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MANAGING URBAN NOISE IN CITIES – AN INTEGRATED APPROACH.

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1. INTRODUCTION

The tasks involved in managing urban noise in cities are many and varied – from solving noise complaints to noise mapping, from noise monitoring to noise abatement and zoning. In addition, there are a wide variety of noises from different sources such as industry, road traffic, rail traffic, aircraft and many different forms for recreational activities. Each of these often requires different management, measurement and evaluation approaches due to the differing nature of the sources. However, an integrated approach to the overall problem of urban noise management has the potential to make this task more effective through the sharing and reuse of data, optimisation of noise abatement activities and prevention of new problems arising.

2. CHALLENGES TO BE OVERCOME

The myriad of tasks facing today's urban noise manager, combined with the variety of sources, each requires different management, measurement and evaluation approaches. But what is actually involved? To solve noise complaints involves investigating the situation and finding the cause before solving it and, at a later stage, following up to ensure compliance with agreed solution. In many cases, the parameters to be determined and the limits to which these parameters are to be compared is determined by local legislation. In some cases, this is solved either by using simple sound level meters to measure a simple parameter such as the L_{Aeq} and comparing this to a fixed limit. In other cases, the evaluation requires objective analysis such as a rating level, L_r [1], or even an evaluation on a case-by-case basis with subsequent negotiations between the affected parties. This often involves more complex analysis instrumentation to document the low-frequency penetration of amplified music, to locate the source of irritating tonal components or perhaps to detect the presence of infrasound. The basis in all cases is usually a Type 1 instrument. In addition, post-processing software (such as Brüel & Kjær's Evaluator software) is often required to extract and calculate a required rating level.

For noise mapping, the process is influenced by whether the mapping is part of a greater plan such as that proposed by the European Commission [2]. In any case, some parameter, for example, under long-term average weekday conditions, is collated either from monitoring longer-term levels and plotted onto maps or by predictive means, allowing more detail. Measurement-based maps require an outdoor microphone system, protection and power and some form of data storage for the large amounts of data that such a system produces. The predictive maps are normally based on empirical algorithms that give satisfactory accuracy. They usually require sound power values, traffic data and long-term average noise levels with positional information and average weather data. They provide an acoustic model of the area, preferably calibrated, giving long-term average levels, possibly combined with other demographic data. In both cases, results are presented in maps of various formats or in a database. Having put a lot of effort into producing a map, the optimal situation is to maintain the map, particularly as it is a useful tool for urban noise management enabling focus of resources on noise black spots, public awareness and improved knowledge of dose-response relationships among the authority's noise specialists. To do so requires monitoring of acoustical and non-acoustical (such as traffic flow) parameters and quality data management to ensure retrievability of historical data and prognoses.

For noise monitoring, whether used for updating noise maps or for monitoring noise levels over a period of time such as at construction sites or at stadium concerts, appropriate sites (both temporary and permanent) need to be found, often requiring preliminary surveys. More systematic monitoring, temporary and permanent are then used to locate legislation violations and monitor ambient noise levels for long-term trends. Where problems are identified, action can be taken to resolve them.

Monitoring stations can be permanent installations, fast-wired to a central control centre for viewing and analysis of data from several positions. These stationary, mains-supplied units with robust microphone systems, would have regular download of data, perhaps integrated with other data collection and may provide output of short-term and/or long-term average noise levels to a public display system to create public awareness and positive PR for the authority. Alternatively, they can be permanent mobile units or sound level meters with outdoor microphones placed in vans, buildings or in cases with tripods to place the microphone at a suitable height. These portable, battery-operated and tamper-proof units, possibly with positional identification, often have data transfer facilities via phone lines to a computer. In all cases, Type 1 instrumentation is still central for these data gathering operations.

Being used over longer periods of time, monitoring stations are more susceptible to the effects of humidity, temperature, wind, corrosive atmosphere and animals on the measurements if not taken into account – in particular the microphone as is the most exposed part of the system. Thus, a special weatherproof microphone unit made of corrosive-resistant materials and with built-in protection against humidity should be used. In addition, it is an advantage if the noise monitoring system can automatically perform acoustical verification as well as system checks, such as that achieved using charge injection calibration (CIC), to check that it is working properly. Simpler microphone systems for semi-permanent noise monitoring also need to withstand severe environments for up to several months without inspection or maintenance. Again simple acoustic calibration and automatic systems checks are a benefit.

In connection with planning permissions for new developments, prognoses using the same predictive software as described under noise mapping, often using the same standardised algorithms, determine long-term levels and, in some cases, noise exposure criteria based on the noise levels weighted by population density. These are then compared to limits and to alternative scenario to determine if and how planning permission can be granted.

However, in certain critical situations, more advanced methods such as boundary element modelling or parabolic equations may be useful [8]. These lie outside the scope of this paper. There is currently little or no independent approval of commercial software regarding implementation of a standardised algorithm.

Another noise management tool is the actual noise abatement of noise black spots identified through one of the above activities. Once the source of the problem is identified and located, a solution (technical or administrative) is provided and implemented. This often requires more advanced instrumentation to first locate the cause and then suggest alternative solutions. This may be predictive software or measurement techniques such as narrow-band analysis (real time CPB or FFT) and sound intensity. Often, measurement instrumentation is used in conjunction with post-processing and analysis software; particularly where the required parameters cannot be determined in situ. Again, in many cases, Type 1 instrumentation is still desirable to ensure the quality of the input data.

After implementation, an evaluation of the efficiency of the solution is required both immediately and after a period of operation to determine any possible deterioration of the chosen solution with use. All of the above normally require the authority to approach each problem differently and usually with different instrumentation due the variety of legislation and parameters required by the variety of applications.

Examples, in the UK, include evaluation of industrial noise by a rating level, Lr [3] for planning permission, noise insulation claims for noise from new roads by a calculated daytime L_{A10} [4] or complaints about music noise at night measured by a 5-minute L_{Aeq}, compared to the $L_{99.8}$ [5]. In some cases, the local authority does not have the resources (manpower, equipment and instrumentation) or the prior level of experience to be able to implement this wide variety of legislation and standardisation. And, in combination, the challenge of urban noise management can appear insurmountable. So what can we do?

3. POSSIBLE SOLUTIONS

The approach taken to solve the myriad of individual solutions can be grouped as follows into:

- Fragmented urban noise management: the traditional approach whereby each application has its own solution. This situation is the typical approach used today and is described above.
- Communicative urban noise management: a more advanced approach where each application has its own solution and data, where relevant, can be exchanged between one solution and another to enable reuse. For example, average levels from long-term monitoring can be directly imported into predictive software to enable the updating of noise maps.

This is, in practice, the currently achievable top-of-the range system, although not a total solution. The additional lack of an industry-standard data format (due to the plethora of solutions, both commercial and homegrown), today, makes exchanging data from one application produced by instrumentation from one manufacturer to that of another extremely limited.

- Integrated urban noise management; a better alternative is an integrated urban noise management system where raw data is collected and can be used for a wide variety of purposes. This integrated management approach promises higher efficiency through the sharing and reuse of data so that complaints, mapping, monitoring, calculations and abatement are, where possible, based on the same raw data. A conceptual integrated urban noise management system is described below.

4. SYSTEM CONCEPT

A new, modular system (see Figure), comprising the latest technology is described here. It is an integrated approach covering complaints, mapping, monitoring, calculations and abatement, and is based on raw 1/3-octave logged data containing a range of parameters such as LAeq, LMax, LMin, LPeak and LN values as the basic building block. This data is measured at permanent and temporary measurement positions using sound level meters and monitoring stations and made available to the individual components (applications) in a central database.

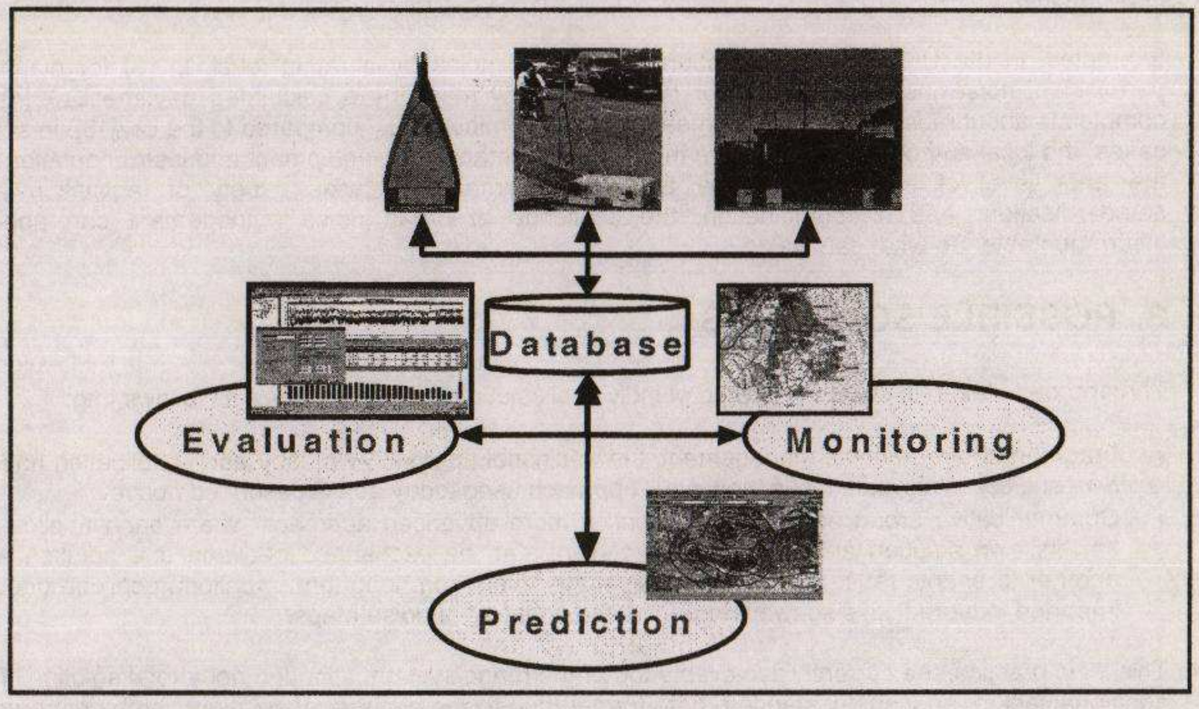

Figure 1. Components of an integrated urban noise management system.

Data are collected whenever required (for example, when investigating a complaint) and stored in the database with other pertinent data such as date and time, position, weather conditions, etc. much as is done for a measurement report.

The 1/3-octave data can include or be combined into overall A- weighted levels and, with the help of electronic annotation, be identified, for example, as noise from specific sources or overall ambient levels. This, together with an objective evaluation of tonal & impulsive penalties from the raw data (for example, by detecting tones from the comparison of levels in neighbouring 1/3-octave bands over a specific period, or impulses from the difference between LAIm and L_{Aeq} [6]), enables a variety of evaluations covering a range of applications, current standards and legislation.

This data can be used to make maps based on measured data or to validate and update calculated maps. With the addition to the database of sound power measurements of tools and machines around an industrial site, noise maps and planning permission of similar sites can more readily and easily be completed, and noise abatement made more quickly and cheaply. The connection to the measurement unit of a GPS or, preferably, DGPS unit to identify the date, time and position of measurement results can speed up reporting and mapping through automatic positioning of measurement data. Although at an early stage, this technique is becoming more accurate and cheaper as its becomes more widespread. The use of mobile phone systems such as GSM enable low-cost data transfer from temporary sites allowing intermediate data checks from the comfort of your office. System integrity techniques such as CIC ensure data integrity. Noise events can be recorded on disk by the monitoring station (for example, as WAV files or in MP3 format) for later analysis and use in court. And, Local and Wide Area Networks allow data sharing, faster transfer and data security through regular system backups. In addition, the internet can be exploited to provide an information service for citizens, updated at regular intervals with the latest data.

Noise data gathering units would all using the same data structure. They could be ordinary sound level meters used in daily survey and analysis work, temporary monitoring units for short-term monitoring or long-term monitoring stations.

The database can thus be used to maintain and update noise maps, to police noise legislation at noise-sensitive and noise-polluting locations and to evaluate complaints. The data can also be used for longer-term strategic planning as the background to planning permission applications. The database can be expanded to include, or linked to cover, other indicators such as traffic flow or air quality recorded from general environmental monitoring stations. Using ActiveX TM components, measurement results obtained via the noise database could even link up with an authority's case notes in the relevant database allowing electronic reporting, archiving and retrieval. GIS (such as Arc View) now offers the ability to combine noise data (calculated or measured) with other factors such as air pollution, population density or property prices and present them professionally in a variety of formats.

Intelligent interfacing with AutoCAD can help create realistic acoustic models of a local area's geography from an entrepreneur's design documentation without increasing calculation time through over-complexity.

An important consideration to take into account is the accuracy required. For calculated noise maps, the objective is strategic and the levels chosen often long-term. The accuracy and scale of such a map lends itself to empirical models. However, care must be taken to balance the resolution of the map (spatial and parametrical) with the modelling effort and cost, the temporal variance and the public response. To appease this, perhaps a graduated map of noise levels rather than a contour map of noise levels or expected annoyance % is preferable. In situations where comparisons with limits are made, the accuracy of data may have to be better, although factors such as errors due to the technique used and temporal variance must be taken into account.

In addition, the noise mapping software should comply with a recognised calculation method which you can adapt (that is, calibrate) to your local conditions and to up-to-date data collated by measurement. It can be hoped that future developments in calculation algorithms and assessment standards such as ISO 1996 [1] will enable direct comparison of calculations with measurements according to local complaint standards (rating levels, Lr).

Thus, it is important that the choice of instrumentation is correct. Not only regarding accuracy but also in regard to ensuring that data collected is of such a documented quality and relevance for use in the future in the event of new parameters being used as the result of research into dose-response relationships.

A fully functioning system for a major conurbation of over 1 million inhabitants would, perhaps cover a dozen or more permanent monitoring stations supplemented by a few mobile units and some temporary units, each containing a removable sound level meter that can be used independently. Add to this the database management software, and networked evaluation and predictive software.

But what is the price of such a system? Although seemingly daunting at first glance, the cost of such a reasonably full-blown system for would be less than 1 USD per capita, equivalent to the cost of mapping [7], an activity that all major urban areas in Europe are expected to perform [2]. As it is modular, the investment can be spread out over several financial years. Thus, an authority, with a small suite of sound level meters and perhaps one or two monitoring units can use these to make the core of a database and a first-shot noise map. This can be updated using predictive methods and maintained through the use of these units and more monitoring stations, mobile as well as permanent. With relatively limited means evaluation software can be added to the system as and when suitable. The price will further be offset through the ability of the system to optimise manpower requirements through reuse and exchange of data from measurements, evaluations and predictions. And the system must be flexible with temporary, mobile and permanent noise monitoring stations each containing a removable sound level meter that can be used independently, thus saving costs. The use of mobile monitoring stations to supplement more permanent units with additional long-term data will further optimise resources. A spin off of the system is the similar data structure and user interface that will facilitate ease of use. And the fact that it is widespread throughout an authority and its partners ensures a large base of experience with the system, reducing operation costs and the risks involved in small-scale operations where the loss of a single person necessitates another person learning the system from scratch.

5. CONCLUSIONS

An integrated approach to urban noise management covering the techniques of noise mapping, monitoring and evaluation, and incorporating the latest advances in technology promises improvements for the benefit not only of the authority but also of industry, infrastructure, tax-paying citizens, and visitors, be they tourists or on business.

1/3-octave logged data containing a range of parameters is the core of a noise database that can be integrated with other databases inside and outside the governing authority. The choice of instrumentation and technique may vary from one urban area to another but common selection criteria can be presented. The cost of a fully functioning system for a major conurbation of over 1 million inhabitants would be less than 1 USD per capita and the cost saving benefits of such a system – that of modularity, manpower optimisation, flexibility and widespread use – further reduce this.

6. ACKNOWLEDGEMENTS

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