 1990 sample

The 1990 sample comprised 1000 dwellings in England and Wales. The sample size was chosen, following an examination of typical standard deviations of environmental noise levels measured at independent locations, to give an expected standard error of the order of 0.3 dB in the estimated national mean $L_{\mathrm{A10,18hr}}$ level.

Stratification of primary units (Local Authority district) by regional population was applied to control for possible regional effects. Primary units within each region, and secondary units (electoral wards) within each district, were stratified by population density. No other geographical factors were controlled for. Within each region districts were selected with probability proportional to population, and two wards were then selected from each chosen district at random. Ten tertiary units (individual electors with their addresses) were selected at random from each chosen ward, with an additional reserve list of ten selected in the same way. The regional population and district and ward population density figures were based on 1981 census data, while the district and ward populations were based on 1989 electoral registration figures.

2.1.2 Modification of the 1990 sample

Modifications were made to the sample for the year 2000 study to allow adaptation of the sample to gradual changes in population distribution between the two studies, without loosing the statistical advantages afforded by paired comparisons.

From the 1990 sample, 16 out of the 50 primary units (Local Authority districts) were deselected. To preserve the regional stratification present in the sample, the number of districts de-selected in each region was determined on the basis of the regional population. Within each region, the de-selection was performed with probability proportional to population.

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[8] all Figures are included in Section 7, e.g. Figure 1 can be found at Section 7.1.

These 16 districts were replaced by 17 newly selected districts. These were selected in the same regions as those deselected, with the addition of one extra district in the south-east region, to take account of the increase in its population. The selection of new districts was carried out with probability proportional to population and stratification by population density. The de-selected districts were excluded to prevent their re-selection.

Before selecting the new primary units, it was necessary to perform a one to one match of each Local Authority in the 1990 sample against a corresponding Local Authority in the new sample whilst allowing for any new administrative boundary definitions. This match was possible in all cases except for two authorities in Wales, for which 1991 census data were used.

Within each newly selected district, two wards were selected with population proportional to population and stratification by population density, using 1991 census data (the latest available at ward level). Ten addresses in each of the new wards were selected by ranking all addresses by postcode and sampling using a fixed interval with probability proportional to the number of residents. Within each of the 34 remaining districts, the same addresses as used for the 1990 survey were retained.

Figure 2 shows the location of the districts where measurements were taken during the two studies, indicating whether each was repeated in both studies, de-selected after the 1990 study, or a replacement district used only in the year 2000 study. Figure 1 shows a flow diagram of the sampling methodology used for each of the 1990 and year 2000 studies, indicating the methods of selection used at each level of sampling.

The result of the replacements was that paired comparisons could be made between the 34 districts (two-thirds of the total), where measurement locations were repeated between the two studies, whilst the whole sample could be used for the purpose of unpaired comparisons.

2.2 The measurement programme

In 1990 the measurement programme ran for 12 months from January to December. In the year 2000 study the measurement programme ran from July 1999 to November 2000. In both studies measurements were only conducted on weekdays between 10am on Monday and 2pm on Friday. Each site measurement was carried out for a continuous period of 24 hours, no part of which fell outside the above weekday limits. No measurements were conducted during local school holiday periods (including half-term breaks and INSET days). The aim was to ensure that the road traffic local to each measurement point was representative of working weekdays during school time. For this reason no measurements were made during the fuel crisis of September 2000.

The measurement programme was carried out in good weather only, by means of close attention to weather forecasts and local conditions. The aim was to avoid corruption of measurements either by rain saturation of the microphone windshields, or by wind-induced vibration of the microphone diaphragm. A guideline limit of 5m/s was set for the local ground wind speed. Short periods of moderate rainfall were tolerated, but a number of measurements had to be repeated after significant rainfall.

2.2.1 Seasonal matching

It was desirable for measurements to be carried out in a particular area during the same time of year as the corresponding 1990 measurements (see Annex A regarding variance and seasonal trends). However, the order of sites visited during the 1990 measurement programme was somewhat fragmented geographically, and progress against any schedule would always be at the mercy of the weather. A pragmatic approach therefore had to be taken which balanced the often conflicting desires to take advantage of good weather in a particular geographical area, reduce geographical fragmentation for the benefit of any future studies, and achieve seasonal matching against the 1990 programme. In the event, a good correspondence was achieved with the 1990 programme. Table 1[9] sets out the number of sites measured in each district in each week of the year, for the two studies.

2.2.2 Alternative site selection

A letter was sent to all 1020 addresses in the sample requesting residents' permission to carry out measurements and indicating the likely timing of the measurements, together with a reply-paid envelope and response-slip. If a favourable reply was received measurements were made at the designated address. If no reply was received, efforts were made to contact the residents on site. In situations where it was not possible to get permission to measure at the designated address, an alternative was obtained that corresponded to similar acoustic conditions, according to the following guidelines:

i. Local road: The same road(s) local to the designated address should be local to the alternative address. In many cases, this simply meant that the designated and alternative addresses lay along the same road.

ii. Orientation and kerb to façade distance: The orientation of the designated and alternative addresses relative to the local road(s), and the kerb to façade distances, were matched as closely as possible.

iii. Existence of screening (for example because of hedges, fences and walls): The presence of screening could be highly variable from one dwelling to the next, and might have a significant effect on exposure. Care was taken also to match the screening of the alternative address to that of the designated address.

iv. Any other acoustic factors/sources: The effect of any other acoustic factors noted on site, or sources of noise other than road traffic (for example commercial premises), were also matched as far as possible.

2.3 Data acquired

During the year 2000 study, the analysers were used with a standard set-up, stored on each analyser, recording a standard set of data from each site. This included L_{Aeq}, L_{Amax}, L_{Amin}, 1/3-octave spectra and statistical levels (L_{A01}, L_{A05}, L_{A10}, L_{A50}, L_{A90}, L_{A95}, L_{A99} and

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[9] all Tables are included in Section 6, e.g. Table 1 can be found at Section 6.1.

$L_{A99.9}$), each over 5 minute, 1 hour and 24 hour time frames. $L_{Aeq,125ms}$ time histories were also recorded over the complete 24 hour duration of each measurement.

In comparison, the 1990 study had involved the measurement of substantially less data, consisting only of L_{Aeq}, L_{Amax}, L_{Amin} and fewer statistical levels (L_{A01}, L_{A10}, L_{A50}, L_{A90} and L_{A95}) over 24 hours in individual 1 hour time frames. Hence all comparisons between the 1990 and year 2000 studies were made on the basis of this reduced number of indices, and longer time periods composed out of this data. Data for such longer periods were composed by means of a logarithmic average in the case of L_{Aeq} indices, or an arithmetic average for statistical levels from the data from both studies.

All measurements were taken at a distance of 1 m from the façade of the building. For ground floor flats and houses, the microphone height was 1.2 m above the ground, and for higher level flats, the microphone was suspended from a window by means of an A-frame, again keeping a distance of 1 m from the façade. The study also involved the measurement of levels at a height of 4 m above ground (as opposed to the height of 1.2m used for the majority of the measurements), in addition to the standard measurement, at approximately 17% of dwellings visited. The figure below shows the position of the analyser at a typical site. The results from these measurements, and a discussion of them will be presented in a separate report.

Other data collected at each site included a site data-sheet completed by the engineer responsible for taking the measurements regarding the physical site layout, dominant noise sources and weather conditions at the start and end of the measurement period. The occupants of the dwellings where measurements were taken also completed a short attitude survey. This was essentially a condensed version of the questionnaire used for the National Noise Attitude Survey, and is to be reported separately.

Typical site set-up showing arrangement of analyser

2.3.1 Instrumentation

Norsonic 121 environmental sound analysers fitted with Norsonic 1211 environmental microphone systems were used throughout the measurement programme. Twenty four such analysers were used during the programme. The analysers were calibrated throughout as described in Section 2.3.2 below.

2.3.2 Calibration

Four Norsonic 1253 calibrators were used during the measurement programme. These were regularly checked against each other and also in the laboratory at the end of each school term against a reference pistonphone calibrated in a UKAS accredited laboratory not more than six months previously.

In the field a calibrator was applied immediately before and after each measurement, to check the sensitivity of each analyser. The analyser sensitivities proved stable, in most cases not varying beyond ±0.1 dB of the nominal value. Measurements were rejected in any cases where the analyser sensitivity drifted by more than 0.3 dB over the measurement period, and laboratory checks on the relevant instruments were carried out.

At the beginning of the measurement programme the sensitivity, linearity and frequency response of each analyser was checked in the laboratory. Analyser sensitivities were trimmed in the laboratory at the end of each school term, and checks on linearity and frequency response made at these intervals.

3 Data analysis

The aim of the data analysis was twofold: firstly, to estimate the current pattern of the noise exposure of the population; and secondly, to compare the current pattern with one based on the 1990 data. This was done on by means of comparisons between mean noise levels for various indices, their 24 hour time histories, and cumulative distributions, allowing for changes in exposure which do not necessarily affect the mean level to be detected.

3.1 Data quality checks

A number of checks were undertaken to ensure the quality of the data recorded during the year 2000 study, and the compatibility of this with measurements from 1990. Details of these checks can be found in Annex A.

3.2 Calculation procedures

3.2.1 Means

The mean values calculated by the procedure set out below are unbiased estimates of the mean for the entire population of England and Wales, based on the sample of that population for which measurements were taken.

The multi-stage clustered and regionally stratified nature of the sample meant that, for each index, an unbiased estimate of the national mean had to be based on estimates of regional means. Unbiased estimates of regional means, in turn, had to be based on estimates of district means, which in turn had to be based on unbiased estimates of ward means.

In these calculations attention needed to be paid to the selection procedures that had been employed at each stage. The primary units (districts) had been selected with probability proportional to population throughout the sample. Therefore, an unbiased estimate of each regional mean could be calculated as an unweighted mean of its relevant estimated district means. The estimated national mean could then be calculated by weighting the regional means according to the corresponding regional populations.

However, not all the secondary units (the wards) had been selected with probability proportional to population: only the newly selected one-third. The two-thirds of wards retained from the 1990 study appeared to have been selected at random. Therefore, in these districts, the estimate of the district mean was calculated from the separate estimates of the ward means weighted according to the ward populations. In the newly selected 17 districts, the estimated mean was simply calculated as an unweighted average of the two constituent ward means.

3.2.2 Uncertainties

An effect of clustering in the sample is to increase the uncertainty in the national mean, by comparison with a notional purely random sample of equal size. However, no specific calculation of the effect of clustering on the uncertainty is necessary, since it is reflected in the increased variance between district means, and the associated uncertainty in each regional mean[10]. The standard errors in the regional means were treated as standard deviations, and their combined effect was calculated (taking into account regional populations) as a standard error in the estimated national mean.

Where appropriate the added component in the standard error due to the uncertainty in the corrections applied to the 1990 data due to the differences between the instruments[11] was included in the final uncertainty.

In general, results have been quoted with 95% confidence intervals, or plotted with such confidence intervals. Hence, as a guide, where the width of the confidence intervals are equal, and the value calculated for each study falls outside the range of the 95% confidence interval for the other, the difference would be found to be significant at an 85% confidence level. Non-overlapping confidence intervals would indicate the difference to be significant at the 99% level. However, it must also be noted, when making large numbers of such comparisons at these levels, that 15% or 1% respectively of all comparisons would be expected to show up as significant even where there is no true difference.

3.2.3 Comparisons with 1990 data

As a preliminary to comparisons with the 1990 data, the 1990 data were “corrected” by adding the estimates of the systematic differences between the Cirrus and Norsonic instrument readings. This effectively provided the best estimate of the data that would have been acquired had Norsonic instruments been used in 1990[12].

Paired comparisons were made by calculating the difference between the 1990 and year 2000 study levels within each ward common to both studies (2/3 of all wards). On this basis an unbiased estimate of the mean difference for each ward could be obtained, and from there estimates of national mean differences and their uncertainties could be calculated according to the principles set out in 3.2.1 and 3.2.2 above. To these uncertainties were added the uncertainties associated with the estimates of systematic differences between the instrument types. The statistical significance of the differences in the national means between the 1990 and year 2000 studies was then established using a paired *t*-test procedure.

No distinction was made in the paired comparisons between pairs where the same address had been used in the 1990 and year 2000 studies, and those for which an equivalent alternative had been necessary in the latter study. This was because no

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[10] Thompson, S. K., Sampling, John Wiley & Sons, 1992.

[11] See Annex A

[12] An additional correction was made to all 1990 levels below 26 dB(A), which were unreliable. These were fixed at 26 dB(A) in line with a manufacturer’s modification made at a later date.

statistical effect of same versus alternative address was found, which indicated that the guidelines for choosing alternative addresses (see 2.2.2 above) had worked well enough in practice.

In the case of East Anglia, only one district was available for the paired tests (i.e. the same district measured in both the 1990 and the year 2000 studies). The presented difficulties in calculating an uncertainty in the regional mean in way presented in 3.2.2 above. Hence the uncertainty for the whole country mean was based on all the other regions, excluding East Anglia, whilst the mean itself included all regions. In effect this made the assumption that the uncertainty in the East Anglia regional mean was equal to the average of those in the other regions.

Unpaired comparisons were also carried out. For these the complete 1990 and year 2000 study samples could be used. The estimates of national means and uncertainties were calculated according to the principles set out in 3.2.1 and 3.2.2 above for both sets of data, with the uncertainties in the systematic instrument differences once more combined with those uncertainties in the 1990 national means. The significance of the differences in the estimates of national means between the 1990 and year 2000 studies was established using an unpaired *t*-test procedure with unequal variances.

In both the paired and unpaired comparisons, an extra component was introduced into the standard errors to account for the uncertainty in the systematic correction applied to the 1990 data as in Annex A of this report.

3.2.4 Frequency spectra and time-histories

Estimates of the national mean spectra and time histories, and their statistical uncertainties, were calculated according to the principles set out in 3.2.1 and 3.2.2 above. No spectra were available for comparison purposes from 1990, but time histories based on the hourly data from 1990 could be calculated. These hourly data were not corrected for the systematic instrument differences because the corrections had been determined for longer-term indices only[13]. Instead, a uniform correction, corresponding to the correction for the relevant 24 hour index, was applied to every hour of the estimated national mean time histories.

3.2.5 Cumulative distributions

Cumulative distributions, indicating estimated proportions of the population exposed to levels exceeding a given value were calculated for both the 1990 and year 2000 study data in terms of the level exceeded at the façades of a given percentage of the population, in 1% steps[14]. For the 1990 dataset, all levels were first corrected for the systematic differences between instruments as set out in Table A1 in Annex A.

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[13] This was because systematic trends within a single analyser at a single site, between consecutive hours would be neglected by correcting individual hours before combination into other indices.

[14] The choice of a 1% step size appeared to give the best trade-off between accuracy of the distribution and smoothing small-scale fluctuations caused by the limited size of the sample.

The procedure was to list all levels (for a particular index), and weight each according to the corresponding ward selection procedure. For the new wards selected for the year 2000 study (with probability proportional to population) each level was given unity weighting. For the levels measured in the wards selected in 1990 (randomly), weights were applied which took account of relative ward population, but still summed to a total of 20 for each district, meaning that all districts were weighted equally. The resulting list of levels and associated weights was then sorted by level. The level for a given percentage on the cumulative distribution was then calculated by adding the weights down the list until the sum corresponded to the relevant proportion of the total sum (i.e. the number of sites measured).

To calculate the statistical uncertainties at each point of the distributions, the datasets were broken down into five equal blocks by randomly allocating two addresses from each ward to each block[15]. Separate cumulative distributions were then calculated for each block, as above. The distributions formed by the means of the five separate level estimates at each cumulative percentage point corresponded closely with the overall cumulative distributions. Meanwhile the variation in the level estimates at each percentage point provided the basis on which estimates of the statistical uncertainty of each point of the overall cumulative distribution could be calculated. For the 1990 study data, the statistical uncertainties in the corrections applied to take account of the systematic differences between the instrument types were combined with this calculated uncertainty.

The uncertainties calculated in these cumulative distributions are only shown in the range of 5% to 95% exposure. Beyond these points the number of sites concerned (less than 51 for the year 2000 study, or 50 for the 1990 study), is too small for the uncertainties (and indeed, the distributions themselves) to be accurately predicted by the method used. In order to calculate the distributions more accurately in this range, and thus produce a more reliable estimate of any uncertainty in these distributions, a different design of study would be required, giving more emphasis to the sampling of these sites.

3.2.6 Proportions and their uncertainties

Proportions of the population of England and Wales exposed to certain noise sources at their homes were estimated from the site data-sheet completed at each measurement location. For these, the estimation procedure was similar to that used for mean levels and their uncertainties in Sections 3.2.1 and 3.2.2 above. The proportion was estimated for each ward calculated from the sampled dwellings within that ward. An estimate of the district proportion calculated for each district, by means of an mean of the two constituent wards. This was weighted by ward population in the case of districts selected (randomly) for the 1990 study, and unweighted for those districts newly selected for the year 2000 study (selected with probability proportional to population). As all districts were selected with probability proportional to population, these district proportions could then

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[15] Alternative breakdowns into two blocks and ten blocks proved inferior to the 5 block breakdown in terms of the trade-off between correspondence of the mean distribution of blocks with the overall distribution, and the basis for estimates of statistical uncertainties.

be combined to form estimated regional proportions by means a simple, unweighted, mean. As for the mean levels, the uncertainties in these regional mean proportions could be calculated directly from the variance of the estimated district proportions on which they were based.

An estimated proportion for the country, and its associated uncertainty could then be calculated in the same way as for the mean levels, by means of a combination of the regional proportions and uncertainties, weighted according to the regional populations.

Proportions of the sample of dwellings that fell into the different site description classifications used in the 1990 study, which were based on those in BS 4142: 1975 (now withdrawn), were also calculated from the same data-sheet. As these were calculated simply as a description of the sample, rather than an estimate of the country distribution, they are simple proportions from all the data, and have no associated uncertainty term.

4 Results

4.1 Means and uncertainties for year 2000 study

Table 2 sets out the estimates of national means and their associated statistical 95% confidence intervals, calculated according to the method described in 3.4 above. These were calculated for every broadband index acquired (with the exception of $L_{A99.9}$) for each of the commonly used 24 hour; 18 hour; 16 hour; 12 hour; 8 hour; and 4 hour time periods. For all these periods the indices were synthesised from the relevant hourly levels (in the form of arithmetic averages in the case of the statistical levels and logarithmic averages for the L_{Aeq} indices, as was the case for the data from the 1990 study).

Table 3 sets out estimates of the percentage of the population of England and Wales for which the façade levels exceed established benchmarks (these have been calculated for both the 1990 and year 2000 studies for comparative purposes). The levels and their statistical uncertainties were obtained from the cumulative distributions (see 4.4 below). The correspondence of the various benchmark levels to current legislation and guidance is also noted. Tables 4 and 5 give the proportions of the population of England and Wales estimated to live in dwellings exposed to levels in 5 dB(A) bands for $L_{Aeq,16hr}$, $L_{Aeq,8hr}$ and $L_{Aeq,24hr}$ indices, for both façade and free-field noise levels. The extreme bands for each index have been chosen to prevent any estimate being based on too few data points.

The World Health Organisation (WHO)[16] states that 'to protect the majority of people from being seriously annoyed during the day-time, the sound pressure level on balconies, terraces and outdoor living areas should not exceed 55 dB L_{Aeq} for a steady continuous noise.'… 'At night, sound pressure levels at the outside façades of the living spaces should not exceed 45 dB L_{Aeq} and 60 dB L_{Amax}, so that people may sleep with bedroom windows open.'

In order to compare our results with these WHO levels we have defined the day as 0700 – 2300 and night as 2300 – 0700, and assumed that all the values represent noise levels measured at the façade of dwellings.

The National Noise Incidence Study 2000 has found that 55±3% of the population of England and Wales live in dwellings exposed to day-time noise levels above the WHO level of 55 dB $L_{Aeq,day}$. In 1990 we now estimate that 60±3% of the population were exposed above the level of 55 dB $L_{Aeq,day}$. This change represents a statistically significant decrease in the proportion of the population exposed above this level in 2000 when compared to the results of the 1990 study.

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[16] Guidelines for Community Noise, World Health Organisation, 2000.

The National Noise Incidence Study 2000 has found that 68±3% of the population of England and Wales live in dwellings exposed to night-time noise levels above the WHO level of 45 dB $L_{\mathrm{Aeq,night}}$. In 1990 we now estimate that 66±3%[3] of the population were exposed above the level of 45 dB $L_{\mathrm{Aeq,night}}$. This change represents a statistically non-significant increase in the proportion of the population exposed above this level in 2000 when compared to the results of the 1990 study. It should be noted that this is the only of the established guideline values where we have detected an increase in population exposure in 2000 when compared to the 1990 study.

The percentage of the population of England and Wales exposed to noise levels exceeding 68 dB $L_{\mathrm{A10,18hr}}$, (the qualifying level for insulation under the Noise Insulation Regulations for new roads[17]), is calculated as 8±1%, numerically equal to that found when the results from the 1990 study are extended in the same way to estimate the exposure of the whole of England and Wales.

4.2 Frequency spectra for year 2000 study

Figure 3 shows the estimate of the national mean A-weighted 1/3-octave spectra and its associated 95% confidence limits, calculated according to 3.2.4 above. shows the equivalent linear 1/3-octave spectra. For both cases, the spectra are shown for the standard 24 hour; 12 hour; 8 hour; and 4 hour time periods.

4.3 Paired and unpaired comparisons with 1990 means

Table 6 sets out the paired comparisons of the 1990 and year 2000 study estimates of the national means, calculated according to the method described in 3.2.3 above. Mean differences and confidence intervals around them are provided for each of the broadband indices common to the two studies. The statistical significance of any increases or decreases in level between the two studies are indicated at both the 90% and 95% levels.

The advantage of paired comparisons is that they eliminate to a large degree the between-site variation within the samples. By assuming the day to day within-site variation to be normally distributed across the samples (as well as the non-systematic sources of variation associated with the measurement instruments), significant differences revealed by paired comparisons are likely to be attributable to systematic trends in either the source conditions, or the meteorological conditions. Given that seasonal matching was achieved as far as possible, systematic differences in source conditions are the most likely cause of any of the significant increases or decreases revealed by the paired comparisons.

Table 7 sets out identical summaries of the unpaired comparisons. Because all between-site variation is included there is greater statistical uncertainty in these comparisons. Consequently the number of statistically significant increases or decreases is lower, but their general patterns are consistent.

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[17] Noise Insulation Regulations, 1975 (as amended).

It must be noted that, even at the 95% significance level, there would be an expected level of significant changes detected even if there were no change in the true levels. This would be one in twenty at the 95% level, or one in ten at the 90% level. The fact that the number of significant changes is greater that this, and has a pattern to it would indicate that there is evidence for change between the 1990 study, and that in the year 2000. The pattern seems to show that indicators used to describe background levels (such as L_{A90} and L_{A95}), during the night-time periods have increased on average (at 90% significance level). It also show the lower percentile indices such as L_{A10}, often used as an indicator for road traffic noise, have decreased during the day-time (at both 90 and 95% significance levels). It must be noted that, although these are statistically significant changes in level, their magnitude is still relatively small, with a maximum of just over 1 dB(A).

It seems surprising that there is a significant decrease in day-time L_{Aeq} levels, despite the accepted increase in activity of transportation noise sources (road traffic being the predominant noise source at the vast majority of measurement locations). This could be explained by means of the decreasing level of individual events (e.g. cars, aeroplanes etc.), compensating for the increased frequency with which such events occur. In fact, the pattern of the significant changes could also indicate a similar explanation. The indices such as L_{A01} and L_{A10}, which show the largest significant decreases since 1990 are most sensitive to the peak noise levels, and hence the levels of individual noise events, rather than how often these events occur. Clearly an increasing frequency of events will still impact on these levels, but to a lesser extent than other indices. On the other hand, the indices most commonly associated with background noise levels (in particular L_{A90}), are the ones to show increases in level (although less of these are statistically significant). As these indices indicate the level exceeded for a large proportion of the time, they are less susceptible to decreases in peak levels of individual noise events.

4.4 Cumulative distributions

Figures 5 to 17 show the cumulative distributions calculated according to the method described in 3.2.5 above. On each figure the corresponding 1990 study and year 2000 study distributions are shown, together with their respective 95% confidence intervals, for comparison purposes. The distributions have been calculated for each of the L_{Aeq}, L_{A10} and L_{A90} indices over each of the standard 16 hour, 12 hour, 4 hour and 8 hour time periods. In addition, the $L_{A10,18hr}$ distributions were also calculated (Figure 17).

Significant differences in mean levels between the 1990 and year 2000 studies (see 4.3 above) are apparent as general displacements between the two distributions along the level axis. However, other changes, such as changes in between-site variation, or interactions between change and noise level, can also be reflected in visible differences between the distributions.

These cumulative distributions generally confirm the changes in mean exposure detected in paired and unpaired comparisons of mean levels, and in some cases add extra information to this. The 18 hour, 16 hour and 12 hour L_{A10} indices shows that the majority of the increase is in the upper 50% of levels. This indicates that the 50% of homes with the highest exposure measured by this index experience a higher level than the equivalent 50% of homes in 1990. From these distributions it is not possible to draw any conclusions as to whether these are in fact the same dwellings in the two years.

The 8 hour night-time L_{A90} must be considered with a degree of caution with regard to the cumulative distribution, as it is subject to the correction applied to the data from the 1990 study at low levels. This correction (as later applied directly to all the meters used in this study), sets all levels recorded at 26 dB(A) or below, equal to 26 dB(A), due to the unreliability of the meters used in the 1990 study below this level). This correction gives an undue bias towards higher levels in this tail of the distribution for the 1990 study. Clearly this means that few conclusions can be drawn from this tail of the distribution, although the increases seen over the remainder of the distribution are still significant.

All the other indices generally show that where a significant change in level has occurred, it has been fairly uniform across the range of levels, possibly with a slight decrease in the width of the distribution (i.e. less sites in the extreme tails of the distribution). Again this does not necessarily imply that each individual dwelling has experienced the same, small, change in level, but simply that the distribution has undergone a shift. Individual dwellings may have undergone much larger changes in either direction, or no change at all, and simply be represented in a different part of the distribution to the previous study.

4.5 Time histories

Figure 18 sets out the mean time histories of the year 2000 study five minute L_{Aeq}, L_{A01}, L_{A10}, L_{A50}, L_{A90} and L_{A95} measurements, together with their respective 95% confidence intervals, calculated according to 3.2.4 above. Figures 19 to 21 show the mean time histories, together with their respective 95% confidence intervals, for the hourly L_{Aeq}, L_{A10} and L_{A90} measurements according to the same method. On each of these figures, the time histories for both the 1990 and year 2000 studies are shown for comparison purposes.

For clarity, the graphs have been plotted with the level for each hour or five minute period represented as a single point at the centre point of that period.

The other side of the pattern in the results seen in the paired and unpaired comparisons of means in Section 4.3 above is the day-time to night-time balance. Decreases in level are seen in all time periods except for the 8-hour night-time period (2300 – 0700), whilst this is the only period during which significant increases in level are seen. The decreases seen in the 24-hour indices (which include this night-time period) can be almost entirely attributed to decreases during the day being greater than the increases at night). This is confirmed by the fact that the magnitudes of the decreases in 24-hour indices are smaller than those in the corresponding day-time indices. With the available one-hour time resolution in the time histories from the 1990 study, it is difficult to attribute the change in night-time levels to either an increase in level during the night-time period, or simply a shortening of this quieter period. In practice it is probably a combination of both these effects. Comparisons with a future study may be able to identify any continuing similar shift to a greater extent, due to the availability of time-histories based on 5-minute noise-levels in the current study.

4.6 Results from site data-sheets

Table 8 shows the breakdown of the sites used as measurement locations in each of the 1990 and year 2000 studies, according to the classification scheme used in the 1990 study which was based on those in BS 4142: 1975 (now withdrawn). These are simply proportions of the samples, and hence do not have statistical errors associated with them.

Table 9 shows the estimated proportions of the population of England and Wales exposed to noise from certain selected sources at their homes, together with the 95% confidence intervals in these proportions, calculated according to the procedure set out in Section 3.2.6 above.

Due to the highly subjective nature of these results, and the fact that they are based on the opinion of the engineer from his relatively short visit to each site, the uncertainties associated with these proportions may be significantly larger than are actually noted[18]. With the errors as calculated, the only statistically significant changes are increases in the proportion of sites where animals, birds and trees rustling can be heard, and a decrease in the equivalent proportion for aircraft noise.

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[18] A better estimate of the noises heard by the population of England and Wales can be obtained from the national survey of attitudes to environmental noise, the findings of which are presented in a separate report.

5 Conclusions

Overall, the results obtained from the current study indicate that there have been statistically significant changes in noise level since the previous study in 1990. These changes are small in magnitude, at most just over 1 dB(A). Indices measuring noise levels exceeded for a small proportion of the time, such as L_{A01} and L_{A10}, during day-time periods, have been shown to have decreased, whilst indices (such as L_{A90}) describing background noise levels at night have increased. This pattern is compatible with a model for noise source changes where the number of noise producing items or events (such as vehicles on roads) has increased, whilst the noise output of individual events has decreased; these two effects approximately balancing each other.

The cause of the increase in night-time background levels cannot be uniquely identified due to the 1-hour time resolution of the data available from the 1990 study. The indications are that the change could be due to either a general increase in level throughout the night, or a shortening of the quieter night-time period. The most likely explanation for this increase is a combination of these two effects.

Cumulative distributions of the estimated proportion of the population of England and Wales exposed to levels exceeding certain values indicate the same trend in the overall changes expressed above. In general the shift is seen to be fairly uniform across all levels. However, the L_{A10} index, during day-time periods, has generally shown a greater decrease at higher levels, whilst many indices show a slight reduction in width of the distribution, indicating less dwellings falling into the extreme high and low exposure bands. This last effect is very slight, and falls into a region of the distributions, where, due to the number of sites concerned, the uncertainties in the distributions, and hence the statistical significance of any changes seen cannot be accurately calculated. Where significant changes in the shape of the distribution have been seen, no conclusions can be drawn from this that individual sites have changed in any given way, but simply that the overall distribution has.

The National Noise Incidence Study 2000 has found that 55±3% of the population of England and Wales live in dwellings exposed to day-time noise levels above the WHO[19] level of 55 dB $L_{Aeq,day}$. In 1990 we now estimate that 60±3% of the population were exposed above the level of 55 dB $L_{Aeq,day}$. This change represents a statistically significant decrease in the proportion of the population exposed above this level in 2000 when compared to the results of the 1990 study.

The National Noise Incidence Study 2000 has found that 68±3% of the population of England and Wales live in dwellings exposed to night-time noise levels above the WHO[19] level of 45 dB $L_{Aeq,night}$. In 1990 we now estimate that 66±3%[3] of the population were

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[19] Guidelines for Community Noise, World Health Organisation, 2000

exposed above the level of 45 dB $L_{\mathrm{Aeq,night}}$. This change represents a statistically non-significant increase in the proportion of the population exposed above this level in 2000 when compared to the results of the 1990 study. It should be noted that this is the only of the established guideline values where we have detected an increase in population exposure in 2000 when compared to the 1990 study.

The percentage of the population of England and Wales exposed to noise levels exceeding 68 dB $L_{\mathrm{A10,18hr}}$, (the qualifying level for insulation under the Noise Insulation Regulations for new roads[20]), is calculated as 8±1%, numerically equal to that found when the results from the 1990 study are extended in the same way to estimate the exposure of the whole of England and Wales.

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[20] Noise Insulation Regulations, 1975 (as amended).

6 Tables

6.1 Table 1 – Timing of measurements

Each table show the number of sites in each Local Authority district measured in each week of the calendar year, for the measurements in 1990 and those in 1999/2000.

Table 1a – East Anglia, East Midlands and Greater London regions

Region		East Anglia				East Midlands								Greater London													
District Name		North Norfolk	Mid Suffolk	Peterborough		Gedling		North West Leicestershire	Hinkley & Bosworth	Nottingham		South Holland		Barnet	Havering	Bromley	Croydon	Enfield		Harrow		Kingston upon Thames		Redbridge		Waltham Forest	
Year		90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00
01-Jan	1																										
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31-Dec	52																										

Table 1b – North and North-West regions

Region		North						North West											
District Name		Carlisle		Newcastle	Sunderland	Wansbeck		Bury		Fylde	Pendle	Hyndburn		Liverpool		Manchester	Salford	Tameside	
Year		90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00
01-Jan	1																		
Week Number	2																		
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	47			2		2					19						19		
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	49										1			1			1		
	50																		
	51								10										
31-Dec	52																		

Table 1c – South-East region

Region		South East																					
District Name		-	Dacorum	Aylesbury	Chelmsford	Gillingham		Guildford	South Oxfordshire	Runnymede		South Wight		Southampton		Spelthorne		Tendring		Tunbridge Wells		Windsor & Maidenhead	Thanet
Year		90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00
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31-Dec	52																						

Table 1d – South-West and Wales regions

Region		South West										Wales					
District Name		East Devon		North Cornwall		Plymouth		Tewkesbury		Thamesdown	North Somerset	Dinefwr		Llanelli		Newport	Caerphilly
Year		90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00
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31-Dec	52																

Table 1e – West Midlands and Yorkshire & Humberside regions

Region		West Midlands										Yorkshire & Humberside									
District Name		Birmingham		Cannock Chase		Dudley	Sandwell	North Warwickshire		Wolverhampton	Stoke-on-Trent	Bradford	Barnsley	Glanford		Kingston upon Hull		Rotherham		Sheffield	Leeds
Year		90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00	90	99/00
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6.2 Table 2 – Means and their uncertainties from year 2000 study

Summary of mean levels from the year 2000 study, together with their uncertainties (standard errors) and 95% confidence intervals.

16 hour day-time (0700-2300)

Index	Mean Level (dB)	Standard Error (dB)	95% Confidence Interval
L_{Aeq}	56.5	0.22	56.07 - 56.93
L_{A01}	65.1	0.23	64.66 - 65.56
L_{A05}	59.4	0.26	58.86 - 59.87
L_{A10}	56.5	0.27	55.96 - 57.02
L_{A50}	48.6	0.35	47.95 - 49.31
L_{A90}	43.9	0.39	43.11 - 44.64
L_{A95}	42.9	0.40	42.11 - 43.67
L_{A99}	41.3	0.41	40.54 - 42.15

8 hour night-time (2300-0700)

Index	Mean Level (dB)	Standard Error (dB)	95% Confidence Interval
L_{Aeq}	48.2	0.24	47.76 - 48.70
L_{A01}	55.3	0.37	54.53 - 55.97
L_{A05}	48.6	0.39	47.80 - 49.32
L_{A10}	45.6	0.40	44.84 - 46.40
L_{A50}	38.9	0.43	38.09 - 39.77
L_{A90}	35.3	0.46	34.41 - 36.20
L_{A95}	34.6	0.46	33.66 - 35.46
L_{A99}	33.4	0.46	32.53 - 34.33

12 hour day-time (0700-1900)

Index	Mean Level (dB)	Standard Error (dB)	95% Confidence Interval
L_{Aeq}	57.1	0.22	56.63 - 57.48
L_{A01}	66.0	0.22	65.55 - 66.41
L_{A05}	60.4	0.24	59.89 - 60.83
L_{A10}	57.5	0.25	57.05 - 58.05
L_{A50}	49.7	0.33	49.09 - 50.40
L_{A90}	44.9	0.38	44.16 - 45.66
L_{A95}	43.9	0.39	43.13 - 44.66
L_{A99}	42.3	0.41	41.51 - 43.10

4 hour evening (1900-2300)

Index	Mean Level (dB)	Standard Error (dB)	95% Confidence Interval
L_{Aeq}	53.1	0.29	52.53 - 53.67
L_{A01}	62.5	0.30	61.92 - 63.09
L_{A05}	56.4	0.35	55.68 - 57.04
L_{A10}	53.3	0.37	52.58 - 54.03
L_{A50}	45.3	0.44	44.42 - 46.15
L_{A90}	40.8	0.47	39.86 - 41.70
L_{A95}	39.9	0.47	38.94 - 40.80
L_{A99}	38.5	0.48	37.52 - 39.40

18 hour day (0600-2400)

Index	Mean Level (dB)	Standard Error (dB)	95% Confidence Interval
L_{Aeq}	56.2	0.22	55.75 - 56.61
L_{A01}	64.6	0.23	64.11 - 65.03
L_{A05}	58.7	0.26	58.22 - 59.24
L_{A10}	55.8	0.28	55.29 - 56.37
L_{A50}	48.0	0.35	47.33 - 48.69
L_{A90}	43.3	0.39	42.55 - 44.07
L_{A95}	42.3	0.40	41.57 - 43.12
L_{A99}	40.8	0.41	40.03 - 41.62

24 hour period

Index	Mean Level (dB)	Standard Error (dB)	95% Confidence Interval
L_{Aeq}	55.1	0.21	54.72 - 55.56
L_{A01}	61.8	0.25	61.33 - 62.32
L_{A05}	55.8	0.28	55.21 - 56.31
L_{A10}	52.9	0.29	52.29 - 53.44
L_{A50}	45.4	0.35	44.70 - 46.09
L_{A90}	41.0	0.39	40.25 - 41.79
L_{A95}	40.1	0.40	39.33 - 40.89
L_{A99}	38.7	0.41	37.91 - 39.50

6.3 Table 3 – Population exposed above selected levels

Estimates of the percentage of the population of England and Wales exposed to noise levels exceeding certain benchmarks.

		1990		2000	
Index	**Level**	**Percentage Exposed above this Level[21]**	**95% Confidence Interval in Percentage**	**Percentage Exposed above this Level**	**95% Confidence Interval in Percentage**
16hr L_{Aeq} (0700 – 2300)	65 dB[22]	12%	10 – 14%	10%	8 – 12%
	55 dB[23,25]	60%	57 – 63%	55%	52 – 58%
	50 dB[24,25]	92%	90 – 94%	90%	88 –92%
8hr L_{Aeq} (2300 – 0700)	59 dB[22]	6%	4 – 8%	6%	4 – 8%
	45 dB[26,25]	66%	63 – 69%	68%	65 – 71%
18hr L_{A10} (0600 – 2400)	68 dB[27]	8%	7 – 9%	8%	7 – 9%

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[21] These figures differ slightly from those quoted in BRE IP 21/93 following the study in 1990, for two reasons:

i. the figures are estimates of the national exposure, rather than proportions of the dwellings sampled,

ii. corrections have been applied to the data measured in 1990 to produce the best estimates of the levels that would have been recorded had the instrumentation used for the current study been available.

[22] Royal Commission on Environmental Pollution, Eighteenth Report – Transport and the Environment, Sir J. Houghton, October 1994. Target level for exposure to road and rail noise.

[23] Guidelines for Community Noise, World Health Organisation, 2000: According to WHO, the level to protect the majority[25] of people from being seriously annoyed during the day-time (day assumed to be 0700 – 2300).

[24] Guidelines for Community Noise, World Health Organisation, 2000: According to WHO, the level to protect the majority[25] of people from being moderately annoyed during the day-time (day assumed to be 0700 – 2300).

[25] There is a degree of ambiguity in the WHO Guidelines for Community Noise. For example:

i. the document is not clear as to whether the day-time levels should be taken as free-field or at the façade. The above table assumes they should be taken at the façade, if they are assumed to be free-field, the results are modified as below. This assumes a level difference due to the façade or 3dB(A).

			1990		2000	
Index	**Free-Field Level**	**Equivalent Façade Level**	**Percentage Exposed above this Level**	**95% Confidence Interval in Percentage**	**Percentage Exposed above this Level**	**95% Confidence Interval in Percentage**
16hr L_{Aeq} (0700-2300)	55 dB	58 dB	41%	38 – 44%	33%	31 – 35%
	50 dB	53 dB	73%	70 – 76%	70	66 – 74%

ii. the word ‘majority’ could be taken to mean just over half of the population, or it could be taken to mean virtually everyone.

iii. regarding the justification for the night-time values, para. 4.2.3 states “Measurable effects on sleep start at background levels of about 30 dB L_{Aeq}”, and para. 4.3.1 implies that the night-time levels have been derived from the internal levels by “assuming the noise reduction from outside to inside with the window partly open is 15dB”. Para 4.2.3 also states that “to protect sensitive persons, a still lower guideline value would be preferred when the background level is low”.

[26] Guidelines for Community Noise, World Health Organisation, 2000: According to WHO, the level[25] not to be exceeded so that people may sleep with bedroom windows open (night-time assumed to be 2300 – 0700).

[27] Qualifying level for insulation under the Noise Insulation Regulations, 1975 (as amended).

6.4 Table 4 – Proportions exposed in 5dB(A) bands – façade levels

a) Day-time (0700-2300) L_{Aeq}.

Façade level dB(A)	1990		2000	
	Proportion in band	95% confidence interval	Proportion in band	95% confidence interval
$L<50$	8%	6 – 10%	10%	8 – 12%
$50 \le L<55$	32%	28 – 36%	35%	31 – 39%
$55 \le L<60$	30%	25 – 35%	30%	25 – 35%
$60 \le L<65$	18%	14 – 22%	15%	11 – 19%
$L \ge 65$	12%	10 – 14%	10%	8 – 12%

b) Night-time (2300-0700) L_{Aeq}

Façade level dB(A)	1990		2000	
	Proportion in band	95% confidence interval	Proportion in band	95% confidence interval
$L<45$	34%	31 – 37%	32%	28 – 36%
$45 \le L<50$	32%	28 – 36%	36%	31 – 41%
$50 \le L<55$	19%	16 – 22%	18%	14 – 22%
$L \ge 55$	15%	13 – 17%	14%	12 – 16%

c) 24 hour L_{Aeq}.

Façade level dB(A)	1990		2000	
	Proportion in band	95% confidence interval	Proportion in band	95% confidence interval
$L<50$	15%	12 – 18%	18%	15 – 21%
$50 \le L<55$	35%	31 – 39%	38%	34 – 42%
$55 \le L<60$	27%	23 – 31%	25%	22 – 28%
$60 \le L<65$	16%	12 – 20%	13%	10 – 16%
$L \ge 65$	7%	5 – 9%	6%	4 – 8%

6.5 Table 5 – Proportions exposed in 5dB(A) bands – free field levels[28]

a) Day-time (0700-2300) L_{Aeq}.

Free field level dB(A)	Equivalent façade level dB(A)	1990		2000	
		Proportion in band	95% confidence interval	Proportion in band	95% confidence interval
$L<50$	$L<53$	27%	24 – 30%	30%	26 – 34%
$50\leq L<55$	$53\leq L<58$	32%	28 – 36%	37%	33 – 41%
$55\leq L<60$	$58\leq L<63$	24%	20 – 28%	18%	14 – 22%
$L\geq 60$	$L\geq 63$	17%	14 – 20%	15%	12 – 18%

b) Night-time (2300-0700) L_{Aeq}.

Free field level dB(A)	Equivalent façade level dB(A)	1990		2000	
		Proportion in band	95% confidence interval	Proportion in band	95% confidence interval
$L<40$	$L<43$	19%	16 – 22%	18%	15 – 21%
$40\leq L<45$	$43\leq L<48$	34%	29 – 39%	38%	35 – 41%
$45\leq L<50$	$48\leq L<53$	25%	20 – 30%	24%	20 – 28%
$50\leq L<55$	$53\leq L<58$	15%	11 – 19%	12%	9 – 15%
$L\geq 55$	$L\geq 58$	7%	5 – 9%	8%	6 – 10%

c) 24 hour L_{Aeq}.

Free field level dB(A)	Equivalent façade level dB(A)	1990		2000	
		Proportion in band	95% confidence interval	Proportion in band	95% confidence interval
$L<45$	$L<48$	5%	2 – 8%	7%	5 – 9%
$45\leq L<50$	$48\leq L<53$	31%	27 – 35%	33%	29 – 37%
$50\leq L<55$	$53\leq L<58$	32%	28 – 36%	33%	29 – 37%
$55\leq L<60$	$58\leq L<63$	19%	15 – 23%	16%	13 – 19%
$60\leq L<65$	$63\leq L<68$	10%	— [29]	9%	— [29]
$L\geq 65$	$L\geq 68$	3%	— [29]	2%	— [29]

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[28] Free field levels assume correction of 3dB(A) for difference in level due to the façade.

[29] These levels are in the extreme tails of the distribution, where uncertainties cannot be calculated accurately.

6.6 Table 6 – Paired comparisons

Paired comparisons of means between 1990 and year 2000 studies; based on sample of 680 sites used in the 1990 study and repeated in the year 2000 study.

16 hour day-time (0700-2300)

Index	2000 Mean Level (dB)	Mean Difference (‘00-‘90) (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	56.5	-0.61	0.26	-1.12 - -0.10	0.02	Decrease	Decrease
L_{A01}	65.1	-0.99	0.19	-1.37 - -0.61	0.00	Decrease	Decrease
L_{A10}	56.5	-0.62	0.23	-1.06 - -0.17	0.01	Decrease	Decrease
L_{A50}	48.6	-0.26	0.35	-0.94 - 0.43	0.46	-	-
L_{A90}	43.9	0.04	0.41	-0.76 - 0.85	0.91	-	-
L_{A95}	42.9	0.11	0.41	-0.70 - 0.92	0.80	-	-

12 hour day-time (0700-1900)

Index	2000 Mean Level (dB)	Mean Difference (‘00-‘90) (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	57.1	-0.53	0.26	-1.05 - -0.01	0.05	Decrease	Decrease
L_{A01}	66.0	-0.99	0.19	-1.36 - -0.63	0.00	Decrease	Decrease
L_{A10}	57.5	-0.59	0.23	-1.04 - -0.14	0.01	Decrease	Decrease
L_{A50}	49.7	-0.30	0.36	-1.01 - 0.41	0.41	-	-
L_{A90}	44.9	-0.04	0.44	-0.90 - 0.82	0.92	-	-
L_{A95}	43.9	0.01	0.45	-0.86 - 0.89	0.98	-	-

4 hour evening (1900-2300)

Index	2000 Mean Level (dB)	Mean Difference (‘00-‘90) (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	53.1	-1.01	0.30	-1.60 - -0.42	0.00	Decrease	Decrease
L_{A01}	62.5	-0.98	0.25	-1.47 - -0.48	0.00	Decrease	Decrease
L_{A10}	53.3	-0.72	0.26	-1.23 - -0.20	0.01	Decrease	Decrease
L_{A50}	45.3	-0.14	0.36	-0.83 - 0.56	0.70	-	-
L_{A90}	40.8	0.31	0.38	-0.43 - 1.04	0.42	-	-
L_{A95}	39.9	0.39	0.36	-0.32 - 1.11	0.28	-	-

8 hour night-time (2300-0700)

Index	2000 Mean Level (dB)	Mean Difference (‘00-‘90) (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	48.2	-0.09	0.30	-0.68 - 0.50	0.77	-	-
L_{A01}	55.3	-0.10	0.36	-0.81 - 0.62	0.79	-	-
L_{A10}	45.6	0.30	0.43	-0.54 - 1.14	0.48	-	-
L_{A50}	38.9	0.90	0.49	-0.05 - 1.86	0.06	-	Increase
L_{A90}	35.3	0.93	0.49	-0.03 - 1.89	0.06	-	Increase
L_{A95}	34.6	0.75	0.48	-0.20 - 1.69	0.12	-	-

18 hour day (0600-2400)

Index	2000 Mean Level (dB)	Mean Difference (‘00-‘90) (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	56.2	-0.61	0.26	-1.12 - -0.11	0.02	Decrease	Decrease
L_{A01}	64.6	-0.99	0.19	-1.35 - -0.62	0.00	Decrease	Decrease
L_{A10}	55.8	-0.62	0.23	-1.07 - -0.18	0.01	Decrease	Decrease
L_{A50}	48.0	-0.23	0.34	-0.90 - 0.44	0.50	-	-
L_{A90}	43.3	0.07	0.40	-0.70 - 0.85	0.85	-	-
L_{A95}	42.3	0.14	0.40	-0.64 - 0.91	0.73	-	-

24 hour period

Index	2000 Mean Level (dB)	Mean Difference (‘00-‘90) (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	55.1	-0.58	0.26	-1.09 - -0.07	0.03	Decrease	Decrease
L_{A01}	61.8	-0.69	0.22	-1.12 - -0.27	0.00	Decrease	Decrease
L_{A10}	52.9	-0.31	0.26	-0.83 - 0.21	0.24	-	-
L_{A50}	45.4	0.13	0.35	-0.57 - 0.82	0.72	-	-
L_{A90}	41.0	0.34	0.38	-0.41 - 1.09	0.37	-	-
L_{A95}	40.1	0.32	0.37	-0.41 - 1.05	0.39	-	-

6.7 Table 7 – Unpaired comparisons

Unpaired comparisons of means between 1990 and year 2000 studies; based on complete sample of 1000 sites from 1990 study, and 1020 sites from year 2000 study.

16 hour day-time (0700-2300)

Index	2000 Mean Level (dB)	Difference in Means (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	56.5	-0.70	0.41	-1.50 - 0.10	0.09	-	Decrease
L_{A01}	65.1	-1.03	0.42	-1.86 - -0.20	0.01	Decrease	Decrease
L_{A10}	56.5	-0.68	0.49	-1.64 - 0.28	0.17	-	-
L_{A50}	48.6	-0.28	0.61	-1.47 - 0.91	0.65	-	-
L_{A90}	43.9	0.00	0.67	-1.31 - 1.30	1.00	-	-
L_{A95}	42.9	0.06	0.67	-1.25 - 1.37	0.93	-	-

12 hour day-time (0700-1900)

Index	2000 Mean Level (dB)	Difference in Means (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	57.1	-0.59	0.40	-1.36 - 0.19	0.14	-	-
L_{A01}	66.0	-0.98	0.40	-1.76 - -0.20	0.01	Decrease	Decrease
L_{A10}	57.5	-0.62	0.46	-1.52 - 0.28	0.18	-	-
L_{A50}	49.7	-0.26	0.58	-1.41 - 0.89	0.66	-	-
L_{A90}	44.9	0.00	0.66	-1.29 - 1.29	1.00	-	-
L_{A95}	43.9	0.06	0.66	-1.24 - 1.36	0.93	-	-

4 hour evening (1900-2300)

Index	2000 Mean Level (dB)	Difference in Means (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	53.1	-1.22	0.52	-2.24 - -0.20	0.02	Decrease	Decrease
L_{A01}	62.5	-1.18	0.54	-2.23 - -0.13	0.03	Decrease	Decrease
L_{A10}	53.3	-0.86	0.63	-2.10 - 0.39	0.18	-	-
L_{A50}	45.3	-0.33	0.74	-1.77 - 1.12	0.66	-	-
L_{A90}	40.8	-0.01	0.76	-1.50 - 1.48	0.99	-	-
L_{A95}	39.9	0.06	0.75	-1.41 - 1.53	0.93	-	-

8 hour night-time (2300-0700)

Index	2000 Mean Level (dB)	Difference in Means (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	48.2	0.00	0.43	-0.85 - 0.85	1.00	-	-
L_{A01}	55.3	-0.04	0.59	-1.20 - 1.12	0.95	-	-
L_{A10}	45.6	0.24	0.62	-0.99 - 1.46	0.70	-	-
L_{A50}	38.9	0.65	0.66	-0.65 - 1.95	0.33	-	-
L_{A90}	35.3	0.64	0.66	-0.66 - 1.93	0.33	-	-
L_{A95}	34.6	0.45	0.65	-0.82 - 1.71	0.49	-	-

18 hour day (0600-2400)

Index	2000 Mean Level (dB)	Difference in Means (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	56.2	-0.69	0.41	-1.49 - 0.11	0.09	-	Decrease
L_{A01}	64.6	-1.00	0.42	-1.83 - -0.17	0.02	Decrease	Decrease
L_{A10}	55.8	-0.66	0.50	-1.63 - 0.31	0.19	-	-
L_{A50}	48.0	-0.25	0.61	-1.44 - 0.94	0.68	-	-
L_{A90}	43.3	0.02	0.66	-1.27 - 1.32	0.97	-	-
L_{A95}	42.3	0.08	0.66	-1.21 - 1.37	0.90	-	-

24 hour period

Index	2000 Mean Level (dB)	Difference in Means (dB)	Standard Error in Difference (dB)	95% Confidence Interval	Statistical Significance	Significant Changes:	
						95% confidence	90% confidence
L_{Aeq}	55.1	-0.67	0.40	-1.46 - 0.12	0.10	-	Decrease
L_{A01}	61.8	-0.70	0.45	-1.57 - 0.17	0.12	-	-
L_{A10}	52.9	-0.37	0.51	-1.37 - 0.62	0.46	-	-
L_{A50}	45.4	0.03	0.59	-1.13 - 1.20	0.96	-	-
L_{A90}	41.0	0.21	0.63	-1.02 - 1.44	0.74	-	-
L_{A95}	40.1	0.19	0.62	-1.03 - 1.41	0.76	-	-

6.8 Table 8 – Classification of sites

Table showing breakdown of site descriptions according to the classifications used in the 1990 study which were based on those in BS 4142: 1975 (now withdrawn), for measurement sites from each of the studies.

Site Description	**Proportion of 1990 sample**	**Proportion of year 2000 sample**
1. Rural (residential)	12.7%	17.0%
2. Suburban, little road traffic	59.4%	52.2%
3. Urban (residential)	7.6%	16.7%
4. Predominantly residential but with some light industry or main roads	20%	13.4%
5. Generally industrial area intermediate between (4) and (6)	0.2%	0.5%
6. Predominantly industrial area with few dwellings	0.1%	0.0%
7. Not Known	0.0%	0.3%

6.9 Table 9 – Audible noise sources

Table indicating estimates (and 95% confidence intervals) for number of people exposed to noise from particular sources at their homes[30], from information recorded by the engineer visiting the site, for both 1990 and year 2000 studies.

These figures are based solely on audible noise sources during the relatively short site visit of the engineer, and hence are likely to contain a larger error that the purely statistical uncertainty calculated.

Noise Sources	**Estimated proportion in 1990**	**Estimated proportion in year 2000**
General Road Traffic	91±3%	87±4%
Motorway	2±1%	2±1%
Aircraft	61±6%	41±10%
Railway	15±4%	12±4%
Industry	4±2%	5±2%
Construction	5±2%	8±2%
Farm Equipment	8±3%	6±4%
Birds/Animals	55±6%	68±6%
School Children	18±4%	21±4%
Trees/rustling	18±6%	29±7%

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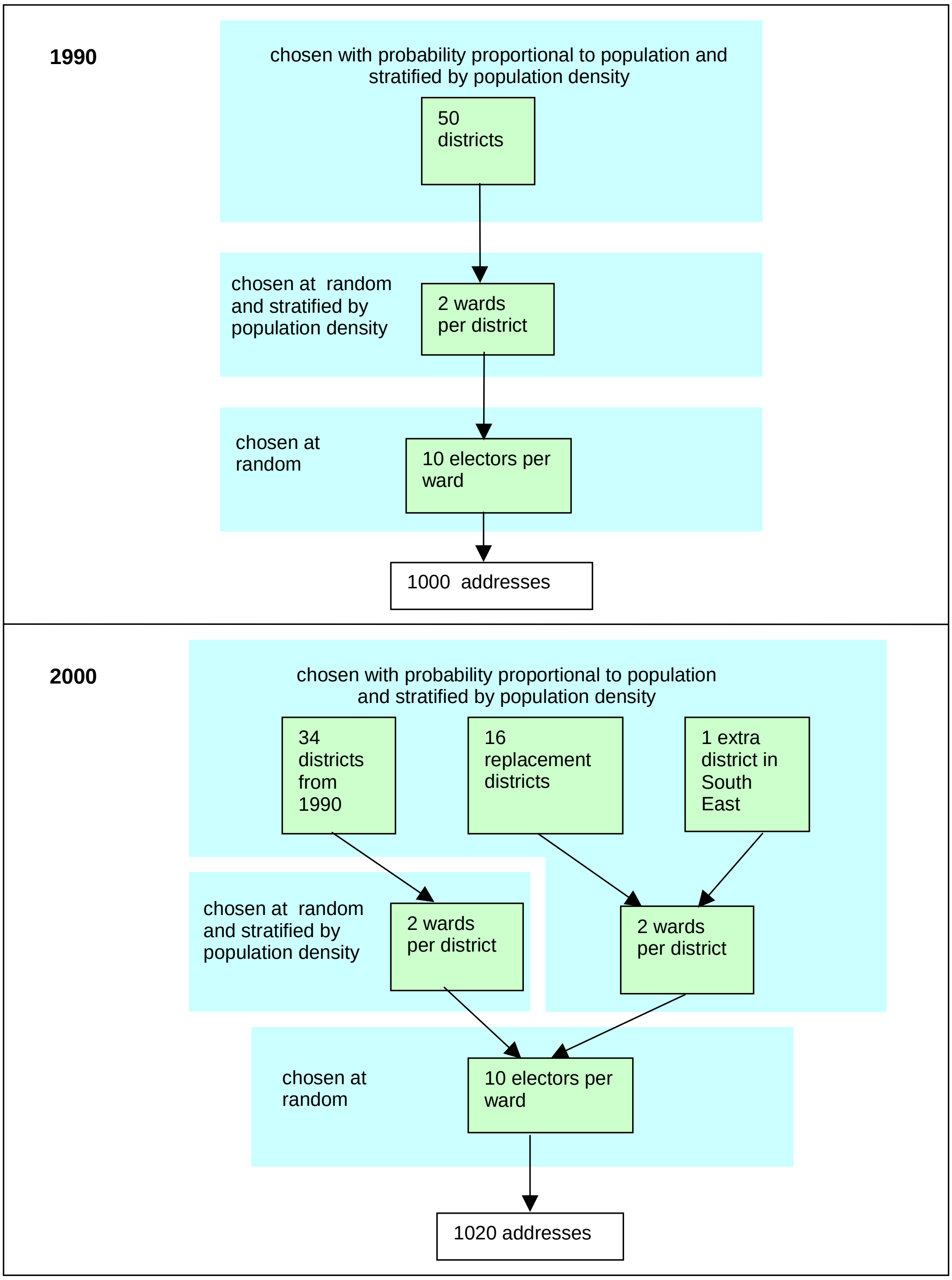
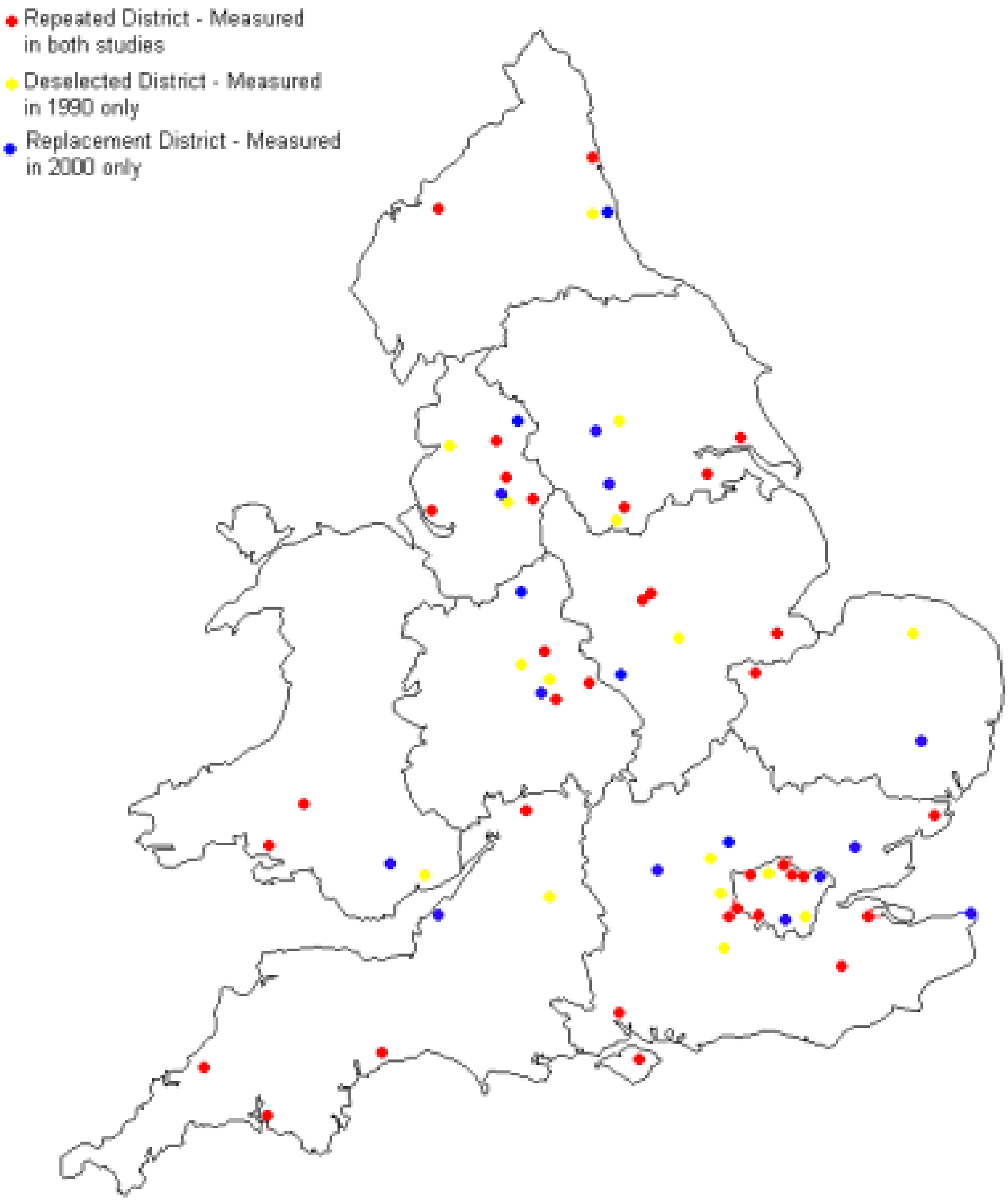
[30] As the study was designed to look at population exposure, i.e. there was an equal probability of the home of any individual being selected for measurement, rather than equal probabilities of any dwelling being selected; the proportions are estimates of proportions of the population exposed to these noises at their homes, rather than proportions of dwellings where these sources are audible.

7 Figures

7.1 Figure 1 – Sample selection

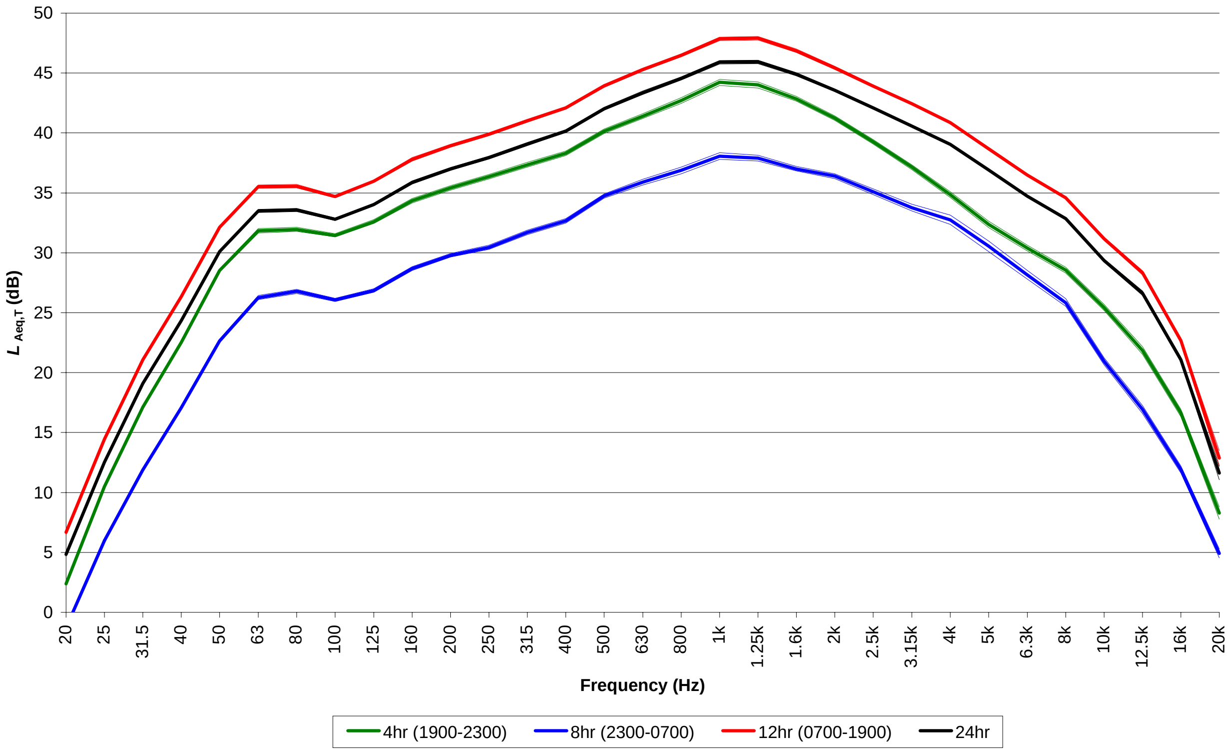


7.2 Figure 2 – Measurement locations for 1990 and year 2000 studies



7.3 Figure 3 – National mean A-weighted 1/3-octave spectra[31]

Note: the 95% confidence intervals are incorporated in the thickness of the lines.



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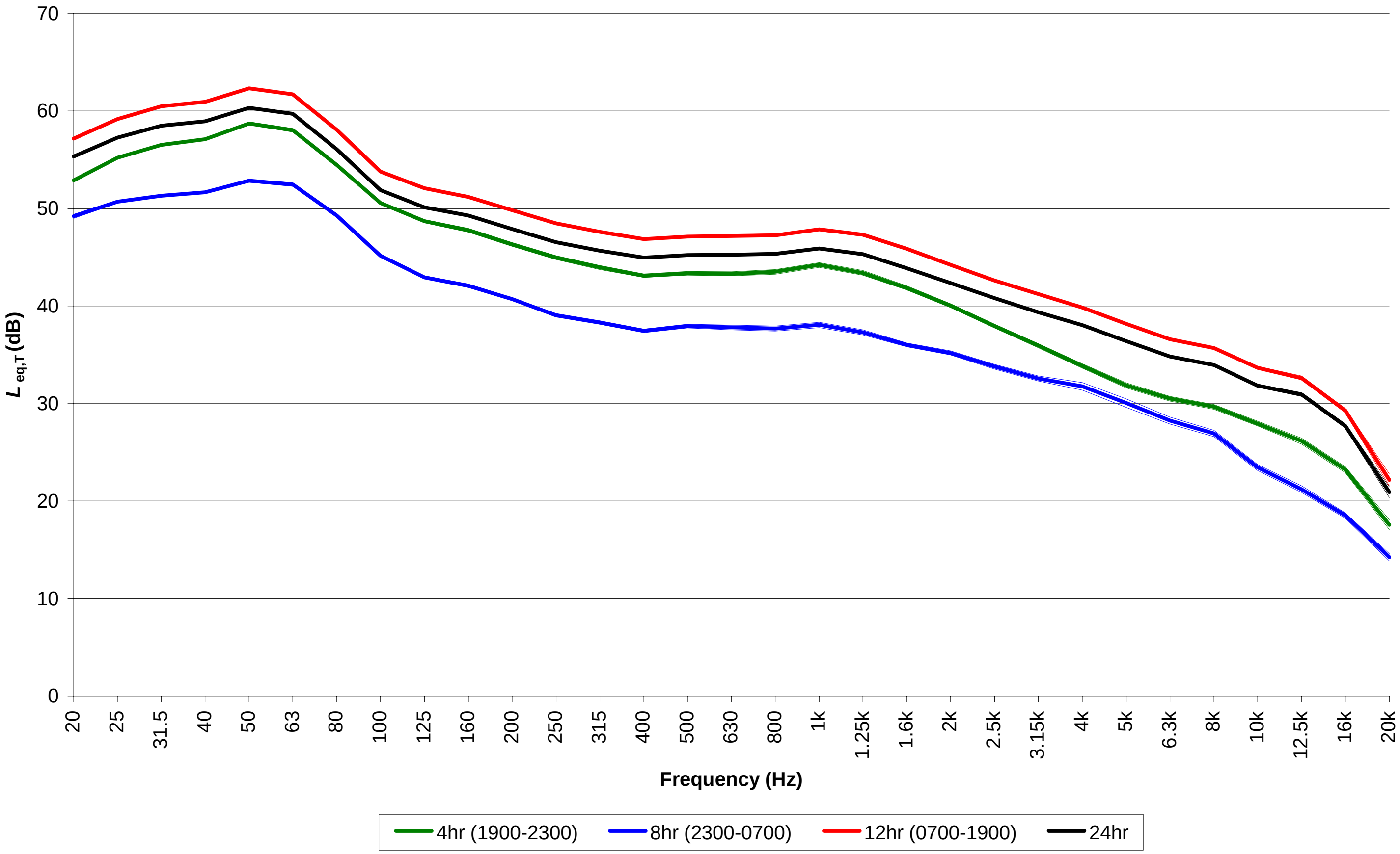
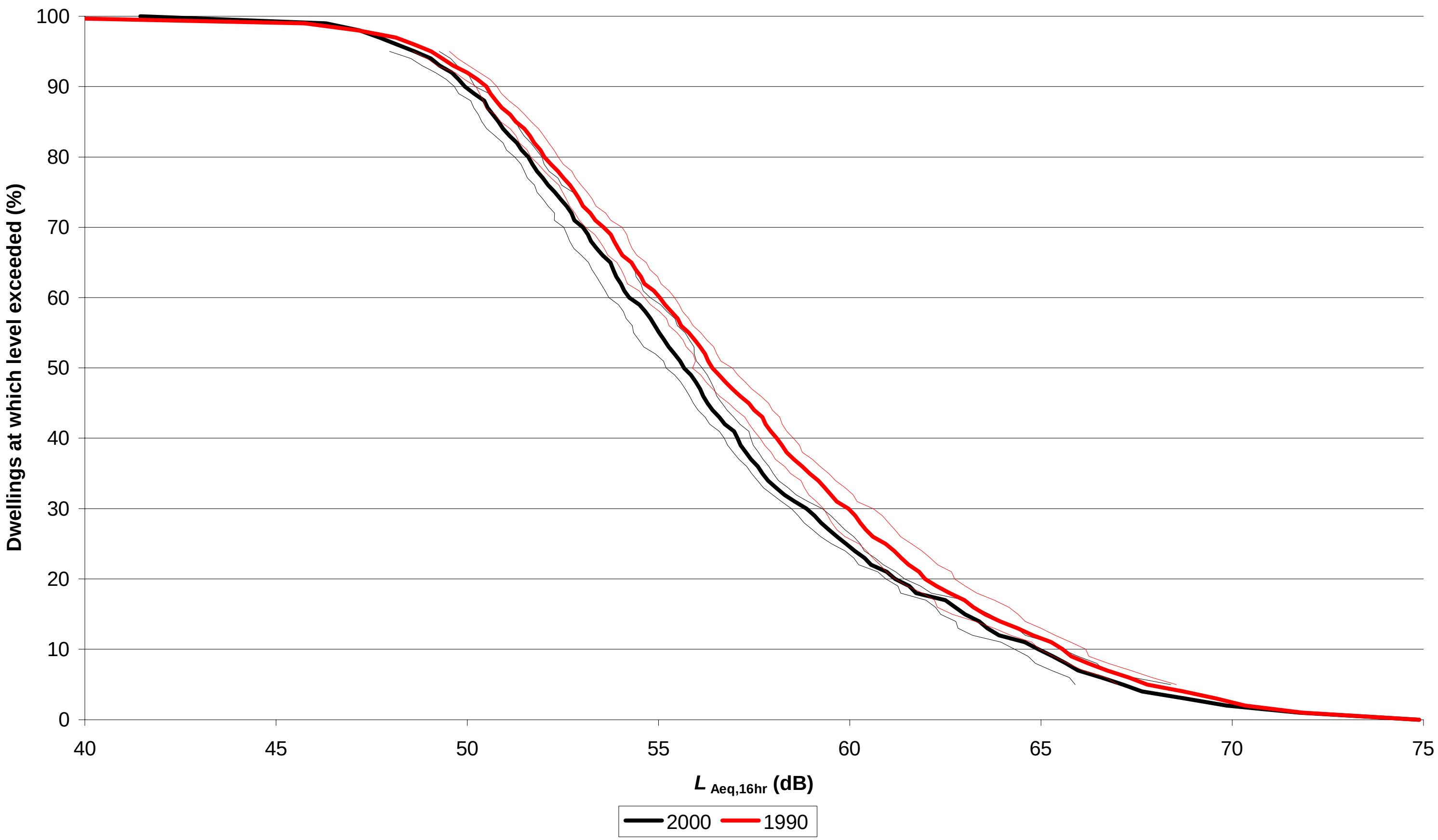
[31] Derived from measurements of linear 1/3-octave spectra.

7.4 Figure 4 – National mean linear 1/3-octave spectra

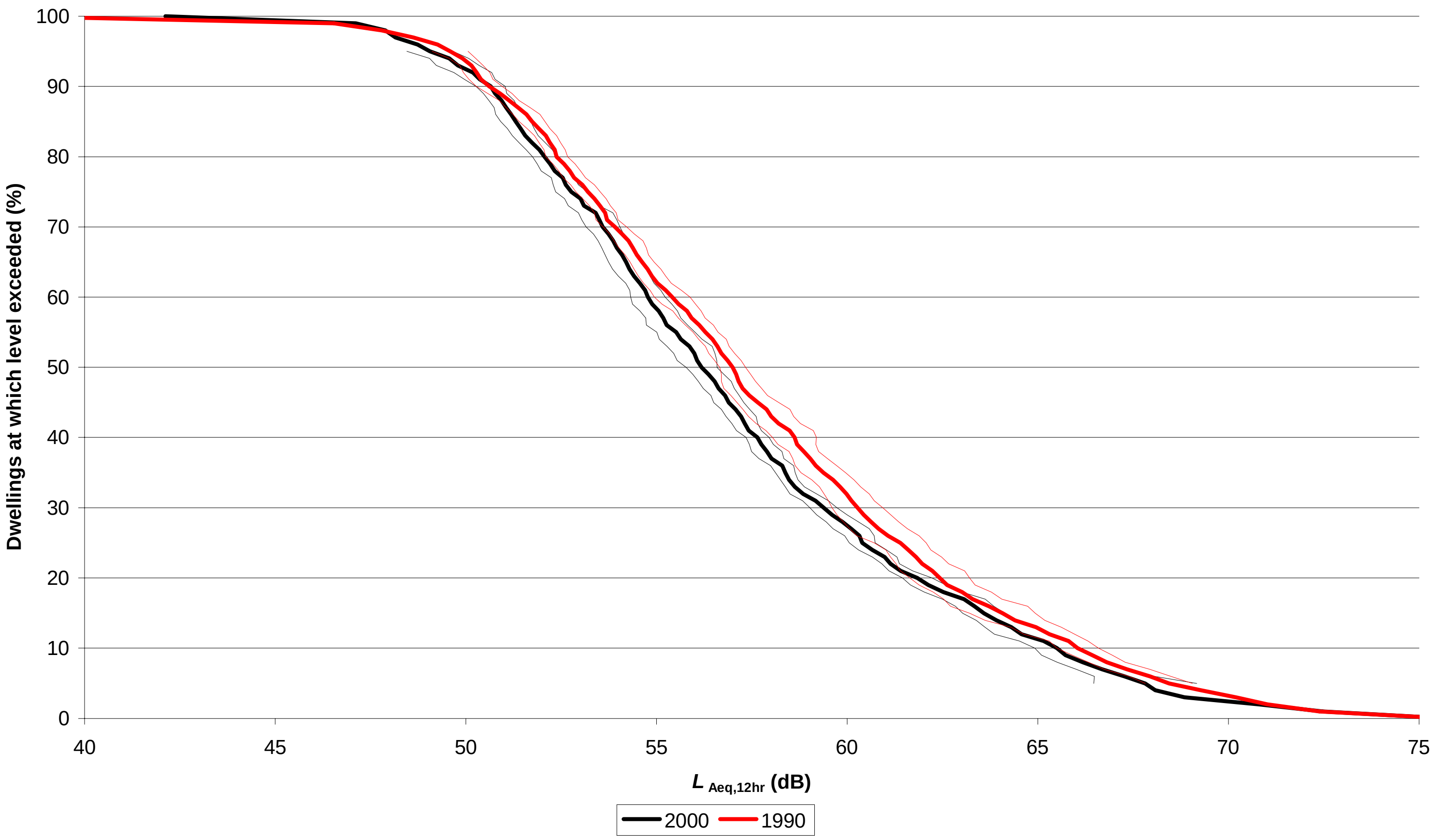
Note: the 95% confidence intervals are incorporated in the thickness of the lines.



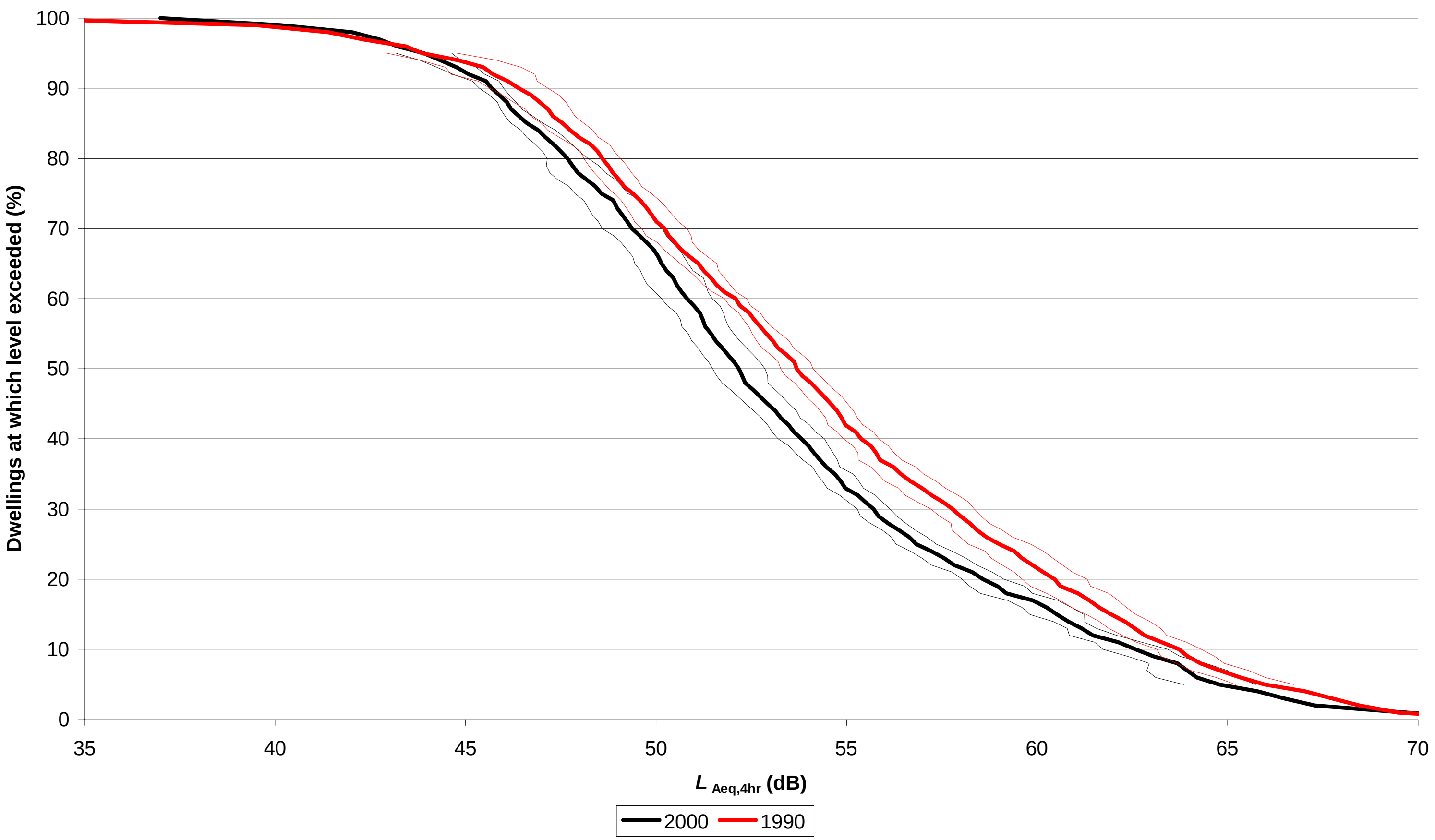
7.5 Figure 5 – Cumulative distribution for 16hr L_{Aeq} (0700 – 2300)



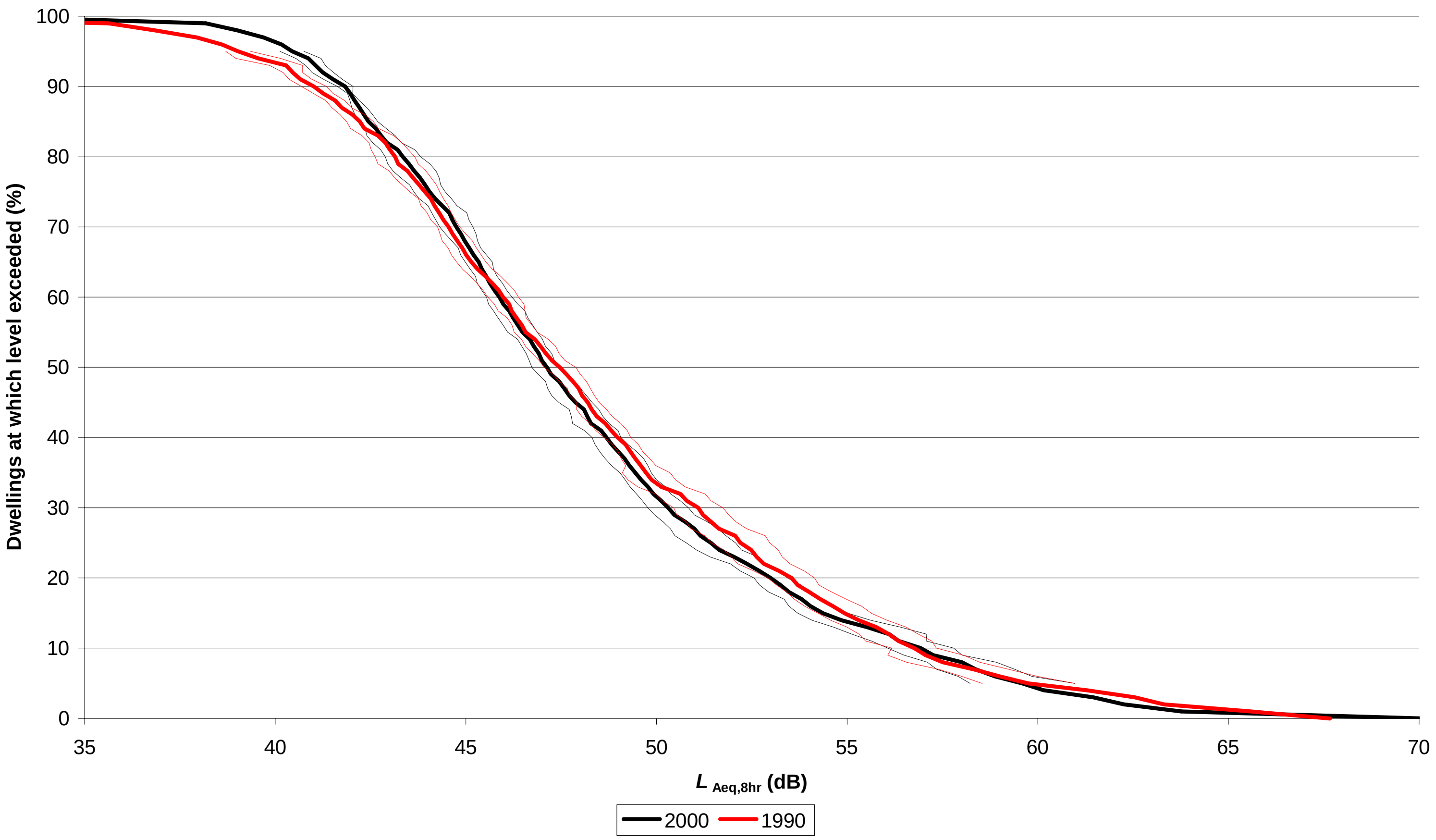
7.6 Figure 6 – Cumulative distribution for 12hr L_{Aeq} (0700 – 1900)



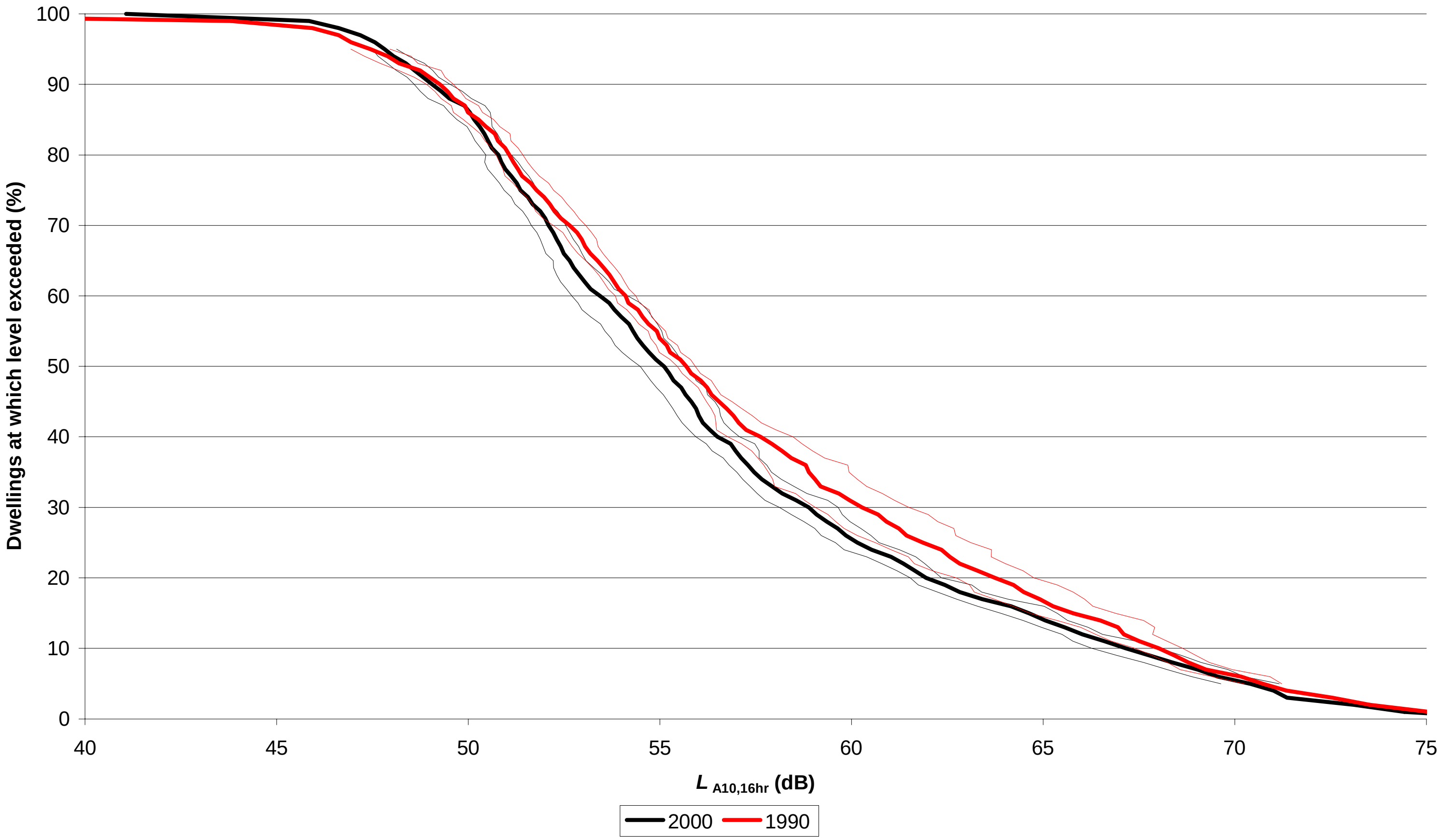
7.7 Figure 7 – Cumulative distribution for 4hr L_{Aeq} (1900 – 2300)



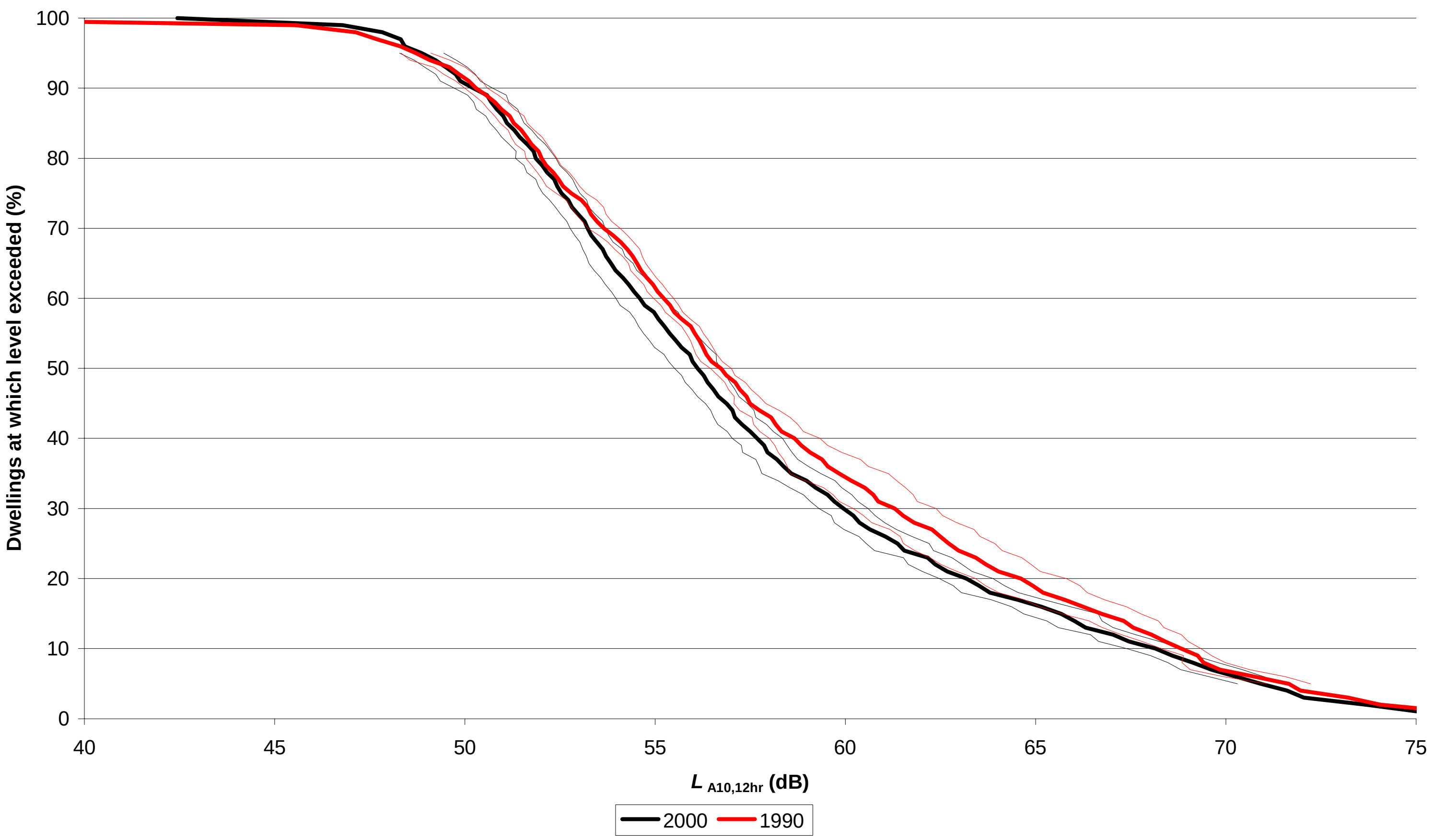
7.8 Figure 8 – Cumulative distribution for 8hr L_{Aeq} (2300 – 0700)



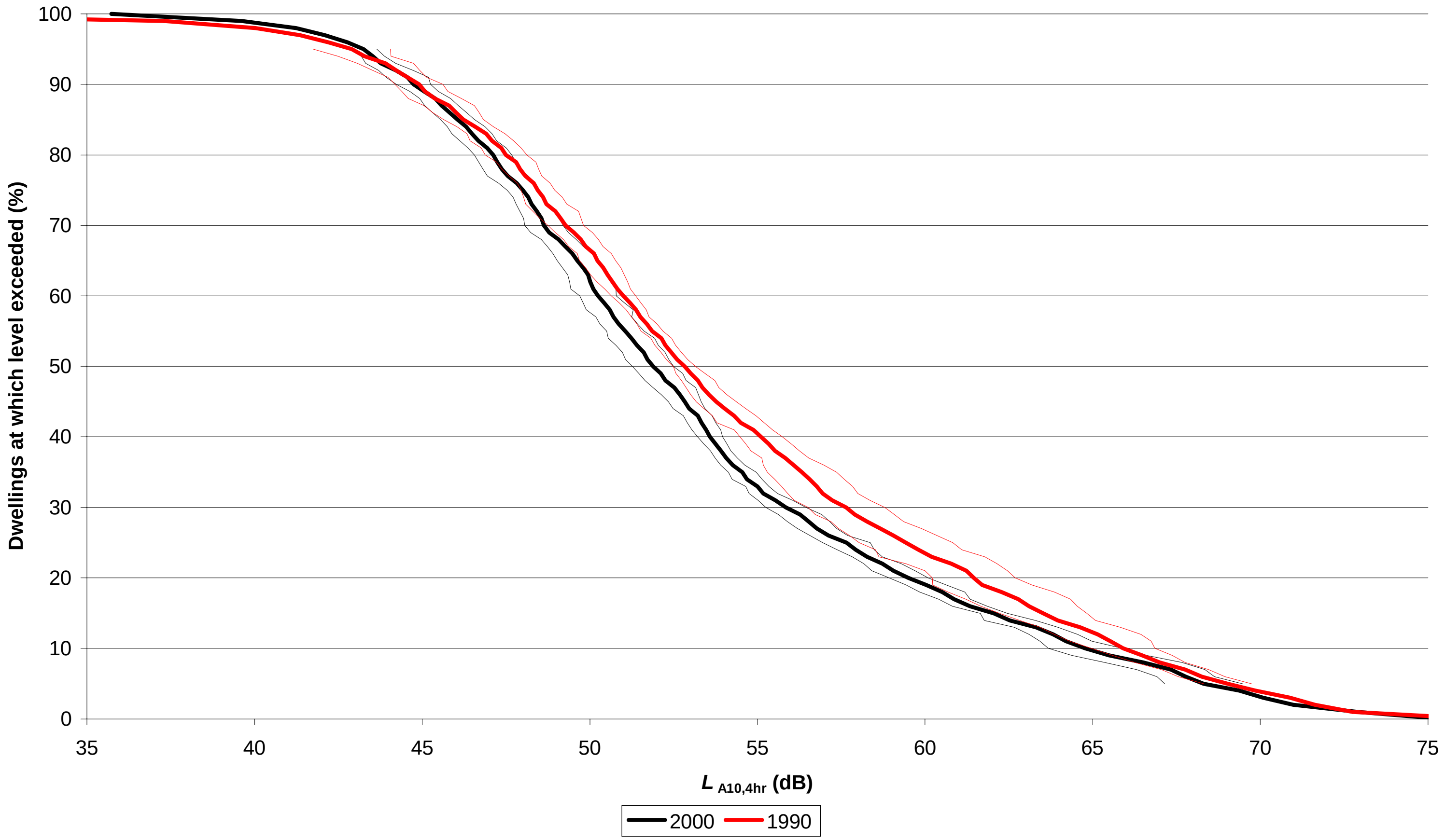
7.9 Figure 9 – Cumulative distribution for 16hr L_{A10} (0700 – 2300)



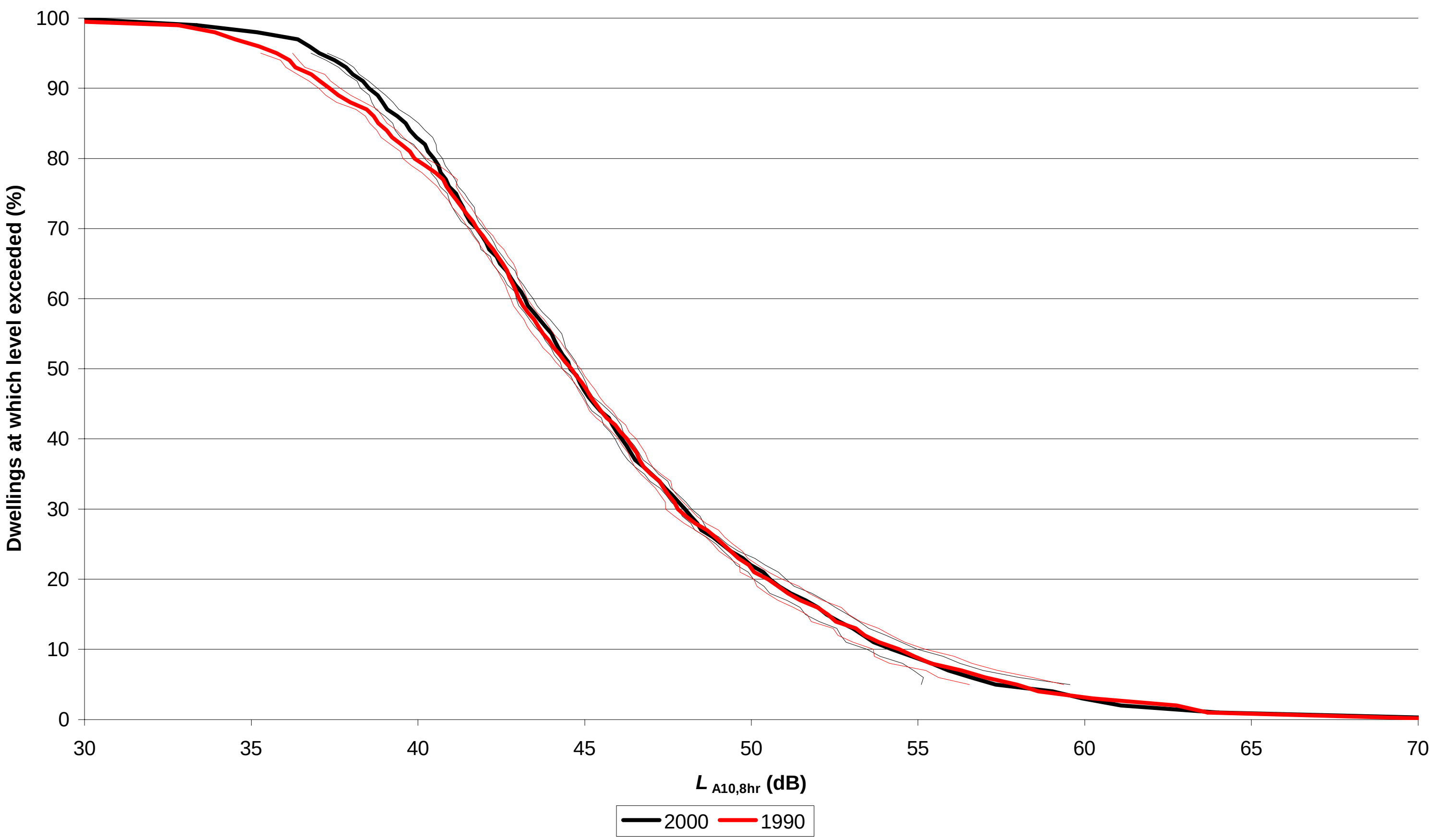
7.10 Figure 10 – Cumulative distribution for 12hr L_{A10} (0700 – 1900)



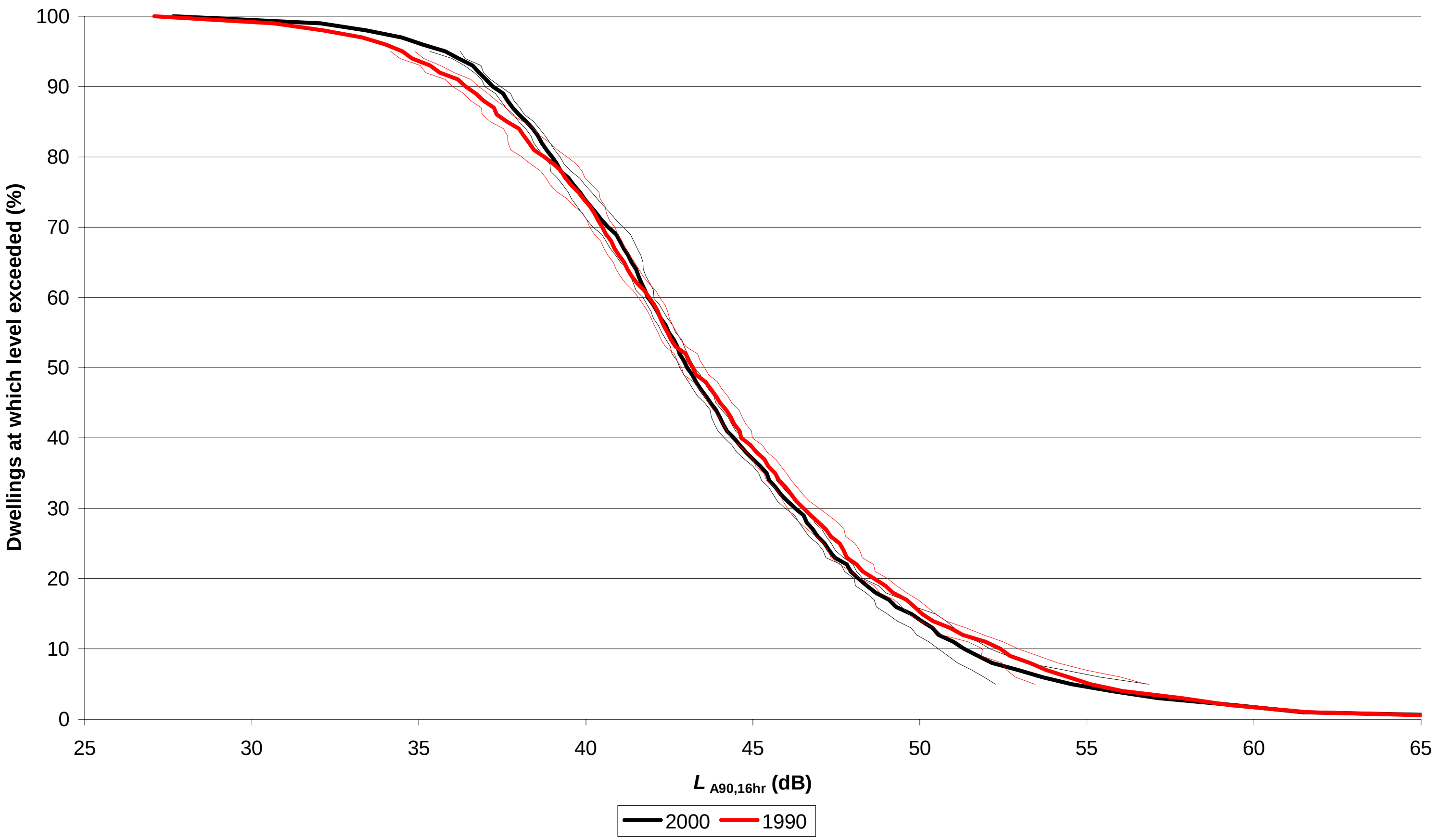
7.11 Figure 11 – Cumulative distribution for 4hr L_{A10} (1900 – 2300)



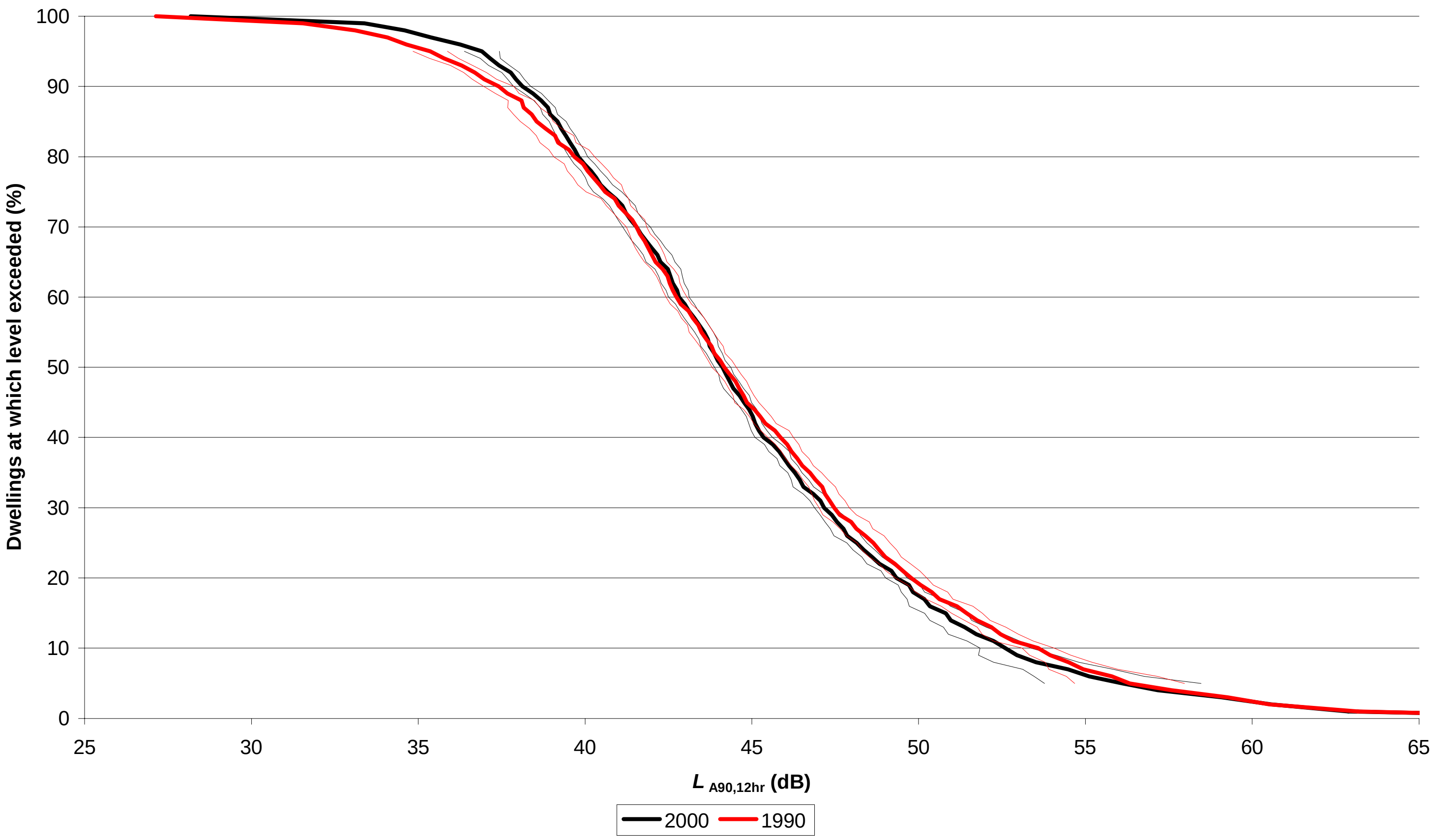
7.12 Figure 12 – Cumulative distribution for 8hr L_{A10} (2300 – 0700)



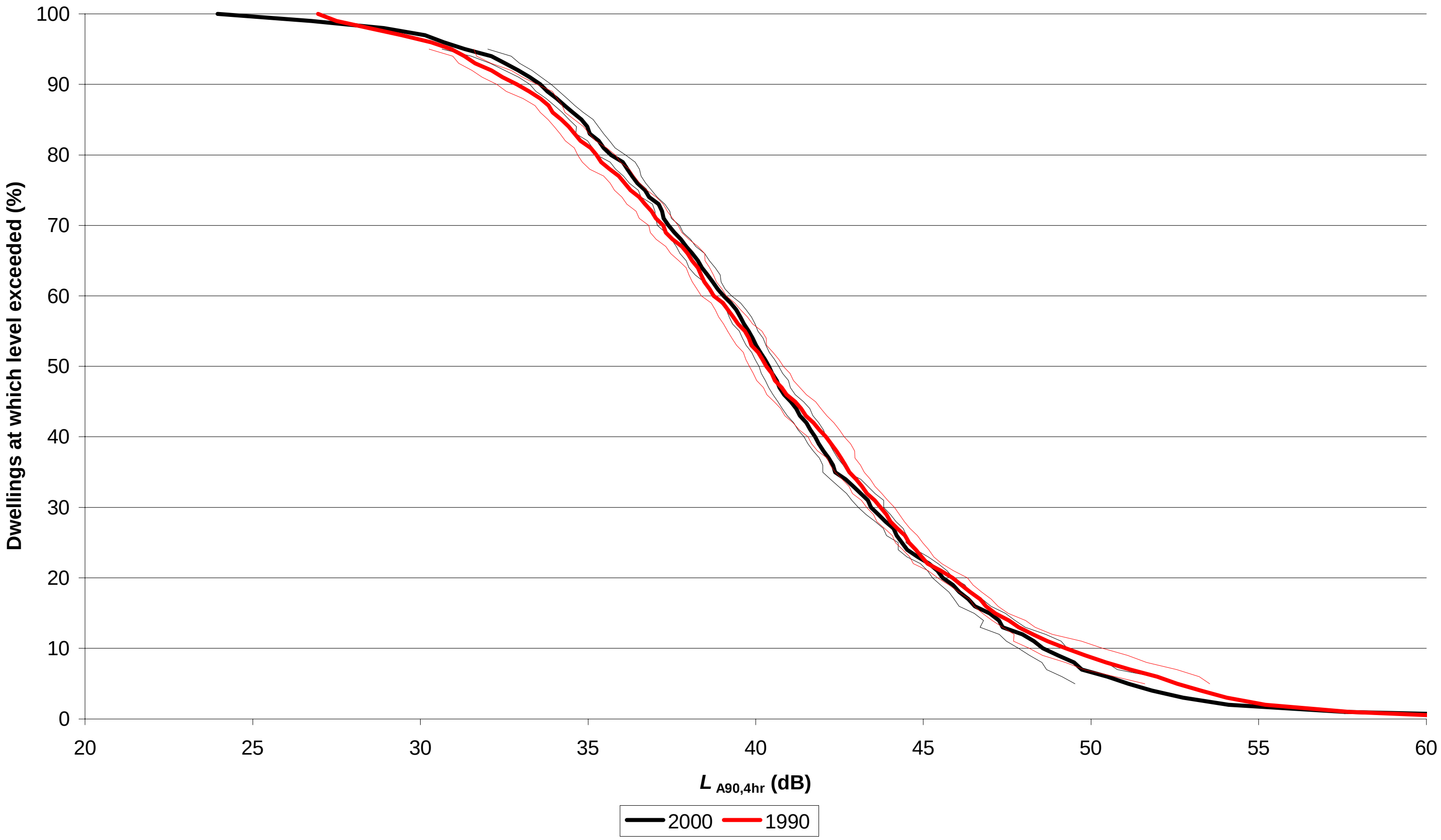
7.13 Figure 13 – Cumulative distribution for 16hr L_{A90} (0700 – 2300)



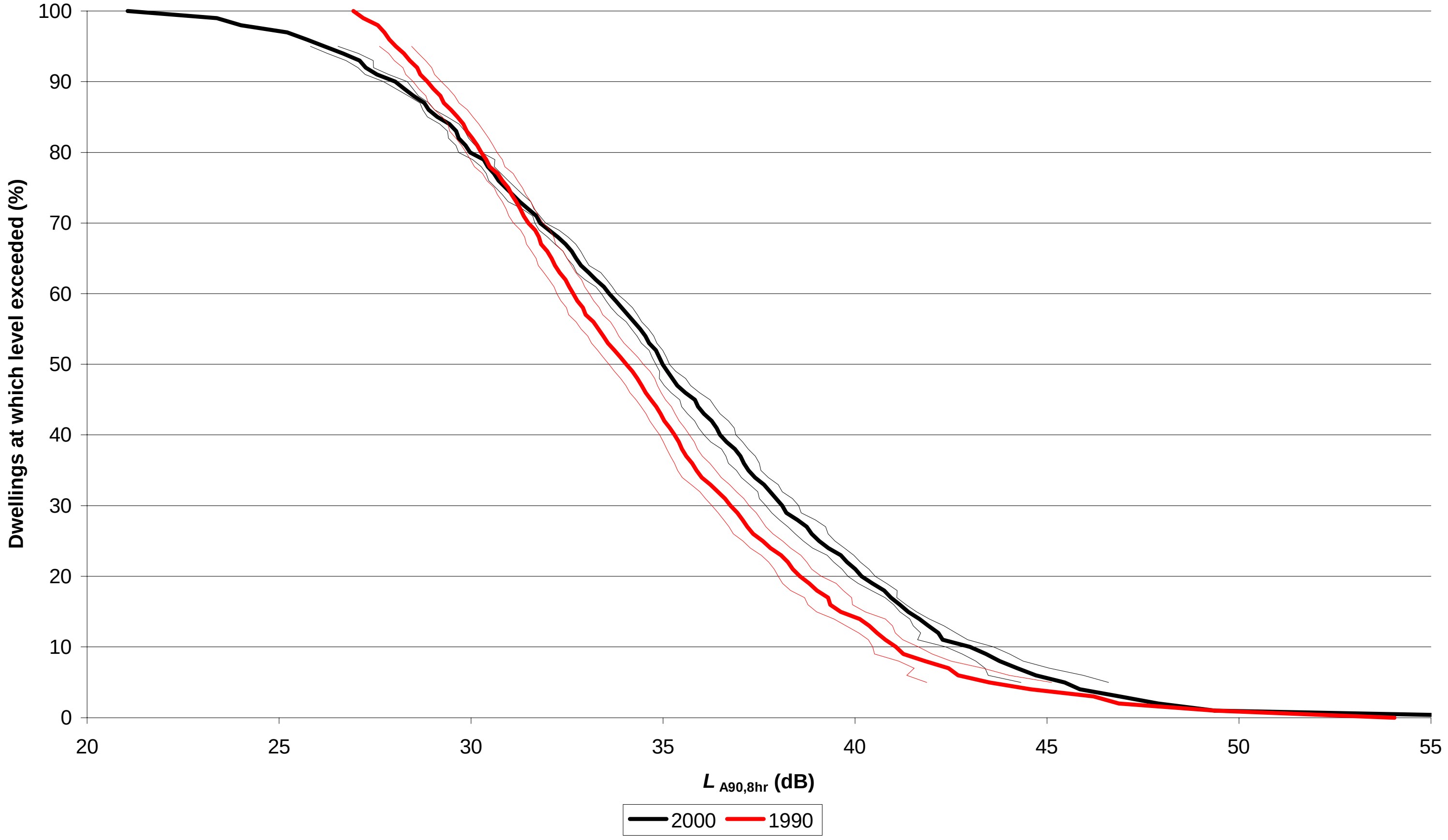
7.14 Figure 14 – Cumulative distribution for 12hr L_{A90} (0700 – 1900)



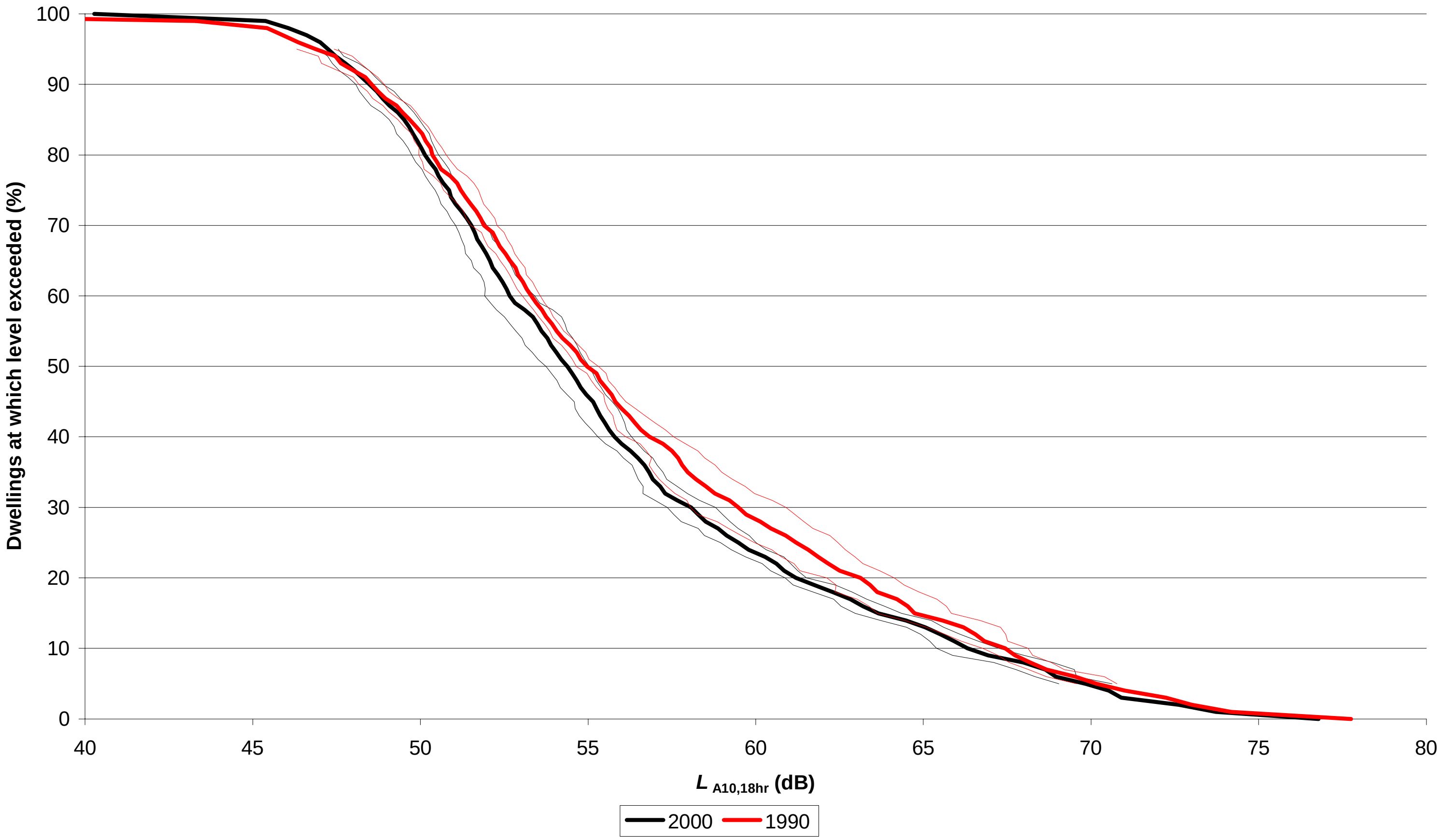
7.15 Figure 15 – Cumulative distribution for 4hr L_{A90} (1900 – 2300)



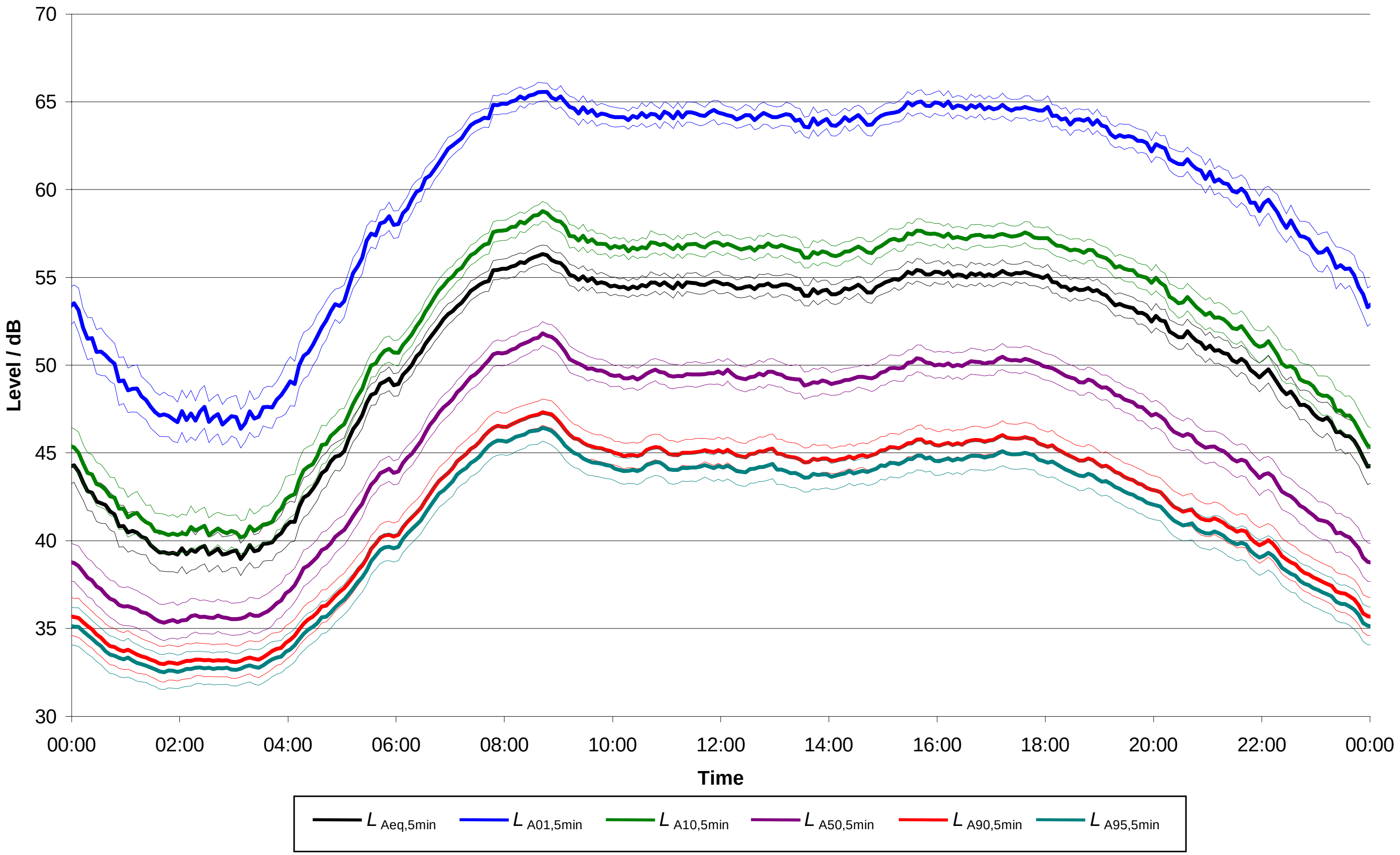
7.16 Figure 16 – Cumulative distribution for 8hr L_{A90} (2300 – 0700)



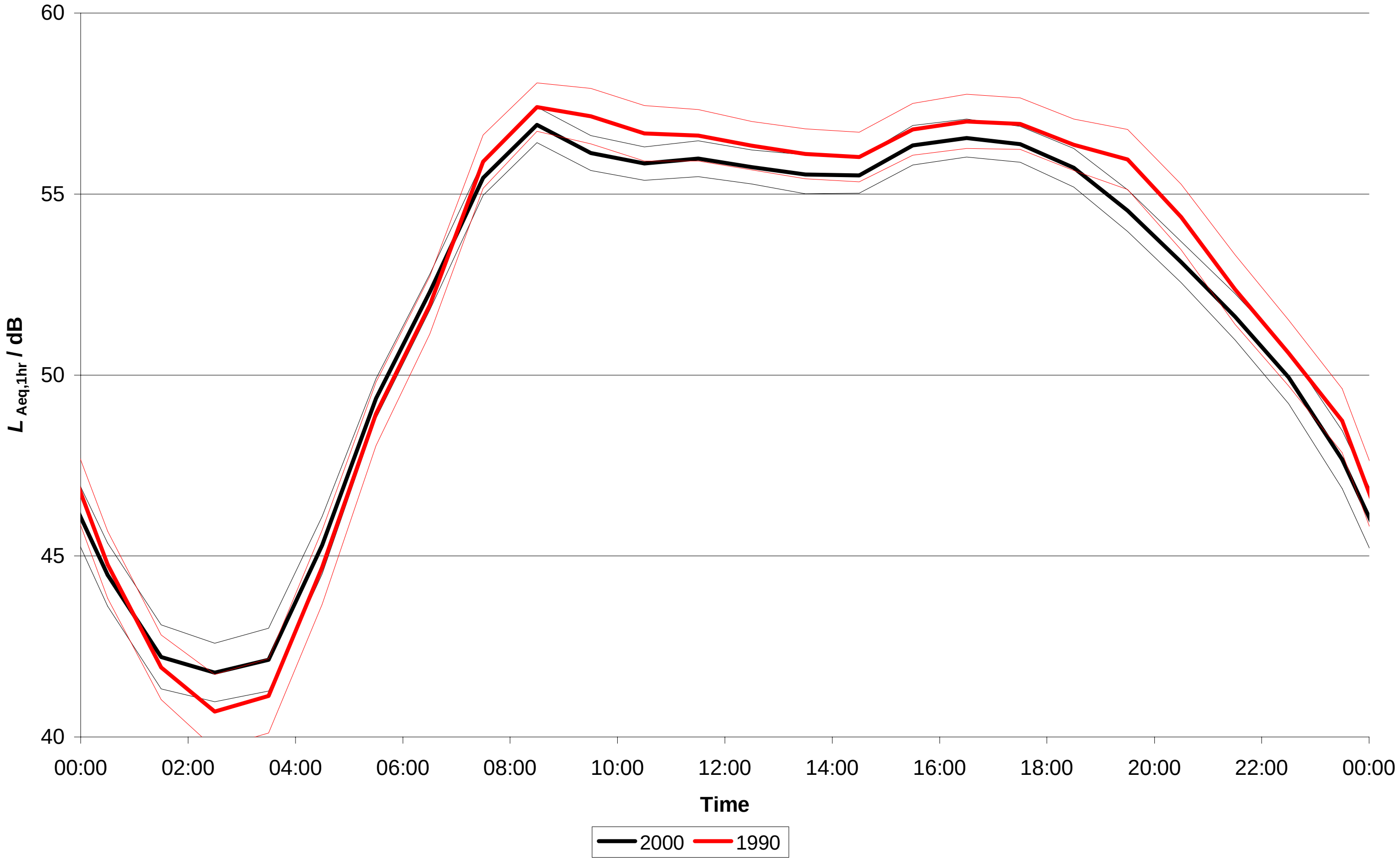
7.17 Figure 17 – Cumulative distribution for 18hr L_{A10} (0600 – 2400)



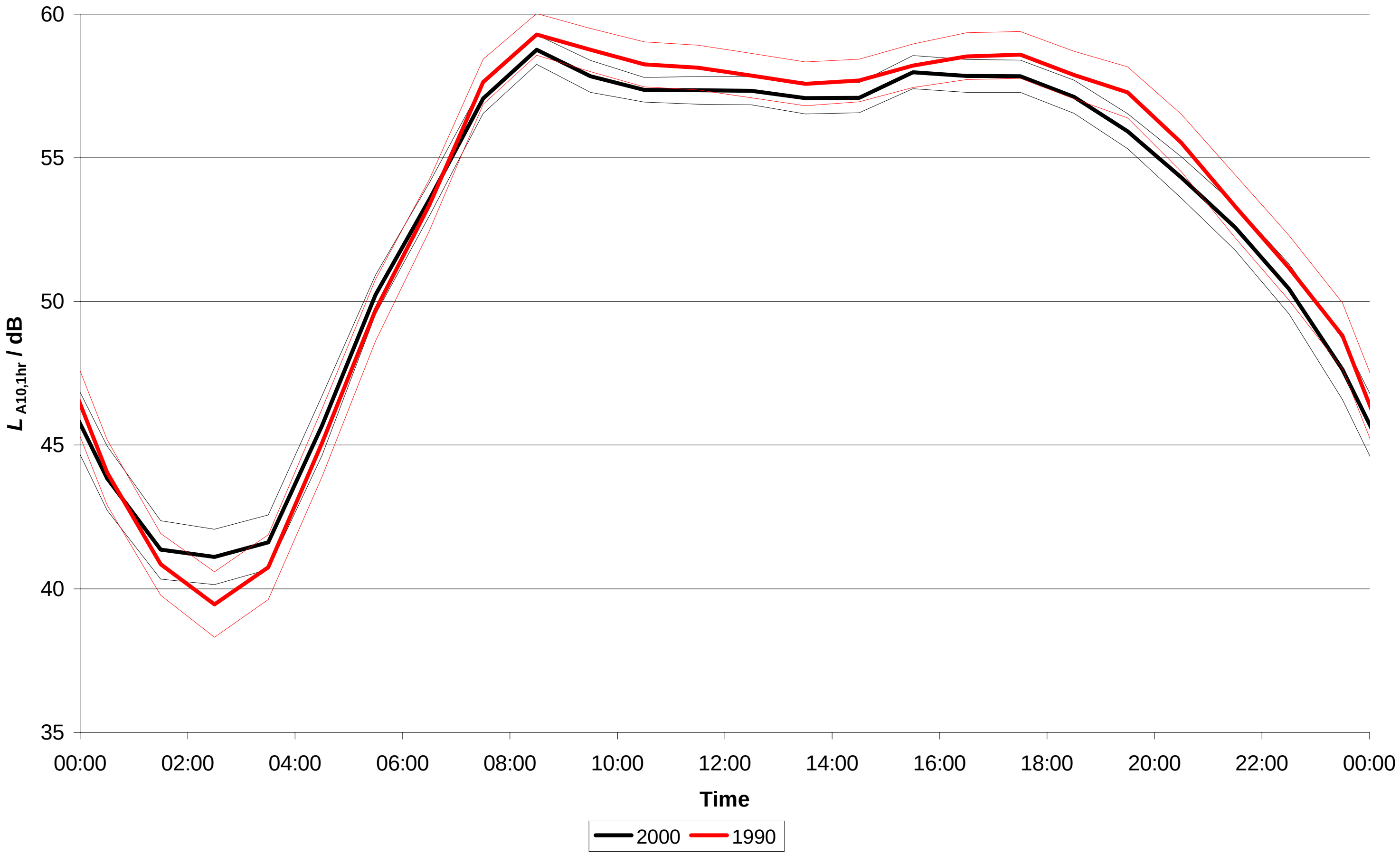
7.18 Figure 18 – Mean time histories for year 2000 study



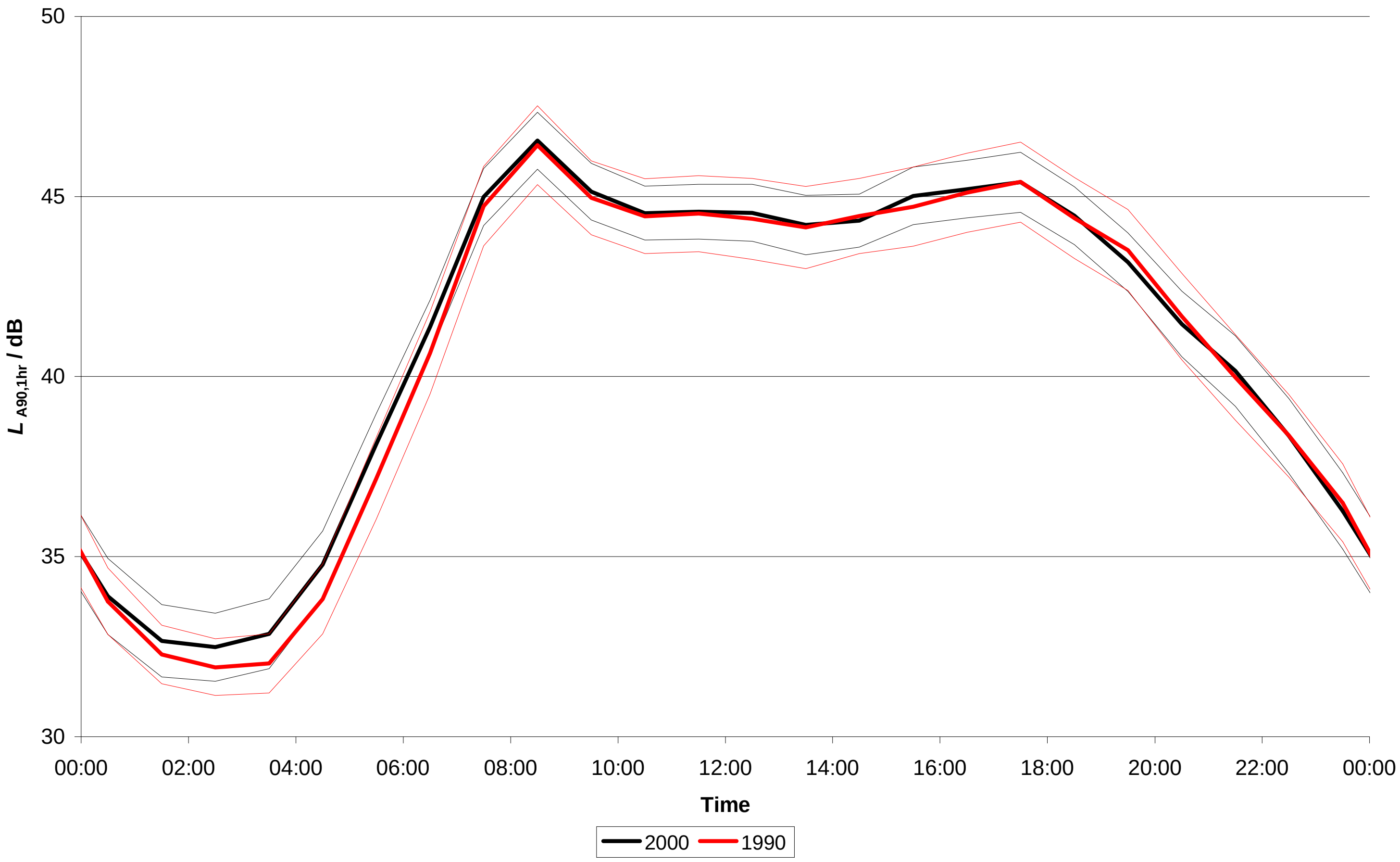
7.19 Figure 19 – Mean L_{Aeq} time histories



7.20 Figure 20 – Mean L_{A10} time histories



7.21 Figure 21 – Mean L_{A90} time histories



8 Acknowledgements

BRE would like to acknowledge the contribution of AIRO Ltd, who undertook all the field measurements in England and Wales.

Sincere thanks are also due to John Sargent, the manager of the 1990 study, for lending the study the benefit of his expertise and to all the residents who agreed to measurements being carried out at their homes.

Annex A – Data quality checks

Sources of variation

The variation between the noise levels at each of the 1020 addresses in the year 2000 study (or the 1000 addresses in the 1990 study) can be thought of as consisting of two separate components. These are simply the between-site variation (the sites are not all equally noisy), and the within-site variation (the noise levels at each site vary from day to day). A distinction is therefore being made between the variation from site to site actually encountered (which includes the within-site variation), and the “true” between-site variation which can be conceived of as corresponding to differences in long-term (say, year averaged) noise levels only.

Within-site variation[32] can be considered to comprise the following elements:

i. Variation caused by day to day changes in meteorological conditions, which affect propagation from the source(s) to the microphone. Within this element, seasonal trends would be expected.[33]

ii. Variation caused by day to day changes in source conditions, such as the flow of road traffic. Again, seasonal trends are likely.

Measurements of site levels were also susceptible to a third source of variation, the intrinsically variable accuracy of all instruments used to make noise measurements. The variation attributable to the measurement instruments may itself be broken down into two elements:

iii. Random variation between the performance of an individual instrument at one site and its performance at another site (i.e. variation with time and conditions).

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[32] A measure of within-site variation can be obtained by comparing corresponding measurements made in the 1990 and 2000 studies. However, any such estimate also includes two further components:

a) Any longer-term trends in source conditions. For example, over a ten year period there may be an increase in road traffic flow.

b) Any longer term trends in meteorological conditions (i.e. year to year variation).

It also corresponds to a within-site variation averaged over the timescale of the two studies. In fact, the within-site variation may change with time. Furthermore, because of seasonal matching (see Section 2.2.1) the effect of seasonal trends in element i. above, are not represented.

[33] The seasonal matching of the 1990 and year 200 studies eliminates as far as possible any systematic differences between the 1990 and year 2000 data caused by any potential interaction between seasonal effect and geographical area.

iv. Random variation between the typical performance of individual instruments from the same manufacturer.

Since the instruments used were different in the 1990 and year 2000 studies, a third source of instrument variation must be considered when making comparisons, namely:

v. Systematic variation between instruments from different manufacturers (differences in the way different manufacturers make use of the allowable tolerances).

Data checking and correction

The $L_{\mathrm{Aeq,125ms}}$ time histories allowed the data from each site to be examined in detail. In particular, they allowed the likely causes of any large peaks in the time histories, which may have a large effect on particular noise indices, to be determined. Even with optimum alignment of the dynamic range of the measurement instrument (80 dB for the Norsonic analysers), overloads caused by a few transient events are inevitable at some sites, but the resulting measurement error will generally be very low. However, certain extended patterns of peaks in a time history usually indicate a source of noise very close to the microphone. The question to be answered, if this occurs, is what is the likely source and why is it close to the microphone?

In certain cases it was felt that such peaks were likely to be caused by people (and in one case a dog) approaching the microphone and making a noise they would not have made had the microphone not been there. To an extent this was likely to have happened in the 1990 study also, but it was felt that it was more likely in the year 2000 study because the instruments used were more conspicuous. Therefore, the decision was taken to correct the measurement data in such cases as far as possible, with little risk of introducing potential bias into comparisons with the 1990 data. In any event only 30 of the 1020 records required correction in this fashion.

Instrumentation cross-checks

Before comparisons of the 1990 and year 2000 levels were made, systematic variation (element v. above) between the instruments used in the 1990 study (Cirrus meters) and year 2000 study (Norsonic analysers) was investigated by field tests. The method adopted was to make simultaneous measurements using five or six surviving Cirrus meters and at least two Norsonic analysers with their microphones arranged as closely as possible in space, at six selected sites. All the microphones were positioned in line at a height of 1.2 m and 1 m from the façade, as in the studies. For most measurements, two Norsonic analysers were used, and the microphones of these two were the first and last in line. For two of the sites, equal numbers of Norsonic and Cirrus instruments were used, arranged in an alternating row.

Any measured differences between instruments are a function of the actual differences in their electro-acoustic characteristics, and the particular noise environment in which they are placed. It was not considered feasible to determine functional relationships between the noise environment (in terms of level) and any systematic differences between instruments. The aim of the cross-checking exercise was restricted to establishing an estimate of the effect of any differences on mean levels.

Care was taken with site selection to ensure that any differences detected would be representative of the effect on the means of the study data. The frequency distributions of each of the noise indices quantified in the year 2000 study were examined, and the 5 dB(A) modal range of values for each index established. For all indices at least two thirds of the distribution lay within +/- 5 dB(A) of the modal range, and it was considered reasonable to conduct most of the cross-check measurements in sites that corresponded to this range for most indices.

It was not practical to go back to actual sites used in the study, so the typical characteristics of those sites that had produced the modal values across the widest range of indices were established. The most typical were houses on quiet residential estate roads, with their façades around 10 m from the kerb. Accordingly, four sites were chosen to correspond with these characteristics. In addition, one site was chosen which was likely to produce lower than modal levels (at the end of a residential no-through road); and one was chosen which was likely to produce higher than modal levels (100 m from the M1).

The standard deviation of the difference between the Norsonic analysers at each site (their microphones were physically the furthest apart) was of the order of 0.1 dB(A) to 0.2 dB(A). Since at least some of this could be attributable to their spatial separation it indicated a low variability between individual Norsonic analysers, which was corroborated by the laboratory checks that had been carried out during the course of the measurement programme. These checks had also indicated that the Norsonic analysers achieved close to the “ideal” performance characteristics laid down in IEC 651:1979 and IEC 804:1985. For these reasons, the average of the readings of the two Norsonic analysers was taken to be the “true” level of a particular noise index at a particular site. On this basis the systematic differences detected between the Cirrus and Norsonic instruments were treated as differences between readings given by the Cirrus instruments and “true” readings[34]. Estimates of the systematic differences, and their uncertainties, are set out for each index in Table A1 below. They are statistically significant for every index common to the 1990 and year 2000 studies, with, on average, a mean of 0.9 dB(A) and a standard error in the mean of 0.12 dB(A). All differences were positive, indicating the Cirrus meters read low.[35]

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[34] This means that the elements of variation iii and iv identified above (and effectively lumped together in the instrumentation cross-checks) are considered to be negligible as far as the Norsonic analysers are concerned, particularly in comparison to the equivalent figures for the Cirrus meters.

[35] It should be noted that although significant differences between the two instrument types were detected, the electro-acoustic characteristics of both were tested to be within the tolerances allowed in the relevant standards.

Table A1 – Summary of meter corrections applied

Index	Meter Correction Applied (dB)	Standard Error in Correction (dB)	Number of tests used to obtain correction	Standard Deviation between tests
$L_{\text{Aeq,16hr}}$	0.57	0.12	31	0.67
$L_{\text{Aeq,12hr}}$	0.60	0.12	31	0.66
$L_{\text{Aeq,4hr}}$	0.50	0.13	31	0.74
$L_{\text{Aeq,8hr}}$	0.61	0.11	31	0.61
$L_{\text{Aeq,18hr}}$	0.57	0.12	31	0.65
$L_{\text{Aeq,24hr}}$	0.59	0.11	31	0.64
$L_{\text{A01,16hr}}$	0.88	0.10	31	0.58
$L_{\text{A01,12hr}}$	0.91	0.10	31	0.57
$L_{\text{A01,4hr}}$	0.79	0.12	31	0.66
$L_{\text{A01,8hr}}$	0.94	0.11	31	0.64
$L_{\text{A01,18hr}}$	0.88	0.10	31	0.57
$L_{\text{A01,24hr}}$	0.90	0.10	31	0.57
$L_{\text{A10,16hr}}$	0.87	0.11	31	0.60
$L_{\text{A10,12hr}}$	0.91	0.10	31	0.57
$L_{\text{A10,4hr}}$	0.78	0.13	31	0.72
$L_{\text{A10,8hr}}$	1.06	0.11	31	0.61
$L_{\text{A10,18hr}}$	0.88	0.11	31	0.59
$L_{\text{A10,24hr}}$	0.94	0.10	31	0.58
$L_{\text{A50,16hr}}$	0.94	0.13	31	0.73
$L_{\text{A50,12hr}}$	0.97	0.12	31	0.69
$L_{\text{A50,4hr}}$	0.84	0.16	31	0.87
$L_{\text{A50,8hr}}$	0.95	0.18	31	0.98
$L_{\text{A50,18hr}}$	0.95	0.13	31	0.73
$L_{\text{A50,24hr}}$	0.94	0.14	31	0.78
$L_{\text{A90,16hr}}$	1.09	0.14	31	0.75
$L_{\text{A90,12hr}}$	1.13	0.13	31	0.71
$L_{\text{A90,4hr}}$	0.95	0.16	31	0.89
$L_{\text{A90,8hr}}$	0.93	0.19	31	1.03
$L_{\text{A90,18hr}}$	1.08	0.14	31	0.76
$L_{\text{A90,24hr}}$	1.04	0.14	31	0.79
$L_{\text{A95,16hr}}$	1.12	0.10	29	0.56
$L_{\text{A95,12hr}}$	1.17	0.10	29	0.52
$L_{\text{A95,4hr}}$	0.96	0.13	29	0.68
$L_{\text{A95,8hr}}$	1.08	0.16	29	0.88
$L_{\text{A95,18hr}}$	1.12	0.10	29	0.55
$L_{\text{A95,24hr}}$	1.11	0.11	29	0.59

Table A2 below shows the effect of the uncertainty in these correction terms on the overall standard error in the mean differences for paired comparisons between the two studies, and in the mean level from the 1990 study, for the purpose of unpaired comparisons. These indicate that this component of the standard error is significantly smaller than the component due to the sampling[36]. Consequently, there would be little gain in increasing the number of sites used to obtain these correction terms, given that the range used matches the conditions typical of sites within the study. A doubling of the

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[36] That is the error associated with scaling up from the sample of dwellings to the entire country.

number of sites would have the effect of reducing the standard error in the correction by a factor of approximately 1.41, and would hence have very little effect on the overall standard errors once the two components have been combined.

Table A2 – Effect of uncertainties in correction terms

Index	Standard Error from instrument correction (dB)	Paired Comparisons		1990 Averages for Unpaired Comparisons	
		Standard Error from Sampling	Total Standard Error	Standard Error from Sampling	Total Standard Error
$L_{\mathrm{Aeq,16hr}}$	0.12	0.23	0.26	0.32	0.34
$L_{\mathrm{Aeq,12hr}}$	0.12	0.23	0.26	0.31	0.33
$L_{\mathrm{Aeq,4hr}}$	0.13	0.27	0.30	0.41	0.43
$L_{\mathrm{Aeq,8hr}}$	0.11	0.28	0.30	0.34	0.36
$L_{\mathrm{Aeq,18hr}}$	0.12	0.23	0.26	0.32	0.34
$L_{\mathrm{Aeq,24hr}}$	0.11	0.23	0.26	0.32	0.34
$L_{\mathrm{A01,16hr}}$	0.10	0.16	0.19	0.34	0.35
$L_{\mathrm{A01,12hr}}$	0.10	0.16	0.19	0.32	0.33
$L_{\mathrm{A01,4hr}}$	0.12	0.22	0.25	0.43	0.45
$L_{\mathrm{A01,8hr}}$	0.11	0.35	0.37	0.45	0.47
$L_{\mathrm{A01,18hr}}$	0.10	0.15	0.19	0.34	0.35
$L_{\mathrm{A01,24hr}}$	0.10	0.19	0.22	0.35	0.37
$L_{\mathrm{A10,16hr}}$	0.11	0.20	0.23	0.39	0.41
$L_{\mathrm{A10,12hr}}$	0.10	0.20	0.23	0.37	0.38
$L_{\mathrm{A10,4hr}}$	0.13	0.23	0.26	0.50	0.52
$L_{\mathrm{A10,8hr}}$	0.11	0.41	0.43	0.47	0.48
$L_{\mathrm{A10,18hr}}$	0.11	0.20	0.23	0.40	0.41
$L_{\mathrm{A10,24hr}}$	0.10	0.24	0.26	0.40	0.41
$L_{\mathrm{A50,16hr}}$	0.13	0.32	0.35	0.48	0.50
$L_{\mathrm{A50,12hr}}$	0.12	0.34	0.36	0.47	0.48
$L_{\mathrm{A50,4hr}}$	0.16	0.32	0.36	0.57	0.59
$L_{\mathrm{A50,8hr}}$	0.18	0.45	0.49	0.47	0.51
$L_{\mathrm{A50,18hr}}$	0.13	0.32	0.34	0.48	0.50
$L_{\mathrm{A50,24hr}}$	0.14	0.33	0.35	0.46	0.48
$L_{\mathrm{A90,16hr}}$	0.14	0.39	0.41	0.52	0.54
$L_{\mathrm{A90,12hr}}$	0.13	0.42	0.44	0.52	0.53
$L_{\mathrm{A90,4hr}}$	0.16	0.34	0.38	0.57	0.59
$L_{\mathrm{A90,8hr}}$	0.19	0.45	0.49	0.44	0.47
$L_{\mathrm{A90,18hr}}$	0.14	0.37	0.40	0.52	0.53
$L_{\mathrm{A90,24hr}}$	0.14	0.35	0.38	0.47	0.49
$L_{\mathrm{A95,16hr}}$	0.10	0.40	0.41	0.53	0.54
$L_{\mathrm{A95,12hr}}$	0.10	0.43	0.45	0.52	0.53
$L_{\mathrm{A95,4hr}}$	0.13	0.34	0.36	0.57	0.58
$L_{\mathrm{A95,8hr}}$	0.16	0.45	0.48	0.42	0.45
$L_{\mathrm{A95,18hr}}$	0.10	0.38	0.40	0.52	0.53
$L_{\mathrm{A95,24hr}}$	0.11	0.36	0.37	0.47	0.48