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VOICE ALARM and EVACUATION SYSTEMS ON LARGE SITES

Sam Wise (1), A K Barns (2)

(1) Sam Wise Associates, 14 Birmingham Rd., Cowes, Isle of Wight, UK, PO31 7BH
(2) A. K. Barns Ltd., 8 The Barns, Stretham Road, Wilburton, Cambridgeshire, CB6 3SQ

1. INTRODUCTION

This paper was stimulated by past work on diverse large site projects carried out by one or both of us, and a current joint project which dwarfs them all - a site which is 1.6 km by 1.3 km having upwards of 340 buildings, plus numerous docks and drydocks and streets, virtually all requiring coverage for emergency announcements. In addition, some of the site is an Heritage Area and Visitor Attraction requiring special attention, and many of the building are listed On this site the voice alarm system begins to resemble one of the utilities (Gas, Electricity, Telephones) with all the associated installation and distribution problems.

[Figure 1] - Site plan - note permitted to publish - see slide at conference

Planning a system and estimating the costs for such a project is an enormous job which, without careful structuring, can run away with man-hours. Our brief is to study and confirm user requirements, produce costed proposals of various solutions along with their benefits and shortcomings, and to estimate the installed cost of all required loudspeakers and amplifiers. In addition, proposals on phased installation are required.

While the design study was just beginning at the time this paper was submitted - much has already been learned which is of value for use on other large site projects. Essentially the project breaks down into several parallel activities:-

- Site survey and data collection
- Interviews with users regarding operational requirements
- Meeting with "owners and operators" of potential transmission links
- Gathering of current data from potential equipment suppliers
- Creating an overview scenario with which to interpret the above information and create proposed solutions.

Tony Barns, being an expert in embedded control systems and having design the control and signal distribution systems for various manufacturers on various projects will first cover control system and central signal distribution issues - giving us the overview which will help to guide and interpret site survey data.

2.TECHNICAL DESIGN CONSIDERATIONS FOR THE CONTROL OF LARGE PUBLIC ADDRESS SYSTEMS

Public Address and Voice Alarm systems at Airports, Industrial sites and Public amenities are often spread over large areas. The technical aspects of these are especially interesting; early analysis and consequent decisions made during the design phase can provide enormous savings at the implementation phase.

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We identify four subjects for consideration here -
Gauging whether a site may be split into smaller sub-systems
Choosing an appropriate topology for transmission of voice and data
Investigating existing or new media for transmission
Procuring a Control System to fit operational requirements

2.1 Would the Site be best split into sub-systems?

Operational requirements will dominate this question. Let's look at some examples -

a) **An Airport Terminal.** Whether or not the Terminal is housed in one building or several, Airport Terminals are usually large enough to present problems of scale. They may have a great many zones, or separately addressed public areas, each requiring amplification and control equipment. Operationally, however, they can be seen in a hierarchy:

- Whole Terminal
  - Landside
    - Shopping Malls
    - Restaurants
  - Airside
    - Departure Lounge(s)
    - Boarding Gates

This rather gross simplification is adequate to illustrate the idea. For the staff helping passengers to board their aircraft, for instance, their main concern is to address people in the immediate vicinity of the Boarding Gate. They may also need to call for lost passengers over a wider area located around the Gate, but they will never call anywhere on the Land-side of the Terminal. Announcements will, however, be received at the Boarding Gate from elsewhere, such as Security and Alarm Announcements from a central location. So the Boarding Gates can be seen as sub-systems which operate at a local level, but have input from other areas.

b) **A Convention Centre.** Merely studying the Booking Office procedures for a large conference or convention centre with multiple meeting spaces will show how it is split up conceptually. There will be public events in different areas of the building - a conference in one area, a drama production in another, a cinema presentation in a third, etc, each individually organised. Each of these events are separate from one another and have some of their own facilities

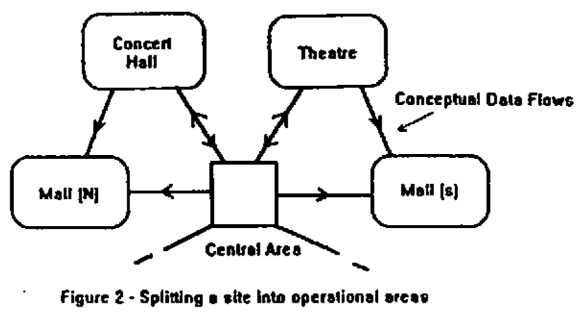

Figure 2 - Splitting a site into operational areas

permanently assigned, others shared. The Auditorium is permanently associated with its Stage, for instance, but shares its Restaurants with other events. When designing the Public Address system for the International Convention Centre in Birmingham (England), for instance, we split the site into eleven areas, each having its own Amplification and Control system, supervised from a central location. In the Symphony Hall there is a large system in its own right, but integrated into the whole for the purposes of sharing Voice Alarm announcements and for calling dressing rooms etc. that are occasionally used for other events.

c) **A Government Department.** Unlike the previous examples, we have found it difficult to split large corporate sites on the basis of operational requirement. This comes about because of the habit of moving departments from one building to another. Their operating procedures move with them. Whereas one might like to constrain which buildings can be called from which others, to simplify technical needs, these sites often demand a very flexible, 'vanilla-flavoured' Voice Alarm System. Even the operational centre is likely to move from building to building.

When a system can be split into smaller sub-systems, often a dramatic reduction in cost can be achieved. Seen in terms of a crosspoint matrix, for example, a number of small control and switching systems with small matrices are preferable to one large system with a massive matrix where a significant proportion of the crosspoints would never be used. Reliability of service is improved, since failure of one autonomous system will only disrupt operations in the area it serves, rather than the whole site. Furthermore, smaller systems are far easier to design so that they are inherently reliable, and can take high-priority announcements from external sources even during failure modes. A large site's Voice Alarm System will decline gracefully during fire or explosion if it is made up of small sub-systems.

2.2 Which transmission topology is best?

Fashion dictates a ring topology at present, but is this always the best method of transmitting voice and data over a large site? First consider the three classes illustrated below.

a) Ring.
Each node in the ring has incoming data and outgoing data. Data, whether voice or control, leaves its source node and is passed from node to node through some uni-directional medium

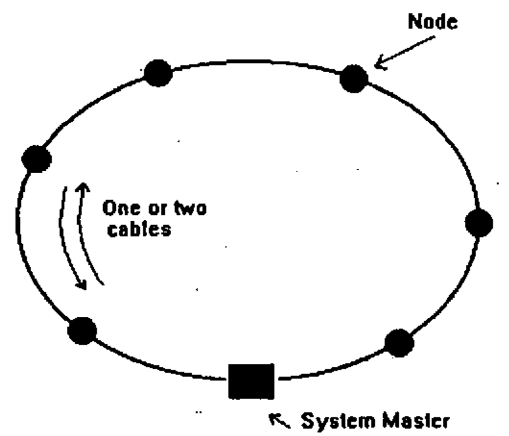

Figure 3 - Ring Data and Voice Transmission System

around the ring until it reaches its destination. On a large site it is usual for data to be actively regenerated at each node and given sufficient power to reach at least the next node. So every node has the opportunity to cause catastrophic failure, should it cease to regenerate or, failing that, pass on data uncorrupted. For this reason Ring systems are built with spare capacity of some kind. An example showing one kind of protection from node failure is the North Terminal at Gatwick Airport. This was designed with a cabled ring topology, but with extra cables that bring the ring back to a central location from several points. It is built as if it had petals. Loss of service due to a catastrophic failure of a node is limited to a small area by automatic re-routing of signals to avoid the failed node. Two, interleaved, rings were installed to further protect from loss of service. The cost of providing these extra cables was not trivial, especially since these coaxial cables carry data at 30.72 Megabits/second.

Often two contra-rotating rings are installed, since this gives data the possibility of being routed back along the incoming cable route, away from the damaged area. On a large military site recently equipped with 120 nodes over 13 miles of cable, both cable rings are constantly monitored for integrity, with the system master advising each node which ring it should use for primary data transfers. This allows fault reporting to show potential failures before any loss of service is experienced. The provision for simultaneous announcements is restricted to the number of audio channels around the ring.

Given that a Ring topology, in reality, needs extra cables to fulfil reliability constraints, how does it compare with a Star topology? With this arrangement, every node is connected by some bi-directional medium to a central location. The central location may transmit to any or all other nodes using these media, and any outlying node can communicate with the central location. An outlying node may communicate to another outlying node through, and with the co-operation of, the central location. This implies some sort of matrix, whether in hardware or software, at the central location which can support as many simultaneous node-to-node transactions as the system requires.

To achieve reliability during fault conditions, however, extra media capacity is required either between the centre of the star and outlying nodes or between nodes.

Provision for simultaneous announcements is a natural attribute of a star system. Theoretically there are as many audio channels as there are points on the star, provided that the control system can administer them all separately.

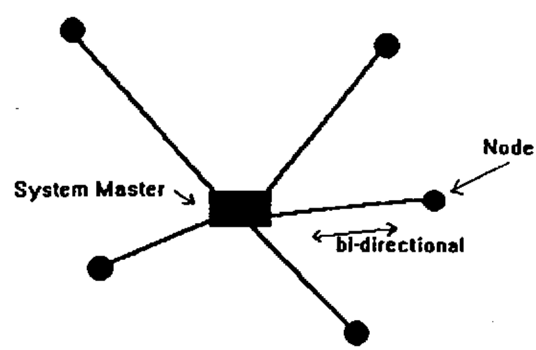

Figure 4 - Star Data and Voice Transmission System

c) Hybrids.
Where operational requirements load parts of the system heavily, and interconnection between such parts is not overly demanding, a combination of ring and star may be best. A ring that has nodes which act as star centres is the corollary of a star system interconnecting ringed sub-systems.

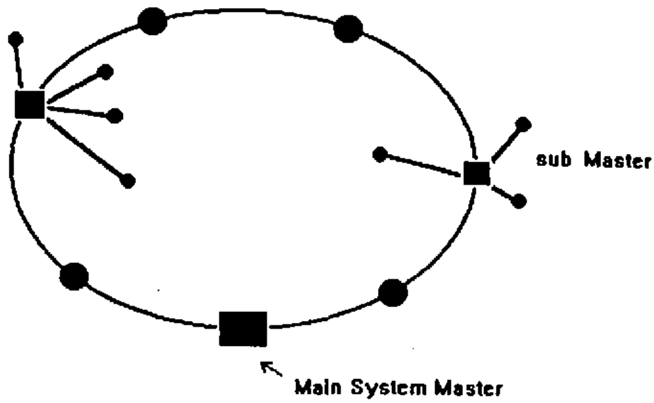

Figure 5 - Hybrid Ring and Star Data and Voice Transmission System

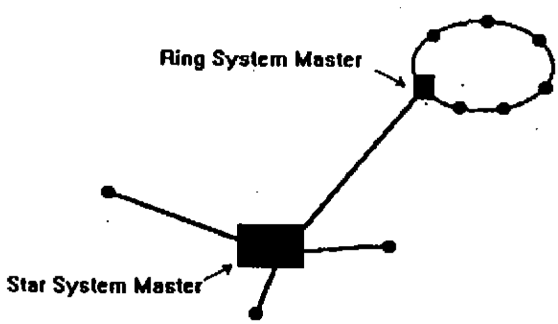

Figure 6 - Hybrid Star and Ring Data and Voice Transmission System

2.3 Choosing a medium for transmission.

Any system designed to provide service during fire or terrorist attack must be fault tolerant. Wherever possible, local generation of pre-recorded warning tones and messages should be provided in preference to distributed audio signals. Audio routing is vital, however, for live announcements. So the system to be provided must provide audio routing which is as reliable as possible given economic constraints.

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Whilst the vast majority of Public Address and Voice Alarm systems use copper cabling for transmission of audio and control data, it may be helpful to highlight some of the issues and to compare with some other media.

2.3.1 Copper - overview

Baseband audio and Modulated audio impose quite different requirements on copper cabling. Audio signals may be transmitted within their natural spectrum through media having, say, 30 Hz to 20 kHz bandwidth. If the medium for a Ring system is made up of a great many components, however, the error budget for each component becomes proportionately tighter. This means that an installation with over 100 repeaters must be very closely controlled. Each cable+repeater combination must be capable of processing signals with amplitude and phase characteristics measured in hundredths of a decibel. Such repeaters are very expensive to manufacture and adjust. Such a system would be used where it was imperative to use existing audio-frequency cables.

By placing the baseband audio signals onto a carrier of some kind, the error budget can be weighted to fall on sub-systems which are error-tolerant or capable of error correction. Most systems of this type use binary coding of the audio signal to allow error correction to be done in the digital domain, where is it more economically viable. Such coding does, however, require a medium with a bandwidth of, say, 300 Hz to 1 MHz. Copper cables to pass this spectrum are readily available but older, existing cabling installations are most unlikely to meet this requirement.

2.3.2 Copper - new installation

2.3.2.1 Baseband audio, separate data
As discussed above, an installation requiring upwards of 100 repeaters is expensive to implement if the audio signals are kept at base band. If the opportunity exists to pull in new cables, it may be better to use modulated audio transmission.

2.3.2.2 Modulated audio, separate data
An argument exists which favours segregation of audio data and control data for reliability reasons. Digital audio has a massive need for data bandwidth compared with that required for administration and control. A 2 MHz link will be fully occupied with two simultaneous audio announcements whilst a 10 kHz (9600 baud) link will be slack even whilst controlling them. Since it is possible to trigger a locally-generated audio alarm using the minimum of control data, a secure and rigid control system backbone can serve even the most hazardous site. Live audio announcements may be slightly less reliable when the system is under stress because of their higher bandwidth demand. So some systems deliberately keep audio and data apart. The equipment for a 23-building installation we designed for Glaxo Pharmaceuticals at Stevenage, for instance, takes this approach.

2.3.2.3 Combined modulated audio and data
Systems which capitalise on the lower bandwidth demands of control data compared with audio data do so by integrating control and audio signals. This reduces the cost of cabling and terminal equipment.

2.3.2.4 Copper, existing cabling
If cables exist on the site, their use can drastically reduce installation costs. It is imperative, however, to have authoritative characteristics of any such cable guaranteed. If more than one cable type is present, each of these must be separately characterised then analyzed in conjunction with the others before a decision can be reached as to their suitability. If the cables are also to be used by other systems, it is important that this be declared and liability for interference must be agreed with all concerned. The maintenance of shared cabling is an issue which must be clearly addressed. Further, if such cables are terminated within other systems such that the availability of routes is volatile, then very close attention needs to be given to whether such an arrangement is suitable for a life-safety system at all.

2.3.2.5 Telephone circuits
These are characterised by having fewer routes than subscribers. This means that a route cannot be guaranteed without possible contention with other users. A telephone system generally has an exchange which is not conscious of priority - it works on a first-come, first-served basis. During periods of emergency, telephone systems can become overloaded as system resources are in high demand. If a telephone system were used as part of a life safety system, allowance would have to be made to guarantee access to routes where emergency announcements were required. Dedicated telephone cables, independent of the telephone switching system may, however, be very well suited to a Public Address and Voice Alarm system.

2.3.2.6 Building Management cables
Some sites have a backbone of multi-pair cabling used for various services. The restrictions for shared, existing cables outlined above apply here.

2.3.2.7 Power Distribution cables
The concept of using power distribution cables for a life safety system embraces all of the restrictions outlined so far:- bandwidth, interference, reliability of routes during emergency, shared responsibility. Added to this is the likelihood of a power-distribution route being deliberately disconnected by those in authority on the site, or by the fire brigade, when fighting an emergency situation. It is, nevertheless, possible to transmit audio and data over power cabling and the author has implemented such a system in a small industrial building.

2.3.2.8 Optical Fibre
With the advantage of wide bandwidth and immunity to electrical interference, fibre-optic systems have advantage especially in harsh electrical environments, such as those with heavy electrical machinery and electro-magnetic radiation (including radar). Cable installation costs may, however, be higher than for copper.

2.3.2.9 Radio
Provided that the audio and control paths carried by radio carrier can be fully monitored for integrity, the broadcast nature of radio systems can be put to good use in systems with a star topology. The cost of implementing point-to-point radio systems may be prohibitive.

2.3.2.10 Laser beam

Where cable access is very difficult, it may be worth considering an optical link. These links are relatively immune to electromagnetic radiation but susceptible to obstruction to their line of sight from smoke, fog and moving objects such as trees and road traffic.

2.4 Deciding on the best Control System Approach

A Control System has to decide which audio routes to make after receiving requests from its users. It is very important here to dissect the three dimensions of that last sentence. A route starts with a source, ends with a destination and is set up by a third party. So there are these three dimensions:-

1. The audio source which is to be heard
2. One or more destinations that this source should reach
3. The user who requested that the route be made

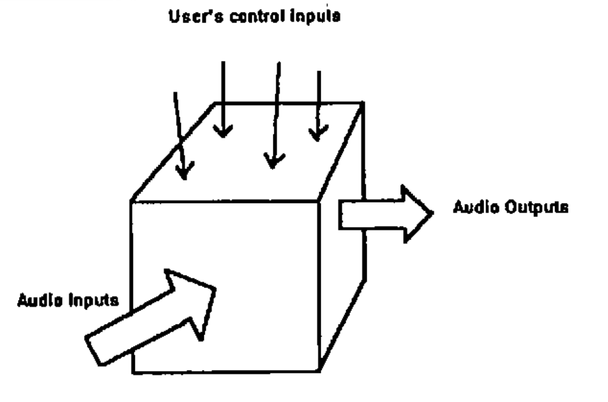

Figure 7 - The three dimensions of an Audio System

It is not always immediately obvious that the user and the source of sound are quite separate entities. In the case of a microphone announcement, the user and the audio source are the same person, but this is a special case. More generally an audio source is routed because of an external agent. This is more clearly seen in the case of a pre-recorded emergency message; the pre-recorded source of sound may be in one location, its destinations at other locations and the alarm trigger comes from yet another location. This means that the control system for a Voice Alarm system must be characterised not only by how many audio inputs and outputs it has, but also by how many independent control inputs it can accommodate.

If a control system is designed with this idea in mind, it will easily accommodate unusual routing requests from remote locations. These may be from telemetry links, telephone interfaces, other building services, and phantom control panels.

Ring systems usually have one or more system masters which administer logical decisions for users of the equipment around the ring. A ring system lends itself to supporting more that one system master, since the transmission media connect all nodes. This becomes important where security dictates more than one control centre. A star system has one natural system master, at its centre.

The system master of a Ring or Star system can receive requests from, and give replies to, any outlying node and may give commands to all nodes simultaneously. One outlying node may communicate with another outlying node with the co-operation of the system master.

Be careful to check that the flow of control data is truly bi-directional. If an outlying loudspeaker zone is busy receiving an announcement from a local source, for instance, is this fact reflected on the central control panels? As an example of this need, consider an airport lounge receiving an announcement detailing a flight, and a central office wishing to make a background security announcement to the same lounge. If the central office is not made aware that the lounge is receiving a local call, either the local call will have to be interrupted, or the security announcement will fail. If, however, the central office is aware of the local announcement, then the security announcement can be delayed until the lounge is ready. Provision of remote data to the system master in this way allows both for the control system to resolve priority conflicts properly, and for human users to gauge the status of the overall system.

A hybrid system will nearly always be described as decentralised, since the autonomy of each part of the system allows it to behave as if it were alone, not wholly dependant on the other parts. The control systems for hybrids are always exciting to design; there is no better way to find out whether the end user has thought his requirements through in detail than to involve him in decision-making about how the system will resolve conflicts between two users wanting to make announcements to the same place!

2.5 System Security

Whatever approach is decided on for a particular installation, it is essential to consider the reliability of the system and the method to be used for fault monitoring. On sites which could be subject to terrorist attack, it is important that disruption of a part of the building by bomb or fire will not disable the system from operation. Therefore either redundant signals routed by physically separated paths must be used, or some other means found to ensure an acceptable level of operation following an "event" - such as automatic triggering of a locally generated digital voice alarm if disconnection from central control takes place. Under this latter approach, there must be a local means of defeating the alarm and/or overriding with local speech to prevent evacuation during an ordinary failure. The important thing is that the system cannot be put out of useful action by cutting one cable route to the central control system.

Remember that both voice and control links, including connections to fire alarm systems must be monitored. On a large site, a decision will have to be made regarding the information presented to central in the event of a failure at a remote rack. At minimum, a common fault warning should be provided at central indicating the satellite area which has a fault - with detailed fault indication at the remote rack. At best, transmission of detailed fault information may help to ensure that action is taken promptly and effectively. Always ensure that a fault warning is transmitted by a reliable route to a person who has clear responsibility for action.

3. SITE SURVEY AND DATA COLLECTION

The objective with any voice alarm system is to ensure that the announcement has a good chance of being heard ***and understood***. If this is to be achieved, then the correct loudspeakers must be selected for use in each area of the site concerned - and action taken if acoustic correction is required. Whether the site is large or small, if is essential to perform an adequate survey to determine the requirements.

To allow the system to be designed for acceptable intelligibility - meeting the standards of BS7443 - I.E. an STI of 0.5 the following parameters are required:-

- RT60 (Reverberation time) - estimated from room type (unless noted for measurement)
- Background noise levels - estimated from room type (unless noted for measurement)
- Approximate Q of devices selected for that area (from selected loudspeaker type)
- Sound power of devices pointing at listener $\propto$ SPL of devices pointing at listener
- Sound power into reverberent field $\propto$ number of devices not pointing at listener
- Volume of the room = Floor area (from plan drawings) x Ceiling height (from survey data)
- Distance to furthest listener $\propto$ Floor area and ceiling height and related to loudspeaker type and proposed mounting position

On a small site, the client might be quite happy to pay for a day or two for site investigation and measurement in order to produce a good overall specification and costing. But on a large site, a process of estimating is required which will average out the requirements to obtain an accurate costing which requires approximate quantities of equipment, wiring and installation costs. This still depends on reasonably accurate design estimates for the system

For this project, a database system was designed which would be used to store the site survey information. Forms matching the database in terms of layout and contents were created - with tick boxes where possible to prevent errors of data entry or later interpretation. The database itself had many of its fields defined to allow the selection of only a limited number of choices from other tables - preventing inaccurate data entry. In addition, there were mathematical properties attached to the system to allow it to calculate loudspeaker quantities, loudspeaker tappings, approximate line losses, and therefore amplifier power requirements. The loudspeaker selection tables can be edited to allow devices from various sources to be calculated to produce overall quantities. Since supplier costs can reduce substantially with large quantities, the tables also allow later entry of item and installation cost estimates to automatically calculate project costs. These data tables not only allow the project to be estimated initially, but will allow for easy revision to cope with an extended project installation timetable. All automatically calculated fields can be manually overridden with as-built data as the project goes through the design detailing phase.

Even with simple forms, the survey staff had to be carefully trained to understand the important relationships that were contained within the data they were gathering. In order to collect the data within the time allotted, understanding had to reach the "automatic" mode, where standard situations were quickly noted - leaving extra time for more complex areas.

You will note from these forms, that usually measurements of actual RT60 and noise levels were not taken. Rather, the areas surveyed were categorised as to their function and usually the expected RT60

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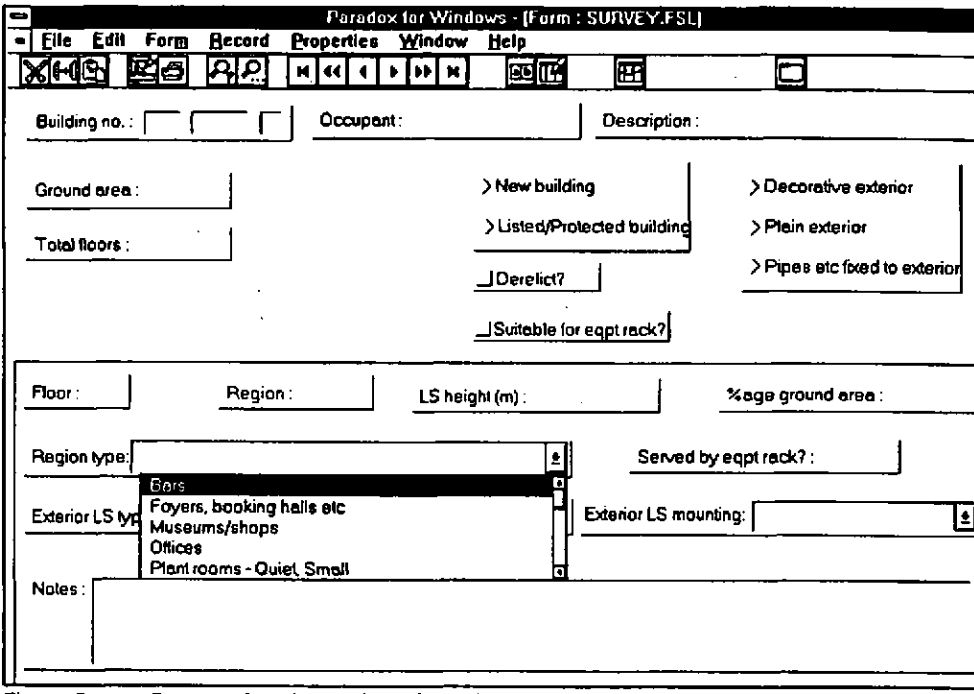

Figure 8 - Screen of early version of database showing room type selection box.

and noise are taken from standardised tables. The forms do allow, however, for measurements to be collected for areas which were outside of norms. See Appendix A for data collection form.

One of the more difficult problems to be encountered relates to proposed satellite rack locations. The cost/benefit for the choice between longer cables and additional amplifiers, etc. proved to be more difficult to "guesstimate" than the acoustic parameters. At the outset we proposed that several adjoining buildings might be served from one rack - but visually tidy, inexpensive and safe routes needed to be found during the survey work. Indications were initially marked on the drawings taken to site and analyzed later in the office by transfer to a large A0.5 plan at 1:1250.

Details of calculation algorithms are still in process at this time but will hopefully be available in time for the conference.

4. STAFF INTERVIEWS

As with many things in life, the initial answers are not always reliable. Prior to our appointment, managers of various departments within the site were polled for their local paging requirements. Few replies were received - this being interpreted as a negative "no requirement" response. However, experience shows that once the system is installed and in use requirements will suddenly begin to appear - accelerated by the success of an enthusiastic individual or two.

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In addition, non-response from potential providers of transmission media - such as the telecoms department - was received as a negative "we don't want you" reply.

The more historic and "civil service" like an organisation, the less likely that any "new fangled" idea will be well received. So planning the interviews to create an open atmosphere is essential.

In both cases, it is our experience that an outside consultant often obtains a better response than in-house directed enquiries. People begin to feel important and can vent their misgivings or ideas without fear of reprisal. But, the consultant must be careful not to promise things which may not finally appear, and must often dig under the responses for the real reasons the user has for blocking or accepting the use of additional systems. As consultant I must be trusted both by my employer and by affected staff who may try to influence things in a direction the employer does not wish to take.

In this large project we are tasked with determining other paybacks and uses for a system which may never actually be used for the purpose for which it is designed - to get people safely off the site in the event of an emergency. To do this, real (rather than hoped for) uses must be identified and provisiion made in the systems design to add further applications in later at minimal cost.

5. GATHERING PRODUCT INFORMATION

Having come to consultancy via a background in contracting and equipment design. we are reluctant to re-invent the wheel, or to design a system which is bespoke for one customer - even if he is a large one. We would much rather use, adapt or mix and match readily available, well proven products from reliable long living companies. Too often in the past (when admittedly fewer standard products were available for a job), products have been custom built for a particular project only to see it fail to complete, or the company disappear shortly thereafter due to the financial risk that they took. Therefore, we decided to collect data on readily available items of equipment from all the required disciplines:-

Loudspeakers Amplifiers Control Systems

Manufacturers were required to consider what products from their ranges might be used on a mixed industrial site having upwards of 340 buildings, and to provide a simple block schematic and a couple of pages of explanation about their proposed solution. What has amazed us to date is the small number of manufacturers who have responded - though the responses received have been clear and well focussed - highlighting the benefits that manufacturer would bring to such a system. As we head toward funding and the tender process, the respondents are certainly more likely to find themselves "in the frame" than those who haven't bothered.

6. SUMMARY

Large sites require all of the insight and understanding of small projects, but demand a "production engineering" approach from the consultant and later from the contractor in order to keep costs under control and make the project happen. This effort, whether on acoustics or staff planning, will help to produce a satisfying result for the customer and hopefully profits for the consultant, contractor and manufacturer.

Sam Wise Associates | **Surveyed by - Jonathan Ellis**

Project Name - | **Voice Alarm Site Survey Form**

Building no:	Description:	Occupant:	Total floors:

Floor:	Region:	%age floor area:	Ceiling/LS height (m)

Eqpt rack zone	
sub zone	

Paging group:

Region type

Private offices	
Open plan offices	
Large office	
Small workshops	
Large workshop	
Small items store	
Large items store	
Dining room	
Bar	
Kitchen	
Car park	
Street	
Dock	

Architectural sensitivity

Don't care	
Be careful	
Very sensitive	
Notes	

Noise measurement?
Excessively reverberant?

Speaker type

Ceiling speaker	
Enclosed speaker (speech)	
Enclosed speaker (music)	
Small horn	
Med horn	
Large horn	

LS mounting method

Roof	
Ceiling	
Wall	
Tower	

Environment

Indoor	
Rain	
Salt spray	

Notes:

APPENDIX A - Example of Site Survey Form