

A Hypermedia/Knowledge Based System to Promote Energy Efficiency in UK Companies

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Abstract

In 1992 a collaborative project sponsored by the DTI helped eight companies take advantage of Expert Systems Technology. A 'focus project' was used to embed the experience in the real world. This project was aimed at giving company managers advice on Energy Management. Reviewing the project, it was felt that the technology used at the time, a backward chaining Expert System, was not appropriate to deliver this sort of knowledge, given the constraints imposed and the characteristics of the end user group. A project to continue the work started in 1992 and to take advantage of the findings, has now been undertaken.

This project is aimed at encouraging Managers and Directors of Small to Medium Size companies to adopt an Energy Management policy and become more Energy Efficient. The problem is not one of making information available, since vast quantities of highly useful information are already available. The problem is to get the target user group to listen to the message and encourage them to act on it. This project will develop a computerised Energy Management Adviser (EMMA) which will present information in a non technical and very direct way. It will adopt ideas which are current in Human Computer Interface technology. Above all, it will implement a system of eliciting and utilising feedback from the target user group.

There have been many constraints imposed on the system. In particular, storage space is critical. This forces the project team to consider each detail of knowledge and access to it very carefully. This is in contrast to the explosive use of memory since the introduction of CD ROM. Good systems, developed through sound research, should use appropriate memory and not simply the maximum available.

Knowledge will be presented through the navigational mechanisms of Hypermedia but will employ a metaphor which will embed navigation in a computerised company. Inference will be used where knowledge is to be specific to a particular class of end user. The system will use a personal guide to provide advice to the user, helping with navigation and providing expert level consultation where required.

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1. Introduction

The North West Artificial Intelligence Applications Group (NWAIAAG) is a Technology Transfer group which promotes the use of Artificial Intelligence (AI) in industry. It was founded in 1988 and is managed by a committee of nine industrial representatives and one academic. The group promotes AI and supports companies through various events, information dissemination and collaborative projects.

1.1 Background

During 1992, the NWAIAAG organised a collaborative project with the support of the DTI under the Manufacturing Intelligence Programme. The project aimed to help eight regional companies, acquire skills in the development and use of Knowledge Based Systems (KBS). The focus of the project was to build a KBS, calling on the resources available within the NWAIAAG and external support. An application concerning Energy Management was chosen because it was equally relevant to all participating companies. In the final project report (Gordon 1992), it was noted that the structure of the knowledge used for the system was not entirely appropriate for a Rule Based KBS. Recommendations were made to investigate an approach which would combine the properties of a KBS and a Hypertext System.

1.2 Aims and Objectives

After examining the results from the DTI project, ETSU agreed to fund a project which would develop a computerised Energy Management Adviser (EMMA). The system, to be completed at the end of February 1996, is to be distributed to at least 30,000 company managers, particularly of Small to Medium Size Enterprises (SMEs).

It is not intended that the proposed system should embody all of the necessary knowledge which every company would require in order to become Energy Efficient. Indeed, this knowledge is already available from ETSU and other sources. The problem being addressed is of a different nature and one which forms a real barrier to improving the efficient use of energy in UK companies. This barrier, put in very general terms, is inertia. Many companies do not see energy as a big problem, possibly because it lies outside the mainstream business of the company or possibly because energy represents a smaller cost to the company than many other overheads.

The proposed system, EMMA, is intended to reach managers in a way which encourages them to adopt an Energy Policy within their companies. It will do this by showing simple measures which can have a direct effect on company profit and also show them the way forward to make more specific and detailed improvements. EMMA must therefore

- be easy to use,
- get to the point very quickly,
- communicate in a clear and unambiguous style which is acceptable to the target group of users and
- contain some information which acknowledges the specific needs of a particular user.

1.3 Constraints

A number of constraints have been applied to this project which will affect the way that the system is developed. Some of these constraints arise from the particular target group of users and the way which they will receive the system. The target user group (TUG) are usually very busy people who have little time for speculative investigation. Indeed, this is seen as one of the main reasons why Energy Efficiency is not pursued more generally in UK companies even though much effort is expended in promotion and information. SMEs are particularly prone to missing out on such initiatives because there is very little spare time to pursue anything other than the company's main business. Given this information about the TUG, EMMA may not have long to run on a managers computer if it does not deliver something useful, fairly quickly. Also, the nature and ease of use of the package, particularly the front end, is of prime concern.

It is not common for SMEs to upgrade hardware and software simply because new systems are available. It is much more likely that a system which functions correctly and efficiently will be retained. This means that when EMMA is released, it will have to run on, what may be regarded in 1996, as old technology. The minimum parameters for EMMA have been set as running on a PC with Windows 3.1, using a VGA monitor with 256 colours.

One final and very restrictive constraint is that the system must be delivered on two 1.44 Meg floppy discs (compressed for installation onto a hard drive). This means that video clips and sound must be avoided and photographic quality images must be kept to a minimum.

These constraints may also be viewed in a positive light however. Whilst in general discussion about the project, one academic insisted that a CD ROM MUST be used. The basis for this was that more memory meant more information would be conveyed and absorbed by the user. We dispute this and argue that the way information is conveyed is critical. For example, does a video clip of someone saying 'YES', convey more information to the user than three well designed letters on an appropriate background? The difference in storage requirement is considerable.

The constraints are forcing the team to put great effort into developing ways of conveying information without a massive memory requirement. The constraints are forcing the team to put great effort into developing ways of conveying information without a massive memory requirement.

1.4 The project Team

The formation of the original project team needed to reflect the bias intended in the proposed system. A further constraint on the project, as on every project, is the cost agreed by the funding organisation. This constraint and the perceived needs of the system lead to a project team composed of:

A part time project manager (1 day per week) with skills in project management, software development and developing AI systems.

A full time research assistant with proven skills in software design and an understanding of the development of Knowledge Based Systems.

A part time Knowledge Engineer (15 hours per week) with skills in the area of Energy Management and computer systems.

A part time Human Computer Interface Specialist (1 day per week) who will be primarily responsible for organising, evaluating and ensuring that feedback from members of the TUG get incorporated into the system through improvements.

Finally, a part time graphics technician (4 hours per week) who can design the screens for the user interface.

More will be said about how this balance has worked out later in the paper.

2. Management and Methodology:

It is claimed that the main reasons that Expert System project fail is through poor management or lack of appropriate methodology during construction and implementation. There is very little evidence concerning this project which could dispute these claims.

2.1 Project Management

If project management is difficult in general terms, running a collaborative project between several companies, each with separate motives and needs, is extremely difficult. During the DTI collaborative project in 1992, the NWAIG learned valuable lessons about project management. One of these is that it is not sufficient to have a team of interested and skilled individuals without careful management and a commitment at a high level. It is always possible, if not likely, that skilled individuals from several companies, will be diverted to 'more pressing endeavours' by their employers during the life of the project.

This problem can only be avoided if the project is 'vital' to all participants (Milne 1992, 1994).

Taking a more realistic look at industrial projects, collaborative input from companies is often vital if the necessary skills are to be utilised. The problem of commitment and diversion is ever present. A good compromise to project management involving industry is to ensure that a core team of skilled individuals are available to complete the project whilst providing this core team with access to expert advice and support through a mutually agreed mechanism. A project management plan can reflect the requirement for regular contact with industrial experts without imposing undue burdens on the experts themselves. A project management plan is absolutely essential, as are the setting of sensible mileposts. The plan should also embody a complete breakdown of the project into separate tasks. This may seem difficult for a Knowledge Based project, but it must be done.

The current project is fully described by a project plan. The plan itself is implemented in a PC Windows based package so that it can remain dynamic to some extent. The project plan also fits in with the methodology adopted by the project team.

2.2 Methodology

KADS, Common KADS and the Client Centred Approach (CCA) (Watson 1992) have been considered as suitable methodologies for this project. Although Common KADS offers a rich structure for defining and refining the specific elements of the project, it was felt that the learning curve for KADS would impose an unnecessary burden on the project team. The CCA however offers a structure which fits much more closely with the demands imposed by the contract. Elements which have been found particularly useful are the specification of 'Stake Holders', the very early delivery and evaluation of a 'Skeleton System' and the use of many 'Demonstration Systems' so that all partners and potential users have a clear view of progress and how the system is intended to look

The Skeleton System was delivered within two weeks of the official start date for the project. This was made possible however, by utilising a students final year HND project. The contract calls for one demonstration system, one working system and a final system. This requirement has been extended to satisfy the methodology. There will be one Skeleton System, four demonstration systems, one working system or usable system and a final system or saleable system.

There is a continuing effort by the project manager to maintain involvement from the stake holders. This is more difficult in the middle stages of a project where there is a general tendency to lapse.

3. Elements of the system

This project is Knowledge Based and has several distinctive elements. The Knowledge itself is central to the system but much of it can be delivered through hypermedia type navigation. Distributed inferencing is required, particularly to deal with any specific user needs.

In this system, it is believed that the most important thing to get right is the User Interface.

3.1 Analysis of the user group

The NWAIG is fortunate in having close ties with industry. A tripartite approach has been adopted to make a first hand assessment of the way users will interact with the system. It is difficult to describe this as 'user needs' since the users may not perceive that they need anything from the project. It is much better to aim to make the system attractive and usable so that the user can be influenced by the system and persuaded to take action relating to Energy Management measures. The approach involves:

1. A set of specific one to one user sessions where a manager uses the system in the presence of one of the project team. Users are asked to verbalise their thoughts whilst using the system and to indicate where they have difficulty. They are also asked to state which parts of the system they like and make suggestions about how other parts can be improved.
2. A programme of group feedback sessions. Each session is attended by about seven or eight managers. The first part of the session is used to inform companies how the project is being developed. This is aimed at helping companies to develop their own systems. The second part of the session involves a scripted demonstration where particular aspects of the system are demonstrated and delegates are asked for comment and suggestion. Discussion follows a prepared script to ensure that items of interest to the team are not omitted.
3. A questionnaire has been sent to about 100 managers in industry. C)Ver 30 of these were completed and returned. The questionnaire attempted to discover general information about how the TUG currently interact with computer systems.

Results from analysis carried out through this approach are considered in section 4.

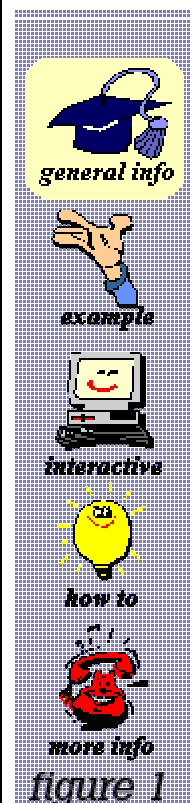
3.2 Eliciting and Formatting the Knowledge

This project is typical of many Knowledge Based System projects in that the main difficulty is not in the Elicitation of Knowledge but in the Analysis of considerable quantities of knowledge from many sources. Knowledge Analysis is known to be a problem in many areas such as law and insurance.

The main place which information will be provided to the end user is the computer screen. Our own work has shown us that a system can only present large amounts of text on a screen if the motivation of the user is extremely high. This cannot be assumed for the current project. It is also important that the information presented is direct and to the point. If it is necessary to explain that leaks in compressed air systems can account for considerable wastage in energy usage and lead to general inefficiencies, then it is better to say, 'Compressed Air Leaks Cost Money', and attempt to quantify and reinforce this with images or graphs etc. Converting all of the available knowledge into this format is not a trivial task. In order to assist in the analysis and presentation of knowledge and to create a consistent way of delivering information to the user, a scheme has been developed and adopted.

The system will contain many leaf nodes which are the main point for knowledge delivery. Each leaf node will have a particular format, using specific icons to help the user separate and absorb the knowledge (Figure 1). A typical knowledge node will contain:

General Information About the current topic.
 Example A relevant example of good practice.
 Interactive User interacts with system to reinforce information.
 How to Implement a policy to achieve related energy savings
 Contacts Where to get additional help and information.



This scheme has helped the team to approach Knowledge Analysis in a structured and methodical way. Using this scheme, it is proposed that the system will contain approximately 75 Information nodes. Each node will contain up to five screens using the format described above. Information nodes are contained in 13 categories. These categories are:

Energy Management,
 Energy Flow and Monitoring,

Process Heating and Cooling,
Compressed Air,
Lighting,
Building Fabric,
Catering,
Energy Sources and Conversion,
Office Equipment,
Motive Power,
Space Heating and Cooling,
Boilers,
Water Heating

Navigation and other support nodes will account for a further 30+ separate nodes in the system.

3.3 Designing a User Interface

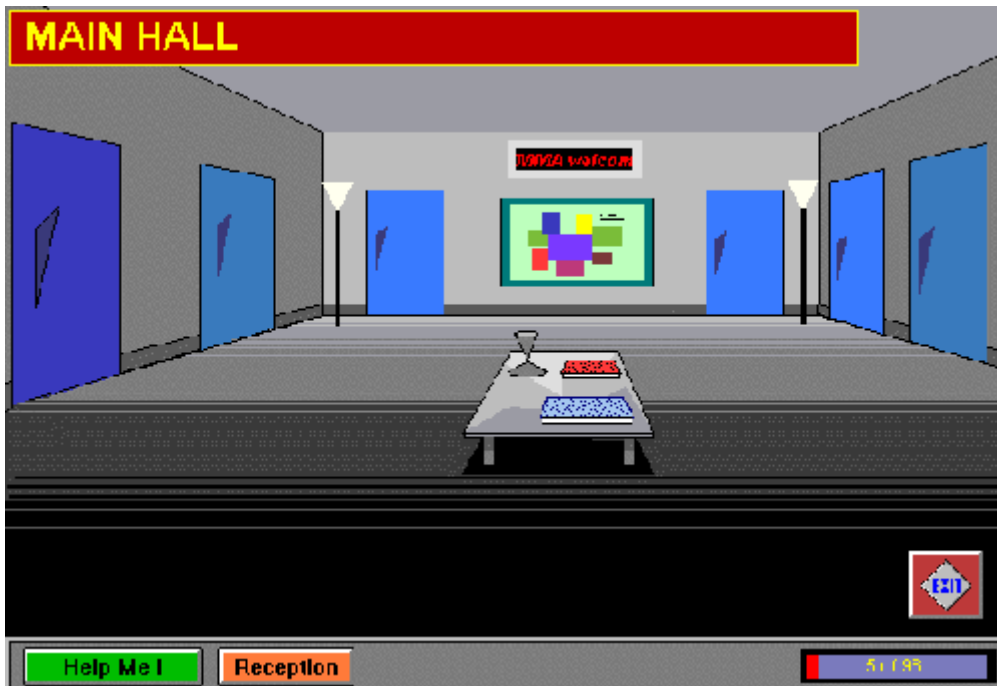
The original idea of using a Backward Chaining KBS to solve specific energy related problems was very restrictive in that it prevented access to knowledge. The proposal to marry this technique with a point and click system embodied in hypertext offered improvements but did not satisfy the objectives of the project. Point and click makes the users life easier but does not provide incentive or encouragement to use a package.

The use of a metaphor can involve the user more actively in the knowledge being presented, through spatial awareness (Ambron 1990). Since this project is about Energy Management in Industry, using a typical company layout to incorporate the knowledge is a fairly logical step. Rather than take the step from answering KBS questions to a point and click navigational system, this project uses the metaphor of a typical company to provide both navigation and inference.

Navigation involves a tour through the company to various places where information is available about energy related issues. For example, The user will enter the system through 'reception' (Figure 2)



where (s)he will fill in a visitors slip or give in a business card before moving into the 'main hall' area (Figure 3).



Leading from the main hall are doorways to the 'board room', 'offices', the 'factory', the 'warehouse' and the 'canteen'. Doorways from the warehouse lead to the 'boiler room' and the 'building site'. Graphic images act as access to information. For instance, pointing and clicking on the lights will provide access to a lighting information node.

The user interface must also provide support for the user and relevant advice if required. In order to achieve this and in keeping with the spirit of the chosen metaphor, a guide will always be on hand to help the user. If the user is unsure what to do next or where to go, the guide will 'pop up' and give advice.

If the user makes an inappropriate action, the guide will provide help. The guide will also meet the user at reception and be available with advice before the user quits the package.

3.4 Constructing the system

At the outset of the project, it was known that the system would be knowledge based and that a hypertext facility was required. The early 'skeleton system' was produced using a package called 'Guide Author'. This provided a comprehensive hypertext interface and a scripting language called 'logiix' which could be used to build inferencing sections. In the two months before the official start date of the project (July and August 1994) several other options were considered. The most promising option was a package called 'KPWin' which was originally designed around an Inference Engine and which incorporated considerable support for hypertext navigation. Visual Basic was also considered. This was being used by a company which is a member of the NWAIG, to develop a battle damage assessment adviser for military use. This company could be relied on to support the NWAIG project through the company's project team. Several other packages were discussed by researchers at The University of Hull (Riley 1994) and this analysis was very useful.

In the event, the team chose to use a package called 'Multimedia Toolbook'. Toolbook itself has a proven track record in simpler systems. For instance, the DTI Neural Network system was developed in Toolbook and works very well. The main problem with this choice was that it does not easily support the requirement for knowledge level advice to be given through an Inference Engine. The development facilities are however, very good and the embedded language is rich and easy to learn. Quite a lot can be achieved after about an hour or so of exposure to the package although a greater depth of study is required to achieve the goals for the EMMA Project. A more detailed justification for the

use of 'Toolbook' can be found in a project report entitled 'Choosing a Development tool for a Knowledge Based Hypermedia System' written by Midiael Edge.

Although Toolbook lacks an Inference Engine, leading to certain system design difficulties, there is a Toolbook News Group on Internet at the University of Arizona. This has provided support from many parts of the world and has solved several major problems in system development.

3.5 The overall structure of the system

The fundamental approach to knowledge navigation adopted in this system is embodied in an appropriate metaphor. The metaphor is a spatial representation of the physical environment in which Energy Efficiency is being considered.

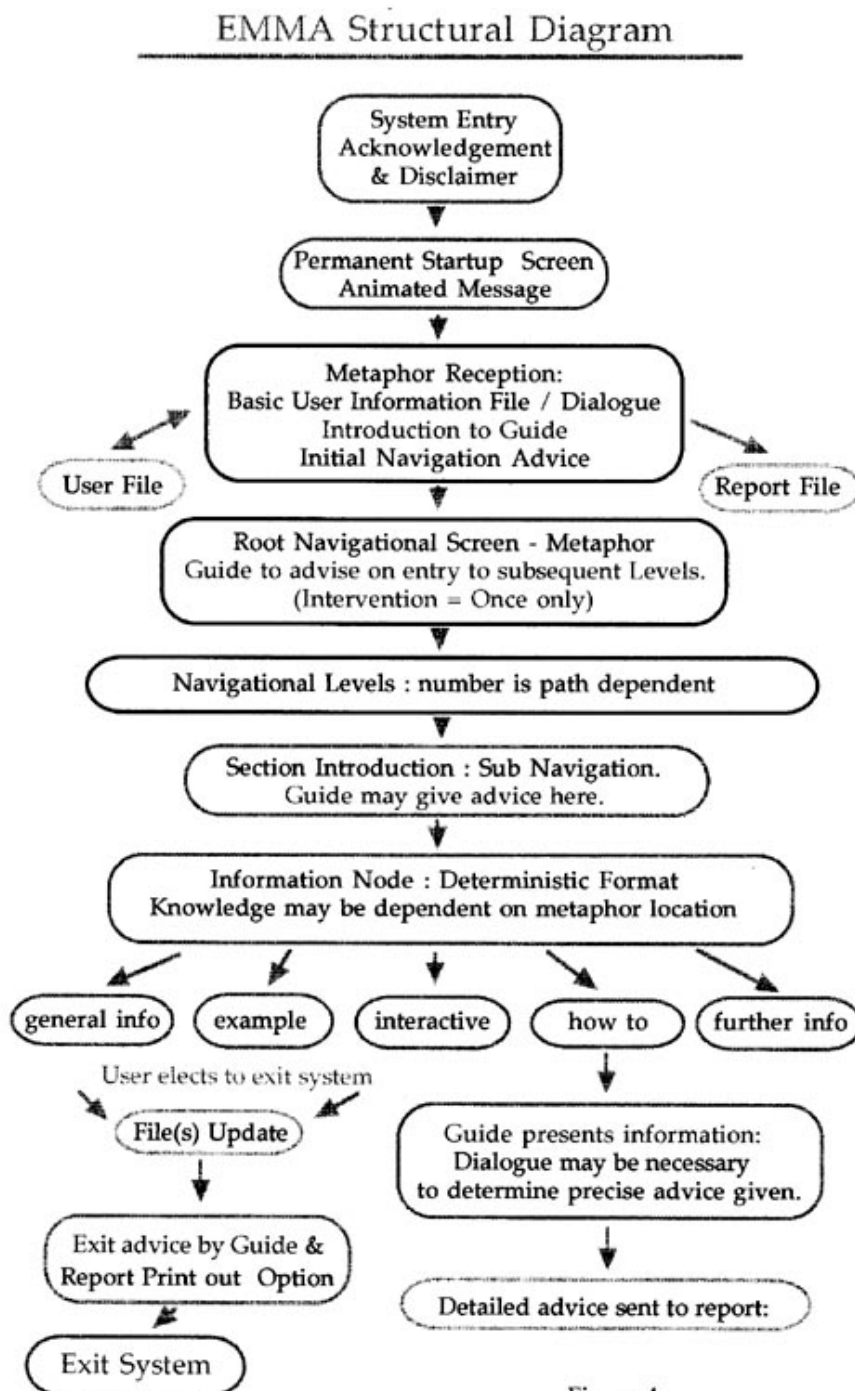


Figure 4

The skeletal structure of the system can best be described with the aid of a diagram (Figure 4). Skeletal elements can be shown to belong to one of three basic structures:

The Knowledge Structure:

The Inference Structure:

The Report Structure:

The Knowledge Structure is further sub divided into two primary components;

Navigation Nodes

Information Nodes

The structure diagram shows that these nodes are also complex. Navigation includes 'introduction' whilst 'information' nodes exist in the fixed format outlined in section 3.2. The Inference Structure consists of four main components which overlap with the report structure:

Location dependent inference.

Dialogue driven inference for specific knowledge.

User Profile inference.

A requirement to produce a report.

The Report Structure consist of two main components:

The User / Company profile.

A personalised action report.

The user profile is updated when the user elects to exit the system and will be saved in a file which is particular to that individual.

The personalised report will contain a header which incorporates personal/company information, an action section derived in the 'how to' nodes of the knowledge structure and a tail section advising the user about subsequent use of the system.

4. Analysing User Response

The tripartite approach to the analysis of the end user group has been outlined in section 3.1. Results from this analysis are being used to influence the design of the system. No further questionnaires will be used but individual and group feedback sessions will be carried out for each new demonstration system completed. It is clearly desirable that feedback should validate changes to the system resulting from earlier feedback, although validation cannot be guaranteed.

4.1 Results from the Questionnaire.

The questionnaire was intended to elicit general information only. Eleven questions were used and were designed to elicit opinion from the end users rather than specific comment. A final section was provided however, to allow users to make any specific comment which they felt would help the design team. Thirty-three questionnaires were received in all, of these, fifteen were from the manufacturing sector; these being of particular interest to the project. Users were asked to indicate which area of energy management they would be most interested.

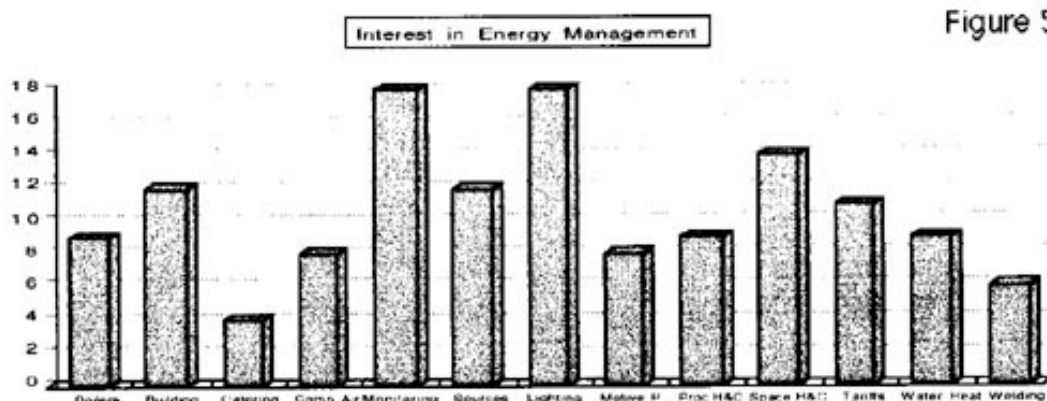


Figure 5 shows areas of interest for all returned questionnaires. Any system intended for this user group must address lighting and monitoring particularly well.

Most of those answering the questionnaire indicated that they have considerable influence in matters concerning policy making at a section level but not at a company level. This would imply that it is vital that the system reaches the correct people in a company. Answers reveal that managers are not greatly interested in Energy Management at present. A factor which reinforces the need for the current project. Managers do seem to spend quite a lot of time interacting with computers and are used to seeing the computer as an information provider. Reading text from computer screens is not seen as a particularly good way of getting information and the user group do not get much enjoyment from computer games or at least, do not wish to admit it. The question about computer games had one of the largest spreads of answers with opinions polarised between extremes.

An agglomerative clustering programme was given the source data from the questionnaires in order to discover how much distance there is between results. This technique highlighted one questionnaire as being completely different from the main group and then three more which were considerably dissimilar. The group identified by the clustering algorithm as more typical, were less interested in Energy Management than the complete group and found reading text from the screen even less effective than the full group.

Some of the general comments were also very valuable. One company, with experience in building Knowledge Based System, highlighted the value of using colour effectively in the final system, using an example to reinforce the point.

4.2 Results from group sessions.

A scripted demonstration in each of two group feedback sessions brought delegates attention to the following areas:

The use of hot words, the use of buttons, the use of graphics and symbols, the quantity of information on a screen, the quality of information on a screen, the help system and ways in which information is being presented. The feedback session was organised to consider each of these areas before delegates were asked to provide any general comment. This format was imposed on the sessions to provide some consistency across separate sessions and a policy to control sessions was drawn up on 7th October 1994. It is intended that comparisons of feedback will be more justified if there is some consistency of method. Several more group sessions are planned.

There has been a general improvement in the package, according to the group feedback sessions, from the Skeleton system to the first demonstration system. Comments from the delegates usually receive general agreement but some of the interactive sections attracted polarised opinion which reflected the answers in the questionnaire regarding the playing of computer games. Some very useful ideas have been received from these sessions. This seems to be because the delegates have the opportunity to refine ideas collectively and reach general agreement. Many of the ideas received from these sessions have been incorporated into the system.

4.3 Results from individual user sessions.

Although data from these sessions is less abundant due to the relatively small number of end users involved, the high quality of the data is extremely valuable. During these sessions, users are asked to explore the system, with little or no help from the observer. They are asked to verbalise their thoughts as they navigate the system and make comment about good and bad aspects.

The project team has been generally encouraged by its decision to ground the knowledge in an appropriate metaphor. Most users are happy with this idea but want the images (often temporary development images) to be better in the final system. All of the users

have experienced problems with navigation. Despite following the general principles of shallow tree structures, the early systems leave users 'lost in hyperspace'. The team have taken careful note of these problems and are testing new designs with users.

The point about 'too much information' has also been made several times. One of the problems with the user group is that they do not have time to spend on activities which 'may' be of interest. Points have been made about 'not getting too technical' and 'not having too much text on the screen' on several occasions.

Much of the advice from these sessions has now been incorporated into the system. This advice is very valuable since the users are given little help and have to rely on the system being friendly in order to make progress and gain information.

Comment from these sessions has been written into general guidelines. These have also been supplemented by information from Eberts, Ledgard, Shneiderman, Sutcliffe, Rich and Badre (see references).

5. Implications for the developing system

The design of the EMMA system will follow the structure described in section 3.5. Some important lessons have been learned during the design of this and previous systems which will influence the final form of EMMA. Some lessons are of a general nature whilst some are specific to this type of project.

5.1 Composition of the team

The composition of the project team will have strong influence on the team's ability to complete a project. This is not just a matter of choosing the right people with the right skills. It is also making certain that the level of commitment of individuals is high and that the project features as a high priority for each of the team members. Using part time people from industry can only work if the contribution of these individuals does not present a barrier to progress at any point in the project. Realistically, their company comes first. Likewise, part time team members may be diverted from the project due to other commitment. Strong project management is critical in all cases, but particularly so if part time team members are used.

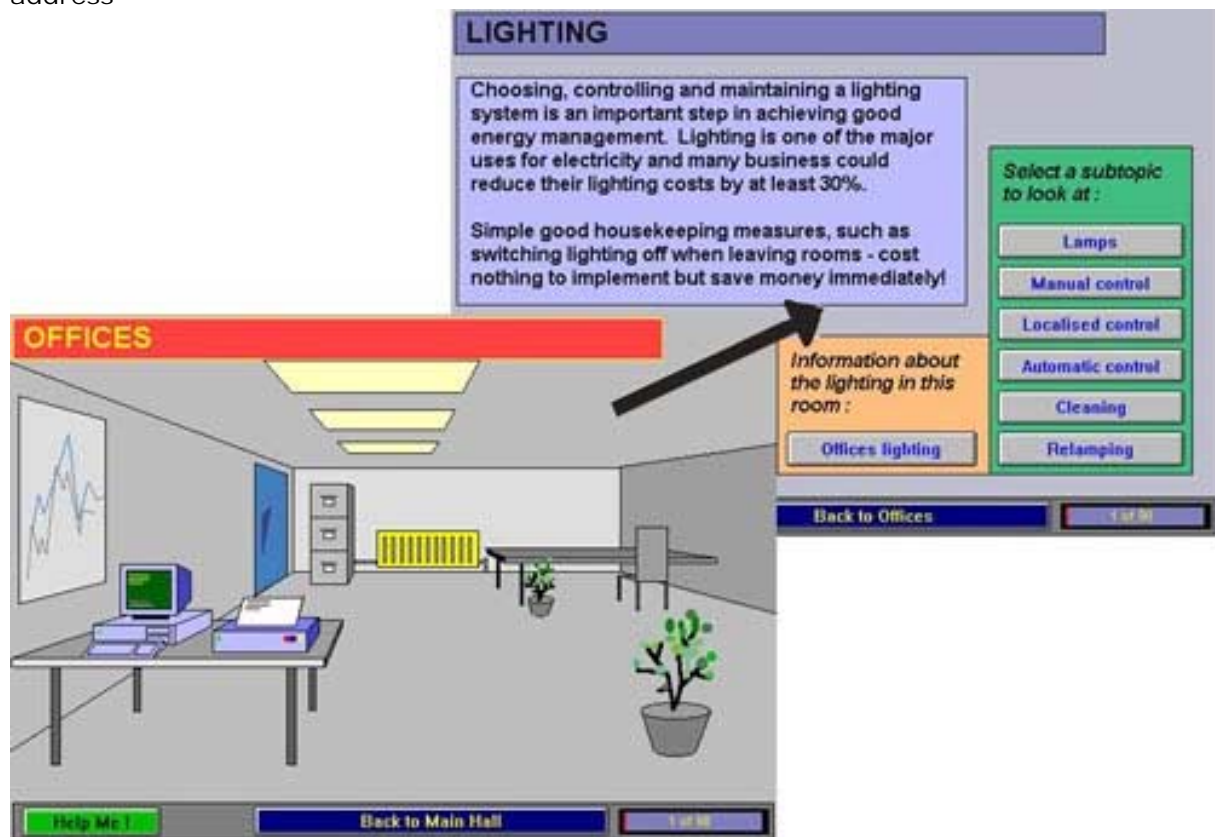
5.2 Project Management and methodology

Project management and methodology are also critical areas. This may seem an obvious statement but even though many confess to knowing these facts, projects still fail due to poor management or lack of method. Two main reasons for this problem seem to be evident. The first is the general tendency for projects to sail through the doldrums after an initial good start and high commitment. If this is not corrected urgently, projects may never recover. The second reason is in the lack of enough real mileposts or deadlines throughout the project. A good way of concentrating the mind of the team is to organise dissemination events at regular intervals where progress has been announced in advance and the team's efforts can be measured against stated tasks. It can be argued that this is not appropriate for a project which contains a strong element of research. This may be true for fundamental research but deadlines can usually be accommodated in near market research.

5.3 Structuring/accessing the knowledge

There is an important point about how the knowledge should be organised. In a traditional backward Chaining Expert System, it is clear where knowledge should be placed. In this hybrid system knowledge is more accessible to the user. The issue of how easily knowledge should be accessed is a difficult one. Consider the following example. A user begins to use ENMA and starts to realise that pointing and clicking on objects is both navigation and access to information. In the metaphor of a factory, lighting will be visible from many sections. Should the user be allowed to access lighting from anywhere and always receive the same information, should the information received be specific to the access point or should lighting information only be available from one point. Each of these options has their advantages and their disadvantages. For instance, if lighting is

specific to access point, the user may not realise that they still have important information left to access. If the same information is presented at many points, the package will start to become tedious. If lighting is only available from one point, the metaphor is contradicted. In EMMA, Knowledge will be accessible from any point where it may be selected. Lighting will therefore be available from several locations. In order to address



the problems outlined above, there will be one element of the knowledge which is specific to access point and the main knowledge will be presented in all cases when the user accesses lighting. This technique has not yet been fully tested, work is continuing.

5.4 Navigation

Navigation has now been given a high priority. In order to address the 'Where am I?' problem, a map was introduced, through a button labelled 'Map', which allowed user to view their location within the system. Although this was an improvement, it was not adequate. A permanent button has been included which is labelled 'Where am I?'. This shows location and the guide also states the users location. The user is not allowed to change his/her location using this facility since this may add to confusion and may also mean that the user misses large areas of knowledge. The more standard technique of using coloured markers to show where the user has been is also being incorporated. In later systems, it is proposed that the guide will provide more suggestions to help the user in navigating to areas which may be of particular interest to that individual.

5.5 Using Screen text to convey knowledge

The quantity of text on any individual screen is being kept to a minimum. Evidence to justify this has been found in each of the three elements of user feedback being employed. Choosing exactly which text to use and summarising complex ideas in a few words poses more problems. The use of graphics and 'hot words' can help with these problems.

5.6 Polarised opinion on Interactive Screens

The reason interactive screens were included in the system is fairly sound. If the system is entirely passive, it is likely that users may learn very little from it and it is less likely to have an effect on Energy Management in companies. However, some of the users do not

like screens which appear 'light hearted' whilst other users find them very useful and entertaining. The system must avoid putting off users but must try to entertain users and make the task of becoming more aware of Energy Management issues less onerous. This problem has not yet been completely solved. At the moment, interactive screens are being kept at a more traditional level with any attempt at humour etc. being left out. One technique being tested is to have all 'visible' (cursor changing shape) screens of this type whilst allowing the more adventurous user to discover (cursor not changing shape) other elements where information is presented in a less traditional way.

5.7 The developing system

This paper covers development of the system up to the second of four demonstration systems. A great deal has already been finalised, out of necessity, but some issues remain unsolved. Possible options concerning these remaining issues will be tested with the end user group and a final policy derived. Final implementation will depend on the acceptance of the sponsoring organisation but evidence for decisions made by the project team will be available. The project is due for final delivery at the end of February 1996.

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