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# Use of a Decision Support Tool and a Network Noise Model to Gauge Community Noise Impacts

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Abstract:

With increasing emphasis placed on environmental evaluation for new and current infrastructure, many methods have been derived to obtain measures of environmental impact. Despite this, there is a lack of readily available tools which allow the user to quickly assess the environmental consequences of road traffic at a suitable network scale. The authors present a prototype model which can evaluate the effects of noise from a road traffic network. A set of Decision Rules are integrated with a network traffic noise prediction model (NetNoise) and a Geographic Information System (MapInfo) to provide an effective tool for reviewing and rating the environmental impact of traffic noise. The tool is intended for use by engineers and planners in planning new infrastructure and maintaining current infrastructure to environmental criteria.

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## Introduction

The adverse environmental effects of road traffic in urban areas has been well documented (Hothersall and Salter 1977, OECD 1988a and 1988b). Air emissions, noise, vibration, visual intrusion, and severance are responsible for significant reductions in roadside amenity. It is generally acknowledged that road traffic noise poses a major problem in urban areas. The Organisation for Economic Cooperation and Development (OECD) has estimated that in the early 1980s 130 million people in its member countries were exposed to noise levels of 65 dB(A) and above and 300 million lived in *acoustic discomfort* being exposed to levels of 55 to 65 dB(A) (OECD 1986) Recent studies have indicated that noise is still a major environmental issue in the urban environment and only slight improvement has been made over the last 10 to 15 years (OECD 1995). In Australia, Brown (1994) has estimated that 19 percent of the population are exposed to noise levels of 63 dB(A) $L_{10}$ (18 hour) and above. Noise *black spots* near major freeways and arterial roads do pose problems to the exposed population. Noise management in Australia has tended to be reactive rather than pro-active but this trend is slowly changing with noise considerations an integral part of the planning process Timing of the noise assessment is also crucial as noise tended to be considered *after* draft transport plans had been fixed. The ability to use an efficient and comprehensive noise planning tool to support planning decisions is therefore indispensable. However, at present, there are very few tools available to practicing engineers and planners which quantify the effects of noise on a community over an area based coverage. The development and application of an integrated decision support tool, including a road traffic model, network based noise prediction model, decision rules, and a Geographical Information System (GIS) forms the main topic of this paper.

## The NetNoise model

The NetNoise model was developed by the authors to provide an area wide estimation of noise levels from a road traffic network. NetNoise forms a stand alone module in the IMPAECT supermodel as outlined in Taylor *et al* (1995). IMPAECT consists of a suite of traffic, pollution and land use models combined through a common database structure (TNRDB) which allows the user to assess the impacts of transportation systems on the urban environment. IMPAECT will be discussed in greater detail later in the paper.

The basic algorithm in the NetNoise model adheres closely to the Calculation of Road Traffic Noise (CoRTN) procedure developed by the United Kingdom's Department of Environment in 1977 (UK DoE 1977) and consequently revised in 1988 (UK DoE 1988) CoRTN has been adopted as the standard noise prediction procedure by road authorities in Australia. The performance of CoRTN under Australian conditions was investigated by Saunders *et al* (1983) and was found to be suitable for Australian conditions. The procedure was found to have a standard deviation of ±2.5 dB(A) and correction factors of -0.7 dB(A) and -1.7 dB(A) recommended for receivers located in the free field and 1 m in front of a facade respectively. Research into road surfaces prevalent in Australia has also led to another set of corrections (RTA 1992). This data may be used in preference to the CoRTN corrections and incorporates chip seal, densely and open graded asphaltic concrete surfaces (non-rigid pavements) and Portland Cement concrete surfaces (rigid pavements).

Several programs have been developed in Australia using the CoRTN procedure. The most prominent of these include NOISE 3 (Fawcett and Samuels 1985) and Tnoise (RTA 1992). Both of these programs require detailed site and traffic information and are therefore labour intensive (in terms of collating the data) and only intended for site specific investigations.

The NetNoise program was designed with an intuitive and easy to use Graphical User Interface (GUI) and run on a personal computer (PC) in the MS Windows environment. The model is described in detail in Woolley (1994) and Woolley (1997). Figure 1 shows the basic interface for the NetNoise program. Once NetNoise is running the user is provided with guidance for data input and stepped through sequentially to set up a calculation run. The user has been given as much control as possible over the input variables without compromising the integrity of a calculation run. NetNoise allows for several sources of input and output. At present input is in the form of delimited text files or ACCESS database files (in TNRDB format). Output can be made to text files, spreadsheets, ACCESS databases and the MapInfo and ARC/INFO GIS. Both input and output may be viewed in NetNoise and summary information such as corrections applied and contour plots are available.

In modelling at the network scale several assumptions and features are added to the basic CoRTN procedure:

- corrections such as facade effect and ground absorbency are applied globally (ie to all links in the network)
- the study area was assumed to be relatively flat with ideal meteorological conditions
- a road hierarchy and scenario planning feature was included into the program to allow the comparison of *what if* scenarios
- a radius of influence feature allows the user to place a limit on how far noise propagates in the urban environment
- a background noise level applies for areas of the network distant from roads

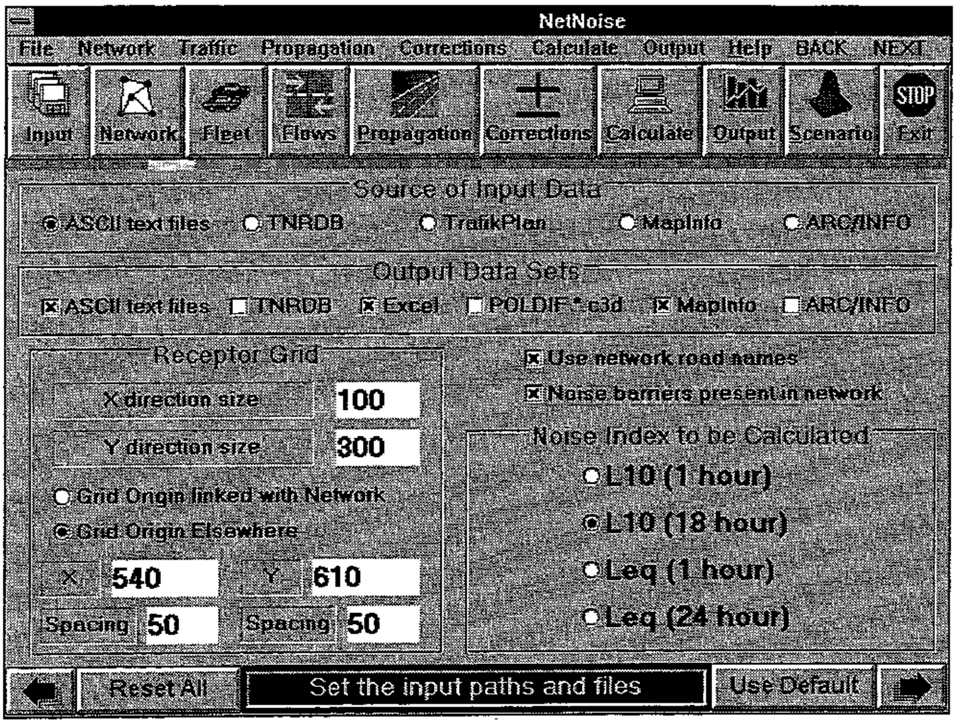


**Figure 1 The NetNoise graphical user interface**

Area wide coverage is achieved by placing a grid of receivers over the study area in question. The user has total control over the coarseness of the grid and its size and location. Traffic volumes can be in any units provided a conversion factor is approved by the user. Vehicle composition on the network roads can be fine tuned according to commercial vehicle counts, AUSTROADS classification data or Australian Bureau of Statistics data. The user has the option of choosing which corrections to apply and information regarding the derivation of the final noise level can be obtained on a link by link basis. Uncomplicated noise barrier configurations can also be incorporated into the network.

The Scenario Manager interface is shown in Figure 2. This allows the user to investigate *what if* scenarios and compare alternative traffic schemes. For example, the scenario manager could be used to determine the effect of banning heavy vehicles on local roads or changing speed limits. Another advantage of the hierarchy system is its ability to incorporate tunnels, elevated roadways and other link based modes of transport (such as trains and trams) into the network. This feature can be used as a powerful tool for urban planners and traffic engineers to compare and investigate the suitability of several proposed traffic noise management schemes.

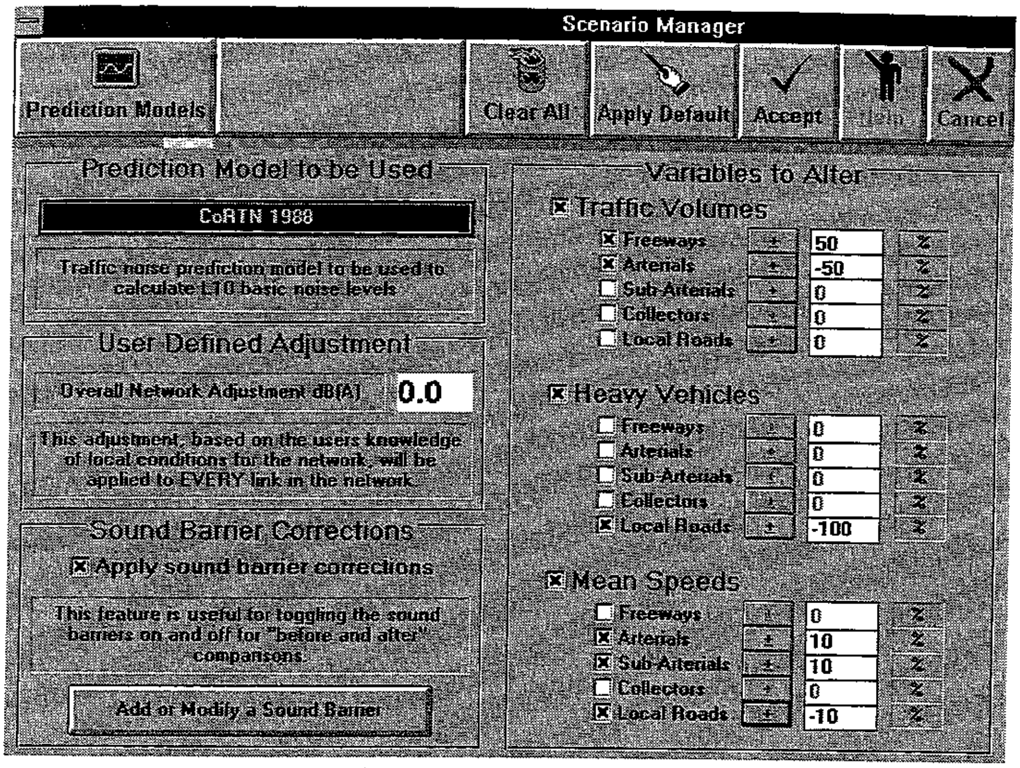


**Figure 2 The NetNoise Scenario Manager interface**

Whilst the NetNoise model can predict noise levels for individual points in the network its use is not intended to provide absolute values of noise Noise can be a very localised phenomena and accurate prediction requires detailed representation of the urban form, which may be viewed as unnecessary for planning purposes and not feasible for use on a PC at the network scale. A further point to note is the source and accuracy of the input variables. Most traffic network coordinates can now be obtained easily from GIS databases and are, generally speaking, more than adequate for noise modelling purposes. Traffic variables such as flows, speeds and composition of heavy vehicles will always have varying degrees of accuracy.

Although CoRTN is the default noise prediction model within NetNoise, a capability has been added in which the user can use a different noise prediction model. This feature is similar to the proposed methodology as outlined by Wigan (1976) and is primarily restricted to regression models of similar form (see figure 3). Unless the customised model has its own attenuation terms the CoRTN attenuation algorithms are applied The feature allows NetNoise to be customised by a user to suit the region in which the model is being used and also enables the assessment of one model over another for a given scenario or set of noise measurements A number of built in models are also included for the convenience of the user This feature will be expanded and refined by including a knowledge-based expert system developed for providing the recommendation and guidance concerning the suitability, limitations, merits and demerits of noise models to be used for different modelling circumstances.

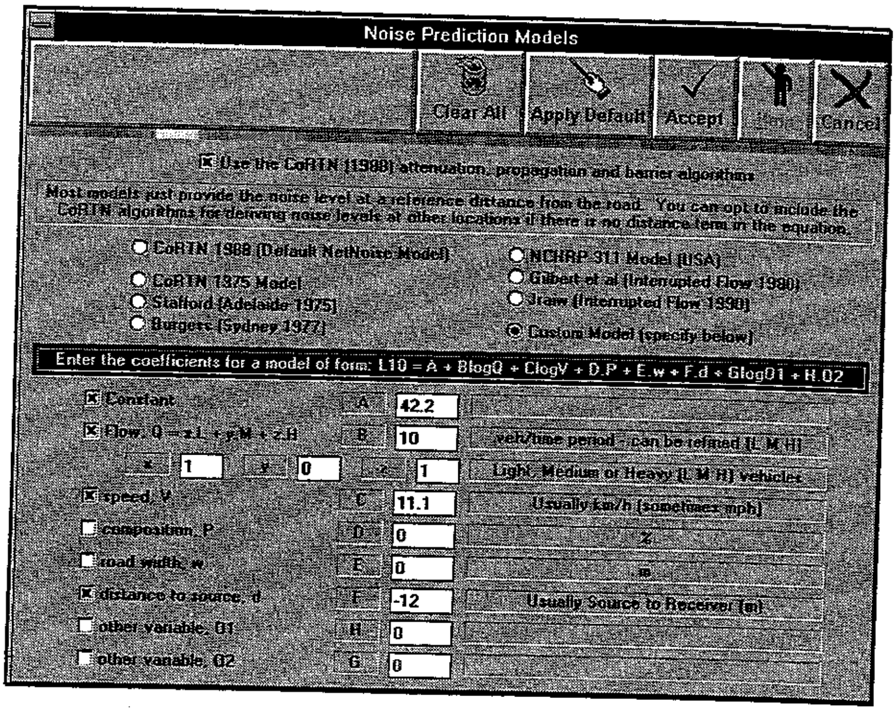


**Figure 3 NetNoise prediction model customisation screen**

The NetNoise model must also be used with caution in environments where traffic flow is heavily congested or where interrupted flow conditions exist. The development of interrupted flow prediction models been slow and only the ITFNS model (Samuels and Shepherd 1991) and shock wave model (Mohammed 1995) exist for simple signalised intersections. It is not considered feasible to implement either model into the PC based network model at this point in time.

## The noise decision rules

The NetNoise model provides the user with the capability to investigate the area wide distribution of noise from a road network. What is also needed is the ability to provide guidance as to where problem areas may exist and what remedial action can be applied. A knowledge-based expert system (KBES) is being developed by the authors to provide such a capability. As similar to the development procedures of a traffic noise screening (TNS) approach introduced by Barboza et al (1995), a modelling approach was adopted to analyse and extract the relevant knowledge at the knowledge acquisition stage. However, while the TNS method is primarily based on the US STAMINA 2.0 model, for traffic noise decision rules, the NetNoise model was used to estimate traffic noise levels for various scenarios These scenarios were set up corresponding to the guidance derived from various research papers and other publications including Brown and Patterson (1990) and the Department of Environment and Planning (1988) The decision rules take into account various important factors such as traffic characteristics (eg traffic volumes, speeds, heavy vehicles etc), road physical and land use characteristics (eg *effective* road width, building setback distances, land use types, etc) and others. The following assumptions were made when estimating traffic noise:

i. Noise levels ($L_{10}$(18 hour)) at different distances perpendicularly from the centre line of a 400 m road length are assumed to be representative of critical noise levels for any road section;
ii. Noise source height is 0.5 m above the road surface and receivers 1.2 m high and 1.0 m in front of a building facade;
iii. Road surface type is a densely graded asphaltic concrete (DGAC);
iv. The effects of road gradient, absorbent ground coverage, presence of screening and the existence of an opposite facade were not taken into account In addition, it is also assumed that all road sections are physically homogeneous along their lengths and symmetrical about their centre line. Traffic was assumed to be free flowing in typical off-peak conditions The corrections for Australian conditions were applied in this study

The decision rules are intended to be used to assess the traffic noise impacts on pedestrians and residents in land uses immediately adjacent to the road in question. As suggested by Brown and Patterson (1990), the main focus of the traffic noise impact is geographically bounded within the areas between the first row of buildings located on both sides of roads in urban road networks It should be noted that the end results derived from the TNS method were sets of graphs which can be used to indicate the numerical noise levels according to the given road physical characteristics and traffic conditions However, the outcomes obtained from the decision rules were traffic noise rating scores in terms of five ranges: very low, low, medium, high, and very high. These ranges are results of studies published by the OECD concerning the general noise effects in several member countries (OECD 1986) The noise impact ratings are shown in Table 1

**Table 1 Noise rating system used for community noise impacts in the present study**

| Rating | Notation | Lower Limit | Upper Limit |
|---|---|---|---|
| | | $L_{10}$ (18 hour) | |
| Very Low | VL | | < 58 dB(A)58 |
| Low | L | 58 dB(A) | 63 dB(A) |
| Medium | M | 63 dB(A) | 68 dB(A) |
| High | H | 68 dB(A) | 73 dB(A) |
| Very High | VH | > 73 dB(A) | |

The ranges have been displaced upwards by 3 dB(A) to convert the noise indices from $L_{eq}$ measures to $L_{10}$ measures (Brown 1989). The scoring system is useful as it can be used to evaluate not only desirable or acceptable noise levels but also annoyance according to Table 2.

**Table 2 Impact of noise based on the noise rating system adopted for the study**

| Rating | Impact |
|---|---|
| VL | Impact of noise is slight. The majority of activities are (including noise sensitive activities) can continue normally and without disruption |
| L | Noise impact remains limited but some disturbance is probably occasioned to the sensitive individual (eg elderly people) |
| M | Behaviour to reduce annoyance is exhibited although this is not too constraining. The effects of noise on sleep and level of annoyance can vary appreciably |
| H and VH | Constrained behaviour patterns arise, symptomatic of serious damage caused by noise |

An example of the resultant rules is given below:

**IF** *Average Daily Traffic is between 12500 and 17500 vehicles per day*
**AND** *Mean Speed is between 55 and 65 kilometres per hour*
**AND** *Heavy Vehicle Composition is between 7.5 and 12.5%*
**AND** *Distance from Centre Line of the Road is between 12 and 28 metres*
**THEN** *Traffic Noise Rating is High (H).*

Decision rules are intended to be used as a simple (but objective) traffic noise impact assessment tool to understand traffic noise impact at the local level, identify potential traffic noise problem locations and suggest the possible contributing factors for those locations. Their accuracy lies between subjective approaches such as the amenity sensitivity (AS) method (Loder and Bayley 1980) and rigorous approaches such as IMPAECT (Woolley *et al* 1996). The Decision Rule approach can take the effects of different land use types into consideration, tackle the misinterpreted meanings of high degree of numerical exactitude of estimated noise levels, and reduce time, effort and resources required in traffic noise estimations. The Decision Rule method is not intended to replace the more comprehensive traffic noise predicting model, such as NetNoise, but used as a screening or preliminary assessment tool for more detailed investigations to take place. Decision rules can be applied to road hierarchy classification and traffic noise management planning.

## An Integrated Approach - IMPAECT

During the mid seventies Wigan (1976) proposed a methodology for environmental impact assessment. It is surprising to find that this seemingly logical methodology has never been fully implemented to date. The Impact Model for the Prediction and Assessment of the Environmental Consequences of Traffic (IMPAECT) consists of a framework in which many models interact towards a common goal as shown in Figure 4 (Taylor *et al* 1995). A traffic network model generates the traffic flow conditions on the road network for various scenarios. Then, noise, air emission and fuel consumption models are used to calculate local intensity levels of pollutant emissions and fuel consumption, given the estimated traffic flow conditions. This information together with appropriate meteorological information allows the appropriate pollution dispersion model to produce spatial pollutant distributions. Finally, the land use impact model geographically overlays the derived pollutant distributions with a given population distribution in the concerned area. This is best achieved by using the comprehensive spatial modelling capabilities that exist in a GIS. The clear patterns of likely environmental problem locations and their severity are therefore highlighted in a manner which is readily intelligible by the user.

In order to allow models to communicate with each other, a Traffic Network Relational Database (TNRDB) (Thompson-Clement et al 1995) is proposed to store many levels of related traffic data and network attributes. Ultimately, it is hoped that IMPAECT will be able to provide network optimisation based on environmental criteria and added functionality can be achieved through the use of KBES technology.

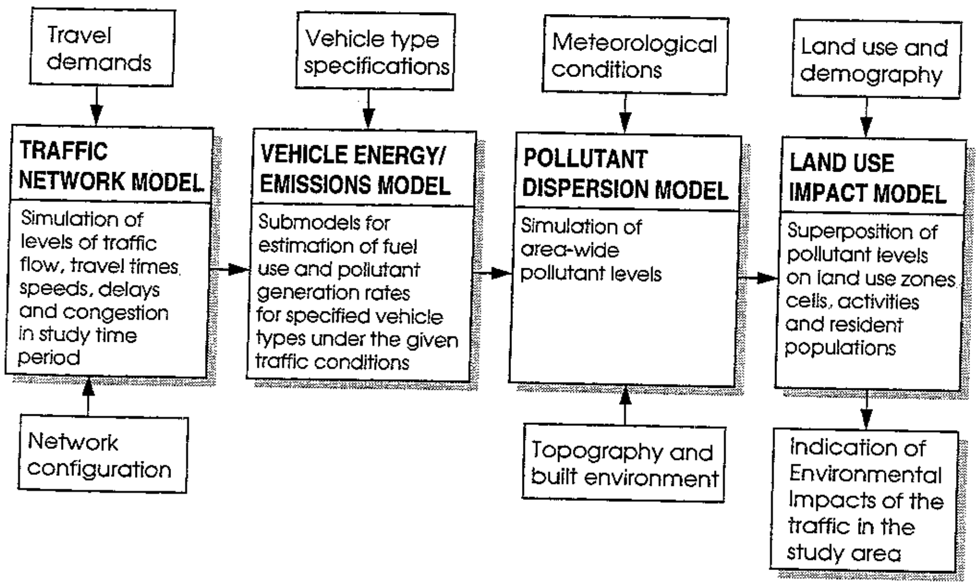


**Figure 4 IMPAECT supermodel framework**

Perhaps the only other alternative noise model oriented towards planning assessment and an integrated approach is SMIRC (Losee and Brown 1996). SMIRC runs entirely within the MapInfo GIS environment and maps the présence of individual houses in an area and as such requires detailed site data. A simplified CoRTN procedure is used for predicting noise at the road link level but data regarding number of houses exposed can be obtained. Losee and Brown put forward a good case for using PC based GIS (namely MapInfo) and highlight the feasibility of the integrated approach given recent advances in PC technology.

**A noise based decision support system (NODSS)**

Investigations are continuing into the integration of NetNoise with a Knowledge Based Expert System (KBES) (Woolley *et al* 1996). Within the context of IMPAECT (as described previously) the KBES can assist in identifying suitable prediction models for various flow conditions, exposing pollution "hot spots", possible contributing factors and suggested remedial action. In addition, this KBES can also provide intelligent guidance in the modelling process such as recommendation of suitable percentage of absorbent ground for different land use types, different acceptable or desirable noise levels for different land use types, the type of noise prediction model to use, and so on. In addition, the focus is also placed upon the integration with GIS technology to store, manipulate, analyse and present both spatially based input and output data. The conceptual framework of this integrated modelling system, called a Noise Based Decision Support System (NODSS) is shown in Figure 5.

The NetNoise shell can be used as the basis for an air emissions program with the same degree of flexibility regarding input and output formats. Ultimately, the environmental impacts of traffic such as air emissions, noise and traffic safety (or risk) can be estimated, assessed and combined by using a systematic framework such as the multi-criteria decision support tool presented in Klungboonkrong and Taylor (1996).

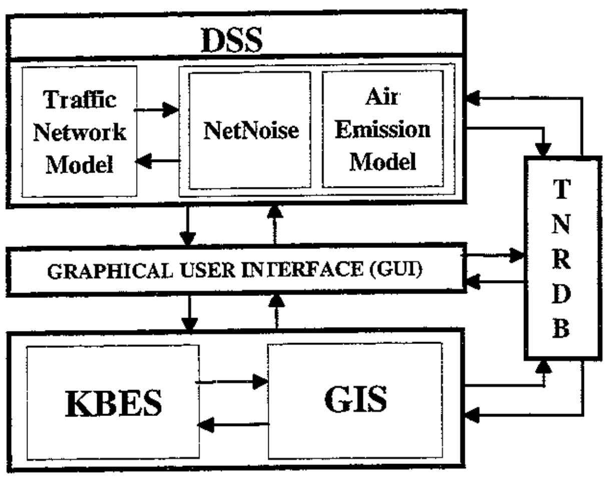


**Figure 5 The Conceptual Framework of NODSS system**

**The case study**

The City of Unley in Adelaide, South Australia is a well established inner suburban area immediately abutting the southern part of the Adelaide Central Business District (CBD). The road network is based on a traditional grid system common in Adelaide. The central part of the Unley area as shown in Figure 6 was used as the case study area due to its relative flatness, mix of land uses and availability of traffic data. The area has formed part of a trial 40 km/h urban speed zone and is surrounded by Greenhill Road (link 11), Unley Road (links 7-10), Cross Road (link 12), Victoria Avenue (link 6) and King William Road (links 1-5). Unley Road and King William Road bear the brunt of traffic travelling to and from the CBD especially during peak periods. Greenhill Road and Cross Road have high volumes of cross-suburban traffic which skirts around the CBD. The main roads in urban areas serving both traffic mobility and frontage related activity functions (access, shopping, etc.) were the primary subject of this study. These roads were divided into twelve homogeneous road sections corresponding to the uniformity of physical conditions, consistency of abutting land uses, configurations of road junctions, and derived road sectional lengths (Singleton and Twiney 1985) as illustrated in Figure 6.

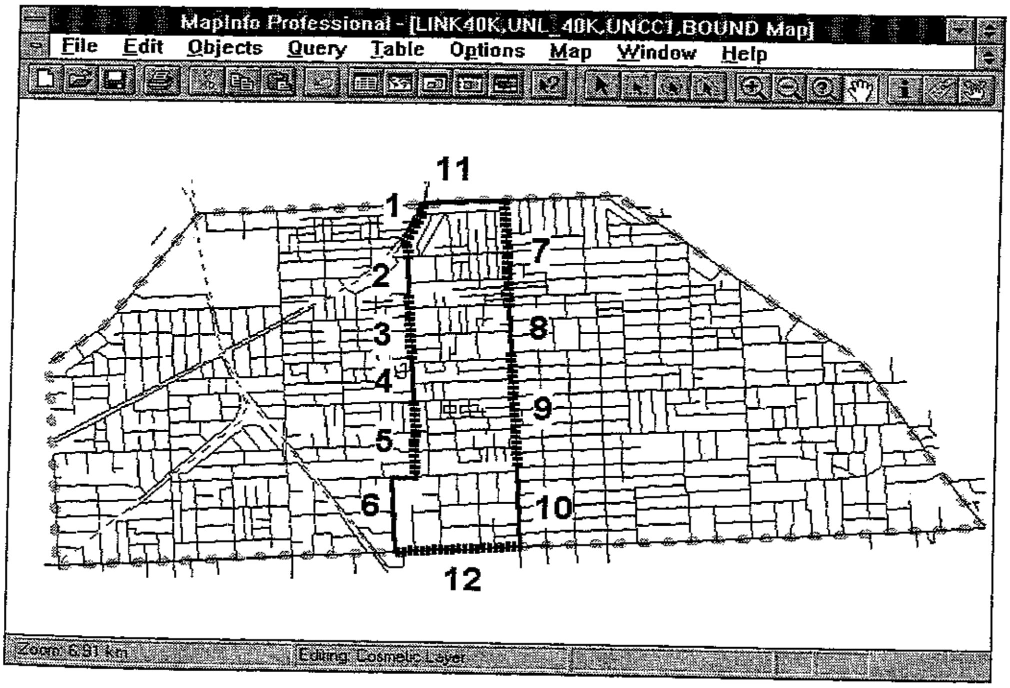


**Figure 6 Breakdown of links in the Unley study area**

A database of the area was built up using available data, manual site surveys and equipment including noise loggers, vehicle classifier/counters, radar guns and Global Positioning Systems. The database consisted of:

i physical road characteristics (eg surface types, width, number of lanes, etc.);
ii. adjacent land use types;
iii. building setbacks;
iv. building facade orientation;
v traffic volumes (daily, annual and peak flows);
vi. composition of heavy vehicles;
vii. instantaneous spot speeds;
viii. measured noise levels;
ix. in-vehicle GPS data.

Data was refined and verified by using on-road video recordings, aerial photographs and other relevant documents. Databases were constructed in the MapInfo and TNRDB environments.

## Assessment of the Case Study Area

Output from the NetNoise model for the study area is shown in the form of a thematic map in Figure 7. Receivers were placed across the network at 5 by 50 metre intervals. The backdrop to this figure is a low resolution aerial photograph which provides a useful indication of ranges of affected areas and land use types. The bands of noise emanating from the traffic network can be used to calculate regions of exposure based on land use. This can lead to estimations of the number of households exposed to certain noise levels when combined with a demographic land use layer. It is interesting to note through casual observation of the predicted noise levels that the commercial land uses (represented by large rooftops immediately adjacent to the road link) seem to occur in the higher noise level bands.

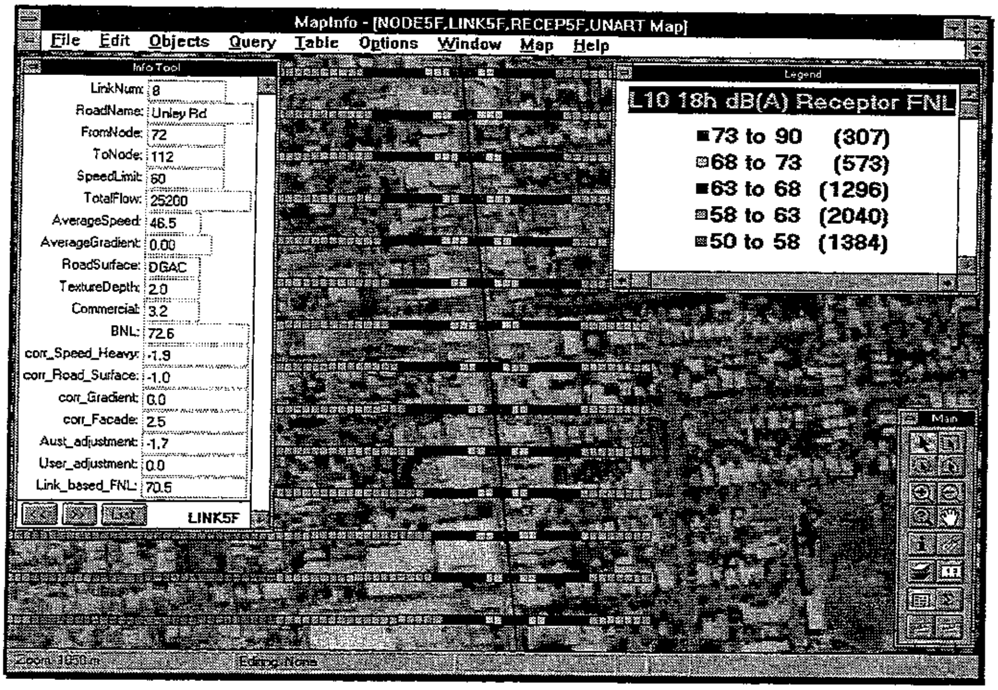


**Figure 7 MapInfo thematic map showing noise bands for Unley Road**

When applying the Decision Rules each link was classified with a noise rating score as shown in Figure 8. This immediately identifies the links which require treatment or special attention. Links 1, 11 and 7 to 9 are rated as *very high* and attention must be paid to the land uses adjacent to these links. In the case of the study area, the high rating is brought about by a combination of high traffic flow and the close proximity of buildings to the roadway. This is of particular importance when graphically presenting traffic environmental impact results to decision makers and effectively communicating with affected residents or public representatives during any public consultation process. The map layer in Figure 8 could be combined with the aerial photograph in Figure 7 to provide a clear notion of impact proximity to the road link.

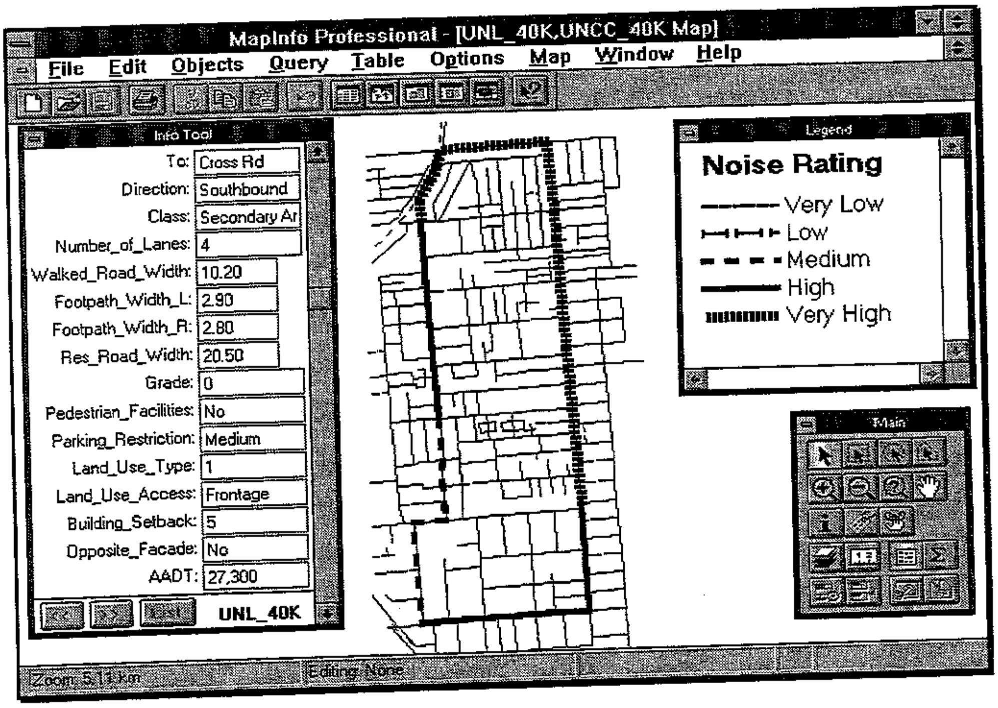


**Figure 8 Link based noise ratings for the Unley study area**

## Conclusion

Noise still forms a major concern in OECD countries and conditions have not improved significantly over the last 10 to 15 years. While there are many noise prediction models in use, these tend to be labour intensive and intended for site specific investigations. The authors have proposed an area based tool using a network noise prediction model (NetNoise) and a set of Decision Rules which, when combined with a GIS, is capable of identifying problem roads and the exposure of land uses to noise levels. The tool is made easy to use through intelligent guidance to the user when setting up calculation scenarios and its graphical user interface. The initial application of the prototype tool to the Unley case study area has already indicated its utility for transport and land use planning.

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