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THE POTENTIALS OF NEW TECHNOLOGIES IN INTEGRATED URBAN NOISE MANAGEMENT SYSTEMS

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ABSTRACT
The tasks involved in managing urban noise are many and varied - for example, solving noise complaints, noise mapping, noise monitoring, noise abatement and zoning. In addition, there is a wide variety of noises from different sources such as industry, road traffic, rail traffic, aircraft and many different recreational activities. An integrated approach to the overall task of urban noise management has the potential to increase efficiency through the sharing and reuse of data, optimization of noise abatement activities and prevention of new problems arising. Modern technology can ease this process. At Internoise in 1999, a paper on "Managing Urban Noise In Cities - an Integrated Approach to Mapping, Monitoring, Evaluation And Improvement" was presented highlighting what advances in technology can be used in new, modular systems based on an integrated approach covering the techniques of noise mapping, monitoring and evaluation. This paper will present an investigation into the implementation of these technologies such as GPS/DGPS to identify measurement date, time and position, mobile phones to allow low-cost remote access to all monitoring units, CIC to ensure data integrity, WAV and MP3 files for later analysis and use in court, GIS for multi-parameter analysis and presentation, ActiveX to link measurement results to case notes, AutoCAD for intelligent interface for optimizing accuracy and calculation time, LAN/WAN for data sharing, security and for faster transfer, and internet for citizen information service and dialogue. The potentials of the various technologies, their status and limitations will be highlighted.

1 - INTRODUCTION
The tasks involved in managing urban noise are many and varied and cover a wide variety of noises from different sources. An integrated approach to the overall task of urban noise management has the potential to increase efficiency through the sharing and reuse of data, optimization of noise abatement activities and prevention of new problems arising. At Internoise in 1999, a new, modular system based on an integrated approach to noise mapping, monitoring and evaluation was presented (see Figure 1) [1].

This paper will present an investigation into the implementation of some of the more useful technologies and will highlight their potentials, status and current limitations.

2 - INTEGRATING IN GEOGRAPHIC INFORMATION SYSTEMS (GIS)
The contents of a noise database created by the above system can be integrated with other data to further increase its potentials and optimize its use. This leads naturally to the use of GIS. A powerful tool, it is widely used in several areas of a national or local authority and enables multi-parameter analysis and presentation.
With a GIS such as Arc View, the user can link alpha-numerical information with graphical information so that it can be shown on a topographical map. For the presentation of environmental impact, like

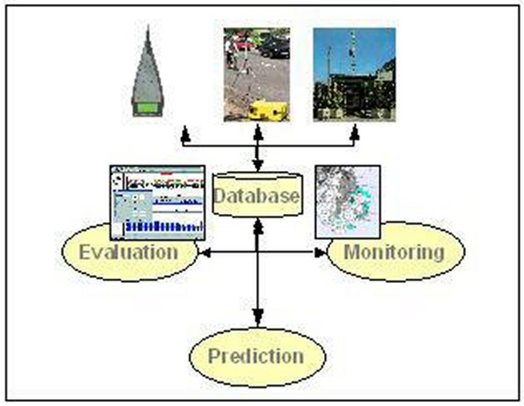

Figure 1: A modular, integrated urban noise management system for gathering noise data.

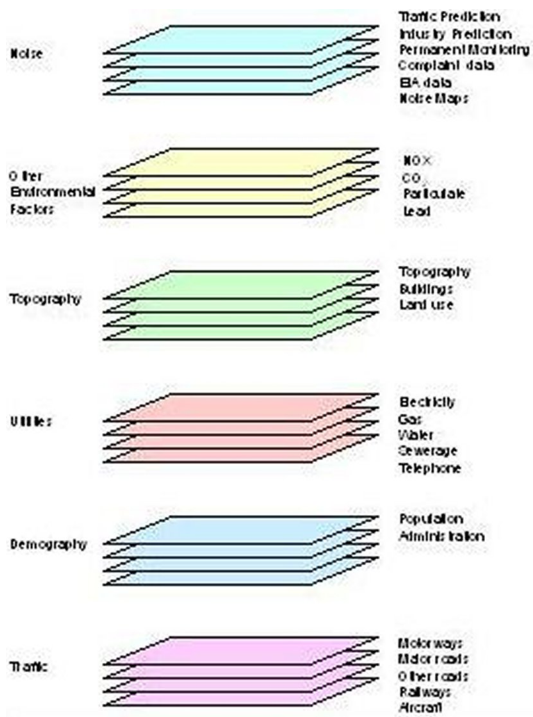

Figure 2: Integrating noise in a GIS system; typical layers are shown and grouped by topic.

air and water pollution, external safety and noise, desk-top GIS is becoming a standard tool for the environmental engineer.

Within local authorities, GIS is mainly in use in the land survey and land registry departments. Other departments usually use different software for their purposes. The traffic department usually has software to monitor and predict the distribution of urban traffic. The environmental department also has its own software to predict noise from different sources. In addition, noise measurement data is also available in some form. With GIS, departments can work together and share data advantageously. For example, to make a noise map for road traffic in a city, the topographical details can be imported from GIS into the noise prediction tool and the traffic flow can be imported from the traffic department's software. After calculation of the noise levels, a noise map can be generated by the noise prediction software. The noise levels can then be exported to GIS and compared to demographic information to determine the number of inhabitants per noise class.

A database of measured and predicted noise data can be used to modify noise maps and aid noise management, and may be imported into GIS in the layers shown in Figure 2:

- Noise Prediction: created in the noise prediction software and representing a particular situation in an area at a set time with a chosen scenario.

- Noise Monitoring: created from a map based on the noise database and representing actual levels over a shorter or longer period of time.
- Noise Complaint Data: imported from case notes and referenced both to the complainant site and at the identified or suspected source(s) of noise causing the complaint.
- Environmental Impact Assessment (EIA) noise data: imported from case notes and used as to compare to or combine with results from current maps.
- Noise Maps: typically a large-scale noise map combined from one or more of the above maps (e.g. the MKM maps in NL [2]) or of building classifications according to noise [3]. It would represent current, future or alternative situations and would form the basis for correlation with other factors such as population, complaint statistics or sir pollution.

ActiveX^{TM} is a technique that enables different objects (files, routines, programs, pictures and text) to be linked together so that they can be activated and accessed from one source. Thus, measurement results in the noise database could be linked with an authority's case notes allowing electronic reporting, archiving and retrieval. A user could then listen to recorded noise, see measurement results, read the report on screen, see the major noise sources in the vicinity, including traffic flow data, check for correlation with air quality indicators, and observe complaints and population density all from his GIS.

3 - DATA TRANSFER & IMPORTING NOISE DATA

Most GIS systems can work with both vector based (DXF) and raster based (BMP) file formats. Raster formats are likely to be superseded by vector-based formats due to the lower size and increased presentation possibilities. The SHP (shape) file format developed by ESRI, the manufacturers of Arcview is gaining widespread use as a standard exchange format for GIS. It is suitable for exchanging data between GIS and the noise database. It may also aid the import of other data such as traffic flow into noise prediction software, replacing a wide range of current formats, often software-specific.

4 - IDENTIFYING MEASUREMENT POSITION

Global Positioning System (GPS) is an all-weather, continuous satellite navigation system developed for the United States Air Force. The fully deployed operational system is intended to provide highly accurate position and velocity information in three dimensions, with precise time and time interval on a global basis, to an unlimited number of users. Although developed primarily for military use, current policy calls for civil availability with degradation in system accuracy, SA (selected availability), in order to protect U.S. national security interests.

Inclusion in GIS of measurement data requires knowing where to put it. Connecting GPS to any transportable measurement unit can automatically identify its position as well as the date and time. This speeds modeling, calculation, reporting and mapping.

GPS itself allows accuracy of around 100 m worst case, mainly due to the SA (selected availability) applied to the system by the US government but also due to temporal shifts due to atmospheric distortion. In addition, line-of sight contact with a satellite is required to receive the signal. Thus, trees and buildings and heavy cloud cover reduce accuracy. However, using a Differential Global Positioning System (DGPS), improves accuracy to a sufficient $2-3$ m at a moderate and falling cost.

Both GPS and DGPS have much lower altitude accuracy of only $30-50$ m in practice but this is normally not a practical problem as height can be accurately measured in other ways and is less critical.

DGPS depends on using a local reference signal either from a FM-radio service or using a mobile phone network. For environmental noise measurements, the mobile phone solution is the most cost-effective. And, mobile phones are now being developed with DGPS built in. Alternatively, acquired GPS data can be post-processed to obtain the accuracy available with DGPS. There is a rapidly expanding number of internet-based services that offer correction of GPS data. Since most noise measurements do not require real-time correction of the GPS positional data, this may be very handy and cheap.

GPS-produced longitude-latitude-altitude positional data needs to be correlated with the XYZ-coordinate systems utilized by software for mapping, drawing, prediction and GIS. This is simple and accurate once the effect of the latitude and longitude on the ratio between degrees and meters is accounted for (a 1° degree change in latitude in Istanbul does not give the same change in Y coordinate as it does in Oslo).

5 - REMOTE COMMUNICATION

The communication media used for transfer of data from the measurement site to the central database has to be carefully selected, as the running cost of an unattended system is heavily influenced by this choice. Firstly, the amount of data needed from the system has to be estimated:

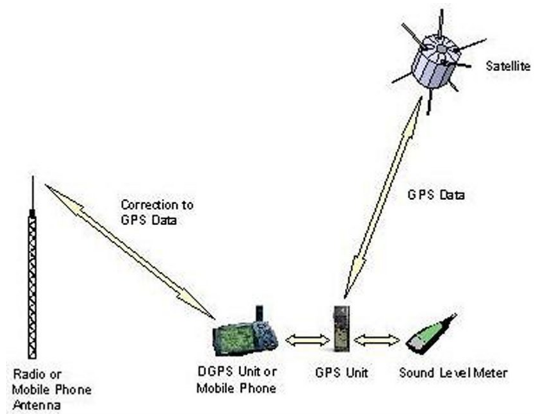

Figure 3: The principle behind DGPS.

- If real-time data is needed, communication is probably by wireless radio modems or wireless Local Area Network. The disadvantages of these techniques are high investment cost and the limited distance between measuring site and central database (a few km). As an alternative, leased telephone lines are very reliable, but the operation cost is high.
- If the need for data is not time critical, daily downloads are probably the most cost-efficient way of communication. This type of communication does not require a 24 hour connection between the measuring site and the central computer.

Therefore, ordinary public switched telephone network (PSTN) or ISDN can be used. However, mobile phone systems, such as the GSM system that is dominant in Europe, enable mobility and low-cost data transfer and allow data to be checked remotely from a remote (central) computer without distance restrictions.

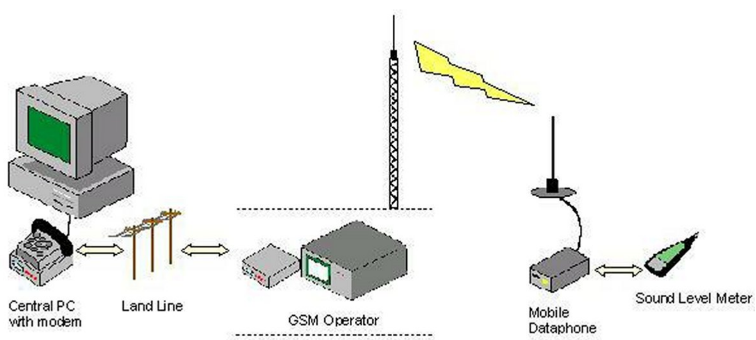

Figure 4: Downloading noise data using mobile phones.

In all cases, a modem is required at the central computer. At the field end we need a device which is a combination of a mobile phone and a modem such as the Siemens M20T, usually with a simple antenna [4].
Currently the maximum data transfer rate of this system is typically 9600 bits/sec (baud), determined by the network operator. This allows 1/3-octave values over the audio range to be sent at 0.5 s intervals for "real-time" (with ~0.25 s delay) remote monitoring, including some headroom for commands and retransmission in the event of bad data. Most data can be compressed by the network, the modems or by software, thus increasing the speed and capability of the transfer. Knowledge of the noise environment and noise monitoring applications enables good data compression without loss of data. Currently, it is also possible to download acoustic data and listen to short samples of the signal at the same time.
In some networks (e.g. in Sweden), data transfer rates can be 14,400 baud and this may soon be implemented elsewhere. However, a new technique known as GPRS (General Packet Radio Service) that enables you to send data packages over several channels thus allowing up to 115,200 baud may gain preference. Many GSM-networks are expected to implement GPRS soon and GPRS-GSM units may be available next year [5]. With this high baud rate, on-line remote audio monitoring of the noise signal in

analysis quality in parallel with data download and remote control will be possible. This will open up for new, smaller and cheaper monitoring terminals as data analysis requirements can be less.
Even though connection is normally stable once contact is established, data security is an absolutely necessity. Thus, local data storage at the measurement site is recommended to ensure data backup and prevent data loss.

6 - SOUND RECORDING (WAV AND MP3 FILES)

Noise events can be recorded on disk by the monitoring station (for example, as WAV files or in MP3 format) for later analysis or source identification, and inclusion in the noise database.
For post-analysis of recorded noise, a WAV file is necessary. However, the file is quite big, meaning long download time.
If noise recording is only for source identification, the new compression technique Mpeg1 Audio layer 3 (MP3), is the most efficient compression technique on the market today.
MP3 compression is based on a complicated psycho-acoustic model based on the fact that the human ear cannot hear all audio frequencies. The MP3 compression scheme tries to eliminate the frequencies that the human ear is unable to hear, thereby reducing the overall size of the file, yet maintaining a very high level of quality.

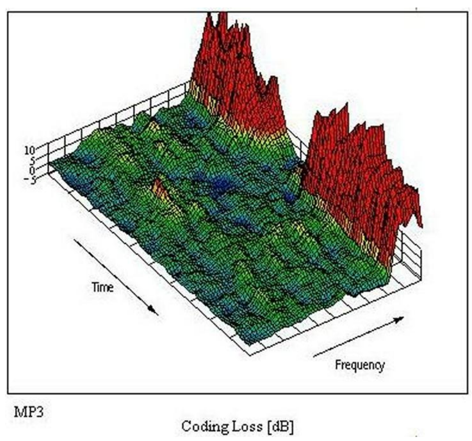

Figure 5: Coding loss of a MP3 file.

Thus, we can now easily transmit a noise event via mobile communication. A compressed 4-minute event is smaller than 4MB (uncompressed it would be over 40MB). It should be noted that MP3 files cannot be further compressed.

7 - OTHER ISSUES

Space prohibits discussion of other useful techniques. These include:

- Charge Injection Calibration [6] to automatically perform acoustical verification.
- Local and Wide Area Networks for controlling noise measurements from a central site, for data sharing and for restricting access to data to authorized personnel.
- Internet is ideal as a citizen information service and dialogue as it can rapidly reach a wide audience. We recommend some internal approval prior to publication on the internet.
- Intelligent interfacing with Computer Aided Design (CAD) through the DXF export format for transferring geophysical data from an entrepreneur's design documentation.

8 - CONCLUSIONS

The ability to reuse and share data across a wide range of professions promises increased efficiency and a greater potential for urban noise management. GIS forms the basis of a data interchange and analysis system into which an integrated urban noise management system should interface. The technology exists today to enable this to be implemented although we are but a few, small steps short of achieving this.

Standard exchange formats are on the market and the problem of identifying the position of measurements is solved by DGPS. Noise recordings can be stored and accessed on the system and data from remote monitoring units downloaded and shown on maps.

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