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The United Kingdom Noise Mapping Experience

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The paper describes the noise mapping of the Bristol and Bournemouth agglomerations for the United Kingdom Noise Mapping Initiative in compliance with the European Directive on Environmental Noise and the challenges of delivering both compliant noise mapping, noise mapping outputs and shape files, and the associated methodology reports. The paper examines the noise model utilised for the mapping, the various efficiencies built into the system to provide error checking, the external data acquisition and the effects that any uncertainties may have in strategic noise mapping. Additionally, the use of a GIS based toolkit for identifying and amending the location of noise barrier objects was utilised.

1 Introduction

In 2002 Defra Ministers committed to the development of an ambient noise strategy by 2007. Defra (the UK Government's Department for the Environment, Food and Rural Affairs) are developing the National Ambient Noise Strategy in recognition of the need to develop an integrated and targeted approach to noise at local and national level. In order to do this they need to determine the current ambient noise climate in England. This includes establishing the number of people affected by different levels of ambient noise, the source of that noise (i.e. road, rail, airports and industry) and the locations of the people affected. Noise can be assessed in a number of ways and Defra have chosen to carry out the noise assessment project through computer based noise modelling, generally known as "noise mapping".

The results of the mapping will help to identify noise "hotspots" and less noisy areas and so enable Defra to determine the extent of any noise problems across the country. From that, a view can be made of the relative acceptability or otherwise of the current noise environment, and this will allow the identification of where measures might be put in place to manage and, where necessary, reduce noise. ACCON and its partners carried out the contract for the noise mapping for several parts of the UK, including Area 1 which includes the agglomeration areas of Bristol and Bournemouth and this work forms part of the studies required to obtain results to determine the overall road traffic noise impact in England. The agglomeration areas and the 3 km buffer zones are identified in Figure 1 below.

.Fig.1 Contract Area 1 Map: Bristol and Bournemouth

This paper describes the processes of the noise mapping, including the external data acquisition and examines some of the challenges and lessons learnt.

2 Data Preparation

The first stage of the noise mapping process involved the preparation of the data. The data preparation took two forms: the creation of a Noise Barrier Dataset; and the checking and manipulation of the import date from Defra's Central Data Service (CDS) into the noise model.

The principal challenges relating to the Noise Barrier Dataset creation relate to the ability to accurately identify all structures that act as noise barriers on the highway network identified in the agglomeration areas. ACCON and its partners carried out the following measures to mitigate the challenges of obtaining precise and up to date information on specific noise barriers/bunds that would not otherwise be contained within the CDS dataset.

We carried out drive-bys on all major roads for the identified highway networks in order to obtain precise location data for noise barriers/bunds, bridge and viaduct parapets etc. using GPS equipment. We stopped the vehicle, when and where we could safely do so, on non-motorway roads, in order to determine as accurately as possible the locations of the highway features. Motorway barrier locations were obtained via drive-bys using rapid identification of start and end features and offsets related to specific features. These drive-bys used a three-man team for initial coarse area and final identification, which ensured that specific barrier features were not missed. It should be noted that our familiarity with the highway network in the Bristol and Bournemouth Agglomeration areas meant that we were able to pre-identify those roads which were considered to be most significant in respect of traffic flows and where residential developments were likely to have required noise barriers.

ACCON and its partners used the Noise Barrier Capture Tool, HA Noise Barrier dataset and OS MasterMap™ topology line features in conjunction with relevant supporting data (e.g. imagery) and site visits for the Bristol and Bournemouth areas to determine the locations and specified attributes of acoustically significant noise barriers located adjacent to the major road network, defined as Motorways, Primary and A Roads.

We used GPS tools to aid the capture of relevant data for noise barrier location which was then verified as inputs into the Noise Barrier Capture Tool. For the CDS Data ACCON and its partners carried out the following integrity and consistency checks:

- Syntactic checks: check on data domains, search for unexpected values (too high, too low, zero);
- Semantic checks: check on unwanted intersections, invalid heights, invalid attributes of houses, barriers, roads etc.;

- Comparing the aerial photographs and maps with the different GIS data (surface contours, buildings. barriers, etc.). When in doubt, the data is checked by visual inventory, such as with the position and height of noise barriers;
- Determining polygons with zero or less local ground heights in order to identify special features such as building foundations (potentially completed buildings with a localised barrier effect) and sewage works/gas holders which actually have a nil height.

Special attention was given to the height information (ground level), because previous experience had shown that there could be small islands in this data that are not relevant to the noise model. Also the presence of flyovers was checked closely, because the CDS data did not always properly identify this information.

3 Software Selection

The chosen software packages for use in the project were the Geographical Information Software tool, ArcGIS and the noise mapping package CadnaA, both of which are able to import and manipulate data in the CDS Data Product supply format of ESRI shapefiles.

3.1 ArcGIS

Specifically, the ArcMap application within ArcGIS was used to perform most of the tasks required. The ArcGIS/ArcMap system was chosen for the following reasons:

- ArcMap is not only compatible with the CDS Data Product supply format of ESRI shapefiles, it also creates and works with these files.
- ArcMap is able to quickly import and store large amounts of data. This data can easily be viewed at any scale to allow visual verification of data. In addition, ArcGIS has numerous powerful tools for further verification or manipulation of the associated tabular data.

3.2 CadnaA

CadnaA noise mapping software was chosen to calculate noise maps for this project. CadnaA is a leading noise-mapping package, which is both technically precise, with the model having been developed by acousticians, in addition to being user-friendly and flexible. CadnaA has a clear modular and integrated software architecture, which means it can be adapted to various modelling scenarios. Large-scale strategic noise mapping projects can be implemented according to EU directive 2002/49/EC, with the user selecting the national calculation method (in this case, the Calculation of Road Traffic Noise, CRTN).

CadnaA was chosen for the following specific reasons:

- CadnaA can quickly import ESRI shapefiles.
- CadnaA can calculate the 6 required noise indicators.
- CadnaA has an in-built Program Controlled Segmented Processing (PCSP) feature that allows the parallel calculation of a project using several computers (in this case 24 computers), thus saving time and reducing error.
- CadnaA can automatically calculate the Area within Noise Level Bands as required by this project.
- CadnA can show 3-D views of the data, with the ability to edit objects. These views can be verified against digital photographs.
- CadnaA has tools to allow manipulation of data, for example to attach roads and other objects to the ground and to modify the ground surface to known ground heights at object locations.

4 Data Import into CadnaA Noise Model

The final modified datasets were imported into the CadnaA Noise Model. Therefore for the CDS Data and for the data prepared by ACCON and its partners, we carried out the following integrity and consistency checks:

- Syntactic checks: check on data domains, search for unexpected values (too high, too low, zero);
- Semantic checks: check on unwanted intersections, invalid heights, invalid attributes of houses, barriers, roads etc.;
- Comparing the aerial photographs and maps with the different GIS data (surface contours, buildings. barriers, etc.). When in doubt, the data was checked by visual inventory, such as with the position and height of noise barriers.

5 Efficiency Techniques

The CadnaA software offers a number of efficiency techniques that had already been tested and validated by ACCON in order to ensure that they were appropriate for the project. They are:

- Data correction and manipulation (building polygons from lines, adaptation of objects to ground);
- Data simplification (to delete unnecessary points from contour lines); and
- Calculation (maximum error, maximum distances source-receiver, reflector-source and reflector-receiver, grid-interpolation).

The efficiency techniques have been utilised to reduce computer run times without any subsequent loss of calculation accuracy. The maximum error capability is a very useful procedure that produces at each grid point before the start of calculation a ranking of all relevant sources. After calculation of each source this ranking is updated using the real contribution of the calculated source. All sources that cannot contribute to a larger total deviation than that defined in the “maximum error” are not included in the calculation. This speeds up the calculation in areas where specific dominating sources exist.

The grid interpolation facility is also an intelligent and dynamic procedure. As a first step the grid points at the outer four edges and one point in the middle of an n x n array of grid points are calculated with full precision. Then the level at the grid point in the middle is interpolated from the outer four grid point values. If the calculated value differs less than 0.1 dB from the interpolated value (and as an additional condition, if the differences between neighbouring grid points are smaller than 10 dB) then the interpolation is accepted and the levels at all other grid points in the n x n array are also interpolated. Otherwise the array of n x n points is replaced by four arrays (n-1)/2 x (n-1)/2 and the process is recursively repeated.

This feature makes calculation of maps very efficient outside of the immediate agglomerations, where very few objects attenuate the propagation of noise. As soon as diffracting objects disturb the propagation, the calculation-squares get smaller and smaller and then each point is calculated with full precision.

The Maximum Error facility enables a pre-sorting of all sources for each receiver, and those sources which cannot contribute, are neglected. During calculation, this selection is updated after each contribution has been summed. The total error is always smaller than that defined here. This setting accelerates the calculation if dominating sources determine the overall result.

The Maximum Search Radius (MSR) is generally set to 1000m. For special cases with a motorway or any other dominating source influencing large areas this value is set to 2000 m.

Grid interpolation allows a quick calculation in areas where the spatial variation of levels is smooth and where no screening objects disturb free propagation.

The CadnaA software provides a number of other efficiency techniques that have been tested on a variety of other noise mapping projects and based on that experience we were confident that they were appropriate for the Noise Mapping England Project without any loss of accuracy.

5.1 Data Reduction

All the data and formats used in the Noise Mapping England (NME) project were imported into CadnaA without any difficulty and this was successfully demonstrated to the Defra Project Team in August 2006. Some modifications were carried out, because the imported objects were unnecessarily detailed.

5.2 Ground Model

The number of points within the contour lines can be reduced with the feature “Simplify geometry”. We deleted the points with displacements smaller than 1 m horizontally and 0.1 m vertically.

5.3 Ground Cover (Ground Absorption)

The polygons to define the ground absorption (ground cover) are extremely detailed, because all buildings are surrounded. We transformed this information into a bitmap; for the further calculation the ground property polygons were not needed. The resolution is 2m x 2m geometrically and 0.01 for ground absorption. The induced deviation is negligible.

5.4 Buildings

When importing the building data set into the CadnaA file the data was verified and changed to take account of abnormal building heights and those specific buildings identified during on site surveying.

For the case where different polygons can be found inside each other e.g. when there is a courtyard inside a big building the problem has been resolved by using the CadnaA option “Process Ring Polygons”. With this feature CadnaA is checking if there is a ring polygon with a certain area (the value of the area can be chosen) inside another one and then cutting out the inner one.

5.5 Roads

The road data set was imported from the shp and dbf files. Roads which intersect at junctions were viewed to ensure that they were being accurately modelled.

5.6 Noise Barrier

The noise barrier data set was imported from the shp file created within the Noise Barrier Datatset Tool. For all noise barriers it was assumed that they are reflective on both sides.

6 Calculation

The calculation using the computer-cluster of ACCON/DataKustik (24 computers) took about 16 hours for both the Bristol and Bournemouth agglomeration areas. The complete area of the agglomeration is automatically covered with tiles at a size of 1km x 1km. Experience from many similar projects, principally carried out in Germany, has shown that the tile size of $1km^2$ is the optimal size to use for the computer cluster utilised on this project. However, it should be noted that the choice of an alternative tile size would hardly affect the delivery time for a project of this size given the relatively large computer cluster available to the project team.

A computer loading all the data related to a tile additionally loads the objects from the 8 surrounding tiles; in order to calculate the grid for one tile all the data from 9 tiles needs to be loaded and processed. All linked computers automatically process the project file tile for tile. The result is a noise map ($L_{10,\,18h}$).

Figure 2 shows the output from the initial mapping run for testing of the dataset and the calculation procedure as carried out by ACCON for the Bristol Agglomeration.

The transformation of different maps for L_d, L_e, L_n, L_{den} and L_{de} are performed for motorways and non-motorways separately using the representative equations. From the two different maps for motorway and non-motorway one map can be derived combining both situations and including all parameters ($L_{10,18h}$, L_d, L_e, L_n, L_{den} and L_{de}).

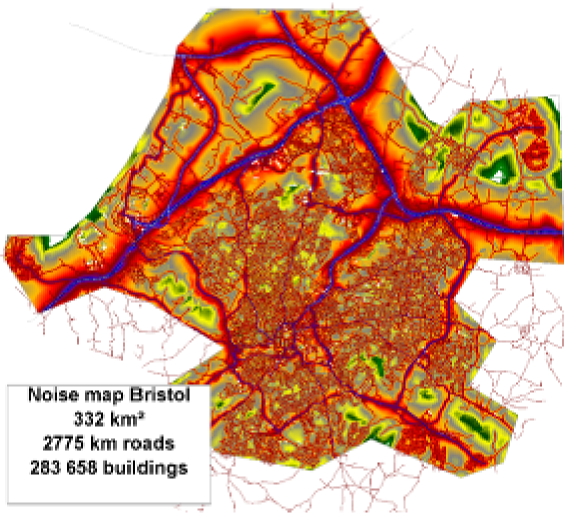

Fig.1 Initial mapping run for the Bristol agglomeration

7 Internal Audit

An internal audit was carried out to check against the documented methodologies the way in which all the different types of data have been processed since receipt, that the values are as expected, and that all associated information is readily available.

The consistency and integrity of the main data for each dataset provided (buildings, ground cover, ground model, road network and noise barrier) were checked in Stage 1. For the Stage 2 audit the main focus was the transfer and import of the different datasets into the noise model CadnaA and the calculation of the noise maps.

A list of the different types of data used in the project were prepared and signed off for each one, to indicate that in general the processing has been checked. Individual components for each type of data were checked for quantity / completeness and discrepancies.

7.1 Data Elements used at Stage 2

The principle data elements used at Stage 2 were:

- Buildings
- Ground Cover
- Ground Model
- Road Network
- Noise Barriers

The details of the auditing procedures are described below:

7.1.1 Buildings

The building datasets were checked for completeness after transferring the building data from ArcView (shp) into CadnaA (cna). This was to ensure that all buildings had been transferred correctly without any loss of data.

As a second step the height of the buildings was checked to ensure that there are no buildings with heights other than those additional heights provided by ACCON and its partners. This means that the lowest and the highest value from the dbf file was compared with the lowest and highest value from the cna file.

7.1.2 Ground Cover

After importing into CadnaA, the noise ground cover dataset was checked for quantity to ensure the complete transport of data.

Apart from the quantity check the dataset was checked for ground absorption to guarantee the correct transfer of ground absorption into the CadnaA file.

In order that CadnaA could utilise the ground cover model in an efficient way, the data was rasterised.

7.1.3 Ground Model

The ground model dataset was checked for completeness after transferring from ArcView (shp) into CadnaA (cna). This was to ensure that all contour lines had been transferred correctly without any loss of data.

The values of the polygon heights were reviewed to ensure that they were within reasonable limits. For example, data was checked for extraordinary low or high values, as this would indicate that the data values were not imported correctly.

7.1.4 Road Network

The road network dataset was checked for completeness after transferring from ArcView (shp) into CadnaA (cna). This was to ensure that all roads have been transferred correctly without any loss of data.

This check was accomplished for motorway and non-motorway separately.

Besides the quantity checking, several components e.g. number of vehicle in 18h, traffic speed, surface type and curb to curb distance have been reviewed to ensure that they were within sensible limits and that they had been transferred correctly into CadnaA.

7.1.5 Noise Barriers

After importing into CadnaA, the noise barrier dataset was checked for quantity to ensure the complete transport of data. In addition the height of all barriers was reviewed to ensure that they were within sensible limits and imported correctly. For example data was checked for negative and for extraordinary high values.

7.1.6 Methods of Checking and Creating Noise Maps

After creating CadnaA files for all different datasets (buildings, ground cover, ground model, road network and noise barrier) all files were put together into one main file named Calculation configuration.

In this file all calculation settings are double checked to ensure a maximum of correctness to the interim results for $L_{10.18hr}$.

7.1.7 The Calculation Method in CadnaA

The correctness of the calculation according to CRTN was tested and confirmed by DataKustik, the developers of the CadnaA program.

After calculating the noise map L_{18h} for motorway and non-motorway all other noise maps like L_d, L_e, L_n, L_{den} and

$L_{Aeq,16hr}$ are calculated using the equations provided in the Detailed Specification (given by Defra).

The outputs of all calculated noise maps, using this method were checked for discrepancies and interruptions in ISO-lines.

By placing noise level boxes (a CadnaA tool which allows identification of noise levels at specific points and receptor locations) into the map the noise level on different positions and for different situations such as $L18_h$ L_d, L_e, L_n, L_{den}, $L_{Aeq,16}$ were checked to ensure that the noise level values for all of the different maps were authentic.

8 Lessons Learnt

A number of important lessons have been learnt during the lifetime of the project although because of the consultant team mix the lessons have been relatively restricted in number and these include:

- Because of the very large number of ground polygons for each agglomeration area it is useful to rasterise ground data.
- Noise barrier data capture and attribute identification is a relatively lengthy process and accordingly the earlier this process is started then the quicker the final mapping can be delivered. This also applies to the identification of buildings where they may form significant noise barriers.
- It is particularly useful to have access to a GIS based tool to examine the detail of specific attributes.
- CadnaA allows rapid identification of anomalous attributes and general inconsistencies.
- CadnaA was an excellent platform for manipulating input data and allowed rapid noise mapping using the sub-consultants dedicated computer network. In particular this allowed the identification of mapped areas and on-going mapping to track the progress of the noise mapping resulting in almost unmatched calculation times for the size of agglomeration areas.
- It is very important to scrutinise in close detail specific elements e.g. bridges and flyovers, large buildings, stadia, round objects such as gas holders in order to ensure that their attributes are properly identified.
- Need to carry out final identification of all mapped areas in order to ensure no missing tiles. This is important on the boundary of the agglomerations where overlapping tiles may only just touch within the area to be mapped and would not appear as a significant item of missing data.

The use of CadnaA allowed the Project Team the opportunity to produce plans and 3-D representations of the model inputs which greatly enhanced confidence in the end product. It has also enabled a number of in-house audit checks to be carried out and was able to provide high quality graphics for presentation to interested parties. Examples of the graphical output capabilities are shown in Figures 3 and 4.

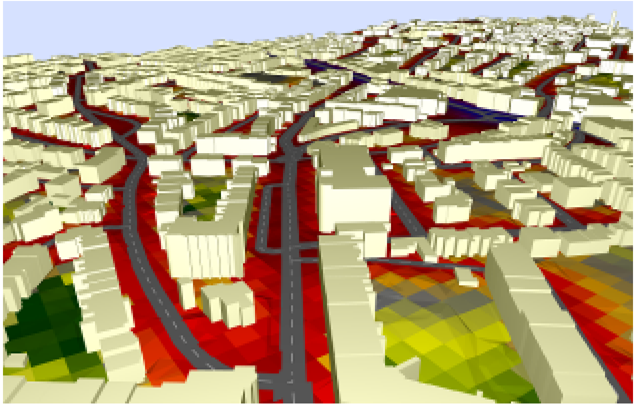

Fig. 3 Three-Dimensional View of the Bristol Noise Map with Noise Contours

Fig. 4 Three-Dimensional View of the Bournemouth Noise Map with Aerial Photography