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Identification and Evaluation of Factors Affecting Use of Knowledge-based Systems in a Manufacturing Environment

An in-depth investigation of parameters that particularly influence the effective adoption of knowledge-based systems in manufacturing by various end-users

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MSc Thesis

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Abstract

A large amount of work has been carried out in the field of developing knowledge-based systems from initial analysis of the domain task, through formalisation and computerisation of knowledge to a completed knowledge-based system. However, issues relating to the use of such systems appear not to have been so clearly identified. It is essential to pay detailed attention to all of the human as well as technological issues which affect the practical use of such systems. The factors that influence the use of a knowledge-based system need to be identified to ensure that any systems developed will in fact be used by the intended end-users.

In this thesis we propose a model for effective utilisation of knowledge-based systems. We will discuss how this model has been validated, then used as a basis for the identification of factors that affect system use. We will describe how we select and evaluate factors which we believe have a significant impact on the use of a system. We will present a set of initial findings based on experimental work we have performed as to the most significant factors. A set of conclusions are drawn on the approach we have adopted, the results we have obtained and the success of this work.

We have identified a four phase model of system use, namely, acquisition, handover, operation and maintenance based on current literature. The model depicts the relationship between roles, functions and entities. By validation of the model, we have identified an initial set of 55 parameters that impact the effective use of a system. We have selected a subset of these parameters (those which we believe have significant impact and those which have less impact on the utilisation of knowledge-based systems) which we are able to control in order to evaluate a set of 17 hypotheses. The important parameters were: *Role of system, Familiarity with system, Functionality, Robustness of system, Breadth of knowledge, Depth of knowledge, Method of displaying information (HCI), and Method of selecting options (HCI).* The less important parameters were: *Familiarity with domain tasks, User role, Fit with user requirement, Provision of system help, Provision of explanation, Response time, Security features, Error reporting, and Maintenance procedure.* The experiments we performed allowed a systematic examination of the degree to which each parameter we selected impacts system use. From the data we obtained we identified a number of key parameters and the impact they have on effective use of a system. Specifically, from our experimental work we have identified the following factors as having the greatest degree of impact on system use: *Role of system, Breadth of knowledge, Depth of knowledge, Provision of explanation, Provision of system help, Method of displaying information (HCI), Method of selecting options (HCI), Functionality, and Maintenance procedures.*

We also identified areas where additional work is required to further investigate the factors that impact on the effective use of knowledge-based systems.

Acknowledgements

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Statement of Copyright

Table of Contents

List of Figures

List of Tables

1. Introduction

Over the past thirty years the manufacturing environment has begun to utilise a variety of computer systems for various applications, e.g. Computer Aided Design (CAD), Computer Aided Manufacture (CAM), Computer Aided Production Management (CAPM). Many areas of manufacturing have benefited from the introduction of these systems. In addition to just manipulating information, computer systems have been developed that try and encapsulate expert knowledge. One method of achieving this, has been knowledge-based systems. A knowledge-based system (KBS) can be defined as "a system which processes and applies human knowledge". Alongside knowledge-based systems, there are expert systems, these attempt to access and apply human expertise. The terms knowledge-based systems and expert system are commonly used to refer to the same type of system, although they differ in operation. Expert systems tend to be focused onto specific aspects of a domain, whereas knowledge-based systems tend to cover a more general area of a domain.

In the last decade there has been a resurgence of interest in the use of knowledge-based systems particularly in the field of manufacturing. This technology has been seen as a possible method of maintaining competitiveness in an increasingly competitive marketplace. Knowledge-based systems are being introduced into various application areas throughout the industrial and commercial environment, e.g. adhesive selector, fault diagnosis systems, production planning systems, CAD\CAM systems, pension advisor, production control systems (Shaw, 1990). At present these systems represent only a small fraction of the potential opportunities.

1.1 Knowledge-based Systems

A KBS is a computer program that contains the problem solving knowledge of a domain expert. A KBS is constructed from three main elements, namely, a knowledge-base, an inference mechanism and a human-computer interface. Figure 1.1 shows how these elements are joined together to form a complete system.

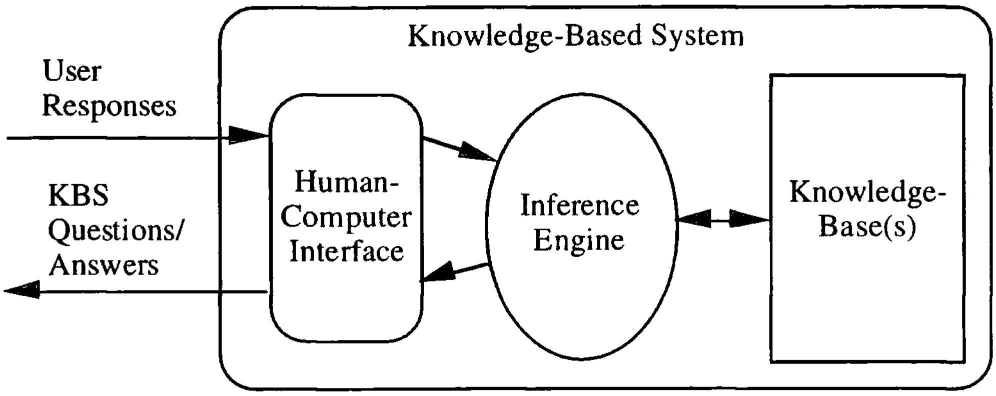


Figure 1.1 Elements of a knowledge-based system

Figure 1.1 depicts the initial interaction between a user and a KBS. The KBS prompts the user with questions or answers it has formulated (to a given situation from responses already received), the user in turn provides responses. These are then further processed by the KBS to give more correct answers or further questions. A discussion of the main elements that form a KBS now follows.

Knowledge-base

A knowledge-base is a store of information that holds domain information about a given task. The knowledge-base contains different types of knowledge, i.e. facts (entity attributes) and relationships (membership, sub-classes etc.). The construction of the knowledge-base accounts for about 40% of the development time. Specialised people called knowledge engineers are normally used to create the knowledge-base.

Inference Mechanism

This is the controlling software algorithm that uses the knowledge-base to interpret a user's query and provide an answer. There are a number of different inference mechanisms that can be employed. Each have different characteristics and functions. It is up to the software engineer to select the most appropriate mechanism to be employed. Common forms of inference mechanism are forward and backward chaining. Forward chaining involves establishing a set of preconditions that will result in achieving a goal. Backward chaining is the process by which given a set of conditions, the system is able to determine what they satisfy.

Human-Computer Interface

The human-computer interface (HCI) is the 'front-end' of the system. It is the method by which the user is able to input information into the system and receive an answer. The type of interface employed will depend on numerous factors, such as type of package employed, type of knowledge to be displayed, user requirements etc. A large amount of research has been carried out into this field as it constitutes approximately 40-50% of development time.

1.2 Research Background

The development process by which knowledge-based systems are created is well understood and defined. However, the process by which these systems are effectively integrated and employed is less well defined and understood. In order to gain maximum benefit from development of a system it is necessary to have some formalised method by which that system is introduced and supported throughout its lifetime.

A vast amount of effort is usually devoted to the development of knowledge-based systems (Shaw, 1990). In order for a company to gain maximum return from this investment it requires a method by which it can ensure that these systems will be introduced, monitored and controlled effectively. To this end it is necessary to define in a clear and concise manner the tasks and goals that need to be achieved if a system is to be used effectively. Furthermore, to aid effective use it is necessary to be aware of factors that have significant impact of the use of a system. Once these factors are identified then appropriate action can be taken before the system is introduced into the working environment.

When considering the adoption of a knowledge-based system (or any system) it is normal that a cost/benefit analysis will be performed. However, this tends to relate to the acquisition issues, rather than the utilisation issues. It is therefore necessary to consider both benefits and costs that will accrue from the potential system's use. The following list contains a number of benefits that can be expected from the use of a knowledge-based system, this list is not exhaustive or definitive as each application will have its own unique benefits associated with it.

More exhaustively-evaluated solutions
24 hour availability of advice
Lower training costs
Preservation of expertise
Improved job quality by reducing routine tasks carried out by a domain
Improved level of performance by non-experts
Faster decisions
Lower cost of advice
More consistent decisions
Availability in remote locations

Improvement in user attitudes
Improve task's quality
Reduce losses due to unavailability of experts
Increase equipment utilisation and availability
Improve company profile
Better use of scarce resources

In addition to the benefits that can be expected from use, it is desirable to know costs. Again, the costs associated with each individual system will be unique to that system. However, some of the costs that can be expected include:

Increased maintenance cost because of the knowledge
Greater difficulty in system adoption due to 'threat to jobs' - as a system replaces human expertise
Question of liability (who is responsible for problems arising from system use)

Although identifying the benefits and costs is an important part of system adoption, it does not give a full picture of how a system should be integrated into current working practices. Rather, there is a need for a process by which a system can be formally integrated into an environment. This process needs to identify the significant factors that have the greatest impact on system utilisation.

Although we can make some general observation as to the benefits and costs associated with system use, it is more desirable if we can formally determine the issues that have significant affect on the uptake and use of a system. In order to help solve industries problems with the use of this new technology it is necessary to outline in a clear and concise manner how knowledge-based systems should be managed.

Having said there are problems in the adoption of knowledge-based systems, we propose a process by which systems should be integrated into working practices. Furthermore, we will identify significant factors through practical examination and experimental evaluation that affect system utilisation.

1.3 Aims of our Research

In this section we propose the work that we wish to carry out. It is necessary to explain the context of the work, i.e. how we intend to carry out practical evaluation of KBS utilisation within a 'live' environment. Furthermore, we also propose a set of issues that form a starting point for our investigation.

Context of the Work

With the help of a collaborating company (Lucas Engineering and Systems Ltd), a practical examination of issues relating to the utilisation of knowledge-based systems can be carried out. The end product of this work will be a set of process models and factors that indicate the most valid approach to the adoption of knowledge-based system technology in order to gain maximum benefit. Assuming that the knowledge can be formalised and computerised, the actual use of the knowledge-based system tools will depend upon a number of factors. These factors have been initially determined from current literature and practical experience of personnel involved in knowledge-based system development and use.

The important factors being;

a. The scope of the knowledge-based system
b. Confidence in the knowledge-base
c. Level of detail provided in the knowledge-base
d. Ease of modification of the knowledge-base
e. Amount and level of detail of the guidance provided
f. The type of user
g. Steady state and dynamic nature of the knowledge-bases
h. Ease of audit to assess the impact of changes to the knowledge-base
i. Robustness of the knowledge-base and the stability of the advice offered.
j. Usability of the system by personnel other than those providing the knowledge built into the knowledge-base.
k. Presentation of advice or help to the user
l. Effect of adding new knowledge on the performance of the system.
m. Level of explanation provided by the system
n. Type of explanation
o. People outside the company developing the approach, in a different culture

It is anticipated that the research work will concentrate on factors a to j, although the remaining factors will clearly have to be taken into account. It is necessary to investigate each of the factors in order to determine their individual as well as their collective impacts on the utilisation of knowledge-based systems. Additional factors may be identified once investigation of existing knowledge-based systems is undertaken.

1.4 Criteria for Success

The criteria against which this work will be evaluated are as follows:

1. A detailed literature survey to identify research and practice in the area of knowledge-based system utilisation.
2. A detailed literature survey to identify methods for the analysis of the findings and means for experimentation work.
3. Evaluation of the usage of the knowledge-based systems in a 'live' environment by different types of personnel, namely the managers, systems engineers, and trainees. This activity will determine the relevance and helpfulness of the knowledge-based system within a manufacturing environment.
4. Monitoring of the process of using the knowledge-based systems.
5. Identification of the factors which inhibit or promote the use of knowledge-based systems.
6. Categorisation of the identified factors into the method and knowledge-based system related issues.
7. Development of feasible alternatives to minimise the effect of factors which inhibit the utilisation of the knowledge-based systems.
8. Implementation and exploration of the alternative solutions.

We believe it is necessary to emphasise particular activities or issues that have a significant impact on the use of a system. A set of process models will be defined and then justified based on current literature and experimental work. The process models are used to show the tasks that should be performed when undertaking a given phase, the personnel involved, the main inputs to and outputs from each activity and the relationships between activities, personnel and input/outputs. Particular attention has been paid to the activities associated with the utilisation of a knowledge-based system, as this is often an area that is neglected, but is fundamental to achieving benefit from a system.

1.5 Thesis Outline

The following chapters report the work we have carried out and the results we have obtained when examining the issues that affect system utilisation.

Chapter	Content
1	Thesis introduction
2	Development of a model of KBS utilisation
3	Discussion of case study and experimental methods
4	Case study validation of our utilisation model
5	Identification, selection of experimental parameters and design of experiments
6	Discussion of the experimental results obtained (actual results are shown in appendix C)
7	Discussion of our findings
8	Conclusions of the work we have performed
Appendix A	Evaluation questionnaire used during experimental work
Appendix B	Full experimental parameter selection table
Appendix C	Experimental findings containing the source data and graphs discussed in chapter 6

1.6 Summary

In this introduction we have described the components a knowledge-based system. Furthermore, we have outlined what work we propose to carry out in order to establish a model for effective system utilisation.

In the following chapter we will propose a model based on current literature. This model provides the basis for the examination of the issues that affect system use.

2. Model Definition

2.1 Introduction

Issues relating to the use of a knowledge-based system are often not addressed and seem to be of secondary importance when compared to those of developing a system. However, it is necessary to establish the factors that will influence the use of a knowledge-based system to ensure that any systems developed will in fact be used by the end-users.

This chapter develops a model of utilisation based on current thinking from available literature. The results are presented in terms of a four stage model that will be used later in this thesis. The model identifies what are believed to be the key stages in the operational life of a system, namely acquisition, handover, operation and maintenance. Having identified these key stages it is then possible to focus attention as to the activities, personnel and data flows that should exist. Figure 2.1 depicts at a top level the position of the utilisation phase in terms of the whole lifecycle of a system, namely before a system can be used it first needs to be justified as being beneficial to an organisation (this justification phase is outside the scope of this thesis). Assuming that there is a need for a KBS, then a system needs to be acquired before utilisation can occur. Underlying all the stages of utilisation is a KBS strategy, this is a business policy which actively promotes the adoption and investment in the use of a KBS.

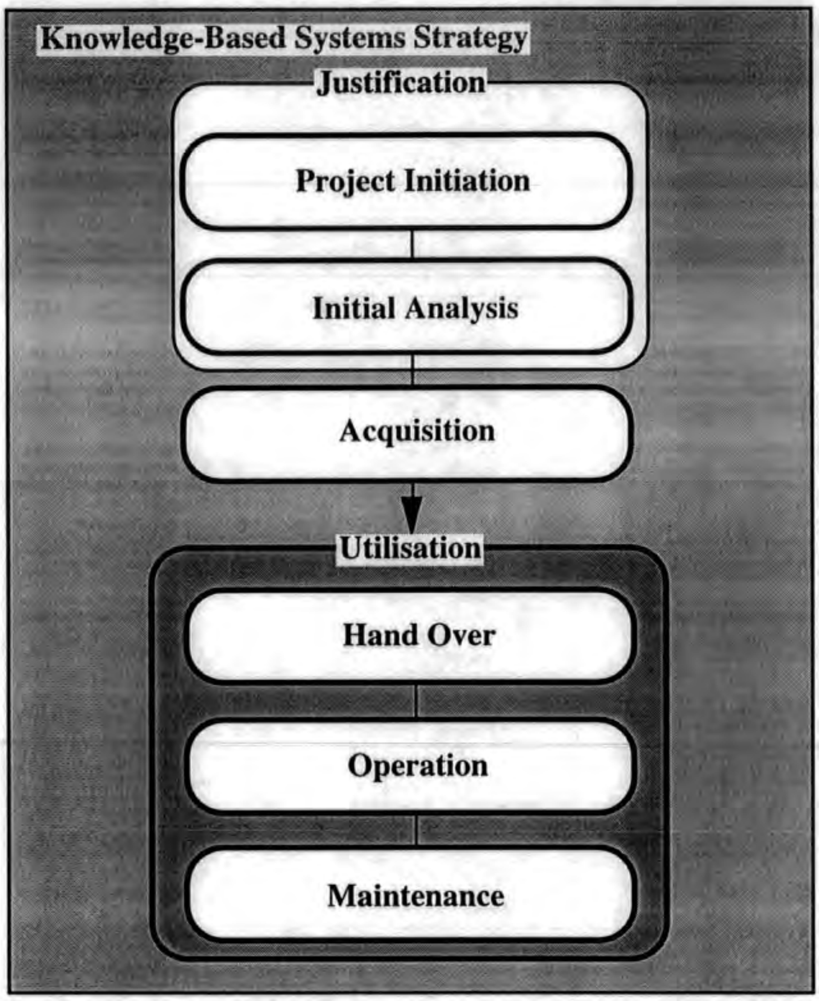


Figure 2.1: Top-level context model of utilisation

Each stage of the utilisation model has associated with it a set of entities. These entities are classified as activities, roles or influencing factors. All these entities are linked together via labelled arcs. The labels are used to show the type of action that should be taken or can be expected for a given entity. The arrow on each arc shows the direction of influence. Each of the individual stages contain links to either the previous stage or the next stage. These links indicate that at any given stage it may be necessary to go back to the previous stage of the model or alternatively, the current stage is complete and the next stage can begin. These links provide a sequential flow when first establishing a system. However, they allow movement to the previous stage if problems are encountered.

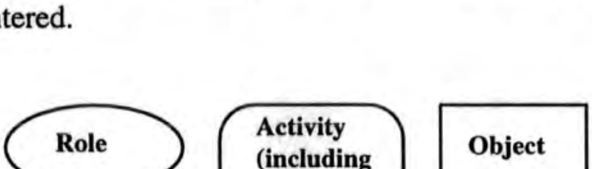


Figure 2.2: Entity key

2.2 Four Stage Utilisation Model

The following subsections describe the activities that compose the four stages of utilisation that we have defined. After we have discussed the four stages of utilisation, we shall examine the roles of people who are involved in the four stages.

2.2.1 Acquisition

Acquisition is the process by which a system is obtained, it is the first phase of utilisation since you can not use a system until you have acquired it!. The method adopted is dependent upon a number of issues, e.g. the organisation, its needs, the availability of skilled people. This stage in the utilisation model in shown below in figure 2.3.

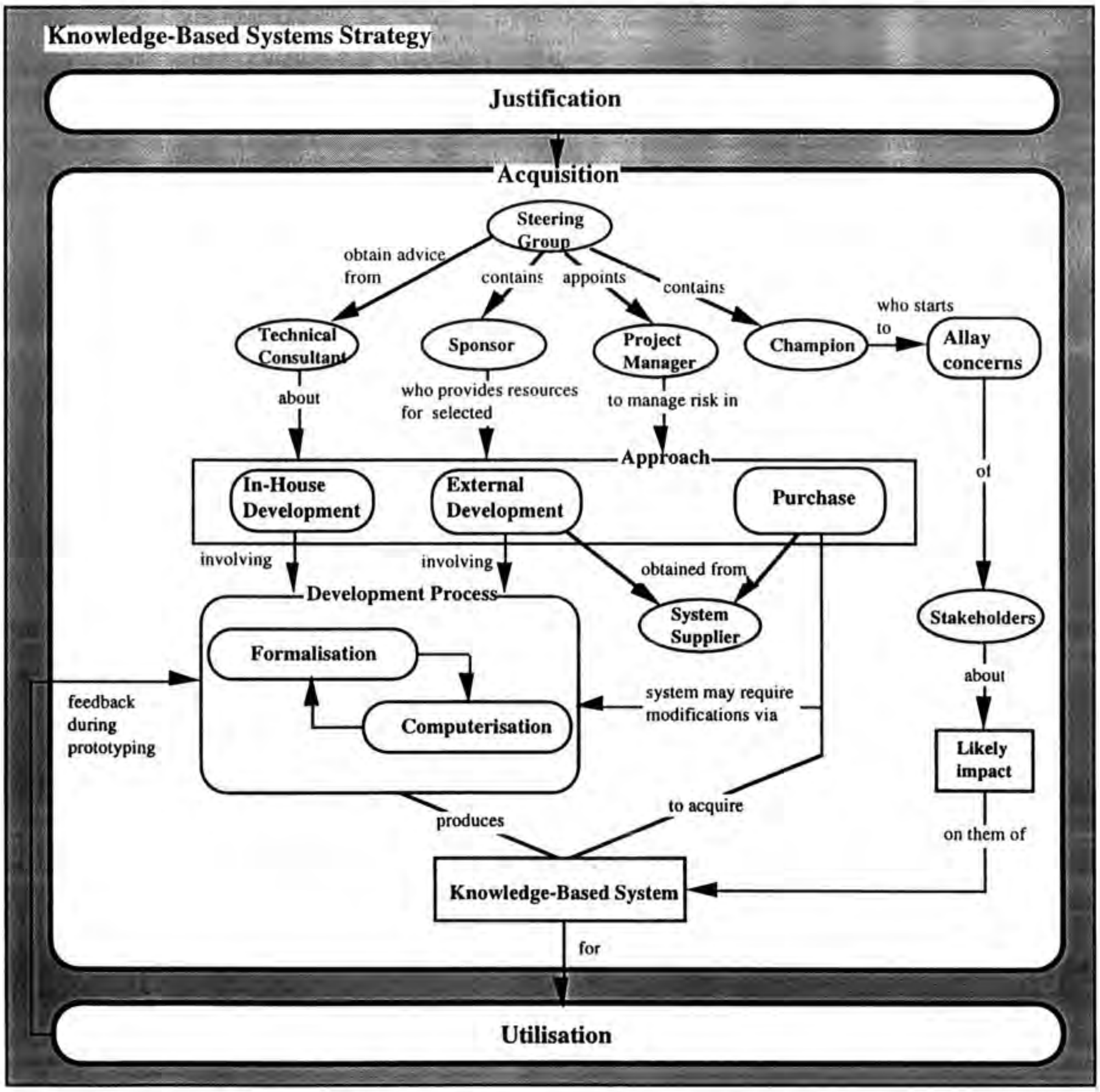


Figure 2.3: Model of system acquisition

Acquisition needs to address three questions (assuming that it has already been decided that a knowledge-based system is needed), namely,

> Does a suitable knowledge-based system already exist?
> If not, do we develop it in-house?
> or do we get it developed elsewhere?

If the answer to the first question is no then a system has to be developed either in-house or externally. The decision is influenced by whether several different systems are to be developed and whether the necessary skills already exist in-house. Development of a system involves issues highlighted in (Oldham, Hather et al., 1993; Oldham, Hather et al., 1993). A number of other methods can be used to develop a system, e.g. KADS (Hickman et al, 1989), Gemini (Montgomery, 1988). If a system already exists, it still may require modification to meet the exact needs of the users. It is up to the sponsor to ensure that resources are available for this process (Leonard-Barton and Kraus, 1985).

Once the decision has been made to acquire a knowledge-based system, whichever acquisition route is adopted, the champion should begin to allay any concerns that the stakeholders may have about its likely impact on them. These concerns may arise from fear of the unknown, lack of information, rumours and misinformation, perceived threats to core skills, competence, status or power base, reluctance to experiment, fear of failure or looking stupid, low trust organisational climate or strong peer group norms (Plant, 1987). These concerns can be addressed by involving the stakeholders as early as possible and keeping them fully informed as to what the system is intended to do, how it is likely to affect them and when the utilisation phase is likely to start. This activity should continue in different guises until the system is fully operational (Main and Oldham, 1993).

2.2.2 Handover

As the name suggest, handover is the process by which an organisation takes control of a system. It is the process by which control of a system is passed onto the users and their management. Figure 2.4 represents this stage in the utilisation model.

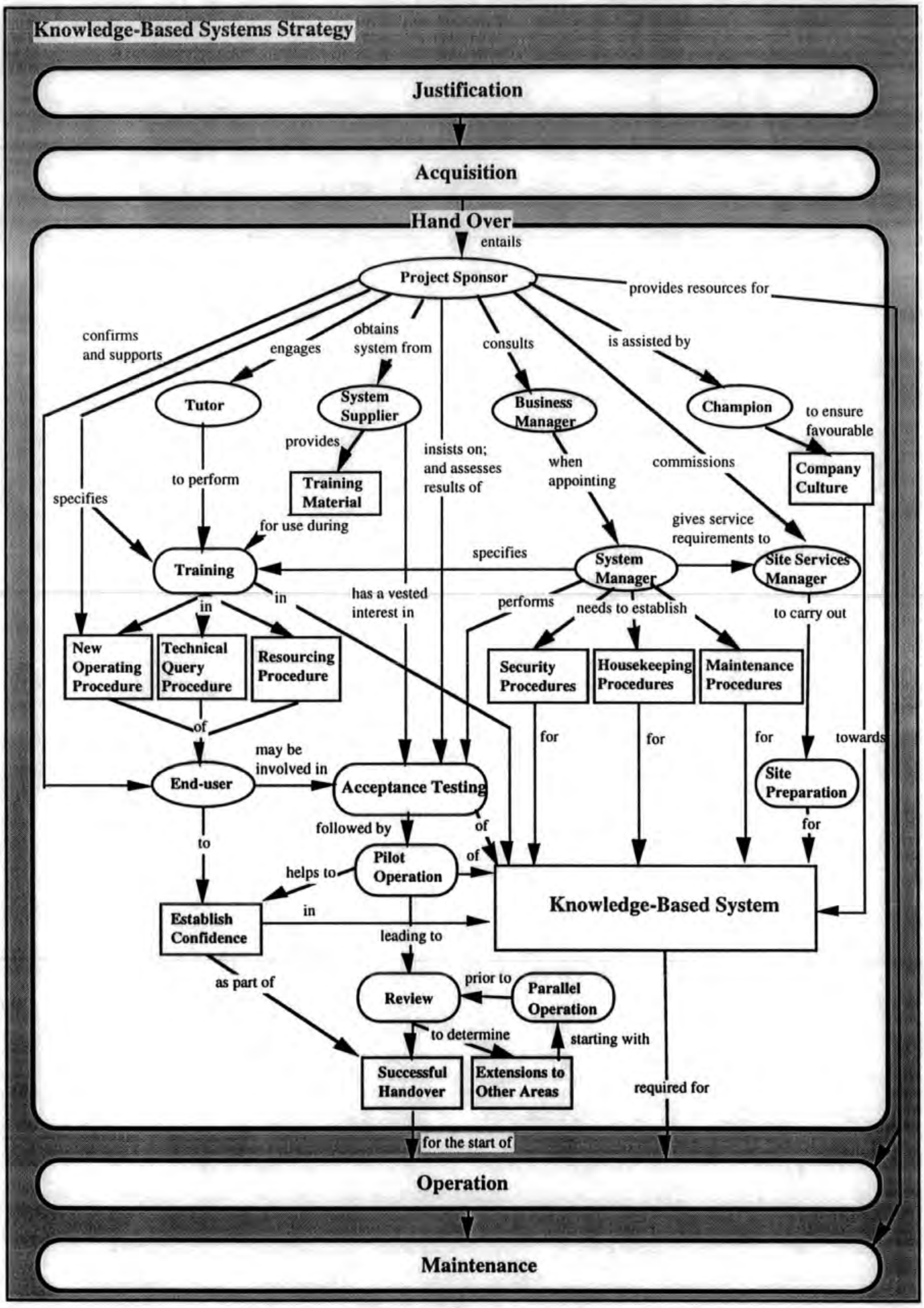


Figure 2.4: Model of handover

During handover the overall responsibility for the system transfers from the sponsor to the business manager while day-to-day responsibility changes from the project manager to the system manager. Shaw states that " at the corporate level, the consequences of introducing a knowledge-based system should be thought through and preparations made to handle any disruption that this may cause, for example, organisational or strategic effects or changes in working at a personal or technical level" (Shaw, 1990). Gaining acceptance of new systems by all the users has proven to be a particularly difficult area and one that needs special attention (1993).

One aspect of a company which can have a significant influence on the success or otherwise of handover is the culture. This term is used to describe the attitude prevailing in a business unit to the adoption and exploitation of new technology. If the corporate culture is geared to the adoption of relevant technology, the integration of a knowledge-based system into working practice may be easier than if the corporate culture favours only tried and trusted methods. Corporate culture is affected by the attitudes and experiences of senior management. It is therefore necessary to ensure that, if a knowledge-based system is to be introduced, senior management must be clearly aware of the benefits, costs and risks associated with the system.

One of the main activities of the champion is to ensure that the corporate culture is receptive. Keen (Keen, 1985) considers the barriers that may hinder the implementation of a new information system. To overcome these, the champion needs to be aware of not only the formal organisation structure but also the informal communication and power networks (Krackhardt and Hanson, 1993). Knowledge of these will help to ensure that the champion convinces the true influencers of the desirability of the system so that they become favourably disposed towards it. Leonard-Barton et al advocate an implementation team which combines a mix of authority levels with continuous involvement. They recommend that, as well as the sponsor, champion and project manager, the team should include an integrator to manage conflicting priorities and mould the group through communication skills (Leonard-Barton and Kraus, 1985).

Before full operation can start, the system must be installed properly into the working environment. This entails preparing the site and establishing procedures covering security, housekeeping and maintenance.

2.2.2.1 Site Preparation

Depending on the type of environment in which a system is to be located, it may be necessary to prepare the site. This preparation may include the installation of communication and power cables, provision of sufficient space to locate the computer physically, installation of appropriate signs, for example, warning that a system should not be switched off or moved. The amount of preparation required will be specific to each system and each site. The site may also require facilities such as fire-proof safes to keep copies of the system and knowledge-base protected in case of catastrophe. If a system is purchased rather than developed then hardware may need to be allocated.

Having prepared the site, it is necessary to provide the consumables that a system will require, e.g. printer paper and ribbons, monitor cleaning equipment, diskettes, disk boxes and error reporting sheets. These resources help in the day-to-day operation of the system.

2.2.2.2 Security Procedures

During handover, a detailed security policy should be established, although at present it is still unclear as to what constitutes such a policy (Sennett, 1990). Any security procedures relating to a system should not unreasonably interfere with the operation of that system. Walters et al (Walters and Nielsen, 1988) state that security procedures are necessary to ensure that information held within a system is not intentionally or accidentally modified, deleted or accessed by unauthorised people. Hence it can be seen that security procedures need to consider two main aspects, namely unauthorised access to the system and unintentional modification.

Preventing unauthorised access requires the identification of the user and their access rights to the various parts of the system. If a system is to be used over a network, then additional problems can arise, e.g. hacking via the network, availability and monitoring of remote access. Passwords provide a convenient method of providing some security against unauthorised access. If a system is to be used in a location which may lead to unauthorised access, measures should be taken to ensure system integrity, e.g. use data encryption algorithms to hamper unauthorised duplication or access, lock the computer away when it is not being used, remove the hard disk with the knowledge-base on or only issue the system on removable diskettes.

To avoid unintentional modification, the system needs to contain sufficient functionality to limit a user from altering information held in the knowledge-base (unless he has appropriate access rights). Several protection mechanisms exist to stop unintentional modifications, e.g. double checks on actions taken, access rights and read only access to the knowledge-base. However safe-guards against accidental changes are critical in environments in which users are unfamiliar with the system's capabilities. If the security features do not exist then users may introduce (unintended and often unknown) inconsistencies into the knowledge-based system. To help prevent the users from altering the knowledge-base, it may be desirable to compile the knowledge-base and make the maintenance part of the system separate (O'Leary, 1990).

In addition to protecting the software, it may be necessary to protect the hardware from theft. In 1992, more than £90m of computer equipment was stolen. This has forced companies to start physically locking the machines away or to desks to deter the thieves (Evans, 1993).

2.2.2.3 Housekeeping Procedures

During handover, procedures must be established for managing the system on a day-to-day basis. The procedures should cover when incremental and full backups should occur, who should perform them, where they should be stored, who should have access to them, how they should be managed, what resources are required daily/weekly/periodically and how to obtain the resources particularly consumables etc. System backups act as an insurance against any system failure. It is assumed that the system manager will establish these procedures, in conjunction with the business manager.

2.2.2.4 Maintenance Procedures

Maintenance is an essential part of the lifecycle of a knowledge-based system. This process ensures that a system will continue to operate effectively throughout its planned life. In order to carry out maintenance, it is necessary first to identify the need, i.e. maintenance to fix a problem or enhancement of the system. End-users are in the position to identify problems with the system, e.g. bugs in the software or required features, and domain experts can identify changes in the knowledge. Hence it is necessary to have a method by which either the end-users or domain experts can contact the maintenance personnel to initiate maintenance of the system, such as a pro-forma to report any problems located within the system to the system manager for authorising appropriate action. The pro-forma should provide sufficient information for the maintenance personnel to replicate the actions that brought about the problem under investigation. The maintenance procedure should contain a quality plan which sets out the steps to be taken to ensure that any changes do not adversely affect the quality of the system. The maintenance procedure should also clarify who is responsible for the system and who is responsible for the knowledge.

2.2.2.5 Education and Training

For effective operation of a system, it is necessary to educate the managers in the basic concepts of a knowledge-based system and hence what the system can and cannot do. Managers need to be aware of what benefits can be expected, what the costs are etc, so that they do not unreasonably criticise the system or its users due to unrealistic expectations. Education should take the form of presentations or small reports.

There also need to be proficient users who understand the purpose and capabilities of the system. Thus training should be based on clearly defined operating procedures. This should also increase the confidence of the users in the system and enable them to derive the most benefit.

Training can take a variety of forms, e.g. on-the-job, formal training courses or interactive video courses. Each form of training is suited to a particular need. For example, on-the-job training allows the trainee to learn while actually performing the task. Interactive video can offer an attractive method of training when compared to formal training courses where there are many people who require training, as users are able to be trained on-site and training can be fitted in when the users have sufficient time. In addition, interactive video allows the trainee to progress at his/her own rate rather than at the rate of the course (Palmer, 1988).

The training will often make use of material provided by the supplier which should complement the user manual. Even so, technical queries may arise during operation of the system and so a procedure should be established by the system manager to cater for them. This procedure may require the creation of a help desk if there are sufficient systems in use to justify it, otherwise the system manager may take on this role. Whoever does it will need an in-depth understanding of the system and so may require more detailed training than the users. This training should be sufficient for the system manager to set up housekeeping and maintenance procedures as described above.

2.2.2.6 Acceptance Testing of the System

Before a system commences operation, acceptance testing should be undertaken to ensure the system meets the specification originally agreed with the sponsor and the business manager. To help in this process, there should be a set of acceptance criteria and test data (obtained from the requirements specification). Any faults found need to be corrected by the development team before the system is released to the users. The following list contains some of the criteria that can be applied (McDermid and Rook, 1990) -

- Acceptance test results
    - satisfaction of software requirements
    - demonstration of suitable performance

- Software product packages in a deliverable form
- Installation notes and trained installers
- Acceptable manuals for user, operation and maintenance
- Training course and trained lecturers

It is on satisfactory completion of the acceptance tests that the business manager starts to assume overall responsibility for the system.

2.2.2.7 Pilot Operation

When the system has passed the acceptance tests, it can be used on a limited scale by users selected by the business manager. This pilot operation offers several advantages. It acts as a beta test as proposed in (Maus and Keyes, 1991). The users should be encouraged to comment freely on the system without any adverse repercussions. They should identify areas where further improvement of the system is desirable, e.g. user interface, task reasoning, changes to logic, detail of information, or areas where problems exist within the system (Walters and Nielsen, 1988). This process of allowing the user to comment on the system helps in establishing the system in the domain, establishing the robustness of the system and confirming appropriate functionality.

During pilot operation, any existing systems and procedures should continue to be used in parallel with the new system. This provides an independent check on the output and ensures that complete reliance is not placed on the system until it is well proven. As confidence in the system increases, the group of users can be increased gradually until the business manager decides that the existing procedures can be discontinued.

2.2.2.8 Review

A review should then be undertaken to determine whether the use of the system should be extended to other areas of the company. A similar process to that in the first area should be followed until parallel operation has been discontinued in all the designated areas. Handover is then deemed to be complete and full operation commences.

The decision to extend the use of the system to other areas may be influenced by the one-off costs. These are the costs incurred during acquisition and handover, namely purchase and installation costs. Purchase cost relates to the resources required to acquire the system. Installation costs refer to the resources required during the handover stage of utilisation, e.g. provision of cabling, training time, time to become proficient and time required to use the system. The handover review provides an ideal opportunity to compare the actual costs with the anticipated costs.

2.2.3 Operation

Figure 2.5 shows the activities and roles that are involved in the operation of a system within the working environment of the end-user. Management performs a key role in the use of a knowledge-based system by making the integration of the system into the corporate environment possible. It also helps to ensure that the system will be used effectively and that the necessary resources are available. The company culture should be such that the users have a secure environment and that the introduction of new technology will not affect their status or value to the organisation (Walters and Nielsen, 1988; Alger, 1990; Shaw, 1990). The important activities are now discussed.

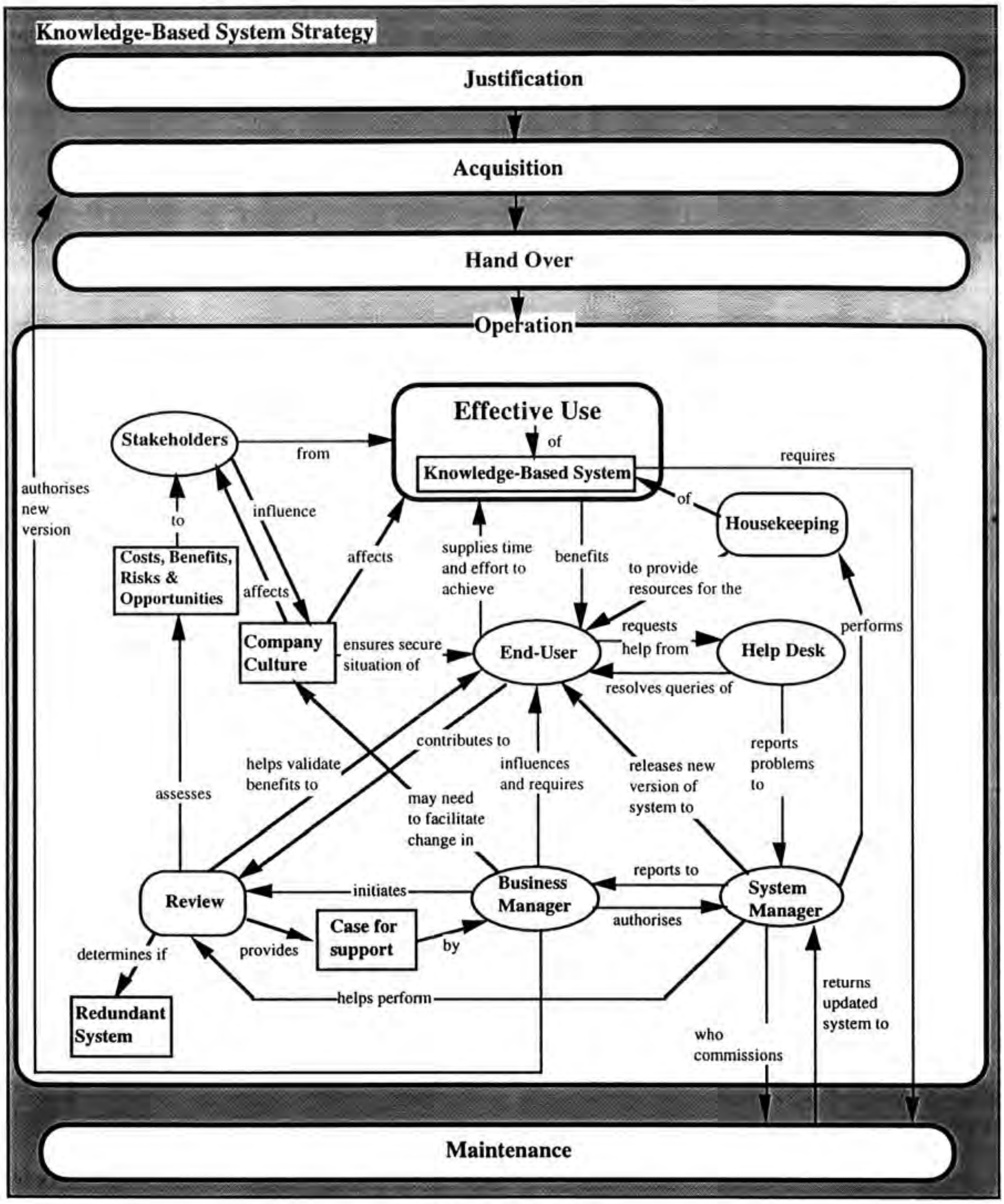


Figure 2.5: Model of operation

2.2.3.1 Effective Use

The ultimate goal of acquiring and operating a knowledge-based system is to achieve effective use of that system so that the desired business benefits are achieved. Effective use depends on a large number of factors. Two activities that influence these are housekeeping and system review.

2.2.3.2 Housekeeping

During normal operation, the housekeeping procedures established during handover should be followed. These tasks provide the users with a system that will be usable when it is needed. It is the responsibility of the system manager to either perform these tasks himself or delegate someone else to perform them.

2.2.3.3 System Review

During operation, there should be a regular review of the system. The review needs to establish how well the system is operating and if there are any problems. Clegg et al have proposed a comprehensive set of questions for this purpose covering equipment and working conditions, usability, job quality and performance, and organisational aspects and effectiveness (Clegg, Warr et al., 1988). For the review to be effective, a measure of task performance before the system was introduced should have been established. The business manager should be involved in the review as he will wish to know how the system is affecting the business. Furthermore, he is in the position to authorise any resources that may be required if problems are found. The review process also allows the end-users to justify the use of a system to management, thus helping to ensure its continued use.

The review needs also to identify if the knowledge-based system has reached the end of its life (Grisona, 1987). This is assessed on several criteria including significant alteration to the domain task, fragmentation of the knowledge and/or software making maintenance increasingly difficult, the product or process which the system covers no longer needs to be supported and the availability of better solution platforms. Examples of systems near the end of their useful lives are described in (Bennett and Carr, 1991).

In order to provide the case for continued support to the business manager, the review needs to identify the costs, benefits and risks that have accrued from the use of the system during operation. A brief discussion of some of the costs, benefits, risks and opportunities that can be expected now follows.

Utilisation Costs

Utilisation costs are made up of one-off and recurrent costs. The one-off costs are considered during the handover review.

The operational review will monitor the recurrent costs which are those incurred during operation and maintenance. During operation, a system will incur running costs such as consumables (e.g. disks, printer paper and cartridges) and additional hardware (e.g.

new machines, tape backup units and printers). During initial operation, as users become familiar with the system, it is possible that the system will impair their performance of the task and hence increase costs. This should reduce as the users become more proficient in the use of the system. The final costs that can be expected relate to maintenance. These costs include upgrades to hardware and the operating system, support of the knowledge-based system (e.g. help desk), additional knowledge formalisation when required and further training of the users (e.g. new users may arrive or existing users may require more detailed knowledge).

Resources have to be made available to ensure the effective use of the knowledge-based system. A number of resources may be temporarily diverted from being directly involved in the domain task, e.g. personnel unable to work due to training and sources of knowledge (reference manuals) being used to verify information provided by the knowledge-based system.

Utilisation Benefits

A company can expect to receive a large number of benefits from the introduction of a knowledge-based system (Walters and Nielsen, 1988; Shaw, 1990). These benefits can be broadly categorised into the following - infrastructure, personnel, efficiency/productivity and external competitiveness. The expected and possible benefits under each section are now discussed.

Infrastructure

Once a knowledge-based system has been developed, the domain knowledge is represented in a formalised manner. In formalising the domain task, the method of performing that task may be optimised and hence altered. By creating a knowledge-based system, it should provide access to the best expertise available for the domain task modelled within the system (Walters and Nielsen, 1988; Shaw, 1990). It also provides a representation for a code of practice for the performance of the task. In addition, the domain knowledge is preserved within a company and will not be lost due to retirement or staff leaving.

Personnel

A knowledge-based system frees a domain expert from routine or mundane tasks allowing him to investigate unresolved problems or enlarge the sphere of expertise. It also allows less skilled personnel to perform part or all of a domain task, hence improving the use of scarce resources, i.e. allowing the domain expert to perform more important tasks. In addition, the knowledge-based system can provide a useful tool to assist in the training of personnel.

End-users can expect to receive a number of benefits such as the ability to consult an 'expert' at any time when any problems arise, provision of reference material and reduction in the time required to perform a task by getting it right first time. The knowledge-based system can act as a checklist for the user when performing the domain task, e.g. ensuring all factors are examined when carrying out a certain activity. In addition, a knowledge-based system can often provide a second opinion as to the best solution to a given problem.

Efficiency / Productivity

A knowledge-based system can allow a company to improve its throughput and timeliness by formalising how the domain task should be performed. By creating a knowledge-based system which represents the best practice, it should be possible to make better decisions, improve performance by using, if appropriate, the advice presented by the system. The knowledge-based system can also improve equipment utilisation by reducing the number of operations that need to be performed. In certain applications, a knowledge-based system provides an effective method of preserving and recording knowledge about the actual operations performed on a component, e.g. the number of repairs made to a given product. The system also promotes a greater understanding in the user of the domain task and the knowledge required to perform that task. Overall a knowledge-based system provides a structured approach to the domain task and allows quality and consistency to be introduced into the performance of the task (Shaw, 1990).

External Competitiveness

Knowledge-based systems can sometimes provide a prestige image within the company's market. A company that uses these systems can be seen to be at the forefront of technology in an attempt to provide better services to its customers. By the use of a knowledge-based system, a company can ensure that there is an increase in reliability and less risk involved with its product(s). A knowledge-based system allows new activities and products to be developed, since resources can be diverted to new projects rather than having to maintain old ones. If a company's product is seen to be effective and there is excellent after sales service resulting from the use of a knowledge-based system, then it is possible to increase product penetration into the market (Shaw, 1990).

Utilisation Risks

Associated with the use of a system are a number of risks. The level of risk will vary from system to system. Risks may include loss of skills, total reliance on the system, inability to maintain a system to meet changes in the task, incorrect advice from the system leading to problems in performing the task and users becoming unwilling to use the system after pilot operation. The review process should anticipate such risks and formulate possible solutions where necessary.

Opportunities

If the potential end-users have not used computers previously, a system will provide an opportunity for them to acquire new skills. As they become more proficient in using the system, their productivity will increase, thereby offering an opportunity to raise throughput. Having successfully implemented one system, it may be possible to identify new opportunities within the business where similar systems can be employed. Once a technology has been shown to work effectively and generate benefits, it should make the justification and development of new systems easier.

2.2.4 Maintenance

To ensure that a system is used on a regular basis, it must be maintained (Brown and Van der Berg, 1990). The need for maintenance can stem from alteration to the domain task, the emergence of new or refined knowledge or the detection of any errors or bugs within the system by the end-users or domain experts. The other aspect of maintenance is that of the user skills. This entails training new end-users and updating existing end-users including the provision of a help desk. Maintenance thus ensures that the system will continue to operate correctly throughout its operational life. Figure 2.6 shows a model of the maintenance process with the activities and roles involved.

Maintenance can take the form of updates to the system to remove problems or extensions to the system's functionality. The software environment under which the system runs may also contain as yet undetected errors which could affect the operation of the knowledge-based system, hence maintenance is required to remove these errors when detected. (Walters and Nielsen, 1988; Hollnagel, 1989). At present, most knowledge-based systems have not been in use long enough for maintenance to be an important issue (Maus and Keyes, 1991). However, one notable exception is XCON (DEC's configuration system). This package has had to be maintained as new hardware and software options have become available in order to meet the changing market. Clearly maintenance will become increasingly more important in the future (Chorafas, 1992).

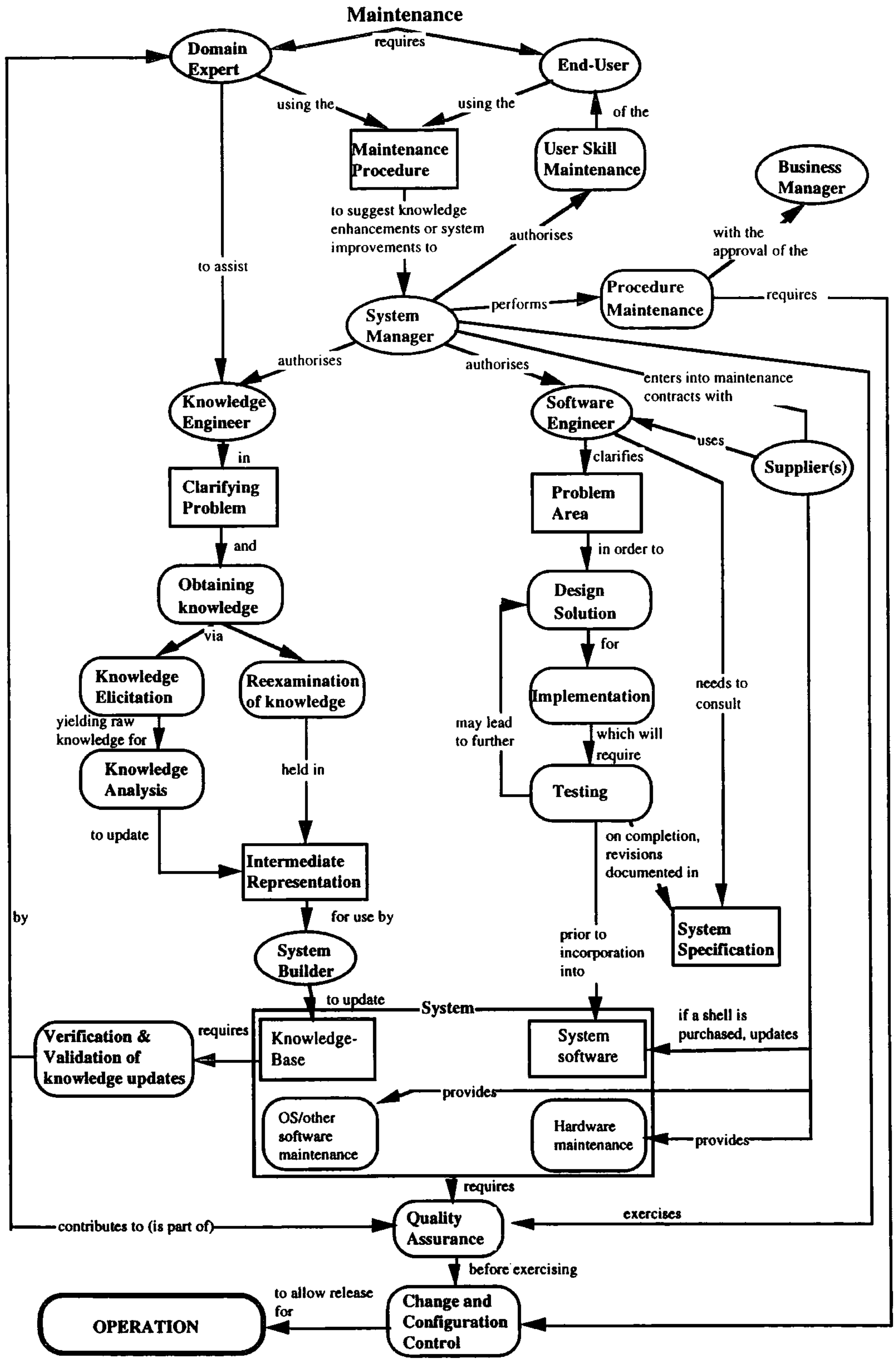


Figure 2.6: Model of maintenance

The process of maintenance can be broken into three distinct sections, namely knowledge, software and hardware. A brief discussion now follows of each of these sections. In each case, any associated documentation should be maintained so that it accurately reflects reality. If a system was purchased then the system supplier may be responsible for the maintenance of both the knowledge and the software.

2.2.4.1 Knowledge Maintenance

This involves the identification of any omissions or incorrect advice provided by the system. If problems with the knowledge are identified then it may be necessary to elicit, analyse and encapsulate new knowledge from a domain expert. This form of maintenance may be required due to changes in the domain, changes in operating procedures or changes in the law (Walters and Nielsen, 1988). To aid knowledge maintenance, it is possible to detect omissions or inconsistencies within a knowledge-base through the use of a number of algorithms, e.g. regression testing, problem-dependent monitoring or rule firing-order variation (Rich, 1987). However, these algorithms tend to be relatively slow, inefficient and require a large amount of processing time (depending on the size of the knowledge-base) to test the knowledge-base for possible problem areas. A more viable option is to provide a method of tracing the reasoning of the system through the knowledge-base, i.e. what rules have been fired and why they have been activated.

Figure 2.7 represents a model of the knowledge maintenance process. Based on the information received from the help desk and elsewhere, the system manager decides which areas of knowledge require attention. An expert acting as the knowledge supplier provides the new knowledge to the knowledge engineer who formalises it into an intermediate representation for encapsulation by the system builder. Other experts acting as knowledge verifiers can then validate the new knowledge. However, if they disagree with the new knowledge then the system manager will need to arrange a meeting between them and the knowledge engineer in order to reach a consensus and determine what knowledge should be encapsulated. If the new knowledge constitutes a significant update, it should be verified in the intermediate representation form before the system builder encapsulates it. Chorafas refers to knowledge maintenance as knowledge sustenance to reflect the need of the system to be fed with new knowledge as it becomes available (Chorafas, 1992).

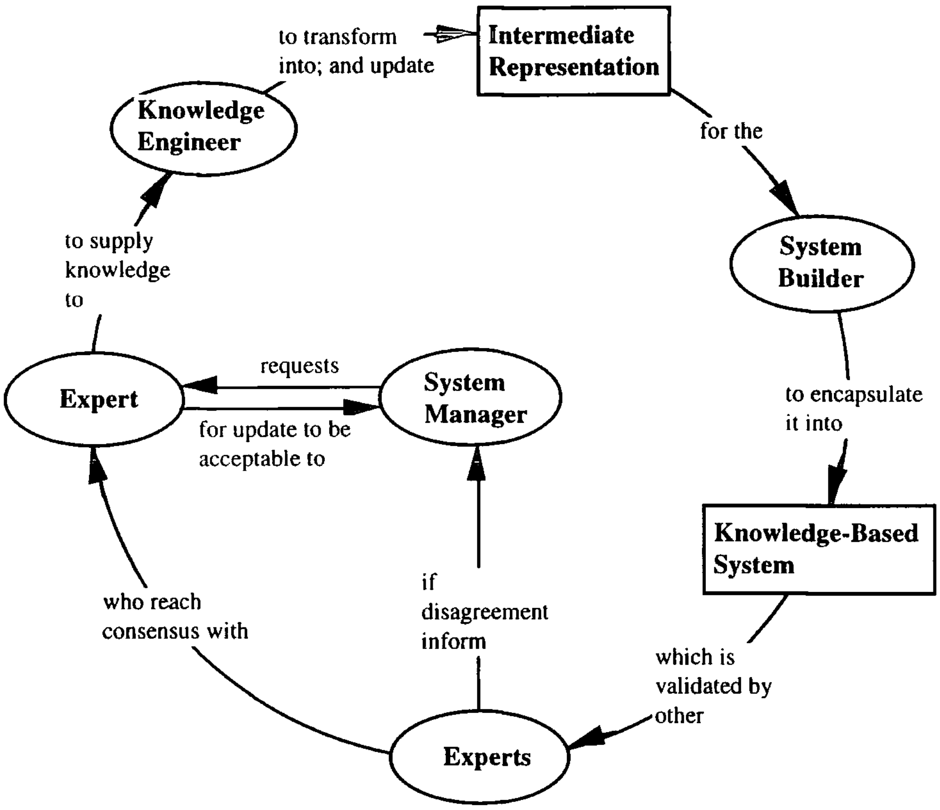


Figure 2.7: Model of knowledge maintenance process

2.2.4.2 Software Maintenance

One definition of software maintenance is :

> Software maintenance is the modification of a software product after delivery to correct faults, to improve performance or other attributes, or to adapt the product to a changed environment (ANSI/IEEE, 1983).

Three type of software maintenance can be distinguished, namely, corrective (removal of faults), adaptive (a new version of the operating system or existing program) and perfective (a change in the requirements of the users) (Bennett, Cornelius et al., 1991). It can therefore take three forms. In increasing complexity, these are removal of a function, modification of the internal operation or the user interface where the one does not affect the other, and finally, modification of both the user interface and the internal operation where there is mutual interaction. Maintenance of the user interface can account, on average, for 37% of the maintenance effort (Myers and Rosson, 1992). The first task that needs to be performed is the clarification of what the problem is. A solution should then be designed and implemented. The software engineer may need to consult and update the system specification during the maintenance process. After carrying out software modifications, the system should be tested to ensure the modification works correctly, as there is a 20-50% chance of introducing another problem (Brooks, 1982).

The software can be divided into two classes - that developed in-house and that developed externally. The latter will include the operating system and may also include other software with which the system interfaces. Maintenance of the software would usually be carried out by the corresponding supplier. The decision to update from one version of an operating system or package to another will depend on a number of factors, such as, cost, upward compatibility, additional functionality and company policy. If a system is part of another system, then problems may occur in ascertaining where maintenance is required, e.g. is the knowledge-base at fault or the other system?

2.2.4.3 Hardware Maintenance

All computer programs have to run on some form of hardware platform. It is possible that during the life-cycle of the system, new and faster versions of the hardware platform become available and a system may be expected to be able to operate on them. Computer hardware is usually reliable, but maintenance will be required if it breaks down. If the business is dependent on the system being available at all times, i.e. it is essential to company operations, consideration should be given to back-up hardware and a maintenance contract guaranteeing a short response time. In addition, if the power supply proves unreliable or the environment in which the system is to operate contains high voltage equipment, an uninterruptable protected power supply may have to be provided.

2.2.4.4 Quality Assurance

Quality assurance is necessary to ensure that any changes made to the system are of a suitable level of quality so as not to reduce the effectiveness and reputation of the system. In particular, it should ensure that any changes to the knowledge are correct and do not affect other parts of the system (Bennett, Cornelius et al., 1991). This activity should be performed by the system manager and domain expert and follow the quality plan in the maintenance procedures. Reviews are commonly used for quality assurance. They require detailed testing of the system using a number of techniques, e.g. structured walk-throughs, regression, white box and black box testing.

2.2.4.5 Change and Configuration Control

Change control is the process by which the system manager ensures that an updated system is ready for release in a controlled manner to the users. Change control can be seen to act at two levels, i.e. system and support facilities. Bennett et al (Bennett, Cornelius et al., 1991) propose that the following five activities should be performed to exercise change control of the system -

1) Select the highest priority problem for solution
2) Reproduce the problem (if there is one)
3) Analyse the code (and system specification if there is one)
4) Design the changes and test
5) Carry out quality assurance

The system manager needs to exercise configuration control on the support facilities. This will involve keeping track of who has copies of the system, which versions of the software work together and on which hardware platforms etc. In addition, the system manager would need to install new versions of the system and inform the relevant people (the help desk and the business manager). If the operating procedures have changed then end-users need to be informed and possibly retrained.

2.3 Personnel Issues

The following section discusses the various roles that need to be performed during the acquisition and utilisation phases of a knowledge-based system's life cycle. Figure 2.8 is a Venn diagram showing in which of the phases different roles are involved. A role appearing in the intersection of two or more circles implies that it is involved in the phases represented by each of those circles.

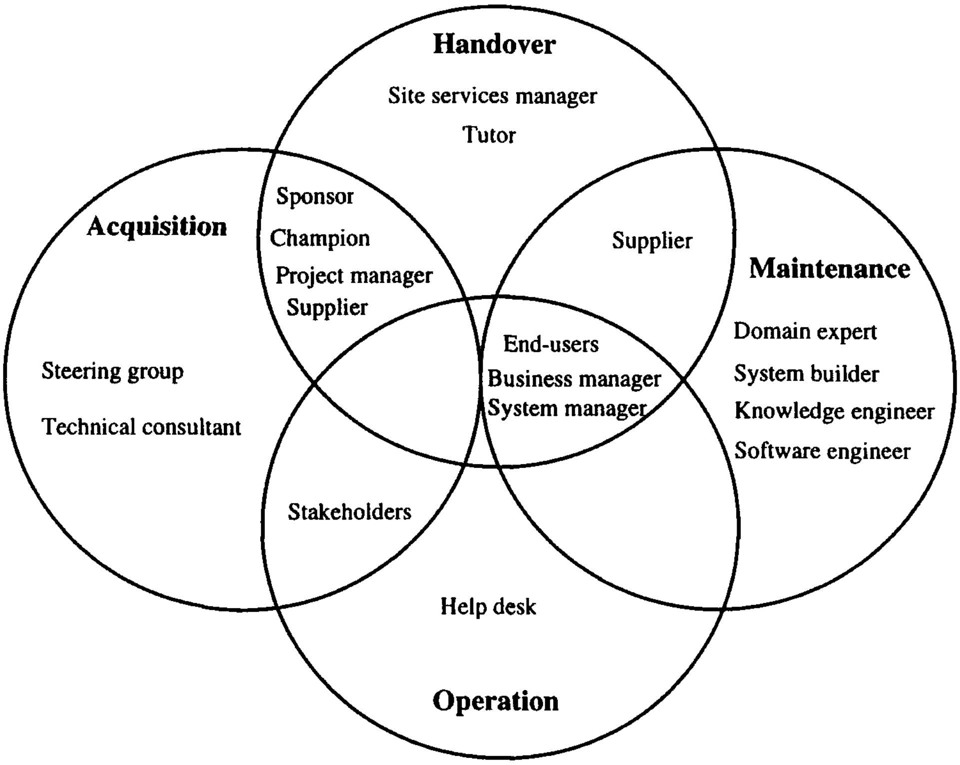


Figure 2.8: Roles involved in utilisation of a knowledge-based system

A discussion of all the different roles now follows in alphabetical order.

Business Manager

The business manager manages the people and functions who use the system (Main and Oldham, 1993). The role of the business manager alters with the different phases of utilisation. During handover, he is responsible for safeguarding the interests of the users. The business manager will require an acceptance test of the system before he is convinced that it should go into full time operation. Ideally, the business manager should take on the role of the operational champion of the system as he will then actively promote the use of the system. During operation, the business manager needs to review the system to ensure that it is producing the desired benefits at the expected costs. Furthermore, the review enables the business manager to gain user comments to see where further improvements can be made (which may involve the acquisition of a new version of the system). It also allows an assessment of the new operating procedures to ensure that the users are following them.

Champion

The MICIM consortium state : "a champion is a person, reasonably highly placed in the company's structure, who will fight for and defend the project in the face of any opposition. Without a champion, in today's harsh business climate, most projects will founder. They strongly recommend that you do not embark on a project without someone to take this role. Furthermore, if a champion does not emerge without any prompting, you have the wrong project" (1993). Thus, the champion should be a salesperson, diplomat, and problem solver for the innovation (Leonard-Barton and Kraus, 1985).

Domain Expert

During maintenance, if new knowledge has to be added, then domain experts must be available to act as the source of that information or to validate it after it has been encapsulated into the system. The domain expert may also be an end-user of the system (Walters and Nielsen, 1988).

End-Users

Main (Main and Oldham, 1993) has distinguished two classes of end-users, namely, direct and indirect users. Direct users are those people who use the system as part of their job. They must be convinced that the system will be of direct benefit to them if the full potential of the system is to be realised. Indirect users benefit from the use of the system but do not use it directly. An example would be where the system produces some results at the behest of the direct user who then passes them on to the indirect user so that the appropriate action can be taken based on the information therein (Main and Oldham, 1993).

Clearly the direct users are far more important than indirect users as far as achieving effective use of the system is concerned. A direct user should possess a number of characteristics such as willingness, proficiency in using the system, and familiarity with the system.

The willingness of a user to use a system will depend on the user's attitude and ability, and the quality of the system, i.e. does it help the user without demoting his/her position? This willingness appears to be increased by the reputation of the system "as word of the system spread to the field engineers, we began to get requests for additional copies of the system" (Kearney, 1991). Furthermore, to promote the use of a knowledge-based system, the system must be carefully integrated into the domain and must not threaten the end-user or intimidate him.

The level of familiarity a user has with the system will affect the user's view on the system's usefulness. If the user has good knowledge of the system, it is more likely he/she will find the system useful (Edmonds, Candy et al., 1990). During acceptance testing, the attitude of the users toward the knowledge-based system should be identified as this plays a role in the utilisation of the system and hence familiarity with it. It is necessary to establish the user's perceptions of the system, i.e. ease of use, helpful advice, system capability, acceptance of recommendations of the system by the user, improved performance and anticipated versus actual benefits, as these will have a direct influence on a user's familiarity with a system. In addition, the user's expectations should be identified, i.e. does it meet the user's expectations, is the quality of advice sufficient, is the organisation receiving as much benefit from the system as anticipated? (Walters and Nielsen, 1988).

Help Desk

The help desk role may be filled by an individual or a group. The help desk provides a first point of contact for requests for help and offers support in the form of information or actions to the day-to-day operations of the system (Dearden and Bridge, 1993). The help desk is able to log the queries and pass this information onto the system manager who can then decide if the end-users need training or the system requires maintenance.

Knowledge Engineer

A knowledge engineer is primarily employed to elicit the required knowledge from a domain expert to create the knowledge-base. The knowledge engineer may be required to help maintain the knowledge held within a system, since it may be necessary to elicit, analyse and formalise extra knowledge from domain experts if any omission or problems are found (Kidd, 1987; Walters and Nielsen, 1988).

Project Manager

The project manager oversees the administrative details and manages the risk during acquisition and handover. During handover, the project manager oversees the acceptance test and pilot operation of the system. He ensures that the necessary administrative procedures are created and in place before the start of pilot operation. If any problems are located, then he is responsible for ensuring a solution is found. During pilot operation, the project manager begins to relinquish control of the system and passes the responsibility onto the system manager.

Site Services Manager

The site services manager is the person responsible for providing the services that maintain and enhance the fabric of a site, e.g. repairing and installing new wiring, installation of office furniture, replacement of faulty lighting etc. The site manager may be involved in handover in order to provide the facilities required by the knowledge-based system, e.g. network cabling, new power sockets and ruggedised equipment where the system is to be used in an environment unsuited to computers. This manager may also take on the role of health and safety officer to ensure that the equipment and its installation conform to the latest regulations and that the ergonomics of the workplace will not cause any hazards such as repetitive strain injury.

Software Engineer

Software engineers are involved in the implementation of the knowledge-base and the knowledge-based system. The software engineer should possess the necessary skills required to alter the functionality of the system, i.e. programming skills, testing skills etc. If a system was developed using a software shell, then it may not be necessary to identify the software engineer. However, it is still necessary to identify the system builder and the person or people with the necessary knowledge of the shell to help perform maintenance (Walters and Nielsen, 1988).

Sponsor

The sponsor is usually a fairly high level person who makes sure that the project receives financial and manpower resources and who is wise about the politics of the organisation. (Leonard-Barton and Kraus, 1985). The sponsor is the person ultimately responsible for acquiring the system and ensuring that the business manager takes over that responsibility during handover. As part of this, the individuals in the two roles should agree on the appointment of a system manager and tutors. They should also agree with the system manager on the siting of any services and the acceptance test procedure.

Stakeholders

Stakeholders are people who have a vested interest in the acquisition and use of a knowledge-based system, e.g. business manager, other managers, end-users, employee representative, system manager and domain expert. In the limit, the shareholders of the company are stakeholders as they have a vested interest in whether the system increases the profitability of the company. Although the overall effect of the system should be beneficial, it could have a detrimental impact on some stakeholders and provision should be made to lessen the negative aspects.

Steering Group

The steering group is responsible for making the decision on how and where to obtain the system. In addition, it is responsible for addressing any concerns of the stakeholders as to the anticipated effect of the system and so prepare the way for a trouble-free introduction of the system.

System Builder

This role requires a person to have detailed knowledge of how to add new knowledge into the system or modify existing knowledge without introducing undesirable side-effects. The system builder may also be required to assist the domain expert in verification, validation and testing to ensure that no inconsistencies have been accidentally included into the system (Main and Oldham, 1993).

System Manager

The system manager assumes operational responsibility for the system during handover and is then responsible for authorising and exercising control over maintenance. The system manager should be given sufficient authority by the business manager to authorise the necessary resources for maintenance.

During handover, the system manager should establish the necessary procedures for the operation of the system, i.e. maintenance, security, housekeeping, technical query and user resource requests. In addition, the system manager needs to specify what facilities the site service manager needs to provide for the system. The system manager also needs to ensure adequate acceptance testing of the system so that it meets the desired requirements.

During operation, if any problems are found within the knowledge-based system, they should be communicated to the system manager who can then decide whether to authorise maintenance to occur. If maintenance does occur then the system manager should oversee the maintenance process and exercise quality assurance and change control on the system (Bennett, Cornelius et al., 1991).

System Supplier

The system supplier is responsible for providing a system that meets the requirements of the steering group. Depending on their decision, this can be either a complete system or the associated software and, possibly, hardware.

Technical Consultant

During acquisition, technical consultants supply the steering group with the necessary information to help them make the decision on whether to develop a system in-house, use an external agency or purchase an existing system.

Tutor

As mentioned previously, it is necessary to train end-users in how to use the system and any new operating, technical query and resourcing procedures. Training can be provided by specialised training personnel. The tutor should have detailed knowledge of the system in order to be able to pass the necessary information onto the end-users. It is therefore necessary for the tutor to use the system to gain sufficient knowledge to train the intended users. In addition, he should be able to present and explain concepts and actions clearly, otherwise the end-users may not understand what is being presented to them sufficiently well to use the system effectively. As well as providing the initial training during handover, the tutor should train any new users and, if necessary, provide refresher courses as part of user skill maintenance. The tutor should provide special training for the system manager whose needs differ from those of the end-users as he needs in-depth knowledge of the complete system.

2.4 Summary

A model for the utilisation phase of a knowledge-based system's lifecycle has been defined. We have divided utilisation into four stages, namely acquisition, handover, operation and maintenance. The model defines the activities, role and influencing factors that can be expected.

To ensure that a knowledge-based system is used effectively, four main phases need to occur. Operation must be preceded by an effective handover from acquisition and be supported by adequate maintenance. Associated with each phase are several issues that need to be considered. Behind each issue are many factors. Research into a number of these issues appears to be limited.

In the next chapter we will describe the method we have adopted by which we gained practitioners' views as to issues affecting the operation of KBS, which helped in the validation of the model presented in this chapter.

3. Methods for Experimental Design and Model Validation

3.1 Introduction

As we have shown in Chapter 2, the utilisation phase of a knowledge-based system contains a large number of activities, roles and influencing factors. The model we have developed provide a convenient method of showing the relationship between different activities and roles. Although a theoretical model for the utilisation of a knowledge-based system has been created, it is necessary to validate it with practical findings. By examining how users interact with knowledge-based systems any areas that are seen as being of importance can be formally identified and the model refined.

Before we can examine the practical use of KBS, it is necessary to first establish the methods by which we are able to collect and analyse the necessary data. The following sections describe the current thinking about how to obtain and analyse behavioural data (which would need to be obtained if we are to examine the practical use of systems).

3.2 Research Methods

In order to carry out research on a given topic, it is necessary to make three assumptions. These are:

1. the researcher has clearly defined the required information,
2. the respondents have the required information, and
3. the respondents can access the required information under the research conditions. (Foddy, 1993)

It is essential that when undertaking a study, the researcher is aware of all the dimensions of the area he is investigating. It is them possible to focus attention on to the required aspects of the topic under investigation. The investigator needs to be aware of the assumption that respondents do possess the required information could be false. It is reported by Foddy, that a number of studies have been carried out that show this not to be the case, and that respondents have placed different emphasis/interpretations on questions (Foddy, 1993).

In order to perform practical evaluation of a system, it is necessary to adopt a framework by which to plan and perform any experimental work. Basili et al (Basili, Selby et al., 1986) propose a four stage approach to the evaluation task, i.e. Definition, Planning, Operation and Interpretation. Each of these four stages are further broken down into a number of activities. The definition stage deals with establishing the hypothesis that need to be tested, taking into account the motivation, the perspective, the object (its purpose), the domain and the scope of the project itself. The second stage deals with the actual experiment design, the criteria to be used to measure a hypothesis and the measures that can be used to assess the criteria. The third stage deals with the actual experimental work, from a pilot study (used to determine problems/weaknesses with the assessment method), actual experimental work and finally the analysis of the results. The final stage proposed deals with the interpretation of the information obtained, i.e. the use of a evaluation framework, extrapolation of results and the degree of impact they have.

Pfleeger has published a number of papers on the best approach to adopt when attempting to evaluate software (Pfleeger, 1994). The approach suggested is based on six steps, namely:

- conception
- design
- preparation
- execution
- analysis
- dissemination and decision-making

The first step deals with identifying what it is you wish to learn and the definition of the goals of the assessment. The second step deals with the design of formal hypotheses that you wish to test. In addition, formal designs of the experimental work is also carried out at this stage. The preparation stage ensures that all necessary resources are available for the experiments, i.e. necessary software, personnel etc. Once the preparation stage is complete, the actual experimental work can be carried out. During this stage it is necessary to ensure that there is consistent treatment of each subject to allow sensible comparison of results. During the analysis stage, results are organised to make sure they are valid and useful. Statistical analysis can then be used to determine if the results support or refute the hypothesis defined earlier. The final stage deals with the dissemination and documentation of the results, thus allowing repeat experiments to be performed (if required), and to provide structured information for future use, e.g. support material for decision making. (Pfleeger, 1994)(Pfleeger, 1994)

In the following sections we will build on the ideas briefly described in the previous paragraphs and explain in detail the approach we have adopted for the evaluation of knowledge-based systems.

3.3 Investigation Using Case Studies

There are a variety of methods that can be used to undertake research. These include experiments, surveys, histories and the analysis of archive information. (Yin, 1984). Each strategy has its own advantages and disadvantages depending on the following:

the type of research question
degree of control on the events being investigated
focus on contemporary rather than historical phenomena

In general case-studies provide the best method when attempting to investigate contemporary phenomena within in some real-life context, where the investigator has little control over events. The type of questions to be asked also affect the decision to use a case study as the means of investigation, i.e. if we require and explanatory response from a subject, then a case study approach is more appropriate (Yin, 1984).

The degree of control over actual events will affect the selection of history, case study or experimentation as the means of investigation. Histories are the preferred strategy when there is no access or control possible. Case studies allow direct observation and systematic interviewing and are able to deal with a variety of evidence, e.g. documents, artefacts, interviews and observations. A formal definition of a case study has been provided by Yin. A case study is an empirical inquiry that:

> "investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used".

The final strategy is experimentation. This requires the investigator to manipulate behaviour directly, precisely and systematically.

In order to produce a case study it is necessary to follow a set of pre-specified procedures. The following section, describes a number of issues that need to be taken into account when developing the case study and interviews.

There are five components to formulating a case study, namely:

1. a study's questions
2. its proposition, if any
3. its unit(s) of analysis
4. the logic of linking the data to the propositions; and
5. the criteria for interpreting the findings.

According to Yin, "the case study strategy is most likely to be appropriate for 'how' and 'why' questions, so the initial task is to clarify precisely the nature of your study questions in this regard". Thus, it is necessary to decide if the questions that need to be asked are appropriate for use in a case-study. A description of data collection is provided later on in this chapter.

The second component of a case study relates to the propositions of the study, i.e. what entities are to be studied. In a number of case studies, propositions may not be appropriate since the study may be 'explorational'. However, every exploration should have a purpose. Instead of propositions, the design for exploratory study should state this purpose, as well as criteria by which an exploration will be judged successful.(Yin, 1984).

Defining the unit of analysis is a major problem. In the classic case study, a 'case' may be an individual. In each situation, an individual is the case being studied, and the individual is the primary unit of analysis. (Yin, 1984). Information about each relevant case would be collected, and several such 'cases' might be included in a multiple-case study. The definition of a unit of analysis (and therefore the case) is related to the way the initial research questions have been defined. For example, to study the utilisation of a application, the primary unit of analysis is the user(s) of the system to be studied, and the propositions would relate to aspects of the system.

The fourth and fifth component of a case study represent the analysis of the data. One approach that can be adopted is that of 'pattern-matching' proposed by Campbell, where several pieces of information from the same case study may be related to some theoretical proposition (Campbell, 1975). Additional analysis techniques are described later in this chapter. The final component of a case study, that of, criteria for interpreting a study's findings if difficult. According to Campbell, it is hoped that the patterns found in the data are suitably contrasting so that the findings can be interpreted in terms of comparing rival propositions (Campbell, 1969).

3.4 Nature of Qualitative Data and Methods for its Capture

Qualitative data consist of detailed descriptions of situations, events, people, interactions and observed behaviour; direct quotations from people about their experiences, attitudes beliefs and thoughts; and excerpts or entire passages from documents, correspondences, records and case histories. In order to elicit this kind of information open-ended narratives can be used. These allow a subject to express his own views without attempting to fit program activities or peoples' experiences into predetermined, standardised categories such as the response choices that comprise typical questionnaires or test. This kind of quantitative measurement relies upon the use of instruments that provide a standardised framework in order to limit data collection to predetermined response or analytical categories. Qualitative measures describes peoples' experiences in depth. The extent of depth and detail will vary depending upon the nature and purpose of the study. These measures allow one to understand the world as seen by the respondents. Analysis of qualitative measures are longer, more detailed, more variable in content, analysis is difficult because responses are neither systematic not standardised. Furthermore, there are several limitations to open-ended questions, e.g. limitations related to the writing skills of respondents, the impossibility of probing or extending responses, and the effort required of the person completing the questionnaire. Therefore, the task of the qualitative methodologist is to provide a framework by which people can respond in a way that represents accurately and thoroughly their point of view about the world, or that part of the world about which they are talking - for example, their experience with a particular program being evaluated (Patton, 1980). To determine the most appropriate questions to assess a given topic, and to gain some precision in their formulation, it is desirable to perform a literature review (Yin, 1984). This will allow focusing on the issues that are thought to be of significance.

When planing interviews, there are three main approaches that can be adopted. These approaches are described below.

1. Holistic approach - this strives to understand a situation as a whole. It assumes the whole is greater than the sum of its parts. It is insufficient to gather data about isolated variables, scales or dimensions. In contrast to experimental design (with a few selected and narrowly defined variables) a holistic approach is open to gathering data on any number of aspects of the setting under study in order to put together a complete picture.

2. Inductive approach - this attempts to make sense of the situation without imposing pre-existing expectations on the research setting. Qualitative design begin with specific observations and build toward general patterns. Qualitative design allows the important dimensions to emerge from analysis of the case under study without presupposing in advance what those important dimensions will be. It also allows an attempt to understand the multiple interrelationships among dimensions which emerge from the data without making prior assumptions about the linear or correlative relationships among narrowly defined, operationalised variables.

Inductive approach means that an understanding of program activities and outcome emerges from experience with the program.

3. Naturalistic inquiries - research setting is a naturally occurring event, program, relationship or interaction that has no determined course established by and for the researcher.

Having decided on the approach that is to be adopted, it is necessary to plan for the interviews and who will carry them out, the duration of the interviews and how the results will be recorded and analysed. There are three types of approach to interviewing, namely:

1. informal conversation interview,
2. general interview guide approach
3. standardised open-ended interview

Informal interviewing relies upon spontaneous questions being generated during the natural flow of an interaction. This form of interview is typically occurs as part of ongoing participant observation fieldwork. General interview involves outlining a set of issues (in any order) that are to be explored with each respondent before interviewing begins. This set of issues (or interview guide) acts as a checklist to ensure all topics are discussed during the interview. A standardised interview consist of a set of carefully worded questions, intended to take each respondent through the same sequence and asking the same questions. Flexibility in probing for more information is limited, but can be achieved depending on the interview and the skills of the interviewer. This type of interview reduces the likelihood of bias that comes from having different interviews for different people, including obtaining more comprehensive data from certain persons while getting less systematic information from others. Three major reasons for using standardised open-ended interviews -

1. the exact instrument used in the evaluation is available for inspection by decision makers and information users;
2. variation among interviewers can be minimised where a number of different interviewers must be used, and
3. the interview is highly focused so that interviewee time is carefully used.

3.5 Development of the Interview Tool

To aid the development of the interview structure and any questions, it is desirable to have the participation of the information users and decision makers during the development of the interview guideline. This will show them exactly what topics are to be addressed and what questions are to be used to assess each topic. This will help later to reduce the likelihood of any attack on the data obtained because questions were missed or asked in the wrong way. By making it clear in advance of data collection, exactly what questions will be asked, the limitations of the data can be known and discussed beforehand. When collecting and evaluating information from a group of people it is often helpful to minimise the legitimacy and credibility by carefully collecting the same information from everyone who is interviewed. A weakness of this technique, is to limit the flexibility of obtaining other information. It will also put constraints on the use of different lines of questioning with different people based on their unique experiences. Therefore, this will reduce the extent to which individual circumstances can be taken into account.

When developing a questionnaire to be used in an interview, issues relating to the types of question, sequence and wording of questions needs to be addressed. The following section gives a brief description of some of the issues that need to be considered.

Types of questions

When developing a set of questions to be used to elicit information, it is necessary to be aware of the type of questions that can be asked. A brief description of some of the question types now follows.

Experience/behaviour

These are questions about what a person does or has done. They are aimed at eliciting a description of experiences, behaviours, actions and activities that would have been observable had the observer been present.

Opinion / value

These are questions aimed at understanding the cognitive and interpretative process of people. Answers to this type of question show what people think about the world or about a specific program.

Feeling questions

These are questions aimed at understanding the emotional responses of people to their experiences and thoughts.

Knowledge questions

These are asked to determine what factual information the respondent has. The assumption, is that, there are certain things that are known, i.e. they are not feelings, opinions.

Background/demographic questions

These questions are concerned with identifying characteristics of the person being interviewed. Answers to these questions help the interviewer locate the respondent in relation to other people. Education, occupation, age and the like are standard background questions. They are distinguished from knowledge questions primarily because of their routine nature.

Sequence and wording of questions

The sequence of questions is not important. However, it is common to get background / demographic information at the start of an interview. It is desirable to break interview into sections. Each section focuses on a given aspect that is to be investigated. It is necessary to give a context to allow the respondent to focus his attention on the issue that is being investigated.

The wording of questions is an important factor in how the interviewee will respond. Questions act as stimuli for the respondent. For the purpose of a qualitative measurement, good questions should be at a minimum, be open-ended, neutral, singular and clear.

Closed questions and dichotomous (yes/no) questions restrict the ability of a respondent to express his own feelings/experiences. Rather they form a restrictive investigation of the domain. These questions, do allow some control to be maintained on the progression of the interview. Neutral questions do not force the respondent to have a fixed opinion, e.g. did you use SSADM?, would be better phrased as what design methods have you used?

It is necessary to ask singular questions, i.e. questions that investigate a single issue at any one time. Patton expresses that confusion and tension is likely to occur if singular questions are not used. Asking several questions at once can also cause the interviewer to lose control of the interview. Giving multiple stimuli may prompt the interviewee to give information that is irrelevant to the issue under investigation.

Clarity of the question is important. If questions are unclear then it can make the interviewee uncomfortable, ignorant, confused or hostile. By asking singular questions, it is more likely to make things clear and easier to understand. It is desirable to find out the terminology used by the respondents when referring to the program being evaluated. It is necessary for the interviewer to word questions in terms of the language used by the respondent (Patton, 1980). Being clear on what is being asked helps to develop the rapport between the interviewer and the respondent.

In addition to open-ended question, it is possible to use rating scales as a means of assessing actual and perceived behaviours. A rating scale is a measuring instrument that requires the assessor to assign the rated object to categories or continual that have numerals assigned to them. However, this form of question is open to bias, but can still provide valuable information when used correctly. There are a number of types of rating scales, i.e. category, numerical and graphic. Errors associated with this form of question include, errors from marking more severe or lenient, marking central options (i.e. the middle of the road). A rating scale does have a number of benefits including, ease of use by the observer, wide variety of applications, can be used with a large number of characteristics, can be used to aid in behavioural observations, such as interviews. (Kerlinger, 1979)

According to Foddy, when formulating questions it is advisable to adhere to the three rules proposed by Sudmand and Bradburn. These rules are:

- do not formulate specific questions until you have thought through the research question.
- write the research question down and keep it handy while formulating specific questions.
- keep asking, 'why do I want to know this?'

These rules will help to guarantee that the questions asked will be relevant to the researcher's goals. (Foddy, 1993)

3.6 Data collection and Analysis

In order to analyse qualitative data, it is necessary to have some sense of purpose and direction, i.e. what is the end result of doing an evaluation study?, what is it supposed to produce? There are no formal universal rules to follow in analysing interpreting and evaluating qualitative data. Analysis is the process of bringing order to the data, organising what is there into patterns, categories and basic descriptive units. Interpretation involves attaching meaning and significance to the analysis, explaining descriptive patterns, and looking for relationships and linkages between descriptive dimensions. Evaluation involves making judgements about and assigning value to what has been analysed and interpreting it.

When performing analysis, it is useful to bear in mind that its purpose is to provide useful, meaningful and credible answers to the evaluation questions of decision makers and information users. To be meaningful the answers provided must relate directly to the questions that have been asked, to be useful the answers must be understandable and clearly presented, and to be credible the evaluator must demonstrate that the perspective presented will hold up under careful scrutiny.

It is essential to perform the following when analysing the results of interviews:

3.6.1 Organising data

It is necessary to ensure that all interview responses are transcribed correctly and that any gaps have been rectified by further interview or reference to the original interview material. Ensure that copies of the data are made, as this is a unique source of information and can not be replaced easily if lost or marked incorrectly during analysis.

3.6.2 Data analysis

There are a number of analysis methods that can be employed to identify patterns in the data obtained. A brief description of some of these techniques, now follow.

Content Analysis

A process of labelling the various kinds of data and establishing a data index is the first step in content analysis. It is essential to have a classification system, otherwise chaos will ensue (Patton, 1980). This analysis helps when trying to establish patterns and themes within a particular setting or across cases. The data index is generated by the evaluator who selects a scheme by which information can be grouped together, e.g. group responses related to use of other computer systems.

Inductive Analysis

This is the process by which patterns, themes and categories, come from the analysis of the data. They emerge from the data, rather than being imposed on them before the data collection and analysis. Patterns derived from the data can be represented in two ways, namely indigenous and analyst-constructed typologies. Indigenous typologies are classification systems made up of categories that divide some aspects of the world into parts. This classification is based on the concepts used within the program being investigated. Analyst-constructed typologies require the analyst to identify variations and contracts in activities, participants and/or staff. This needs to be done with considerable care to avoid creating things that are not really in the data. To validate any of these analyst-constructs, it is possible to take the results back to the interviewees and ask their opinions.

Logical Analysis

Having generated the constructions during inductive analysis, it is possible to create cross classification matrices. This involves creating potential categories by crossing one dimension with another, and then working back and forth between the data and one's logical constructions, filling the resultant matrix. When using this method, it is easy for a matrix to manipulate the data and to force it into categories created by the cross-classification rather than using the matrix as a system of logically generated sensitising concepts to be tested on the actual data. For example, in matrix analysis, an empty cell (generated by crossing two dimensions) can sensitise the analyst to the possibility of a category of activity or behaviour that has been overlooked or that is logically a possibility in the setting, but has not manifested.

Process/Outcome Matrix

The linkage between process and outcomes is a fundamental issue in many program evaluations. To create a process/outcome matrix, major program processes or identified implementation components are listed on the left side of the matrix. Types and level of outcome are listed on the top. The contents of the cells created by the cross-classification of a program process and type of outcome, describes linkages, patterns, themes, program content or actual activities. that help understanding of the relationship between the process and the outcome.

Causes, Consequence and Relationships

It has to be noted that there is a fine line between data organisation and casual interpretation of data. It is necessary to qualify any statements made about causal links especially if they are based on speculation, conjecture or are hypothesis.

3.7 Validation and Verification

There are two parts to the issue of trusting the data, i.e. trust in the assessor's own confidence in his analysis, and presentation of results to allow others to verify and validate the findings for themselves. There are several major strategies for validating and verifying the results of qualitative analysis.

Rival Explanations

Once the patterns, linkages and accompanying explanations that have emerged from the analysis have been described, it is important to look for rival or competing themes and explanations. This can be done both logically and inductively. Inductively involves looking for other ways of organising data that may lead to different findings. Logical analysis involves thinking about other logical explanations and seeing if these can be supported by the data. When considering rival hypothesis, it is necessary to look for data to support these, rather than disprove them. Failure to find strong supporting data, gives strength to the original results.

Negative Cases

Closely related to the testing alternative explanations is the search for negative cases (Patton, 1980). Greater understanding of a pattern found in the data can be gained by considering the instances and cases that do not fit within the pattern.

Triangulation: reconciling qualitative and quantitative data

This is the process by which data obtained through qualitative methods is compared to that obtained through quantitative method. This is a difficult task to perform as it is highly likely information provided by the two methods will relate to different aspects of a given situation (Patton, 1980).

Design Checks: keeping methods and data in context

The method of data collection can bring distortion into the results obtained. It is therefore necessary to examine alternative approaches for data collection. There are three types of sampling errors, i.e. distortion in the situation that were observed, distortion introduced due to time period when sample taken, and finally distortion may occur due to the selectivity in the people who were interviewed.

Evaluator Effects

There are four ways in which performing the evaluation can impact on the results obtained. These are:

- reaction of the participants and staff to the presence of the evaluator
- instrumentation effects
- biases of the evaluator
- evaluator incompetence

Objectivity and Subjectivity

The qualitative analysis method is open to the acquisition of subjectivity. In order to reduce this, it is possible to use formalised methods for data collection and analysis. To further reduce the affects of subjectivity it is important to be factual about observations (Scriven, 1972). Guba proposes that to reduce subjectivity, data collected should be reliable, factual and confirmable (Guba, 1978).

Subject and Audience Reactions

Accuracy, fairness and validity of the data and the results obtained from its analysis can be gained by having the people used in the interviews examine the data and results to gain their reactions. It is reported in Patton, that the detail of analysis will affect the reactions obtained from the original subjects. (Patton, 1980)

Intellectual Rigor

There are no clear cut rules for maintaining intellectual rigor, rather it is dependent on the evaluator to revisit data and try to establish different patterns and justify his reasoning. (Patton, 1980)

3.8 Experiment Design

As we have mentioned earlier, experiments provide a means of formally assessing the relationships between various factors. This appropriateness of this method of obtaining behavioural information is dependent upon a number of issues. In order to carry out experiments, it is necessary to have someone act as an evaluator. This role is performed, in its simplest form, at two points in time, pre-test and post-test, and compares the treatment group to some control group on a limited set of standardised measurement treatment. Experimental evaluation works best when it is possible to limit program adaptation and improvement so as not to interfere with the rigor of the research design (Parlett and Hamilton, 1976) (Patton, 1980)

In experimental work, the investigator has to have manipulative control of at least one active variable. The following diagram represents the basic structure that is commonly used for conducting experiments. Two sets of parameters need to be identified, i.e. Important (A_f) and Less Important (B_f). If parameter $A_{f(n)}$ is important then improvement with $A_{f(n)}$ will produce a positive result. Parameter $B_{f(n)}$ should have no affect if it is unimportant. If parameter $B_{f(n)}$ does have an affect, then it can be assumed to be more important. Conversely, if parameter $A_{f(n)}$ has little or no affect, it can be assumed to be less important.(Kerlinger, 1979)

Group 1

Condition 1 Condition 2
$A_{f(n)}$ $B_{f(n)}$ ----------------------------> $A_{f(n)}$ $B_{f(n)}$
Improve system with
parameter $A_{f(n)}$

Group 2

Condition 1 Condition 2
$A_{f(n)}$ $B_{f(n)}$ ----------------------------> $A_{f(n)}$ $B_{f(n)}$
Improve system with
parameter $B_{f(n)}$

Two sets of experimental subjects are required, group 2 will act as a control to ensure that the set of parameters (B_f) do in fact have little impact.

In order to carry out experimentation work, the following steps based on work proposed by Patton should be carried out (Patton, 1980). As in pure experimentation, participants are randomly assigned to the treatment or control group. In-depth interviews are carried out with both groups to establish their current views. A second set of interviews are conducted after the participants have performed a set of defined exercises (these exercises are designed to give each subject the same level of experience with the system under investigation). After results have been obtained through the use of detailed interviews, content analysis can be performed separately on the data from the control and experiment group. The patterns found in the experiment and control group can then be compared and contrasted.

3.9 Summary

In this chapter we have described the methods by which qualitative behavioural data can be collected and analysed. These methods can now be used to gain a practical examination of the models we developed in the previous chapter. The following chapter describes the means by which the practical examination of the KBS models was performed and the results obtained.

4. Model Validation through Examination of Knowledge-based System Use

4.1 Introduction

Having developed a model of utilisation based on current literature, it is necessary to validate the model against practical experience of the use of KBS. To this end a case study was developed along the lines suggested in the previous chapter. The term 'case study' is used here to denote a practical examination of issues, rather than formal experimental work. The case study comprised a detailed structured questionnaire which was used to elicit a user's views relating to the issues identified in our model for a given KBS. A number of systems were examined as part of the case study. This allowed for a more detailed and comprehensive examination of issues affecting KBS use.

In order to explain how the case study was structured, used and analysed, a small sub-section (of the actual case study used) has been selected for detailed analysis. The procedure which will be described in the following section was applied to the whole of the case study. The main results of the case study are then presented.

4.2 Case study for the practical analysis of KBS use

In chapter 2 we described a model of KBS utilisation which we have developed based on current literature. This model contains a number of parameters (activities, objects and roles) that are believed to affect the use of a KBS. These parameters can be seen as the propositions that will form the elements to be examined within the case study.

4.2.1 Case Study Structure

The following structure was adopted when constructing the case study. The first section was used to obtain demographic information about a subject. The subsequent sections formed the main body of the case study. These sections contain the questions related to the propositions identified in the literature. A brief description of the sections of the case study now follows.

1. Personal Details of the End-user

   Identify the relevance of the person being interviewed to the task under discussion. Establish their expertise and experience within the domain.
2. Identification of the Knowledge-based System(s)

   Identify the knowledge-based systems that are being used in the user's domain and the user's familiarity with the systems.

3. User Issues

Establish the user's willingness to use the system(s), and their role in the use of the system under investigation.

4. Training Issues

Identify the amount of training provided and its effect on the use of the knowledge-based system.

5. Identification of the factors that influence the use of the system

5a Functionality

Identify what the system does for the user, the help facilities offered, the security features and features the user would like to have.

5b Robustness

Identify whether the system hangs up or breaks down and what (if any) are the recovery procedures. Determine how the robustness of the knowledge-based system affects the system's use and determine the effects of maintenance.

5c Human-Computer Interface

Identify the features of the human-computer interface that the user likes and dislikes, how the user interacts with the system and how information is displayed.

5d Confidence in the Knowledge

Determine if an underpinning methodology (a formal definition of the domain task showing when, where and how the knowledge-based system should be applied) affects the use of a system and identify factors that increase the user's confidence in the system.

5e Knowledge Issues

Identify the level of domain information held in the knowledge-based system (breadth and depth), any measures of performance to determine the usefulness of the information provided and determine if the advice provided is found useful by the user.

5f Maintenance Issues

Identify the maintenance features of the system, determine how the maintenance process is carried out and identify how, if the domain task changes, will the knowledge-based system be affected.

6. Environmental Considerations

Identify the role and mode of operation of the knowledge-based system and the effect (if any) of the physical environment on the use of the system.

7. Identification of cost/benefits of the system

Identify the various costs and benefits from the use of a knowledge-based system. In addition, identify how the domain task has altered as a result of the introduction and use of a knowledge-based system.

4.2.2 Structure of the Case Study Questionnaire

In order to carrying out the case study, a questionnaire was developed which contained a series of questions designed to test the propositions in our model of utilisation. These questions were structured so that a subject was required to examine each proposition in a structured manner. In the main, open-ended questions were used to ensure that a subject was able to express in his own words, his views on a given proposition. In addition, to help analysis, a set of rating questions were also used where it was apparent that a fixed scale of responses would produce the required results.

An extract of the case study interview now follows covering the area of the human-computer interface, more specifically, the method of displaying information to the user.

Proposition : Method of displaying information to the user.

Case study question

5.12 Please describe how any information from the operation of the knowledge-based system is displayed. (please describe the method/format of displaying information and the explanation facilities offered by the knowledge-based system)

5.12.1 Do you think there is a more suitable method of displaying the information ?

Yes *No - Go to 5.13*

5.12.2 Please describe how you would like the information to be displayed.

5.12.3 Why was the information not presented in this manner ?

4.2.3 Analysis of Case Study Responses

As mentioned earlier, a number of KBS were used with the questionnaire to gain an overall insight into the issues affecting KBS use. Although different KBS were evaluated, the same interview structure was used. It is not the system we are concerned with, rather the attributes of the system that make it useful or otherwise. Once a subject had complemented the questionnaire used to elicit his view on a system the results obtained were transcribed to make analysis possible. An extract of the transcription now follows.

Case study responses

1 The interviewee stated that the human-computer interface provides a simple to use menu based system to select the required operation. The interviewee did not know of any alternative methods of displaying information.

2 Information is displayed in the form of formatted text within a Clarion window. There are separate windows for Help, Advice and Questions. The windows can be displayed in a hierarchical fashion and can be selected from one another. The interviewee stated that there was no real alternative to this method of displaying information. The interviewee stated that user requirements does have an influence on how the system looks and operates. Users were involved in the specification of the system through discussion with the development team.

3 Information is displayed in formatted text and a series of menus and buttons to select options. The interface was not of real consideration to the interviewee, the final report was more important. The interviewee was unable to suggest any alternative methods of displaying information. The interviewee stated that the user needs to be involved at the development stage, to get his/her input to the specification of the system. In addition, user involvement will get him/her on-board and will keep him/her excited about the project and its development.

4 Information is displayed in a series of hierarchical networks and tables of data. At the time of the interview, the interviewees stated that a number of problems existed with the human-computer interface. These problems tended to be trivial, i.e. the need to change the colour of a particular box. The interviewees stated that it would be desirable to be able to have technical diagrams within the system to aid in the explanation of a task.

5 Information is displayed in a series of single screens with a keyboard operated menu bar to select a number of functions. The interviewee stated that there were no other suitable methods of displaying this information. However, he points out that he does not have any knowledge of other forms of output, e.g. window systems, mouse driven systems. It is necessary to stick to one format, i.e. window based system or DOS system so that a tool can be integrated into a suite of other tools for a engineer.

6 Information is displayed in windows, options are selected via menu bars. The interviewee stated that there are no other suitable method of displaying information and options.

Having obtained these results, it is necessary to determine any patterns that exist. The analysis of the results obtained from the practical examination of knowledge-based systems was directed toward the identification of issues that users saw as having the greatest impact. To this end, it was necessary to analyse each section of the questionnaire separately. Furthermore, it was necessary to sub-divide these sections into the specific issues that they covered. When analysing the answers provided to descriptive questions, the following factors were taken into account:

- detail of the answer provided
- experience of the subject
- identification of keywords related to the subject area

This required a value judgement to be made by the assessor, as to the relative merit of the answers provided. This value judgement allowed answers to be rated in an attempt to remove any bias that may exist on the subjects behalf.

When looking at scalar questions, a simple cut off point was established, it was deemed anything below 50% was seen as detrimental to the use of a system and any value above facilitated the use. By using this simple boarder line, quick comparisons could be made between answers. This boarder line was established by the scale used in the questions, since the possible answers below 50% dealt with negative aspects of system use, e.g. 0% = Unusable, 25% = problematic etc.

4.2.4 Case Study Conclusions

The following represent the conclusions that were drawn from the case study for the proposition of the method of display. The conclusions were drawn from detailed examination of the answers provided and from current literature. This involved rigorous assessment of the answers with relationship to the proposition being investigated. During this process it was paramount that no bias was introduced so as to gain a true representation of practitioners thinking.

Case Study Conclusion

A wide variety of output formats exist. The use of window-based interaction is increasing. Windows provide the user with the ability to interact with a variety of information sources at any one time. From the case studies, single windows are used to display information in the form of formatted text. If more information were required it may be desirable to use a multiple window-based system, e.g. a window to display advice information, a window for help information, a window showing where in the *system the user is. The information displayed within a window must be kept clear and concise. If possible and appropriate, it is desirable to include diagrams to help clarify the information displayed. Diagrams are able to display information in a more clear and easy to understand form rather than describing it by using text.*

Having reached these conclusions, it is then possible determine the impact the proposition has on the operation of the system. By performing similar analysis on all the propositions that have been identified, it is possible to construct a matrix which shows the impact of each proposition. It is then possible to determine, whether or not a given proposition can be manipulated and so be part of experimental work to formally determine their impact on the use of a system. An extract of the matrix is shown below (Table 4.1). The table is constructed using the following rule: an entry is defined as facilitating, if the answers to the case study was positive, otherwise an entry is defined as inhibiting if the answer tended to be negative. These ratings are based on judgements made on the answers provided by the subjects (as shown earlier).

Sec	Proposition	System						Lit Survey	Overall	Control
		SEAMS			Cell def	Dipl	QA			
		S1	S2	S3	S4	S5	S6			
5c	Method of displaying information	f2+	f2+	f1+	f1+	i1-	f1+	f2+	f2+ i3-	uD
	Features users like/dislike	f2+		f1+	f2+	f2+	f1+	f1+	f2+ i2-	Ud
	Method of selecting options	f2+	f2+	f1+	f1-	0	f1+	f2+	f2+ i2-	D

Table 4.2.1 - Matrix for the identification controllability

KEY

Degree of Influence + = Slight ++ = Medium +++ = High 0 = None
Direction of Influence + = Positive - = Negative
Parameter Values F = Facilitating I = Inhibiting
Controllability:

Controllability Label	**Table Value**	**Meaning**
Indirect Development Control	d	The system developer is able to influence the value of a parameter, but is unable to directly control its value
Direct Development Control	D	The system developer has direct control of a given parameter. He is able to take action to directly alter its value
Indirect User Control	u	The user is able to influence the value of a parameter, but is unable to directly control its value
Direct User Control	U	The user has direct control of a given parameter. He is able to take action to directly alter its value

Table 4.2.2 - Controllability of experimental factors

In addition to the facilitating and inhibiting factors of the case study, conclusions of the literature survey are also included. An overall facilitating or inhibiting factor can then be determined for each proposition. A judgement can then me made as to the controllability of the proposition, i.e. whether it is under direct or indirect control of the users or the development team. This value is an initial step toward the identification of parameters that can be controlled by the user.

Having performed the above analysis, it is then possible to establish the impact of a given proposition on the use of a system. The following example shows the likely impacts on the use of a system if the method of displaying information has a positive of negative affect.

Impact (none, slight, medium, high) (+ve or -ve)

Slight - Medium Positive / Negative

If the user finds the method of displaying information unreadable or confusing, then his view of the system will be adversely affected. It is necessary to display information in a clear and easy to follow format. Furthermore, information and progression through the system should be easily carried out by the user. A single format for screen layout and menu selection enables the user to gain confidence in the system.

if negative, solution

The users should be involved in the specification of the interface, since they will be the personnel who will have to use the system. By specifying how they would like the information displayed and the format of menu bars a system can be made to match their requirements. Once a system has been developed it is very difficult to alter the interface, hence it is necessary to involve the user during the development phase, rather than after the system has been introduced into the domain.

Having described the method used to obtain and analyse the practical use of KBS through the use of an example extract, the following section provides some of the more interesting findings of the work. A set of conclusions are then drawn from these findings.

4.3 Findings of practical use of KBS

The wide spread use of knowledge-based systems is still at an early stage, however, a number of systems are now being used in 'live' environments. The users of such systems are beginning to see the benefits from the use of these systems, e.g. reduced problems in handover between shifts, increase in productivity/reduced time to perform task, provision of a check list of activities. Several factors have been identified that influence the effective use of a system.

Costs and benefits from the use of a knowledge-based system need to be identified clearly. The users should be aware of the potential benefits that they can directly receive from the use of the system. Benefits to the business need to be identified before the development of the system to help persuade management to develop knowledge-based systems. By identifying potential benefits a user's willingness to use the system can be increased. The total cost of implementing and using a system need to be considered. The costs of using a system can include training of the users and consumables. The cost from a user's viewpoint will be the demand on his time and a possible loss of standing (this should be kept to a minimum). The benefits received by the users and the company/department should outweigh the costs of the system for the system to be cost effective.

It is necessary to establish the scope (breadth and depth) of knowledge within a system. Initial boundaries for the scope of a system should be established by the development team and domain experts. It may be necessary to alter the boundaries to meet the user requirements, i.e. novice users may require more detailed knowledge whereas experienced users may just require 'skeleton' information. The scope of the system will influence how useful a user finds the system. The scope should try to meet the overall requirements of the users and not the requirements of one user.

Robustness of the system has to be established otherwise a user may be reticent about using a system in case it breaks down or provides incorrect conclusions. The robustness of the system has to be established prior to the system being used in a 'live' environment. Testing should try to identify all errors, however, it is often impossible due to time, cost and complexity of a system to detect all the errors within a system.

The human-computer interface(HCI) has a major influence on the user's perception of the system (as it is the only part of the system a user sees). The HCI needs to be as simple to use as possible. It should present information in a clear and easy to read format. It is desirable to involve the users during the development of the HCI to determine the features that they like/dislike. The consistent use of function keys based on a user's experience of other systems may help in effective use of a system. Consistent key commands will require the user to be involved in the development phase of the system, or the development team to be aware of standard key commands, e.g. function key f1 for help information.

User confidence in the system has to be established to ensure the system will be used. Confidence can be increased by promoting use of the system by the users, providing a strict guideline(s) for when to use the system and allowing the users to determine if system provides correct results. If a user is a novice in the domain, then it is likely that he/she will assume that the system is correct, it is therefore essential that the system should be thoroughly verified, validated and tested by a domain expert before it is installed for routine use. Furthermore, if a user is a novice in the domain, the system should try to act more as a tutor rather than an advisor to help train the user in the domain task rather than just provide an answer, e.g. provide an explanation behind each step of the reasoning process.

It is necessary to provide the user with training which enables the trainees to use the system effectively and gain confidence in the system. Training can take a variety of forms. The training provided should provide the user with all the necessary information that is required to operate the system. The method of training adopted should be based on the type of personnel to be trained, their willingness and the material that they need to learn, e.g. if they are novice users of a computer it may be practical to provide a brief description of a computer system and then let them explore how to use the computer before attempting to teach them how to use the KBS. It is ultimately up to the person responsible for training to determine what method seems the most appropriate.

It is necessary to establish the ownership of the system and the knowledge-base(s) to aid the maintenance process. Maintenance is a fundamental task that has to be performed to ensure the continued use of a knowledge-based system. It is necessary to identify clearly how maintenance is to be performed. The system should provide facilities to aid in the maintenance process, e.g. text editors, consistency checkers, copy and paste facilities, delete facility and undo facility. Maintenance should be performed by the domain experts/users of the system as they are in the best position to determine what new knowledge/updates are required. The domain experts/users will require a methodology by which they are able to determine when and how to perform maintenance. The domain experts/users need to see the system as an essential tool in performing the domain task to ensure that the system will be maintained and provide continual help in that task.

The type of user and the anticipated system role will influence how the system is used. A system can adopt more than one role, e.g. assistant, advisor and tutor. The role of a system as an automaton has not been identified. The physical environment has a limited effect on the development and use of the system.

The users interviewed are mainly domain experts. However, it is still necessary to address the above issues irrespective of the users' status when establishing a system in a domain. It is ultimately up to the user whether he will use the system.

4.4 Overall Conclusions from the Case Study

The results of the case study seem to support the model we have proposed in chapter 2. The results obtained tended to indicate that the areas we have identified in the model do have an influence on the use of a KBS. The results appear to support our model and suggest that the activities, roles and objects we have defined do occur in a 'live' environment. The degree to which these activities, roles and objects impact the use of a system will form our experimental work. From the results of the case study we have also identified a number of potential parameters which can be used for experimentation these will be discussed later in the next chapter.

The case study has proved to be an effective means by which we have been able to validate the content of the model. It has provided an easy and convenient means of allowing practitioners in the field of KBS use to express their opinions on issues relating to system use.

4.5 Summary

We have shown how we have carried out a practical examination of the issues that are believed to affect the utilisation of KBS. The results of the case study have provided validation of our model. Furthermore, we have shown how the results of this examination have been analysed to identify the parameters that are believed to have the greatest impact on the use of KBS.

5. Experimental Examination of Factors

5.1 Introduction

In this chapter we will discuss the process by which parameters have been selected for experimental work. We will also describe how we intend to perform our experiments as well as stating the hypotheses we wish to test.

5.2 Experiment Design

In the previous chapter we discussed the process by which we validated our model. As part of the validation process we discussed how we were able to determine the degree of influence a given parameter had on the utilisation of a system. Although the method of analysis described in the previous chapter shows the degrees of influence that each proposition can exert on the utilisation of a KBS, it does not lend itself to the overall identification of the significant factors that affect the use of a system, or the relationship between them. In order to identify the significant factors, a form of parameter/entity relationship diagram has been used. This allows a strength to be assigned to the relationship between a parameter, such as the method used to display information and an entity, such as the user or development team.

The parameter/entity diagram was constructed based on the ideas presented in the previous chapter. As a starting point, the results of the literature review and case study data were used to establish the initial strength of a relationship. These strengths were then presented in the above format to selected subjects involved in the case study to determine if they agreed or disagreed with the strength of relationship. Depending on there views, the strength of relationship was modified accordingly. This process allows verification of the findings held within the parameter/entity diagram. The complete table is shown in Figure 5.1.

The concept of controllability is also introduced. In the ideal situation, this represents the parameters which would be investigated as part of experimental work. The higher the value associated with a given parameter, the greater the influence that parameter has over the range of entities. Therefore, the more desirable that parameter is for experimentation to determine its degree of influence. It has to be noted that a number of parameters, although having the highest ratings may not be controllable within an experimental situation. It was therefore necessary to make a decision as to which parameters could be easily controlled in order to carry out experimental work.

In the following sections, the process by which the proposed parameters are formally selected for experimentation is discussed. Furthermore, a set of hypotheses will be proposed for the experimental examination of the selected parameters and the approach adopted for their evaluation will be explained.

5.3 Experimental Approach

The main objective of the experimental work is to validate that the parameters identified as having a significant impact on the use of a KBS, in fact, do impact on the utilisation of a system. In order to do this, it has been necessary to carry out the following activities:

- parameter selection
- definition of a framework for performing the experiments
- selection of suitable systems on which to base the experiments
- select suitable subjects who will be the test subjects in the experiments

A brief description of the activities now follows.

Parameter selection

Having identified a number of parameters for experimentation it is necessary to select the most appropriate for experimentation. In a number of cases, constraints on resources, and the type of parameter will affect that parameter's ability to be assessed in experimental work.

Definition of the experimental framework

The experimental framework adopted has been developed based on the work described in the previous chapter. The experiment framework adopted requires two sets of subjects to perform the same task and record their responses in the same way. In order to achieve this, a set of tasks has to be created to allow a structured exploration of a system. These tasks, are designed to take a subject through a system in a structured and controlled manner. It ensures that all the subjects will have the same level of exposure to the system. Two task frameworks have been created, one for each of the systems selected for the experimental work. These frameworks have been verified and validated through several dummy experiments during their development. The frameworks provide a structured exploration of each system, and provide a subject with a set of real objectives that should be aimed for during the experimental work.

In addition to the task framework, a structured interview (constructed along the lines prescribed in the previous chapter) is used to gain the response of a subject as to the affect a given parameter has on his use of a system. The interview and framework have been validated through several dummy experiments. A copy of the interview framework is provided in Appendix A.

Selection of suitable systems

The systems that are to be used as the basis of the practical experiments are -

System A - A Cell Definition knowledge-based system
System B - A Manufacturing Control System Selection knowledge-base

These provide the necessary features and facilities for our experimental work. They contain sufficient features, functionality and knowledge to allow a full examination of our hypotheses.

Selection of suitable subjects

The subjects of groups 1 and 2 are to be made up from at least:

5 Graduate engineers
2 Experienced engineers
1 Domain expert

A significant factor in the selection of suitable subjects was their availability and willingness to participate in the experiment sessions.

5.4 Parameter Selection

From the outset it was evident that we would not be able to perform experiments to validate all the parameters that have been identified. However, it was possible to establish a proposed relationship between one parameter and the others identified. This proposed relationship is depicted in a parameter/parameter table shown in Appendix B. This table is based on the findings of the literature review and case study evaluations, and has been validated with independent practitioners who use knowledge-based systems.

It is evident from the parameter/parameter relationship table, that there exists a large number of potential relationships which require validation through experiments (there are a possible 3025 direct relationships). However, in order to perform all the necessary experiments it would require more resources and time than was available. Rather, it would be more appropriate and feasible to select those parameters with which we have most control over and examine the relationships between them (this limits the number of possible relationships to 289). The results of this analysis are shown in the Figure 5.1.

Relationships

Strong ● 9

Medium ◎ 3

Weak ○ 1

None

KEY

M = Management

U = User

D = Development

T = Tutor

O = Obvious

E = Experimental

▨ Primary Controllable

▧ Secondary Controllable

▩ Tertiary Controllable

READ

Entity → Parameter

Area	No	Parameter \ Entity	User	Other users (Less frequent)	Management	Malefactors	System manager	System maintainer	Operational champion	Tutor	Development team	KBS	Domain task	Controllability	Rating total
General Systems	1	Use of general computer systems	○	○	◎								○	M/U	6
	2	User likes/dislikes	○	◎								○			5
	3	Time required to become familiar								●					9
	4	Training in conventional systems	○	○	○					●				M/U	14
Type of KBS	5	Role of system	◎	○	○		●		●		●	●	●	U/D/E	50
	6	Demand for system	●	◎	●				●				●		39
	7	Familiarity with domain task	●	◎				◎			◎			E	18
	8	Involvement in domain task	●	◎	◎			◎							18
User Issues	9	Utilisation of KBS	●	●	◎		○	◎	●		○	●	●		55
	10	Familiarity with system (proficiency)	○	◎				●	○	●	◎	◎		U/E	31
	11	Willingness to use system	●	●								◎	◎		24
	12	Necessity to use system	●	◎	●				○			◎	●		34
	13	Manager attitudes	◎	◎	●				◎			●	◎		30
	14	Colleagues attitudes	○	◎	◎	○			◎			●			20
	15	User's role	◎	◎	●		◎					◎	●	U/D	23
Training Issues	16	Training in the use of the system	○	◎	◎		○			●				U	21
	17	Effectiveness of training	◎	◎						●					15
	18	Type and quality of training	◎	◎	◎					●	○	◎		O	24
	19	Duration of training	○	○	◎					●		◎		T	17
	20	Reasons for no training			●					◎		◎			15
User Requirements	21	Fit with user requirements	●	◎							●	●		U/D	30
	22	Functionality	●	◎							●	●	○	U/D/E	31
	23	Provision of system help	◎	◎							●	●		U/D	24
	24	Provision of explanation	◎	◎							●	●		U/D/E	24
	25	Response time	◎	◎							●	●		D	24
	26	Security features	○	○		●	◎				●	●		U/D	32
Robustness	27	Need for robust system	●	●	◎		◎					●		U/D/E	33
	28	How it was established	◎	○							●	◎		U/D	16
	29	User view on robustness	●	●		◎									21
	30	Error reporting	●	●	◎		●	○			○			U/E	32
	31	Passing comments	◎	◎	◎		◎				○			U	13
	32	Effect of maintenance	◎	◎			●	●				●			33
HCI	33	Method of displaying information	●	●				◎			●	●		D/E	39
	34	Features user likes/dislikes	◎	◎				◎			◎	●		U	21
	35	Method of selecting options	●	●				◎			●	●		D/E	39
Confidence in Knowledge	36	Need for methodology	◎	◎	◎		◎				◎		●		24
	37	Factors affecting user confidence	●	●	◎				◎			◎			27
	38	Method of increasing confidence			◎		◎		◎		◎				12
Knowledge Issues	39	Breadth of knowledge	◎	◎				◎			●	●		U/D/E	27
	40	Depth of knowledge	◎	◎				○			●	●		U/D/E	27
	41	How information is used by user	●	●	◎								◎		24
	42	Agreement of user on advice	●	●				◎			◎	●			33
Maintenance Issues	43	Identification of system maintainer			◎		●							U	12
	44	Maintenance features					●	●			●	●		U/D/E	36
	45	Maintenance procedure					●	●			●			U/D	27
	46	Alteration to operating procedures	◎	◎	●		◎						●		27
	47	Flexibility to cope with changes					●	●			●	●			36
Environment Considerations	48	Environment KBS used in	◎	◎	◎		●						◎		21
	49	Effectiveness of KBS	●	●	●	○	○	○		○	◎	●	○	E	48
	50	Mode of operation	◎	◎	◎		●					◎	○		22
	51	Access control	◎	◎	◎	◎	●							U	21
	52	Physical environment			○								◎	U/D	4
Cost/Benefits	53	Benefits from use	●	●	●			◎	●		◎	●	●		60
	54	Cost of use	◎	●	●			◎	◎		◎	●	●		48
	55	Measures of performance			◎										3
		Entity Total	234	204	141	19	120	80	53	67	168	238	100		

Figure 5.1: Ratings of parameters

The decision of whether a parameter was controllable or not was based on a number of factors, including:

- the ability to alter the value of a parameter,
- the amount of effort that would be required to alter a parameter,
- the amount of resources available for the experimentation work, and
- time constraints

The allocation of primary, secondary and tertiary controls was made through a process of careful selection and refinement (due to problems with modification of the systems/time constraints etc). A description of the experiment parameters now follows.

The following table contains the parameters that we have selected as being the most controllable. The 'important parameters' are those which are seen as primary controllable and the 'less important parameters' are those seen as secondary controllable. The two sets of parameters *Af* and *Bf* will be used as described in section 3.8 to perform our experimental work.

Important Parameters (Af)	**Less Important Parameters(Bf)**
Role of system	Familiarity with domain task
Familiarity with system	User role
Functionality	Fit with user requirement
Robustness of system	Provision of system help
Breadth of knowledge	Provision of explanation
Depth of knowledge	Response time
Method of displaying information (HCI)	Security features
Method of selecting options (HCI)	Error reporting
	Maintenance procedure

Table 5.4.1 - Experiment Parameters

5.5 Method of Analysing Proposed Parameters

In this section we will describe for each individual parameter, the significance of the parameter, the measures to be used, the approach to be adopted, the system that should be used and the results that are expected. It is expected that the approach adopted will form the basis of the questions used in the structured interview used to elicit a subjects view of a system. For convenience each of the parameters to be used for experimental work are represented in a table. Tables 5.5.1 - 5.5.17 show these parameters.

Important Parameters

Significance	A system may be used in more than one role
Measure	Effectiveness of the system (qualitative value) in each role
Approach	A subject should define the possible roles of the system from a given list. After completing the experiment framework, the subject is asked to provide a qualitative value as to the effectiveness of the system in performing the aforementioned roles.
Results	If a subject is unable to define the role of a system, then this could imply that the system is confusing and unhelpful. In being able to define the role of the system, a subject is expressing his own understanding of the system, based on his experience and how he would use the system.

Table 5.5.1 - Analysis method for "Role of the system"

Significance	As a subject becomes more familiar with the system, he will find the system easier to use.
Measure	Degree of correctness and time required to perform a set of tasks
Approach	Need for three categories of personnel, i.e. proficient, semi-proficient and no experience. The subject needs to perform a set of tasks (section 2 of the experiment framework) within a given time. The correctness of the results and the time taken to perform the set of tasks will provide an indication of the subjects familiarity with the system. N.B. The degree of training of a subject has been given in a system will affect familiarity with the system
Results	A degree of correctness and time required to perform several problems should be obtained. The resulting graph should indicate that the more proficient a subject is in the use of a system, then the less time a subject requires to perform the task.

Table 5.5.2 - Analysis method for "Familiarity with the system"

Significance	It is necessary for a system to have sufficient functionality so that the user can operate the system as he requires
Measure	Qualitative view of subject on the necessity of given functions/features
Approach	Allow the user to explore the system in a structured manner to gain a view on the functions and features present within the system. Use the questionnaire to gain a qualitative measure as to desirability/necessity of these functions.
Qualifiers	As part of functionality, experimental work can be carried out on maintenance features, system help and explanation. Maintenance Features : Ask subjects to express the necessity for a set of maintenance features, i.e. editor, debugger and consistency checkers providing qualification for their answers. Need to bear in mind the probability that the subject will be expected to carry out maintenance. System Help : Provide subjects with a combination of formats and types of system help. Ask subject to express the most appropriate combination of organisation, method and type (see table 5.5.3.a). Subjects should be proficient, semi-proficient and novice users of the system. In addition, ask the subject to express the usefulness of the help facility (subject needs to quantify his/her answer). Explanation : Provide subjects with different formats and types of explanation. Ask subject to express the most appropriate combination. Subjects should be proficient, semi-proficient and novice users of the system. Ask subject to gauge the level of explanation, i.e. none, brief, useful, very useful, essential. Subject can also provide a qualitative view on the understandability of the explanation (this will need to be quantified).
Results	The result of this should allow a table to be constructed that will indicate the functionality that is essential for the effective use of a knowledge-based system, i.e. the most appropriate help, explanation and required functionality.

Table 5.5.3 - Analysis method for "Functionality"

ORGANISATION	METHOD	TYPE
No help at all	Window-based	Functions of system
Screen	Non-window based	Navigation through system
Indexed	Use of graphics	
Context sensitive	Use of text	
Paper manual		

Table 5.5.3.a - Combination of options for system help

Significance	If a system is not robust, then users are unlikely to use it if they expect it to produce erroneous information or for it to crash.
Measure	Number of errors Correctness of results Bug report history
Approach	It is necessary to classify bugs into an order of seriousness, i.e. trivial, annoying, minor, serious, terminal.
Approach 1	Look at bug reports and gain comments from the person who made them as to their effect on his use of the system.
Approach 2	Error seed system with problems and ask the user to detect them. Ask the user to provide a qualitative view as to the effect these bugs would have had on their use of the system under working conditions.
Results	It is expected that trivial problems will not pose a significant threat to the use of the system if there is sufficient incentive to use it. However, major bugs will cause a subject to discard the system out of hand.

Table 5.5.4 - Analysis method for “Robustness”

Significance	For a system to be effective, it is necessary for it to have sufficient breadth of knowledge covering a specific topic
Measure	Qualitative view by a subject, as to the required knowledge content for a system to perform a given role
Approach	Define the system roles. Ask the subject to estimate the percentage breadth of knowledge in the system relative to the knowledge that is required to cover a particular role.
Results	It is expected that the subject will be able to determine the amount of detailed information in the system. An expert would be expected to locate any omissions, and graduates who have a more limited knowledge of the field, to believe the system to contain a full coverage of the appropriate subject.

Table 5.5.5 - Analysis method for "Breadth of Knowledge"

Significance	For a system to be effective, it is necessary for it to have sufficient depth of knowledge covering a specific topic
Measure	Qualitative view by a subject, as to the required knowledge content for a system to perform a given role
Approach	Define the system roles. Ask the subject to estimate the percentage depth of the knowledge in the system relative to the knowledge that is required to cover a particular role.
Results :	The same result would be expected as those obtained when evaluating the breadth of knowledge

Table 5.5.6 - Analysis method for "Depth of knowledge"

Significance	The Human-Computer Interface (HCI) is a key factor to the effective use of a system. It is the means by which a user will interact with the system
Measure	Qualitative view of the subject on the effectiveness of the HCI Number of actions that can be performed in a given period of time (selection of options) Time to obtain information from the output device
Approach	A subject is asked to express an opinion on the most appropriate output method. It is necessary to use subjects with proficient, semi-proficient and novice experience of computer systems. Alternatively, the time required for a user to gain information from the output device can be measured.
Results	It is expected that the subjects will find the user interface of the cell definition system extremely limited. The system has a number of drawbacks making in suitable for use as the test bed in this case. These drawbacks have been established from people who have independently used or were involved in the development of the system. The drawbacks include: No clear indication of where you are in the system Single screens of information Multiple screens of information need to be displayed at once Unclear links between screens Unclear menu commands and their outcomes Poor presentation of data, headings, and level information

Table 5.5.7 - Analysis method for "Method of displaying information"

Significance	The HCI is a key factor to the effective use of a system as it is the means by which a user interacts with a system
Measure	Qualitative view of the user on the effectiveness of the HCI Number of actions that can be performed in a given period of time (selection of options) Time to obtain information from the output device
Approach	A subject is asked to express an opinion on the most appropriate combination of input methods and devices. The possible input devices and methods are depicted in a relationship diagram in the experimental parameters document. It is necessary to use subjects with proficient, semi-proficient and novice experience of computer systems. Alternatively, the time required for a user to select a given set of options can be measured.
Results	It is expected that the subject will find it difficult to select the appropriate menu options. Again, the drawbacks with the system have been identified from people who have independently used or were involved in the development of the system. The drawbacks associated with the menus are: Unclear what the functions of the menus are Multiple menus have the same format, but it some cases have different meanings Abbreviations are used as the menu options, giving unclear meaning

Table 5.5.8 - Analysis method for "Method of selecting options"

Less Important Parameters

Significance	The role which a user adopts will affect his view of the system
Measure	Qualitative view of a subject as to his role affect his use of the system
Approach	The subject needs to define the role he would adopt if he were a regular user of the system. It is necessary to supply the subject with a list and definition of roles.
Results	Depending of the background of the subject, it is expected that domain experts would use the system in an 'aid memoir' mode, whereas less experienced personnel would use the system more in an advisor/tutor role.

Table 5.5.9 - Analysis method for "User role"

Significance	The amount of knowledge a user has of the domain task modelled by a system will influence his need to use the system and how useful he perceives the system to be
Measure	Rating scale (from expert to novice) to be answered by a subject
Approach	It is possible to select the required type of user during the experiments, e.g. domain expert or novice, thus allowing comparison between answers provided by a domain expert and those provided by a novice
Results	It is expected that domain experts will find the systems less useful than graduate engineers

Table 5.5.10 - Analysis method for "Familiarity with domain task"

Significance	If a system does not meet user requirements, then it is likely that a user will be less inclined to use that system
Measure	Qualitative view of a subject as to the system meeting his requirements
Approach	It is necessary to have the subject provide a judgement as to the ability of the system to fit with his requirements. In this case it is necessary for the subject to list his requirements.
Results	It is expected that in general a system will fit with user requirements. However, if there are major disparities between the system and the user's requirements, then the system will not be used.

Table 5.5.11 - Analysis method for "Fit with user requirements"

Significance	System help provides the necessary information to help a subject use a system effectively
Measure	Subject's view as to the usefulness of the help facility
Approach	The subject needs to make an assessment of the usefulness of the help facilities offered by a system. It is necessary to ensure that the user has accessed the help facilities of a system.
Results	It is expected that novice users will relay on the help facilities more that experienced users. The format of the help facilities will also have an affect on their effectiveness (thus relating to functionality).

Table 5.5.12 - Analysis method for "Provision of system help"

Significance	Explanation helps the user understand the reasoning of the system
Measure	Subject's view as to the usefulness of the explanation facility
Approach	Where possible it is necessary to allow the user to gain explanation of the action of the system. It is then up to the subject to express his views as the easy of gaining the explanation and the quality of the explanation provided.
Results	It is expected that subjects will find explanation of the system's actions useful, as it will explain the reasoning for the decision made and the steps taken to reach that decision.

Table 5.5.13 - Analysis method for "Provision of explanation"

Significance	If response time is too great, then this can have a detrimental affect on the use of a system
Measure	Time required to perform a function Time to return from a key press
Approach	A subject needs to identify areas in the system where they believe that the system's response is too slow providing qualification. The subject has to identify areas in the system where response time is acceptable. Various subjects need to be asked, i.e. proficient, semi-proficient and novice users of the system.
Results	It is expected that the subjects will identify a number of areas in the systems where response time is unacceptable. The subjects will provide a quantifiable measure of acceptable response time.

Table 5.5.14 - Analysis method for "Response time"

Significance	Security is a necessary feature of a KBS. A KBS represents a significant amount of valuable expertise, which can be of commercial advantage. Hence it is necessary to safe-guard this information from unauthorised access
Measure	Degree of security Qualitative view of subject on effect Sensitivity of data Degree of corruption
Approach	Propose scenario with various levels of security. A subject has to state the acceptable level of security providing qualifications for the answer provided.
Results	It is expected that subjects will expect a system to be secure, but without affecting their use of the system.

Table 5.5.15 - Analysis method for "Security features"

Significance	Error reporting is an essential part of the continued use of a system. However, if the process is complicated/time consuming/repetitious etc then this may have an adverse affect on a user's willingness to use a system
Measure	Qualitative view of subject on the necessity to be able to report errors, Qualitative view on the most effective methods
Approach	A subject has to state what is the most appropriate method by which they would like to pass comment on the system. It is possible for the system to log errors, this can be used later to trace problems within the system.
Results	It is expected that if the error reporting procedure is time consuming and/or difficult then this will have an adverse affect on a subject's willingness to use a system.

Table 5.5.16 - Analysis method for "Error reporting"

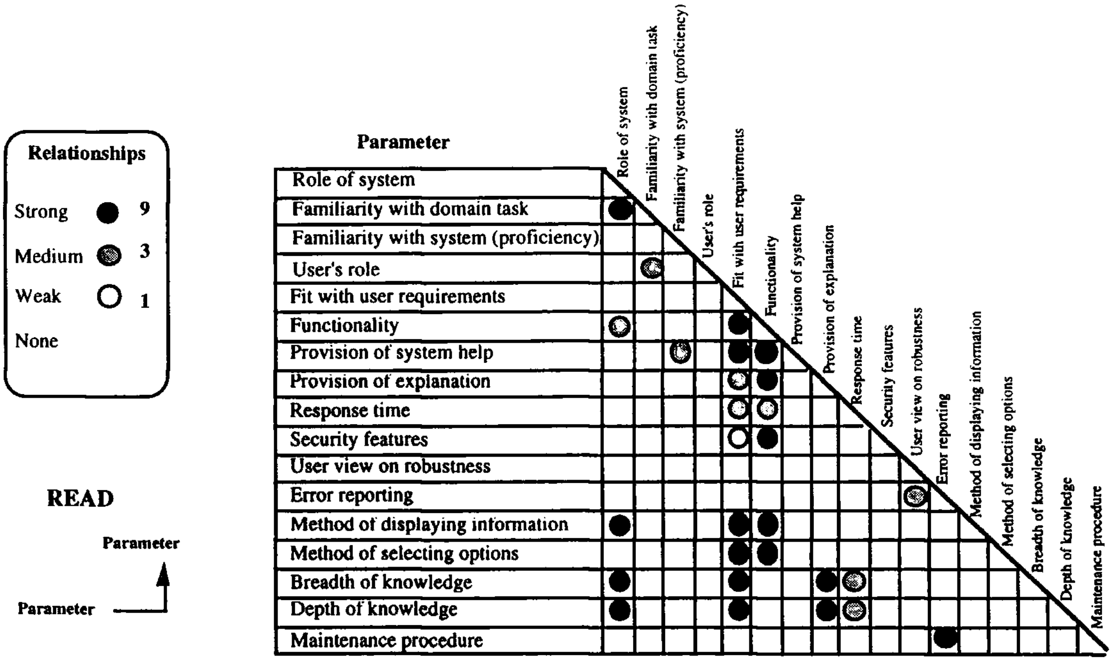
Significance	Maintenance helps to ensure continual use of a system. If maintenance is not performed, then a system will eventually become redundant and the knowledge will become out of date
Measure	Qualitative view of a subject as to the importance of maintenance
Approach	Ideally this would take place over an extended time period, where two systems are used (one remains constant, the other is maintained). Comparison can then me made between the two systems to determine which is the more effective. In order to reduce the time factor, a new version of the cell definition system will be used to represent the maintained system (although not ideal, this will provide a good indication of how maintenance affects system use)
Results	It is expected that maintenance will be necessary to ensure system usefulness over a period of time. However, maintenance will only occur at given intervals and for a relatively short period, so should have a limited impact on system use.

Table 5.5.17 - Analysis method for "Maintenance procedures"

In the following section, we will define the hypotheses we wish to test using the parameters we have just described. We will show how these hypotheses have been formulated and the results that we expect to find, so that we can make comparison after results have been obtained.

5.6 Experiment Hypotheses

From table 5.4.1 presented earlier in this chapter, we can see there are seventeen parameters which we are able to use as part of our experimental work. It is necessary to identify the kind of relationship that exist between them before we can carry out any experiments. To this end a parameter/parameter relationship table was constructed which allowed us to construct a relationship diagram showing the strength of relationship between each parameter. This table (shown in Figure 5.2) is based on the findings of the literature survey and practical examination of the use of systems. Once constructed, it was refined through consultation with practitioners in the field of KBS to ensure that the relationships identified were valid and were testable.



Relationships

Strong	●	9
Medium	◉	3
Weak	○	1
None		

READ

Parameter → Parameter

Parameter	Role of system	Familiarity with domain task	Familiarity with system (proficiency)	User's role	Fit with user requirements	Functionality	Provision of system help	Provision of explanation	Response time	Security features	User view on robustness	Error reporting	Method of displaying information	Method of selecting options	Breadth of knowledge	Depth of knowledge	Maintenance procedure
Role of system																	
Familiarity with domain task	●																
Familiarity with system (proficiency)																	
User's role		◉															
Fit with user requirements																	
Functionality	◉				●												
Provision of system help			◉		●	●											
Provision of explanation					◉	●											
Response time					◉	◉											
Security features					○	●											
User view on robustness																	
Error reporting											◉						
Method of displaying information	●				●	●											
Method of selecting options					●	●											
Breadth of knowledge	●				●			●	◉								
Depth of knowledge	●				●			●	◉								
Maintenance procedure												●					

Figure 5.2: Parameter/parameter relationship table

To help show the relationships we are going to evaluate, the following semantic network has been created. This network shows the parameters we are investigating and the relationship they have to each other. The direction of the arrows indicates the direction of the relationship. For example, breadth of knowledge influences three other factors, the effectiveness of the system, the helpfulness of the system as well as the ability of the system to fit with user requirements. In turn the breadth of knowledge is influenced by expertise.

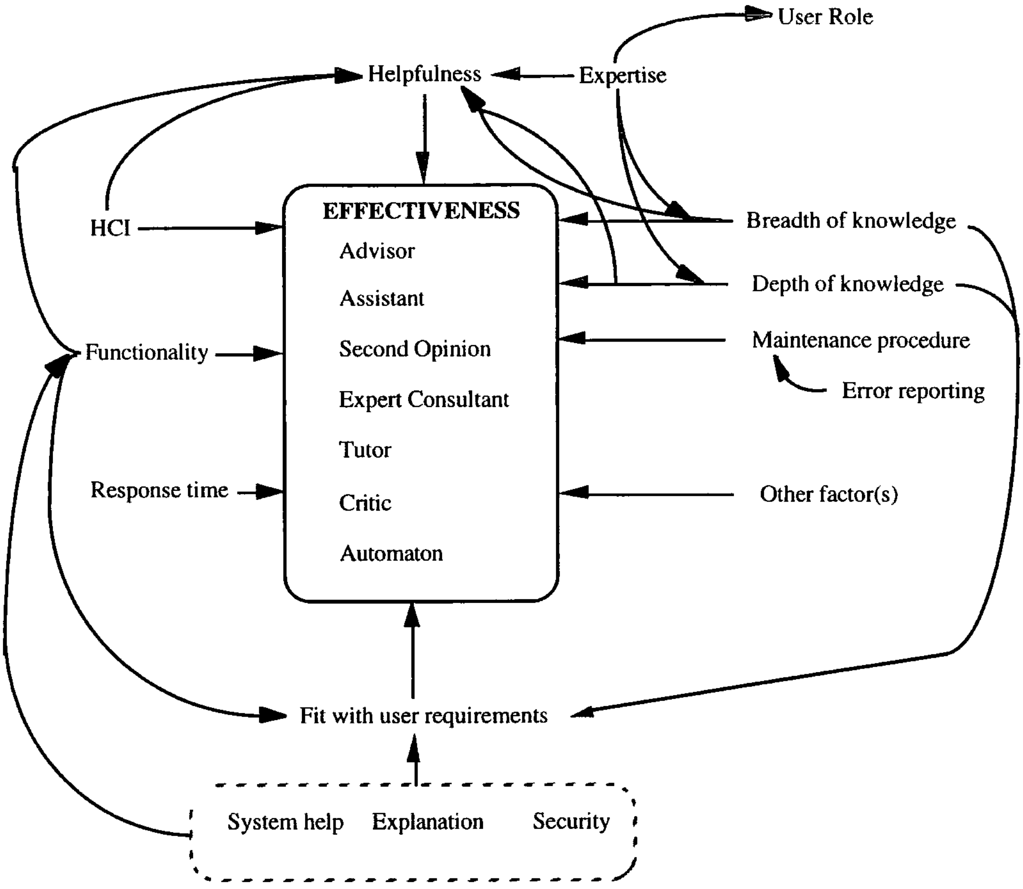


Figure 5.3: Semantic network of experimental parameters

5.7 Hypotheses

Table 5.7.1 represents the hypotheses we will attempt to test. The hypotheses we have formulated test the 'strong' relationships shown in Figure 5.2. For example, "Familiarity with domain task" has a strong relationship with the "Role of system".

Hypothesis No	Hypothesis (-> denotes 'impacts on')
1	Familiarity with domain task -> role of system
2	Functionality -> fit with requirements (usefulness)
3	Provision of help -> fit with requirements (usefulness)
4	Provision of help -> functionality
5	Provision of explanation -> functionality
6	Security features -> functionality
7	Method of displaying information (HCI) -> role of system
8	Method of displaying information (HCI) -> fit with requirements (usefulness)
9	Method of displaying information (HCI) -> functionality
10	Method of selecting options (HCI) -> fit with requirements (usefulness)
11	Method of selecting options (HCI) -> functionality
12	Breadth of knowledge -> role of system
13	Breadth of knowledge -> fit with requirements (usefulness)
14	Breadth of knowledge -> provision of explanation
15	Depth of knowledge -> role of system
16	Depth of knowledge -> fit with requirements (usefulness)
17	Depth of knowledge -> provision of explanation
18	Maintenance procedure -> error reporting

Table 5.7.1 - Experiment hypotheses

5.8 Summary

In this chapter we have shown how we intend to carry out our experimental examination of the significant factors that are believed to affect system use. Furthermore, we have discussed the hypotheses we wish to examine and the approach we will use to achieve this. In addition, we have also indicated the results that we expect to find and the measures that can be used to assess our hypotheses.

6. Experiment Findings

6.1 Introduction

Having described how we intended to carry out experimentation to test the hypotheses we proposed in the previous chapter, we now present the results of the experiments. The findings of the experiments are presented in the following sections. A detailed description of the approach adopted to test the hypothesis, sample size, problems encountered and results are shown in Appendix C.

6.2 Findings

The following sections contain the results from the experiments that were performed. Each of the hypothesis shown in table 5.7.1 are now examined.

6.2.1 Familiarity with domain task -> Role of system

It is proposed that a user's familiarity with the domain task will impact on his view as to the most effective role a system will perform. This seems to be born out with the results we have obtained. It was found that consultants perceive the system A to be very limited in any role, where as in engineer and graduate engineers perceive the system to be generally increasingly effective in the roles of advisor, assistant and tutor. However, it must be noted that although there is a general increase, the overall effectiveness of the system to perform the given roles is still limited. This suggests that although expertise does impact on the perceived role a system can fulfil, there are other factors that impact on the system.

6.2.2 Functionality -> Fit with requirements (usefulness)

A major part of a system is its functionality. It is proposed that the functionality offered by a system will affect the usefulness of that system.

In the case of the system A only 27% of subjects found that the functionality actually met with their requirements, 36% believed that the functionality required major enhancements, and 37% believed functionality required some enhancements. The general consensus was that all aspects of the system A's functionality required improvement. In the case of consultants, it is found that all the consultants believed system A did not meet their requirements.

In the case of system B, 67% of subjects found the functionality met with their requirements, 33% believed that the system required minor enhancements. Areas for system improvement included system returning to a logical place after user completes a task rather than 'just hanging' waiting for input, prioritise possible control systems. In general system B has a higher functionality score than that of system A.

The functionality of a system affects the ability of a system to meet user requirements (as would be expected). If a system has a negative functionality score this indicates that the system does not provide basic functionality to make the system usable.

6.2.3 Provision of help -> Increased fit with requirements (usefulness)

It is proposed that there is a relationship between a system's ability to help a user perform his task and the user's view of the system.

It was found that the subjects tended to agree on the need for a help facility, but were unable to specify the most acceptable format this facility should take. It was seen that for System A, over 73% of the subjects believed that the system required some form of help facility. For system B, 71% believed that the system required a help facility.

From the subjects answers it can be seen that a form of help is necessary for the system to fit with their(users) requirements. However, in a number of cases, the need for a help facility does not bring about a fit with user requirements. This indicates (for those particular subjects) that there are additional features of the system that impact on their view as to the system's effectiveness. From the actual responses in the results questionnaire (not reported here) the subjects reported that the help facility needs to be easily accessible, but more importantly, it needs to direct the user in the task he is performing rather than simply explaining what a specific function does.

6.2.4 Provision of help -> Improved functionality

This hypothesis is closely linked to the previous one. It is our assertion that there is a link with the provision of help facilities and a general improvement in the functionality offered by a system .

In the case of System A it was found that there is no general consensus of opinion as to the functionality score (roughly 50% of the subjects found the system's functionality to be useful). From the results obtained, there does not appear to be a relationship between the need for a help facility and the functionality of a system. Although there is a general opinion as to the need for help facilities, this is not matched with a general view as to the functionality score of the system. It appears (in the case of system A) that there is no relationship between functionality and provision of a help facility. In the case of system B, it was found that the subjects generally found the system to be useful (86%), however, they still expressed a need to have a help facility. This result implies that although the system is seen as useful, there is still areas where improvements need to be carried out (i.e. provision of a help facility).

These results provide some indication that there is a potential relationship between help facilities and improved functionality. However, as they stand, there is insufficient data to make a full evaluation of the hypothesis. In order to fully validate the hypothesis it would be necessary to carry out major alterations to the systems to implement the help features that the subjects identified as being required. Due to time and resource limitation, these alterations could not be carried out.

6.2.5 Provision of explanation -> Improved functionality

This hypothesis is linked to the previous one. We believe that there is a link with the provision of explanation facilities and a general improvement in the functionality offered by a system.

From the subjects answers, 64% believed that system A required some form of explanation facility. As with the previous hypothesis, there is no real consensus of opinion as to the functionality of the system. It appears that the provision of explanation facilities is desirable, but the results obtained do not provide sufficient information in order to validate the hypothesis (in the case of system A). From the results obtained for system B, it was found (as in the previous hypothesis) that although the system is generally seen as useful, there is still need for improvement through the addition of an explanation facility.

These results provide some indication that there is a potential relationship between explanation facilities and improved functionality. However, as they stand, there is insufficient data to make a full evaluation of the hypothesis. To fully test this hypothesis, it would be necessary to implement major alterations to the systems in order to provide the necessary explanation facilities. However due to time and resource limitations, these alterations could not be carried out.

6.2.6 Security features -> Improved functionality

It is our hypothesis that the presence of security features will impact on the functionality of a system. It was found that only 36% of the subjects who used system A believed that security features were necessary. For system B, 57% of subjects expressed a need that the system should have some form of security features.

It appears that there is a relationship between the provision of the security features and the functionality of the system. However, as they stand, there is insufficient data to make a full evaluation of the hypothesis. In order to achieve this, major alteration to system functionality would be required in order to implement the security features that the subjects expressed as being necessary. Due to time constraints and resource issues, these alterations could not be carried out.

6.2.7 Human-Computer Interface -> Role of system

In this hypothesis we wish to try and determine if there is a relationship between the method by which information is displayed to a user and the user's view as to the role of the system.

It was found in the case of system A that there appears to be no relationship between the role of the system and the means by which information is displayed to the user. However, there is evidence to support the view that there are additional factors that impact on the effectiveness of a system to perform a given role. This is evident from the fact that the role scores are different. From the results we have obtained, we can make a preliminary conclusion that the method of displaying information in the case of system A does play some function in the role of a system. It can be seen that if a subject rated the system was relatively highly in the role of an advisor or assistant, then there was a corresponding high rating of the HCI. It must be noted that although there was a relatively high score for the HCI (approximately 2), this is only seen as lying somewhere between an inappropriate interface and an appropriate one. Therefore, the relationship that is seen may imply that a more appropriate interface will result in a more effective system that can perform a given role.

In the case of system B, a similar relationship between HCI score and the role of advisor and assistant can be seen. However, in this case, the general interface score is higher, as well as the scores for the role of the system. Furthermore, the system's ability to act as a tutor is more apparent. These results do suggest that the HCI does have an impact on the role a system can perform.

The results obtained highlight a relationship between the HCI of a system and the ability of a system to perform a given role. However, the lack of agreement by subjects as to the role of a system does imply that there are other issues that influence the system's ability to perform a given role (in the case of system A, that of a tutor). In order to fully test this hypothesis, further work needs to be carried out by providing subjects with a variety of HCI configurations. This work has not been performed due to time and resource limitations.

Due to time restrictions and limitations with the systems used for the experimental work, it has become necessary to group the following four hypotheses in order to present meaningful results. This grouping has allowed for easier representation and analysis of the results obtained. A full discussion of the problems encountered, that has forced this grouping is provided in the following chapter.

6.2.8 Method of displaying information -> Fit with requirements (usefulness)

6.2.9 Method of selecting options -> Fit with requirements (usefulness)

The two hypotheses represent the view that the Human-Computer Interface has an affect on the ability of a system to fit with user requirements. It is our assertion that the HCI will have an impact on a system's ability to fit with user requirements (the ability of a system to perform the tasks required by the user).

From the subjects consulted, 23% (3 out of 13 subjects) believed that the HCI for system A would fit with their requirements (an average HCI score of 2), this compares to 69% (9 out of 13) for the system B (average HCI score of 3). In the case of system B, a more even score for the HCI is visible compared to that of system A. The irregularity of scoring for system A implies that there are additional factors that influence the subjects rating of the HCI. This is further supported by the low number of subjects who state the system fits with their requirements.

The method of displaying information can be seen to have an affect on a systems ability to meet user requirements. The more appropriate the HCI, the more likely the system is to meet user requirements (as would be expected). In order to fully explore the issues relating to why the HCI scores for system A are so irregular, further experimentation would be required. This work has not been carried out due to time and resource restrictions.

6.2.10 Method of displaying information -> Functionality

6.2.11 Method of selecting options -> Functionality

In these hypothesis we wish to determine whether there is a relationship between the HCI and the functionality of a system. It was found that there appears to be a relationship between the functionality of a system and it's HCI. In both systems, the HCI score is less that of the functionality score, although the two are closely matched. Only in the case of a graduate engineer using system A does the functionality score of the system fall below that of the HCI. Generally speaking it can be said, that if there is a relatively high functionality score, then there is a correspondingly high score for the HCI.

The results obtained indicate that there is a relationship between the functionality of a system and the HCI. This relationship seems to imply that high functionality score will result in a relatively high HCI score. However, the results obtained do not provide sufficient information to determine whether the relationship identified is consistent across more subjects and systems. To test these hypotheses fully, it would be necessary to perform more detailed experiments using more subjects as well as different systems offering a range of HCI and functionality.

6.2.12 Breadth of knowledge -> Role of system

It is our hypothesis that there is a relationship between the breadth of knowledge held in a system and the role that system can perform. Due to the limited number of subjects who rated both the breadth of knowledge and system role for system A, no definite conclusions can be drawn on our hypothesis. Where breadth of knowledge has been defined, it was generally seen as appropriate, although there is a wide distribution of results. It appears that the breadth of knowledge does not have any influence on the role of the system. It was found that no consensus of opinion as to the effectiveness of the system in performing a given role could be established. It would be expected that if the breadth of knowledge does influence the role of the system, then if breadth increases, then we would see a corresponding increase in the score for a role.

In the case of system B, a larger proportion of the subjects were able to determine the breadth of knowledge and role of the system. Again, no consensus of opinion as to the breadth of knowledge or system role can be seen.

Problems have been encountered in assessing the breadth of knowledge held within both systems. This stems from a number of factors which include, subjects domain knowledge (a subject may not be fully conversant with the domain information held in each system), limited exposure to the system due to the structured task, misinterpretation of the questionnaire used to record results of the experiment. A full discussion of these issues will be carried out in the next chapter. In order to fully test our hypothesis, it would be necessary to perform a more extensive set of experiments using a wider number of subjects with varying domain knowledge as well as a more detailed structured task and results questionnaire. Due to time and resource constraints it was not possible to perform this work.

6.2.13 Breadth of knowledge -> Fit with requirements (usefulness)

In this hypothesis we wish to establish whether there is a relationship between the breadth of knowledge held in a system and the ability of that system to meet user requirements. In the case of both systems there does not appear to be a significant relationship between the perceived breadth of knowledge and the ability of a system to meet user requirements. In system A (where answered) most subjects saw the breadth of knowledge ranging from general to adequate with a corresponding usefulness of limited to useful (even though the breadth of knowledge in the system is constant and the same for all subjects). If there is a relationship present, then we would expect to see the breadth of knowledge scores in-line of the scores for 'fit with requirements'. This does not appear to occur. Similarly, for the system B there is a greater range of answers. The breadth of knowledge is seen as general to comprehensive, however, there are more scores for 'fit with requirements', but these scores are not consistent with the scores given for the breadth of knowledge.

The lack of a discernible relationship may be attributed to some extent to the limitations of the experiments that have been performed, i.e. limited sample size, structure of tasks, structure of the results questionnaire and the knowledge-based systems used to perform the experiments. In order to fully test this hypothesis it would be necessary to increase the sample size ensuring that the subjects have sufficient domain knowledge to determine the knowledge content of each system. Due to resource and time limitations this repeat experiment could not be performed.

6.2.14 Breadth of knowledge -> Provision of explanation

In this hypothesis we intend to determine if there is a relationship between the breadth of knowledge held in a system and the ability of a system to provide explanation facilities.

It was found that explanation facilities are seen as essential for system A (82% of subjects expressed the need for explanation facilities). In the case of system B, all subjects agreed for the need for explanation facilities. However, it both systems, there does not seem to be a relationship between the breadth of knowledge held within a system and the need for explanation facilities.

As with the previous hypothesis this lack of relationship may stem from the form of experimental work carried out as well as the limited sample size and the systems used as the basis for the experimental work. In order to fully test this hypothesis it would be necessary to increase the sample of subjects, provide a more rigidly defined set of tasks and results recording method and finally use alternative systems that rely more heavily on explanation of its decision making process.

6.2.15 Depth of knowledge -> Role of system

It is our hypothesis that as we believe there is a relationship between breadth of knowledge and the role of the system there is a similar relationship between the depth of knowledge and system role. In the case of system A, there does not appear to be a clear relationship between the role of the system and the depth of knowledge. However, if the system is used as an advisor , then in a number of cases it does appear that there may be a relationship, i.e. the greater the depth of knowledge, the more useful the system acts as an advisor. Furthermore, it appears that no consensus of opinion concerning the depth of knowledge is present, the range is from inappropriate to appropriate. The subjects appear to find the system least useful in the role of tutor.

System B, can be seen to have a more useful role as both an advisor and assistant. Again, the system is seen to be least effective in the role of tutor. As with system A, there does not appear to be a clear relationship between the role of the system and the depth of knowledge. However, a similar relationship seems to be present between the depth of knowledge and the system acting as an advisor.

No conclusive evidence was found to suggest that there is a firm relationship between the role of the system and the depth of the knowledge held within that system. Again, this may be due to the experimental conditions and the number and expertise of the subjects who participated in the experiments. If time and resources permitted, further experimental work using more subjects and detailed tasks to evaluate this hypothesis would be necessary.

6.2.16 Depth of knowledge -> Fit with requirements (usefulness)

In this hypothesis we intend to determine whether the depth of knowledge held in a system will affect the ability of the system to meet with user requirements.
From the result we obtained we are unable to draw a conclusion as to the affect of the depth of knowledge on the ability of the system to fit with user requirements. In a number of cases, the subjects were unable to determine the depth of knowledge in the system or to express whether the system would meet their requirements. An initial observation would suggest that for system A, there is no relationship present, further experimental work would be required in order to fully investigate this hypothesis.

In the case of system B, a number of cases appear to show that a relationship does exist between the depth of knowledge and the ability of the system to meet user requirements (this can be seen from the high scores as to the depth of knowledge and a corresponding high score for the fit with requirements). However, this relationship may be due to other factors that are present when the subject is using the system, e.g. human-computer interface.

In order to conclusively determine whether there is a relationship between depth of knowledge and the ability of the system to meet user requirements, it would be necessary to perform further experimental work. Again, a greater sample size would be required than that shown here. Furthermore, the experiments would need to be redesigned to take into account the impact of other factors, such as the HCI in order to test the relationship.

6.2.17 Depth of knowledge -> Provision of explanation

Here we wish to determine if there is a relationship between the depth of knowledge and the ability of a system to provide explanation facilities.

As in hypothesis 14 (discussed in section 6.2.14), due to the lack of evidence no conclusions can be drawn as to the relationship between the depth of knowledge held in a system and explanation for system A. In the case of system B, although the subjects stated that there is a need for explanation facilities, the depth of knowledge does not seem to influence this requirement (evident from results where depth of knowledge is classed as ranging from none to very detailed; each subject still expressed the need for explanation facilities).

In order to fully test this hypothesis it would be necessary to carry out further experimental work using a larger sample size. In addition, the experiments would need to be redesigned to take into account the impact of other factors, such as the HCI in order to test the relationship.

6.2.18 Maintenance procedure -> Error reporting

In this hypothesis we wished to determine the impact maintenance procedures will have on error reporting. However, due to resource limitations we were unable to test this hypothesis. In order to fully evaluate the hypothesis it would have been necessary to perform experimental work on system that had been in service for a sufficient period of time to allow maintenance activities to be performed as well as requiring a reporting mechanism. Although no experimental work was carried out to test this hypothesis, subjects were asked as to the effect of maintenance procedures on error reporting, 93% of subjects stated that maintenance procedures would be required and that error reporting would form part of these procedures. The impact of the error reporting mechanism on daily use of a system would be negligible and would be outweighed by the benefits provided by the system.

6.3 Summary

In this chapter we have presented our initial findings as to the factors that impact the effective use of knowledge-based systems. In a number of cases we have been able to show that our hypothesis are valid. Furthermore, we have shown that a number of relationships have been found to not exist. We have also identified areas were we believe further work is required.

In the next chapter we will discuss in greater detail our findings and there impact on how systems need to be integrated into a working environment. We will also discuss areas where we have encountered problems and propose solutions.

7. Discussion of Results

7.1 Introduction

In the previous chapters we have described a model which outlines the issues that we believe have a direct impact on the adoption of a KBS. We have described the process by which we have validated the model and selected key issues which we believe have impact the effective use of a KBS. Furthermore, we have carried out a number of experiments to establish the impact certain factors have on the effectiveness of a KBS.

In most cases, a KBS must be used by someone to gain the desired benefits. This use will incur costs and there may be some risks associated with it. This is depicted in Figure 7.1. In order to maximise the benefits while minimising the risks at a reasonable cost, the system must be used effectively. This raises the following questions :

What factors influence the end-user to use the system?
What characteristics should the system have to encourage its effective use?

The costs, benefits and risks of a knowledge-based system will vary from company to company, system to system and user to user. It is necessary to identify the benefits that a user, the management and the company can expect to accrue from the use of the system. The benefits must be seen to outweigh the costs and risks otherwise the system will not be used. It is up to the system champion to convince the users and management of the likely benefits to them. It is essential that management see the benefits from the utilisation of the knowledge-based system. However, they must also be aware of the actual cost of operating such systems.

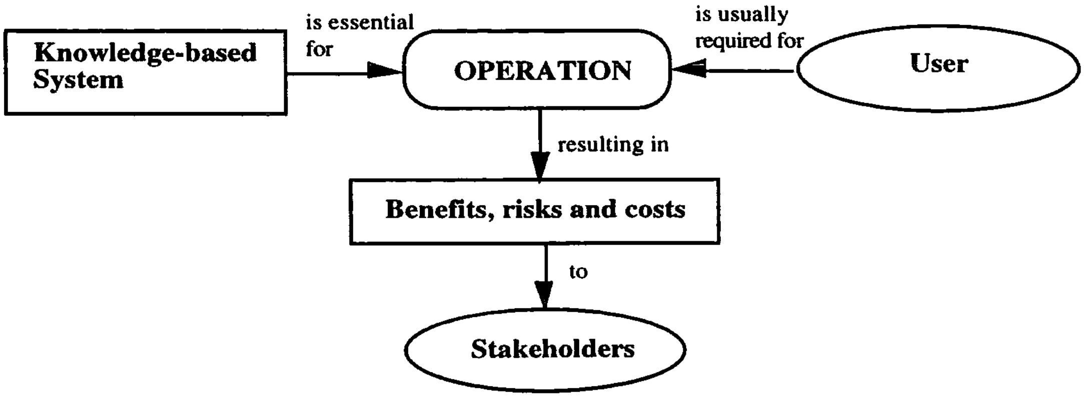


Figure 7.1: Driving forces behind the use of a knowledge-based system

In this chapter we will discuss our findings and suggest areas where further research is required. In addition, we will discuss the problems which we encountered during the development of our models as well as the experimental work and suggest areas where improvements will be required for future studies.

7.2 Utilisation Model

We have proposed a comprehensive model which depict the stages that occur during the utilisation of a knowledge-based system. This model provides a practical representation of the tasks that are performed (or need to be performed) when a system is used or being integrated into existing working practices. Furthermore, the model we have proposed identifies the roles and the activities that they perform at each stage in the utilisation lifecycle. The model has provided the necessary framework by which we have been able to investigate factors that impact on the utilisation of a KBS.

To ensure that a KBS is used effectively, three main phases need to occur. Operation must be preceded by an effective handover from acquisition and be supported by adequate maintenance. Associated with each phase are several issues that need to be considered. Behind each issue are many factors. Research into a number of these issues appears to be limited. More importance is placed on the development of the KBS rather than its effective utilisation.

The user plays a key role in the effective use of a system. Several factors affect the user and hence the use of a system. Figure 7.2 shows (at a top level) a semantic network of the factors that affect the user's view of the system. The factors have been identified from the model and the experimental work carried out. The elements in the semantic network represent factors that influence utilisation and the arcs show how they influence the downstream element. The diagram is read in the directions of the arrows on the arcs, e.g. Utilisation of KBS *affects* Confidence in the system *is a characteristic of the* User. A line connecting a set of arcs indicates that those arcs have the labelled effect on the target node.

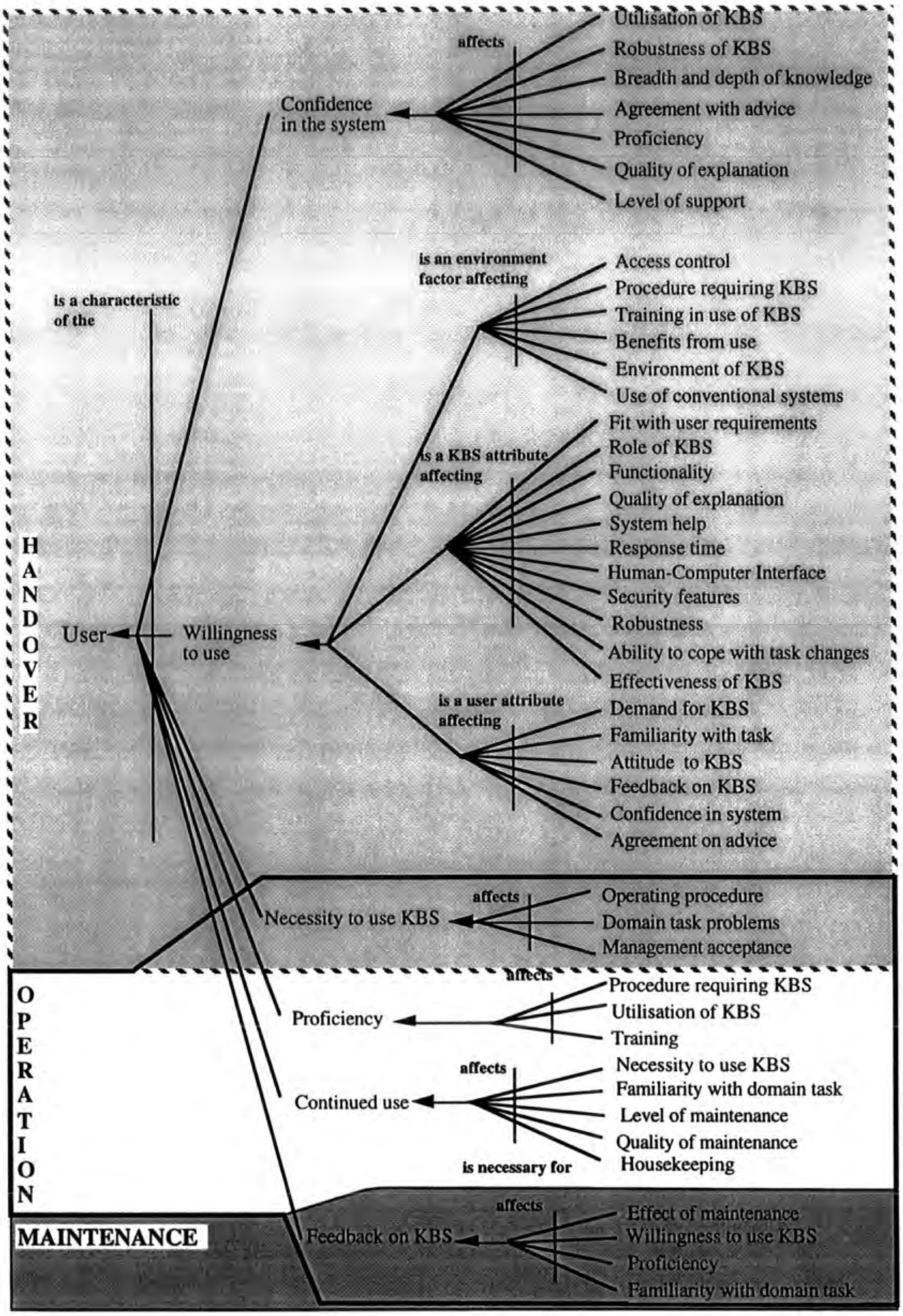


Figure 7.2: Semantic network of the factors affecting the user

Of the factors that affect the user, several can be addressed during handover. Thus the operating procedures will affect the need to use the system and, if they become an accepted part of the working environment, this will influence the user's willingness to use the system. They will encourage continued use in operation which will increase the proficiency of the user. The effectiveness of the operating procedures will be increased if the acceptance testing and pilot operation convince the management that the system will deliver the anticipated benefits as the management will then encourage the users to follow the operating procedures.

Inspirational training will foster the user's proficiency and willingness to use the system. It will build up confidence in the system and so improve the user's attitude to it. This will encourage the users to feed back constructive comments on the system during pilot operation and subsequently during continued use.

The need for security procedures must be explained to the user to promote acceptance of the access controls which could prove onerous, particularly if they have to be invoked regularly during continued use.

The maintenance phase can also have a large impact. If it is clear that suggestions for improvement are acted upon, this will encourage the user to make helpful proposals and encourage a positive attitude towards the system. The level and quality of the maintenance will affect the user's confidence in the system and, if both are high, the user will take it for granted that the knowledge is up-to-date and so will cope with any changes that may have occurred in the domain task. This will obviously promote continued use of the system and ensure that the system continues to deliver benefits to the stakeholders.

The ultimate goal of operation is to continue to use the system while it provides benefits that outweigh any costs associated with using it. A number of factors affect the goal of continued use, e.g. changes in the domain task may lessen the need to use a system, familiarity of a user with the domain task, maintenance and general housekeeping.

The other key factor in establishing effective use is the knowledge-based system itself. Figure 7.3 shows a semantic network that represents the factors that affect the system.

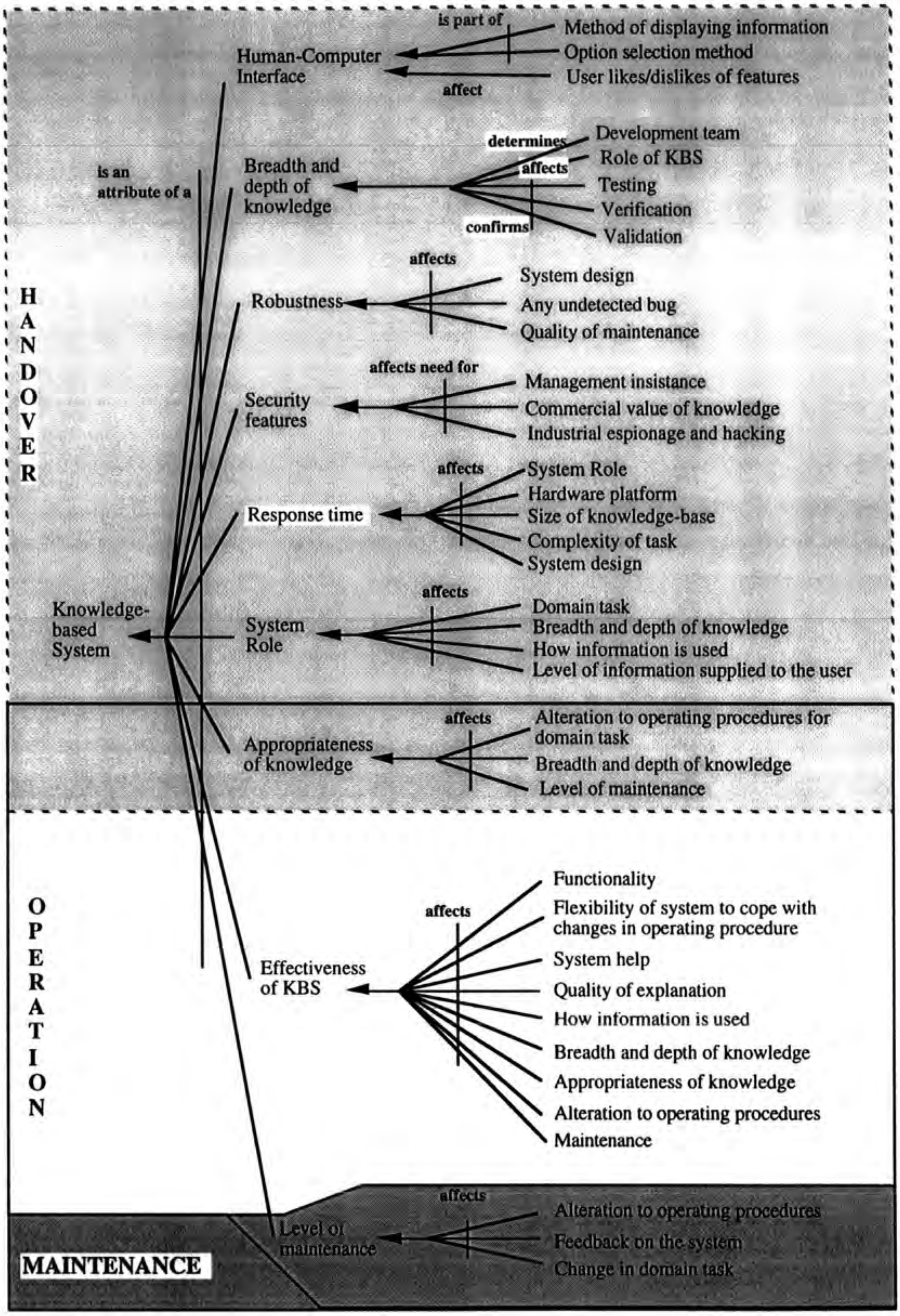


Figure 7.3: Semantic network of the factors affecting the knowledge-based system

During handover, it is necessary to address several factors that affect the use of the system. The handover phase allows a rigorous acceptance test of the system to assess attributes such as the human-computer interface, breadth and depth of knowledge, robustness, security, response time, system role and appropriateness of the knowledge. If any of these attributes do not meet user requirements then the system should be altered before it begins full operation.

Once the system has passed acceptance testing, a number of factors will affect how well it will operate during continued use. As a user becomes more proficient in the use of the system, he may begin to explore the functionality. If the user cannot find the functionality to perform a certain operation, then he may become dismissive of the system even though his expectations may be unrealistic. To a certain extent, the system should be flexible enough to cope with minor changes in the domain task. This helps if one user performs the task in a different way from another. The level of system help and explanation will also contribute to the continued effectiveness of the system. These facilities provide the user with the necessary information about how to operate the system and why the system has performed in a given way. To maintain effectiveness, the knowledge in the system must be appropriate and this will require maintenance as and when the domain task alters.

Maintenance ensures that the knowledge held within the system is kept up-to-date and that any problems with the KBS are resolved. The issue of maintenance is now becoming more important as early knowledge-based systems are beginning to mature. Maintenance stems from alteration in the operating procedures, feedback obtained from the users and changes in the domain task.

As well as taking account of the factors that affect the user and the system, the effects on the in-house domain experts should be considered. The effects relate to knowledge maintenance and depend on the role envisaged for the system. Three possibilities are to:

a) provide assistance to the domain expert directly by manipulating large amounts of information, leaving the intuitive aspects to the expert,
b) act as a tutorial aid for newcomers to the domain,
c) make the knowledge of the expert available to other people in the organisation.

In the first case, where the expert is the end-user, the expert will automatically assume ownership of the knowledge in the knowledge-base and ensure that it is correct and kept up-to-date if the system proves to be a real help.

The need for maintenance of the knowledge in the knowledge-base appears to depend on two factors key factors. Maintenance will be required if the knowledge changes periodically, e.g. it needs to cater for the diagnosis and repair of new products. The requirement for maintenance is much reduced if the system is intended to raise the level of proficiency of the newcomer to a certain level in the domain and thereafter the newcomer is expected to consult the expert if additional expertise is required. In either situation, the domain expert should be aware of when the knowledge in the system is in need of maintenance.

The objective in both the second and third cases is to relieve the domain experts of routine and mundane queries from less knowledgeable users, thereby allowing the experts to concentrate their attention on difficult problems in the domain or to undertake other activities. The latter option must be handled sensitively if the individuals concerned are not to feel threatened by the system. One key remaining task is to assume ownership or responsibility for maintaining the knowledge in the system and keeping it up to date. As well as assisting in the correction of any errors, this entails being aware of the existence and significance of relevant new domain knowledge generated in-house or externally. This represents the "continuous improvement" activity which must follow the step change of system acquisition if the system is to yield benefits over an extended period.

One question is whether there is any incentive for the domain expert to assume ownership of the knowledge in the system. Before the introduction of the system, the users would take all their relevant problems to the domain expert. If a problem were outside the previous experience of the expert, this might necessitate an investigation, thereby extending the expert's knowledge. Once the system is operational, the users would be expected to consult the system in the first instance, rather than the expert. This could result in a user posing a problem to the system that was beyond the competence of the system. In certain cases where the limits of the system validity have been clearly delineated during development, it may be possible to detect this on data input. With a system based on case-based reasoning, it would be clear if the retrieved cases bore little or no relation to the current problem. In that case, the domain expert would naturally be invited to resolve the matter and so increase the capability of the system. In other cases, the user may assess the quality of the output from the system and involve the expert where doubts arose about that output. If any shortcomings in the output were not detected until the results were applied in practice, this could reduce confidence in the system.

The development of a KBS provides an opportunity to capture a consensus view of the domain knowledge from a wide group of experts, both internal and external. The resulting knowledge-base could be larger than that of any individual. Although it means that the user would receive impartial advice, it suggests that team ownership of the knowledge would be preferable to ownership by one expert but how this could be achieved is unclear. It is more likely to succeed in a learning organisation. This is an organisation skilled at creating, acquiring and transferring knowledge, and at modifying its behaviour to reflect new knowledge and insights (Garvin, 1993). One possibility might be for the system manager to accept responsibility for knowledge maintenance and co-ordinate the contributions from the various domain experts as part of the change control activities.

Another aspect worthy of consideration is the impact of the KBS on the successors to the original domain experts. There is a danger that they could become fully dependent on the system and so not develop their own expertise. This may be acceptable if the knowledge has a finite lifetime. An example of this would be knowledge related to an artefact nearing the end of its operational life. Where this is not the case, some other method of encouraging the development of human expertise may be necessary.

The model by itself does not provide a solution to system integration, rather they provide a starting point from which more detailed investigations can be carried out to determine the factors that have the greatest impact on system use. From our model we have taken a number of key areas (under which we are able to exert control) and investigated the impact they have on the use of a KBS. In the remainder of this section we will discuss each of the key areas and its importance with respect to utilisation.

7.2.1 Role of a system

The role in which a system is to be used can impact on how that system is utilised. The role of the system on its own does not affect its utilisation, rather it is the view of the user as to the impact it will have that will affect its uptake. If a system is seen to replace a domain expert, then users may view the system with malice, i.e. it is seen as a threat to their status or worth. Conversely, if a system is seen to support a person in performing a given task, and makes that task easier to perform, then the uptake of the system may be more positive. The role of a system should compliment existing working practices if a system is to be successfully utilised and provide the expected benefits.

7.2.2 Familiarity of a user with a system

The degree to which a user is familiar with the operation and function of a system will impact his view of that system. This degree of familiarity can have either a positive or negative affect. If a user perceives a system to be easy to use, then he may be more inclined to use frequently use that system (or as required), where as if the user perceives the system to be difficult to use, then he may be less inclined to use it.

As a user becomes more familiar with a system this will impact on his view as to the usefulness of that system. He will be able to use a system more effectively, and extract information more quickly/accurately. This can be said for both conventional and knowledge-based systems. It would be expected that if an easier alternative existed then the user would choose that option. It is therefore desirable to ensure that users gain sufficient familiarity with a system in order to allow them to find what a system can or can not do, and to allow them to gain sufficient knowledge of how best to operate the system.

7.2.3 Functionality

In order for a system to be effective, it needs to have sufficient functionality to perform the task it was designed for. If functionality is limited, poorly designed or implemented then this will impair the systems ability to operate effectively and to be used efficiently. For a KBS to be utilised, it needs to have sufficient functionality to allow a user to easily gain the information he requires. If a system does not provide sufficient functionality, then a user would not be expected to use the system, since it can not (easily) perform the required tasks.

A system needs to be able to extract from the user sufficient information on which a decision can be made. If a system can not elicit the required parameters by which it can make a decision, then it is less likely to be able to offer suitable advice to the user (who could be a non-domain expert).

7.2.4 Robustness of a system

Any system whether it is a knowledge-based or conventional needs to be robust. If a system is prone to failure (irrespective of the degree of failure) then this will impact the view of the user. It would be expected that if a system was not robust, then users would be reticent about using it, on the off chance it will fail and be unable to supply the results they are after.

In the case of a KBS it is necessary to establish the robustness of both the system itself and the knowledge-base. When establishing the robustness of the knowledge-base it may be desirable to be able to prove to the users that the system can deliver the information they require. The means by which the robustness of the knowledge-base is established will depend on a number of factors, e.g. size of knowledge-base, user domain knowledge, availability of recognised domain experts etc.

7.2.5 Breadth and depth of knowledge

A major factor that will impact the use of a KBS is the breadth and depth of knowledge held within the system. If the system does not hold sufficient knowledge then it will be unable to deliver the appropriate answers to user queries. For a knowledge-base to be effective it requires the domain knowledge to be well defined. If this knowledge is changing, then it is a difficult task to create a knowledge-base. It would be expected that during development the stability of the domain knowledge would have been established. If the domain knowledge does change, then it will be necessary for the system to be easily updated with those changes.

From the user’s perspective, he is concerned with whether the system can supply him with the answer to a given problem. He assumes that the system will contain sufficient breadth and depth of knowledge to be able to supply an answer. If the user requests an answer and the system can not supply one due to limitations in its knowledge-base, the user’s view of the system will be tarnished.

7.2.6 Human-Computer Interface

A large amount of research has been carried out in the field of human-computer interaction (HCI). The human-computer interface has a fundamental impact on the user's view of the system. Research into interface design highlights the necessity to involve the user during the development phase of the system to help establish how the interface should appear and operate, as well as providing the user with the interface he wants. This provides the user with a sense of being involved in the project. This sense of involvement can help maintain the user's willingness to use the system once it has been completed. It is up to management to ensure that the users are available and willing to contribute to the development of the system.

The interface needs to allow the user easy access to the functionality of the system. Furthermore, the interface needs to present to the user the information he has requested in a clear and controllable manner. It would be expected that if a system has a poorly designed interface, then irrespective of the content of the knowledge-base, a user would be less willing to use the system, since it would be difficult to retrieve the information he requires.

7.2.7 User domain knowledge

It is assumed that during the development stage the required information to perform the domain task will be established. However, a number of problems may occur if the users are not involved or clearly identified during the development phase. Information within the system may be of too little detail to be useful to a novice or too great so as to hinder a domain expert. It is therefore necessary to establish the content and clarity of information from a user's perspective in order to provide the necessary information to make the system more useful for a given type of user. If a system is to be used by a variety of users, then it is desirable to provide a method by which the level of guidance supplied can be tailored to meet a particular user's requirement. This could be achieved through a 'logging on' process, a menu, or an automatic mechanism which detects the user's actions.

Cultural attitudes should also be examined when establishing a KBS within a domain, e.g. there may be peer pressure not to use new technology and just use tried and trusted methods of performing a task instead of using the KBS. It is possible that a system will not be used if it is not developed 'in-house'. The system may be viewed with suspicion or resentment by resident computer personnel. This attitude can have a serious impact on the use of the system. It is necessary during the development phase to ensure that these problems do not occur. It is desirable to include resident computer personnel where possible and to involve them throughout the lifecycle of the system. This involvement may not be possible due to practical problems, e.g. availability, willingness, costs.

Further research is required into cultural issues relating to the use of a KBS. It is necessary to ensure that the correct cultural environment exists for the effective use of a KBS. Issues relating to business organisation and structure need to be explored to determine their effect on the use of the system. It is necessary to determine the role and abilities of personnel involved in the use of the system, to ensure that the system will be used effectively.

7.2.8 Type of user

It is necessary to establish the willingness, ability and necessity of a user to use the system. Furthermore it is necessary to establish the user's familiarity with the domain to ensure that the system will provide the required information in a suitable form, i.e. neither too simple for a domain expert nor too complex for a trainee. Additional research is required into establishing how domain knowledge and expertise will affect a user's willingness or ability to use a KBS. It has to be noted that users may be very reticent about having their abilities being assessed as this may lower their status, i.e. a domain expert may not be found to be a soundly-based domain expert.

7.2.9 System Help / Explanation

The provision of help and explanation facilities in a KBS should make a system more useful and easy to use. It is necessary to determine how these facilities are best implemented to allow a user quick and easy access to the information he requires. If facilities are difficult to access, or are poorly formatted then this is likely to have a negative impact on the user's view of the system.

The ability of a system to provide justification of its reasoning should help a user to understand the answer provided by the system to the user's query. The explanation provided needs to be in a form that is understandable by the user. If the explanation is not in a 'friendly' format, then again the user's view of the system may be adversely affected.

7.2.10 User action on advice

The user's interpretation of the information provided by a system may be idiosyncratic. A number of measures of performance have been identified that provide an indication of how working practices have been altered from the introduction of a KBS and hence the effectiveness of the KBS. Other factors to be considered include the depth, breadth and the sequence in which the information is provided by the system. It may be desirable to carry out further research on how a user will actually use the information supplied by the system and how effective this advice is in helping to perform the domain task.

7.3 Experimental Findings

In the previous sub-section we broadly discussed the key areas that have been selected for the experimental work. These key areas provide an initial starting point from where we can explore the factors that affect the use of a KBS. In the remainder of this chapter we will discuss our findings from the experimental work. We will also indicate areas where we feel additional experimental work is required.

Before we examine the results from each experiment, some of the general problems encountered while performing this work need to be discussed. Due to the number and availability of subjects to perform the experiments it was necessary to group all the experiments in one 'session'. This was not the ideal situation, rather it would have been more controllable if each hypothesis could be tested separately, thus reducing any influence from other factors being evaluated. Furthermore, the format of the experimental framework could be improved to allow easier recording of any findings.

It would have also been desirable to be able to repeat the experiments with several systems rather than rely upon the two KBSs that were available.

One problem encountered was the misinterpretation of questions asked in the questionnaire which was used to record a subject's view on the factors being investigated. This misinterpretation may have led to erroneous results being obtained. To help limit this problem, each subject was briefed before the experiment was performed and was supervised during the experiment, although the supervisor could not prompt the subject only explain what information was being requested.

A major problem encountered was the availability and willingness of subjects to be involved in the experimental work. The unwillingness of people may have had a negative impact on there view of the systems and thus invalidate to some extent the results we obtained from them. The experiments could not be scheduled rather they needed to be performed when and where subjects became available, this has led to a elongated time before results could be analysed. The number of subjects who were able to perform the experiments was also limited, ideally a larger sample size would be used to reduce statistical errors and provide a more true picture. In particular cases subjects were unable to provide responses thus leading to further reductions in the number and quality of the results obtained.

Having identified the major restrictions that the experiments were conducted under, we will now discuss our findings. The results we have obtained do indicate a number of relationships do exist and influence the usefulness of a KBS. Detailed results are shown in Annex C. For example, Hypothesis 1, Familiarity with the domain task impacts on the role of the system is at C.2.1.

7.3.1 Familiarity with domain task -> Role of system

In this experiment we wished to show that a user's familiarity with the domain task will affect the role to which a system is used. The results we obtained seem to show that this hypothesis is valid. As a subjects expertise increases, then the usefulness of a system decreases. From the results obtained, we can make a tentative observation that the roles of a system can perform depend upon the user, i.e. no real consensus of opinion was established as to the most effective role a system could adopt. Due to the limited number of subjects used in the experiment we can not conclusively state a relationship between familiarity of a user with the domain task and the role of a system. In order to achieve this, we will need to perform a larger set of experiments using a larger number of subjects with varying levels of domain knowledge.

7.3.2 Functionality -> Fit with requirements (usefulness)

This experiment was used to identify the relationship between the functionality of a KBS and the ability of the system to meet user requirements. It was found that System A was seen as having little or no functionality, and thus has a poor fit with user requirements. In contrast System B, which offered a greater set of functionality had a greater fit with user requirements. We can therefore make a preliminary conclusion that system functionality does affect the ability of a system to meet with user requirements. However, as with the previous experiment in order to fully test this hypothesis we will need to perform additional experiments with a larger sample size. Furthermore, the results obtained indicate that the familiarity with the domain task of each subject has little impact as to their view on the functionality offered by a system. To explore the relationship between functionality and the ability of a system to meet user requirements in greater detail, an alteration to the experimental framework would be required. It would be desirable to determine what each subject sees as the essential functionality required by a system, we would then have a base line from which to view each subjects opinion of a system.

7.3.3 Provision of help -> Improved fit with requirements (usefulness)

We wished to test the hypothesis that, provision of help facilities in a KBS will affect the ability of the system to fit with user requirements. In the majority of cases provision of help facilities was seen as required. However, in the case of System A, the provision of help on its own does not meet with user requirements. This implies that there are additional factors which impact on the ability of a system to meet with user requirements. In the case of system B, provision of help seems to have the opposite affect as more subjects state this will improve the system's ability to meet their requirements. With contradicting results, we can only suggest that provision of help does impact on the ability of a system to meet user requirements, however, there are additional factors which have a greater bearing on the ability of a system to meet user requirements. In order to fully evaluate this hypothesis it will be necessary to redesign the experimental framework, as well as perform the experiment with a larger sample size.

7.3.4 Provision of help -> Improved functionality

This experiment tests the hypothesis that there is a relationship between provision of help facilities and the functionality offered by a system. The results obtained from the experiments on both systems tend to indicate that there is a relationship between the provision of help and the functionality of a system. Although there is no consensus as to the functionality score for both systems, the majority of subjects expressed the need for the need for help facilities. This indicates that subjects see the provision of a help facility as a necessity, although the provision of such a help facility will not have an impact on the functionality of the system. In order to fully test this hypothesis it would be desirable to repeat the experimental work using a new framework designed to examine this hypothesis in isolation. In addition, a larger subject sample size as well as evaluation of this hypothesis using a larger number of systems offering varying levels of functionality and help facilities would be desirable.

7.3.5 Provision of explanation -> Improved functionality

In this experiment we wished to establish the relationship between the provision of explanation facilities in a KBS and it's functionality. In the case of both systems the majority of subjects saw a need for the provision of explanation facilities. As in the previous experiment, there is no consensus of opinion as to the functionality offered by the systems. From the results obtained we are unable to make a firm conclusion as to the relationship between provision of explanation facilities and functionality, rather it appears that as with provision of help facilities, there is a need for explanation facilities, although this will have little impact on the functionality of the system. As with the previous experiment, to fully determine whether a relationship exists further experimental work is required. It will be necessary to redesign the experimental framework to evaluate this hypothesis in isolation, as well as increase both the sample size and number of systems used in the experiment.

7.3.6 Security features -> Improved functionality

Here we wished to determine the impact security features would have on the functionality of a system. As with the previous experiments there are no consensus of opinion as to the functionality of each system. In the case of System A only a small number of subjects expressed the need for security features, where as in the case of System B, a larger proportion of subjects expressed the need for security features. The lack of consensus as to the need for security features implies that there is no real relationship between security and functionality. However, one observation of interest is that the need for security features increases with the domain knowledge of the subjects, i.e. in the case of System A, the majority of consultants and senior engineers who performed the experiment stated a need for security features, where as engineers and graduate engineers did not see the need for security features. In the case of System B, this relationship is further extended, where graduate engineers are the only group who do not see the need for security features. Again, to fully test this hypothesis, a set of repeat experiments would be required using a new experiment framework which focused on this hypothesis, as well as a larger sample size and increased number of systems.

7.3.7 Method of displaying information (HCI) -> Role of system

This experiment intended to determine whether there is a relationship between the human-computer interface of a system and the role that the system can perform. From the results obtained, it can be seen that in both system A and B there does appear to be a broad relationship between the HCI and the role of the system. Where a system is seen to have a low score for the HCI, there is a corresponding low score for the role the system can perform. However, this relationship may be due in part to the domain knowledge of the subjects performing the experiments or alternatively, the relationship may exist, but the subject sees the system being unable to perform a given role and has a poor HCI. In order to determine if there is a relationship between HCI and the role of a system, it would be necessary to perform further evaluation using a larger sample size as well as a restructured framework to remove the influence of other factors, such as functionality.

7.3.8 Method of displaying information (HCI) -> Fit with requirements (usefulness)

7.3.9 Method of selecting options (HCI) -> Fit with requirements (usefulness)

During the experiments it was necessary to group these two hypotheses together in order to gain meaningful results. It was found that the subjects found it easier to evaluate the whole interface rather than its separate components.

This experiment was used to determine if there is a relationship between the HCI of a system and it's ability to fit with user requirements. From the results obtained for system A, it can be seen that there is no consensus of opinion as to the effectiveness of the HCI. However, there is general agreement that the interface is inappropriate (denoted by scores less than 3). Furthermore, the majority of subjects stated that this did not meet with their requirements. In the case of system B, the scores given for the HCI are generally higher than those of system A. In addition, a majority of subjects stated that system B would meet with their requirements. This implies that there is a relationship between the HCI and fit with requirements.

The results we have obtained do support our hypothesis, however, further investigation would be desirable to explore in greater detail the HCI factors that have the most impact on a subject's view of a system. It would be necessary to use a larger sample size to allow a more detailed examination. It would also be necessary to devise a new framework which could be used to examine the HCI issues in isolation of other factors.

7.3.10 Method of displaying information (HCI) -> Functionality

7.3.11 Method of selecting options (HCI) -> Functionality

As with the previous two hypotheses, it was found necessary to evaluate both of these together in order to obtain meaningful results. In these experiments we wished to determine if there is a relationship between the HCI and the functionality offered by a system.

The results obtained using system A tend to suggest that a relationship does exist between the HCI of a system and the functionality of that system, even though the results obtained reflect that the subjects believe system A has an inappropriate interface and limited functionality. In the case of system B, the results obtained reflect those of system A. The subjects tended to give system B higher scores for its HCI and functionality. It can be generally seen that where there is a high HCI score there is a corresponding high functionality score. It is unclear from the results we have obtained as to the nature of this relationship, i.e. whether it is a linear relationship, what functionality has the greatest impact on the interface, whether the relationship is from functionality impacting on the HCI or the HCI impacting on the functionality of a system.

In order to fully test the relationship that appears to exist between the HCI and functionality of a system, further experimental work is required. Again a new experimental framework would be required as well as a larger sample size.

7.3.12 Breadth of knowledge -> Role of system

In this experiment we wished to determine the relationship between the breadth of knowledge held in a KBS and the role that the system could perform. Due to the limited number of results obtained we are unable to determine whether a relationship exists between the breadth of knowledge and the role of the system. It is evident from the results that were obtained, that there is no consensus of opinion as to the effectiveness of both systems in a variety of roles. This lack of consensus implies that there a number of factors that impact the role of a system, not just the breadth of knowledge.

To be able to determine the affect the breadth of knowledge has on the role of a system it would be necessary to perform additional experimental work. If would be necessary to design an experiment which allows a subject to easily determine the role a system is performing as well as the breadth of knowledge held in the system. It would also be necessary to have a large sample size who have sufficient knowledge to determine the breadth of domain knowledge held in a system.

7.3.13 Breadth of knowledge -> Fit with requirements (usefulness)

Here we wished to determine if there is a relationship between the breadth of knowledge held in a system and the ability of the system to fit with user requirements. As with the previous experiment, the results obtained do not provide sufficient information from which to draw a meaningful conclusion. However, it does appear that in the case of system B, the system is able to meet the requirements of the majority of people except the domain experts (consultants). The inability of subjects to rate the breadth of knowledge is a contributing factor to the lack of results. In order to determine if there is a relationship does exist, it will be necessary to repeat the experiment with a larger sample size with subjects having sufficient domain knowledge to be able to judge the breadth of knowledge held in a system.

7.3.14 Breadth of knowledge -> Provision of explanation

Our hypothesis is that there is a relationship between the breadth of knowledge in a system and the provision of explanation by that system. Again, as with the previous two experiments we were unable to collect sufficient results to draw a firm conclusion. However from the results we have obtained, it appears that the provision of explanation facilities is not dependent upon the breadth of knowledge held in a system. To be able to determine whether this observation is true, further experimental work needs to be carried out, with particular emphasis on the functionality of a system, as well as the knowledge held in a system.

7.3.15 Depth of knowledge -> Role of system

This experiment was used to determine whether there is a relationship between the depth of knowledge held in a system and the role that system could perform. From the results obtained no firm conclusions can be made as to the existence of a relationship between depth of knowledge and system role. However, it can be seen that the systems are seen to act more effectively in the roles of advisor and assistant. Since there is no consensus of opinion between subjects as to the effectiveness of each system in performing a given role, it implies that there are additional factors that influence the role of the system. In order to fully test this hypothesis, additional experimental work will be required using subjects who have sufficient domain knowledge to determine the depth of knowledge as well as redesigning the experiment to reduce the affects of external factors.

7.3.16 Depth of knowledge -> Fit with requirements (usefulness)

Here we wished to determine if there is a relationship between the depth of knowledge held in a system and the ability of the system to fit with user requirements. As with the previous experiment, the results obtained do not provide sufficient information from which to draw a meaningful conclusion. However, it appears that there is no relationship between the depth of knowledge and the ability of the system to fit with user requirements. In the case of system B, it appears that the system is able to meet the requirements of the majority of people except the domain experts (consultants).

The inability of subjects to rate the depth of knowledge is a contributing factor to the lack of results. In order to determine if there is a relationship does exist, it will be necessary to repeat the experiment with a larger sample size with subjects having sufficient domain knowledge to be able to judge the depth of knowledge held in a system.

7.3.17 Depth of knowledge -> Provision of explanation

Our hypothesis is that there is a relationship between the depth of knowledge in a system and the provision of explanation by that system. From the results obtained we were unable to draw a firm conclusion. However, it appears that the provision of explanation facilities is not dependent upon the depth of knowledge held in a system. As with other hypotheses, additional experimental work is required to determine if a relationship does exists, and if so, what form this relationship takes. In order to carry out this experimental work, a larger sample size of suitably qualified subjects would be required. It would also be necessary to design a new experiment which reduces the influence of external factors, such as functionality, when investigating this hypothesis.

7.3.18 Maintenance procedure -> Error reporting

Although we were unable to perform any experiments to determine the relationship between maintenance procedures and error reporting, we were able to identify the strong need for maintenance to occur. It is evident that if a system is to remain effective and to be used, then it is necessary to have a means by which problems are identified and corrective action taken. Unfortunately, we were unable to investigate this area due to resource limitations, however, if sufficient resources were available, then a variety of error reporting strategies could be tested to find the most appropriate for use with a manufacturing KBS, e.g. use of report sheets, automatic system requests, informal user request etc.

7.4 Significance of Factors on Utilisation of a KBS

From the models we have created and the experiments performed, it is evident that no single factor has an overriding impact on the utilisation of a system. Rather, there is a complex series of interactions between a large number of factors. The type and degree of influence one factor has on another is difficult to determine quantitatively. From the models and the experimental work we have been able to perform, the following factors were found to have the greatest degree of impact on system use:

Clear definition of system role,
Scope of the system, i.e. breadth and depth of knowledge
Provision of explanation,
System help facilities,
Human-Computer Interface,
System functionality, and
Maintenance including system improvement.

It is necessary for a system to have a clearly defined role. If the role is not defined, then users seem to be unable to determine how best to use a system. The scope of knowledge held within a system also needs to be specified. It is apparent from the results obtained, that subjects found it difficult to determine the level of knowledge held in a system. This issues become more problematic if a subject does not have any domain knowledge, i.e. how does a subject know the information he receives from the system is correct, or if the system is unable to cope with his request.

As with any computer system the HCI plays an important part in user acceptance. The HCI needs to allow a user to gain easy access to the information held in a system. If a system has a poorly designed HCI, then the utilisation of that system is likely to be impaired. Additional functionality such as explanation and help facilities, was seen as a necessary service offered by a system. These services allow a user to gain more information about how to operate a system as well as understanding the information a system supplies. Although experimental work was not carried out to determine the effects of maintenance, from the responses gathered, it is apparent that maintenance will need to be carried out if a system is to remain useful.

If time and resources permitted, it would be desirable to perform experimental work on all the factors that were identified in chapter 4. This would allow a more detailed and thorough evaluation of factors affecting system use and their interaction.

7.5 Summary

In this chapter we have discussed the models that have formed the basis of out work. We have shown how the issues identified in the model impact on the user and the KBS itself through the use of semantic networks. Furthermore, we have discussed the factors that have been selected for our experimental work, as well as the problems we have encountered, and the results we have obtained. We have also identified the areas where further work is required.

In the next chapter we will draw our conclusions as to the factors that have the most impact on the use of KBS, and suggest areas for future work.

8. Conclusions

8.1 Introduction

Once a company has invested in a KBS, either by development or purchasing one, benefits will only accrue if the system is used. In this thesis we have proposed a model by which system integration can be monitored and controlled to aid the uptake of a KBS. Furthermore, we have identified a number of factors that have a direct impact on the adoption and effective utilisation of a KBS. We have performed a number of experiments to determine the degree of influence a given factor has on the use of a system.

The model we have proposed defines the stages that should occur to allow successful and effective integration of a KBS into working practices. The model provides a convenient and easy to understand representation of the processes involved in the adoption and effective use of a KBS. Furthermore, the model increases the likelihood of achieving effective use of a KBS as soon as possible and maintaining its effectiveness over the whole of its operational life, by providing users with a clear indication of the activities and roles that need to be performed. The model also provides a framework into which new techniques can be fitted, thus allowing a flexible means of maintaining visualisation of how best to adopt and use a system.

In the development of our model, we have identified a large number of factors that can affect the usefulness of a system. These factors have varying degrees of influence. Figure 8.1 provides a representation in which they can be inserted and their values defined. Specifically, from our experimental work we have identified the following factors as having the greatest degree of impact on system use:

Clear definition of system role,
Scope of the system, i.e. breadth and depth of knowledge
Provision of explanation,
System help facilities,
Human-Computer Interface,
System functionality, and
Maintenance including system improvement.

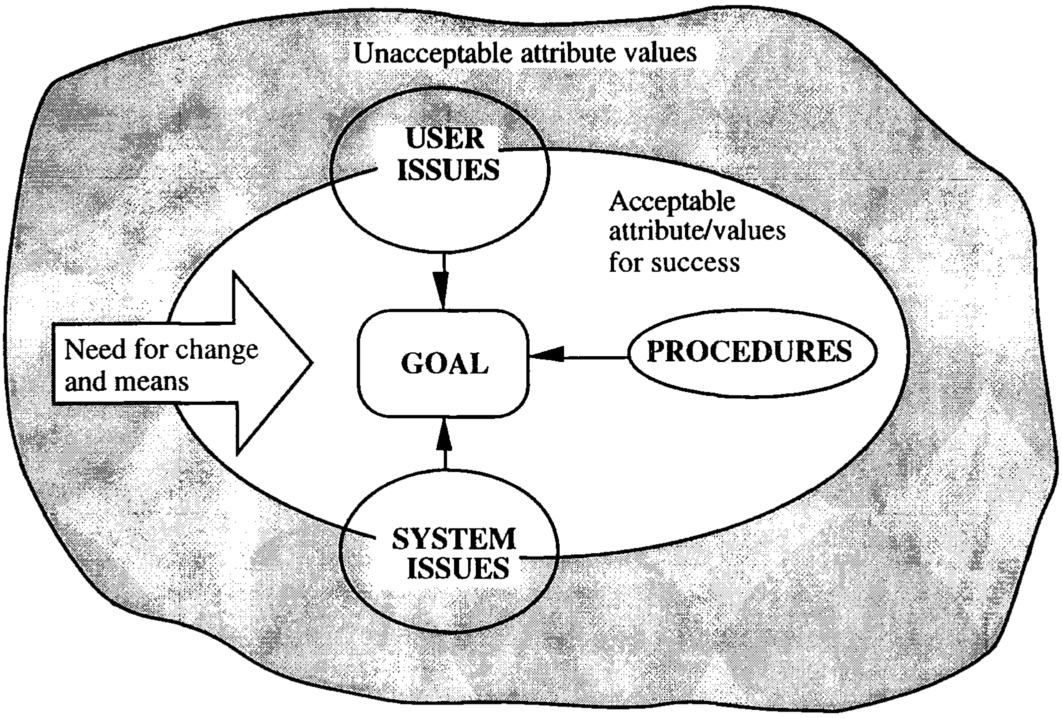


Figure 8.1: State transition of factors affecting use of a KBS

The goal refers to the success of a knowledge-based system being used and yielding benefits that outweigh the costs of the system. There are three entities directly involved in the use of the system, namely, the users, the KBS itself and procedures. Associated with each entity there is a set of factors, each with a range of values. If the values lie within an acceptable threshold then the goal can be achieved. However, if the values lie outside the threshold it is necessary to effect some action to bring these values into the acceptable range.

The selection of factors for investigation was performed using a form of quantitative functional deployment (QFD). This method has proved very useful for identifying the potential impact a factor can have on the use of a KBS. It allowed a quick and easy method for the selection of the most important factors to be investigated further. A prerequisite for the selection of a given factor for further investigation had to be it's controllability. In a large number of cases, factors could not be investigated due to a lack of controllability within the time and resources available to perform experimental work. The inability to control a given factor limited the number of suitable factors that could be investigated. However, due to the large number of issues identified, and the limitations on the amount of experimental work that could be performed, there were still sufficient factors to allow a broad investigation.

The experimental work has been able to identify some of the issues that impact the use of a knowledge-based system. Although the number of experiments that could be performed were limited, we have been able to show a number factors do impact the use of a system. Furthermore, we have been able to identify a number of areas which require more detailed and thorough investigation. We have also identified areas where we believed a factor has significant impact on the use of a system, and found this assumption to be false. The experimental results do not provide a conclusive examination of all the issues that affect the use of a system, rather they indicate the fact that there are a large number of factors which interact with each other to allow a user to gain benefit from a system.

It is still our belief that it is necessary to establish the scope (breadth and depth) of knowledge within a system, even though the experimental results have shown that domain knowledge held in a system has little impact on the role or use of a system. Initial boundaries for the scope of a system should be established by the development team and domain experts. It may be necessary to alter the boundaries to meet the user requirements, i.e. novice users may require more detailed knowledge whereas experienced users may just require 'skeleton' information. The scope of the system will influence how useful a user finds the system. The scope should try to meet the overall requirements of the users and not the requirements of one user.

The human-computer interface(HCI) has a major influence on the user's perception of the system (as it is the only part of the system a user sees). The HCI needs to be as simple to use as possible. It should present information in a clear and easy to read format. It is desirable to involve the users during the development of the HCI to determine the features that they like/dislike.

User confidence in the system has to be established to ensure the system will be used. Confidence can be increased by promoting use of the system by the users, providing a strict guideline(s) for when to use the system and allowing the users to determine if system provides correct results. If a user is a novice in the domain, the system should try to act more as a tutor rather than an advisor to help train the user in the domain task rather than just provide an answer, e.g. provide an explanation behind each step of the reasoning process. The type of user and the anticipated system role will influence how the system is used. A system can adopt more than one role, e.g. assistant, advisor and tutor.

Further experimentation is required in order to conclusively identify issues that have the greatest impact on the use of a system. Due to resource and time limitations we were unable to perform all the experimental work that we would desire. Furthermore, the approach we adopted when performing the experiments has led to a number of problems, which we discussed in the previous chapter. To eliminate these problems, a more detailed investigation focusing on single issues would be required. This would need a significant commitment of resources in order to gain sufficient results to draw any conclusions.

The work we have reported here has given us insight into the complex issues that impact the effective use of a KBS. We have identified issues that impact the use of a system. Furthermore, we have determined a number of key factors that impact on the use of a system. We have also identified areas where further work needs to be carried out, as well as suggestions for the approaches that could be adopted when performing this work.

8.2 Criteria for Success

To help provide a convenient means of assessing the value of the work that has been reported here, we will now evaluate our work against the set of success criteria given in chapter 1. In the remainder of this section we will discuss the degree to which our work satisfies the success criteria. Where we have not been able to fully satisfy a criterion an explanation of the problems encountered and potential solutions are discussed.

In the remainder of this section we will discuss each of the success criteria we defined in Chapter 1 with respect to the work we have performed. For information each of the success criteria are shown in italics.

1. *A detailed literature survey to identify research and practice in the area of knowledge-based system utilisation.*
   In the development of our model of utilisation we have identified a wide range of material dealing with specific parts of the lifecycle of a KBS. However, we were unable to identify any one coherent model of system use. Rather a significant amount of material has been published on system development as well as specific areas that impact use. Generally we found that the issues behind effective utilisation appear to be neglected. We have successfully identified a large number of issues that form the handover, utilisation and maintenance phase of a system's lifecycle. We have successfully incorporated these issues into a succinct model of system use.

2. *A detailed literature survey to identify methods for the analysis of the findings and means for experimentation work.*

A large amount of literature has been identified that relates to the collection of data, design of experiments and analysis of results. From this information we identified a number of key techniques and approaches which we adopted for our use. We have presented the approach we have adopted for the design of experiments we wished to perform, the means by which we intended to collect data as well as the approach we intended to adopt for the analysis of that data.

3. *Evaluation of the usage of the knowledge-based systems in a 'live' environment by different types of personnel, namely the managers, systems engineers, and trainees. This activity will determine the relevance and helpfulness of the knowledge-based system within a manufacturing environment.*
   We have shown how we validated our model of system use, by eliciting from practitioners, their views as to the issues that affect system use. This information was further used to aid refinement of our model. From monitoring the use of KBS in a 'live' environment we established that KBS were a useful tool that could provide tangible benefits within a manufacturing environment.

4. *Monitoring of the process of using the knowledge-based systems.*
   As we validated our model with practitioners, we were also monitored the use of KBS in 'live' environments. The information we obtained while performing model validation from the practitioners also indicated the process that they performed when using a KBS.

5. *Identification of the factors which inhibit or promote the use of knowledge-based systems.*
   Having verified our model of utilisation was valid, we could then begin identification of the factors that affect system use. To this end we used a simplified version of QFD to identify the potential impacts the issues identified in our model had on another. From the resultant table, we were able to select the issues that had the greatest degree of influence. We have performed a number of experiments to determine the impact these factors have.

6. *Categorisation of the identified factors into the method and knowledge-based system related issues.*
   By the use of semantic networks we have identified the issues that impact on a system and on the user. We have further categorised these factors into the main areas where they have the most impact, i.e. handover, operation and maintenance. By looking at the number of connections to other factors we have been able to

identify the potential degree of influence a factor has, i.e. we have been able to identify a given factors sphere of influence.

7. *Development of feasible alternatives to minimise the effect of factors which inhibit the utilisation of the knowledge-based systems.*
   Due to time restrictions it was not possible to develop or implement alternative solutions to the issues identified. However, we have identified in this thesis areas where additional work is required and suggested how this may be carried out.

8. *Implementation and exploration of the alternative solutions.*
   As with criterion 7, we were unable to implement and explore alternative solutions due to time and resource constraints. However, we have identified areas and methods for further work.

8.3 Further Work

The work we have reported in this thesis constitutes an initial step in identifying and controlling factors that affect system use. We have been able to broadly achieve all our goals (discussed in the previous section). However, there are a number of areas that require additional work. In the remainder of this section we will discuss the issues that we feel require further work.

1. It would be desirable to be able to revisit our model of system utilisation in light of the experiments we have performed. The model has provided a firm basis by which we have been able to structure our work. However, the model needs to be maintained and updated if it is to remain effective in describing the processes that occur during system utilisation.

2. To ensure that we maintain our model of utilisation, it would be desirable to continue monitoring of the uptake of KBS in 'live' environments. By continued examination of the process by which systems are installed into a 'live' environment, we can ensure that our model represents a true reflection of best practices.

3. To further maintain our model, we would also monitor and evaluate current thinking as to the best methods, tools and techniques that should be used to allow effective operation.

4. We have already identified in our results the areas that we feel require more detailed investigation before we can perform new experimental work. Particularly we would investigate the following areas: More detailed experimental work on HCI; Breadth and depth of knowledge; and Maintenance procedures. Due to time and resource

limitations we were unable to perform this work. However, if these limitations did not exist then we would perform the additional experimental work as well as a revised set of experiments using a more concise evaluation framework with systems that have been altered to reflect issues we have already identified. Furthermore, we would also attempt to use more subjects with a varying degree of domain knowledge to give a more accurate picture of the influence a given factor has on system use.

5. Having established the significance of factors that affect use it would be desirable to develop solutions to how these factors can be monitored and controlled in a 'live' environment. We would develop a set of measures and controls by which factors can be addressed.

8.4 Summary

In this thesis we have presented a model for the utilisation of a KBS. We have verified this model against practical use of KBSs. We have also identified a number of issues that we believe will impact on the use of a system and performed a number of initial experiments to determine their significance. We have drawn a number of initial conclusions and identified areas where we believe additional work is required, as well as identifying the methods we would adopt to perform the additional work.

9. References

Alger, J., Ed. (1990). A guide to usability, BPCC Wheatons Ltd, Exeter.

ANSI/IEEE (1983). IEEE Standard glossary of software engineering terminology, IEEE.

Basili, V. R., R. W. Selby and D. H. Hutchens (1986). "Experimentation in Software Engineering." Transactions on Software Engineering 12(7): 733-743.

Bennett, K., B. Cornelius, M. Munro and D. Robson (1991). Software Maintenance. Software Engineer's Reference Book. J. A. McDermid, Butterworth-Heinemann Ltd: 20.1 - 20.11.

Bennett, R. and A. K. Carr (1991). COOKER : What's happened since? Handbook of Expert Systems in Manufacturing. R. Maus and J. Keyes, McGraw-Hill: 330 - 337.

Brooks, F. P. (1982). The Mythical Man-Month, Addison-Wesley.

Brown, D. and A. Van der Berg (1990). DEC's Expert system for order scheduling : its development and maintenance. Manufacturing Intelligence: 10 - 13.

Campbell, D. (1969). "Reforms as experiments." American Psychologist 24: 409-429.

Campbell, D. (1975). "Degrees of freedom and the case study." Comparative Political Studies 8: 178-193.

Chorafas, D. N. (1992). Expert Systems in Manufacturing, Van Nostrand Reinhold.

Clegg, C., P. Warr, T. Green, A. Monk, N. Kemp, G. Allison and M. Lansdale (1988). People and computers : how to evaluate your company's new technology, Ellis Horwood: 120 - 134.

Dearden, A. M. and D. G. Bridge (1993). "Choosing a reasoning style for a knowledge-based system : lessons from supporting a help desk." Knowledge Engineering Review 8(3): 201 - 222.

Edmonds, E., L. Candy, P. Slatter and S. Lunn (1990). Issues in the design of expert systems for business. Expert Systems : Human Issues. D. Berry and A. Hart, Chapman and Hall: 98 - 120.

Evans, D. (1993). Technology falls foul of national crimewave. Computer Weekly: 1, 17.

Foddy, W. (1993). Constructing Questions for Interviews and Questionnaires: theory and practice in social research, Cambridge University Press.

Garvin, G. A. (1993). "Building a Learning Organisation." Harvard Business Review 71(4): 78 - 91.

Grisona, M. (1987). "The validation of knowledge-based systems." IEE Colloqium on testing expert systems Digest 1987/110: 4/1 - 4/6.

Guba, E. (1978). Toward a methodology of naturalistic inquiry in education evaluation. Los Angeles, Centre for the Study of Evaluation, University of California.

Hickman, F. R., Killin, J. L., Land, L., Mulhall, T., Porter, D., and Taylor, R. M. (1989): Analysis for Knowledge-based Systems: a practical guide to the KADS methodology. Ellis Horwood.

Hollnagel, E. (1989). The reliability of expert systems, Ellis Horwood.

Kearney, J. R. (1991). The quotation assistant at PMI food equipment group. Handbook of expert systems in manufacturing. R. Maus and J. Keyes, McGraw-Hill: 490 - 496.

Keen, P. G. W. (1985). Systems and organisational changes. Implementing new technologies. E. Rhodes and D. Wield, Blackwell: 361 - 373.

Kerlinger, F. (1979). Foundations of behavioural research. London, Holt-Saunders.

Kidd, A., Ed. (1987). Knowledge Acquisition for Expert Systems : A practical handbook, Plenum Press.

Krackhardt, D. and J. R. Hanson (1993). "Informal networks : the company behind the chart." Harvard Business Review 71(4): 104 - 111.

Leonard-Barton, D. and W. A. Kraus (1985). "Implementing new technology." Harvard Business Review(Nov/Dec): 107.

Main, R. and K. Oldham (1993). Increasing the Acceptance of Knowledge-Based Systems. 30th International Matador Conference, UMIST, Manchester, England, Macmillan.

Maus, R. and J. Keyes (1991). Handbook of Expert Systems in Manufacturing, McGraw-Hill.

McDermid, J. A. and P. Rook (1990). Software development process model. Software Engineer's Reference Book. J. A. McDermid, Butterworth-Heinemann Ltd: 15.1 - 15.35.

Micim-Consortium (1993). CIM Implementation guide, Micim Consortium.

Montgomery, A. (1988): GEMINI - Government expert systems methodology initiative. Research and Development in Expert Systems V, pp. 14 - 25.

Myers, B. A. and M. B. Rosson (1992). Survey on user interface programming, Carnegie Mellon University, Department of Computer Science, Pittsburgh.

O'Leary, D. E. (1990). "Expert System Security." IEEE Expert June: 59 - 69.

Oldham, K., R. Hather, J. Halton and A. Kochhar (1993). "Structured frameworks to produce formalised knowledge suitable for knowledge-based systems." Internal Lucas Publication.

Oldham, K., R. H. Hather, J. Halton and A. K. Kochhar (1993). "A structured framework for the computerisation phase of knowledge-based systems development." Internal Lucas Publication.

Palmer, R. (1988). Designing and using CBT interactive video, NCC Publications.

Parlett, M. and D. Hamilton (1976). Evaluation as Illumination: a new approach to the study of innovatory programs. Evaluation Studies Review Annual. G. V. Glass. Beverly Hills, CA, SAGE. 1.

Patton, M. (1980). Qualitative Evaluation Methods. London, SAGE Publications.

Pfleeger, S. L. (1994). "Design and Analysis in Software Engineering, Part 1: The language of case studies and formal experimentation." Software Engineering Notes 19(4): 16 - 20.

Pfleeger, S. L. (1994). "Design and Analysis in Software Engineering, Part 2: How to set up an experiment." Software Engineering Notes 20(1): 22-26.

Pfleeger, S. L. (1994). "Design and Analysis in Software Engineering, Part 3: Types of experimental design." Software Engineering Notes 20(2): 14-16.

Plant, R. (1987). Managing change and making it stick, Fontana.

Rich, E. (1987). Natural-language Interfaces. Readings in Human-Computer Interaction. R. A. B. a. W. A. S. Buxton, Morgan-Kaufman: 442 450.

Scriven, M. (1972). "Prose and cons about goal free evaluation." Evaluation Comment 3: 1-7.

Sennett, C. T. (1990). Computer Security. Software Engineer's Reference Book. J. A. McDermid, Butterworth Heinemann: 59.1 - 59.11.

Shaw, R. (1990). Expert Systems Opportunities : Guidelines for the introduction of expert system technology, HMSO.

Walters, J. R. and N. R. Nielsen (1988). Crafting knowledge-based systems : Expert systems made realistic, John Wiley and Sons.

Yin, R. (1984). Case Study Research: design and methods. London, SAGE Publications.

APPENDIX A - KBS Evaluation Interview Framework

Introduction

This appendix contains the interview evaluation framework used to elicit user's views on the issues identified in our utilisation model.

SECTION 1. PERSONAL DETAILS OF THE END-USER

1.1 Name ?

1.2 Current position ?

1.3 How long have you been in your current position ?1.4 Please list the main tasks you have undertaken in the last twelve months and the associated activities with each task, the time spent on these activities and the level of expertise you possess in each task (1 = No Knowledge, 2=Understanding, 3 = Working Knowledge, 4 = Good Working Knowledge, 5=Expert)

Task	Activities	Amount of Time (Days)	Level of Expertise

1.5 Do you use computer systems, other than knowledge-based systems in the course of your work ?

Yes No - Go to section 2

1.5.1 Please describe the computer systems that you are familiar with.

System	Hardware	Software

1.5.2 Please list the features that you like / dislike about the above systems.

SystemLikes Dislikes

1.5.3 Can you please indicate how long it has taken for you to become familiar with the computer systems mentioned above ?1.5.4 Did you receive any training in the computer systems mentioned ?

Yes No - Go to 1.5.9

1.5.5 Which system(s) did you receive training in and who performed the training ?

System(s) Training	

1.5.6 Do you think the training was adequate/necessary ?

Yes No - Go to 1.5.8

1.5.7 Why do you think the training was adequate/necessary ?

1.5.8 In what area(s) do you think the training could be improved / is required ?

Go to Section 2

1.5.9 Why did you not receive any training in the use of the computer systems mentioned ?

1.5.10 Do you think training would have been beneficial ?

Yes No - Go to 1.5.12

1.5.11 Why do you think training would have been beneficial ?

Go to Section 2

1.5.12 Why do you think training would not be beneficial ?

SECTION 2. IDENTIFICATION OF THE KNOWLEDGE-BASED SYSTEM(S)

2.1 Please describe what the knowledge-based system(s) is/are used for and what role they were originally developed for.

Roles -

Advisor	- provide possible solutions and the user decides what to do,
Assistant	- invoked by user to perform a specific task,
Critic	- reviews work already completed and comments on accuracy, completeness etc,
Second Opinion	- executes task and compares its results with the results of the user,
Expert Consultant	- offer advice or an opinion given certain information,
Tutor	- trains user to perform 'expert' task,
Automaton	- completes task automatically independent of the user.

Knowledge-based System Bought/Developed as	Use

2.2 What was the level of demand for a knowledge-based system from

Domain Expert

Management

End-User

Customer (the company/personnel who will purchase the product produced)

(1 = No demand, 2 = Desirable, 3 = Required, 4 = Essential)

2.3 For each of the knowledge-based systems listed in question 2.1, please indicate how familiar you are with the domain/task modelled in the knowledge-based system. (1 = No prior knowledge, 2 = Limited knowledge, 3 = Working Knowledge, 4 = Good working knowledge, 5 = Expert)

Knowledge-based System	Familiarity

2.4 Are you actively involved within the domain / domain task ?

Yes No - Go to Section 3

2.4.1 Please indicate how you are involved in the domain task.

SECTION 3. USER ISSUES

3. How often do you use the knowledge-based systems listed in question 2.1 also indicate the time scale involved e.g. daily, fortnightly, monthly etc in the use of the knowledge-based systems ?

(1 = Never, 2 = Infrequently, 3 = Frequently, 4 = Very Frequently, 5 = Always)

Knowledge-based System	Utilisation	Time Scale

3.1 Please identify the knowledge-based system to be discussed.

3.2 How familiar are you with the use of the knowledge-based system ?
(1 = No knowledge, 2 = Limited Knowledge, 3 = Working Knowledge, 4 = Good Working Knowledge, 5 = Expert)

3.2.1 How willing are you to use the knowledge-based system ?
(1 = Not willing, 2 = Willing, 3 = Enthusiastic)

3.3 Is it necessary for you to use the knowledge-based system as part of your job ?

Yes No - Go to 3.3.2

3.3.1 Why is it necessary for you to use the knowledge-based system ?

Go to 3.4

3.3.2 Why is it not necessary for you to use the knowledge-based system ?

3.4 Does your manager expect you or encourage you to use the system ?

Yes No

3.5 Does anyone else show an interest in the use of the system ?

Yes No - Go to 3.6Don't Know

3.5.1 If so, who are they and what is there interest.

3.6 What effect, if any, have the attitudes of your colleagues on your use of the system ?

3.7 What is your role relative to the knowledge-based system ? Please list all that apply.

ROLE

- End-user
- System manager
- Champion
- Maintainer
- Trainer
- Manager of the end-user(s)
- Receives/recipient of the results from the use of the system
- Domain expert
- Knowledge engineer
- System designer
- Software developer
- Other - please specify

SECTION 4. TRAINING ISSUES

4.1 Have you been trained in the use of the knowledge-based system ?

Yes No - Go to 4.2

4.1.1 Who was responsible for your training ?4.1.2 In what form(s) did the training occur ?

4.1.3 How effective was the training ?

(1 = Not Effective, 2 = Effective, 3 = Very Effective).

4.1.4 If ineffective, where could it have been improved ?

4.1.5 How has the training helped you in the use of the knowledge-based system ?

4.1.6 What type of training material was provided ? (course notes, videos, demonstration discs, audio tapes etc)

4.1.7 What was the quality of the training material provided ?

(1 = No Material, 2 = Poor, 3 = Adequate, 4 = Good, 5 = Excellent)

4.1.8 If no material, would having some be helpful and, if so, what would you like?

Go to 4.1.10

4.1.9 If material is poor, what should be changed to make it more helpful ?

4.1.10 What was the duration of the training sessions ?

Go to Section 5

4.2 Why was there no training provided ?

4.2.1 Do you think training would help in the use of the knowledge-based system ?

Yes - Go to Section 5 No

4.2.2 Why do you believe training would not help in the use of a knowledge-based system ?

SECTION 5. IDENTIFICATION OF FACTORS THAT INFLUENCE THE USE OF THE SYSTEM

Section 5a - Functionality

5.1 Please describe what the system does (for you).

5.1.1 Does this match your requirements ?

Yes - Go to 5.2 No

5.1.2 In what way does the system not meet your requirements ?

5.1.3 Were you involved in the specification of what the system should do ?

Yes No

5.1.4 How does the system need to be altered to meet your requirements ?

5.2 How was the functionality of the system (i.e. what it should do) established?

5.3 Is there a help facility in the knowledge-based system ?

Yes No - Go to 5.3.6

5.3.1 Please describe the type of help facility provided.

5.3.2 How is the system help presented (specific help window, audio message, pictures, diagrams, examples etc)?

5.3.3 Does the system help facility assist you in using the knowledge-based system?

Yes No - Go to 5.3.5

5.3.4 How does the system help provided assist you in using the knowledge-based system ?

Go to 5.3.7

5.3.5 Why does the system help provided not assist you in using the knowledge-based system ?

Go to 5.3.7

5.3.6 Do you know why no system help facility has been provided ?

5.3.7 What features should a system help facility possess ?

5.4 Does the system respond quickly to queries ?

Yes No

5.4.1 How does the response time affect your use of the system ?

5.5 Does the system provide any security features ?

Yes No - Go to 5.5.3

5.5.1 What security features are present ?

5.5.2 How do these security features affect your use of the system ?

5.5.3 Do you think these security features are adequate ?

Yes No - Go to 5.5.

5.5.4 Why do you think the systems security is adequate ?

Go to 5.6

5.5.5 What security features would you like to see on the system

Section 5b - Robustness

5.6 Does the knowledge-based system break down / hang up on you ?

Yes No - Go to 5.7

5.6.1 If so, how often does it do this ?

5.6.2 Why do you think the system breaks down / hangs up on you ?

5.6.3 What, if any, is the recovery procedure for this situation ?

5.7 Has the robustness of the knowledge-based system been established ?

Yes No - Go to 5.8

5.7.1 How was the robustness of the knowledge-based system established ? (please indicate the measures and procedures used, and the time required to establish the robustness of the knowledge-based system)

5.7.2 Who was involved in establishing the robustness of the knowledge-based system (Domain Expert(s), End-user(s), Knowledge Engineer, Software Engineer, System Manager) ?

Go to 5.8

5.7.3 Why has the robustness of the knowledge-based system not been established?

5.8 How do you think the robustness of the knowledge-based system influences the actual use of the system ?

5.8.1 What do you think are the causes of the lack of robustness within the knowledge-based system ?

5.8.2 How do you think these problems can be resolved ?

5.9 Are you responsible for reporting any problems with the knowledge and/or the knowledge-based system ?

Yes No - Go to 5.10

5.9.1 How are the problems dealt with ?

5.10 What happens if you are unhappy with the knowledge-based system ?

5.10.1 What (if any) mechanisms exist for you to air your views on the knowledge-based system ?

5.10.2 If known, how is this information used ?

5.11 Does the maintenance of the knowledge/knowledge-based system affect your use of the system ?

Yes No - Go to 5.11.3

5.11.1 How does maintenance of the knowledge-based system affect you in the use of the system ?

5.11.2 Please describe any possible solutions to the problems mentioned in 5.11.1

Go to 5.12

5.11.3 Why do you think the maintenance of the knowledge/knowledge-based system does not affect you ?

Section 5c - Human-Computer Interface

5.12 Please describe how any information from the operation of the knowledge-based system is displayed. (please describe the method/format of displaying information and the explanation facilities offered by the knowledge-based system)

5.12.1 Do you think there is a more suitable method of displaying the information ?

Yes No - Go to 5.13

5.12.2 Please describe how you would like the information to be displayed.

5.12.3 Why was the information not presented in this manner ?

5.13 Please list the features that you like/dislike about the knowledge-based system providing a reason.

Feature	Like/Dislike	Reason

5.14 Please describe the method used to select options/functions.

5.14.1 Do you think there is a more appropriate method of selecting options/functions ?

Yes No - Go to 5.15

5.14.2 Please describe the alternative methods of selecting options/functions.

Section 5d - Confidence in the knowledge

5.15 Do you think an underpinning methodology to support the operation of the knowledge-based system is necessary ?

Yes No - Go to 5.16

5.15.1 Why do you think an underpinning methodology is necessary ?

5.16 What factors do you think influence your confidence in the knowledge-based system ?

5.16.1 How do you think the confidence in the knowledge-base can be improved ?

5.17 Please provide a brief explanation of the methods/factors for increasing confidence in a knowledge-based system.

Section 5e - Knowledge Issues

5.18 What is the level of domain information provided by the knowledge-based system (e.g. practical, academic, enough to get the job done, every detail) ?

5.18.1 How is this domain information displayed (printed, disc, visual, audio) ?

5.19 Please describe how the domain information from the knowledge-based system is actually used.

5.19.1 Can you describe any measures of performance by which the level of advice from the knowledge-based system can be assessed ?

Yes No - Go to 5.20

5.19.2 Please describe the measures of performance for the level of domain information given by the knowledge-based system.

5.20 Do you think the breadth and/or depth of advice provided by the knowledge-based system is sufficient ?

Yes - Go to 5.21 No

5.20.1 Why do you think the breadth and depth of advice is insufficient ?

5.20.2 How do you think these problems can be resolved ?

5.21 How do you know the knowledge within the knowledge-based system is sufficient and does cover the necessary breadth of the domain task ?

5.21.1 Do you agree or disagree with the advice provided by the system ? (1 = Totally Disagree, 2 = Partially Disagree, 3 = Not Sure, 4 = Partially Agree, 5 = Total Agreement)

5.21.2 Please explain why you disagree or agree with the advice provided.

5.22 Is the level of domain information provided by the knowledge-based system of sufficient content and clarity for the task in which the system is employed?

Yes - Go to 5.22.2   No

5.22.1 Please explain (providing examples) why the domain information provided is insufficient or unclear.

Go to 5.23

5.22.2 Please explain why the advice provided by the knowledge-based system is sufficient and clear.

Section 5f - Maintenance Issues

5.23 Please indicate who is responsible for maintaining the knowledge/knowledge-based system and in what role he/she is employed, i.e. System Builder, Domain Expert, Knowledge Engineer, End-user(s), Other Agent.

Person   Role

5.24 Does the system provide any facilities to aid in maintaining the knowledge ?

Yes   No - Go to 5.24.3

5.24.1 Please describe the facilities offered and their effectiveness.

5.24.2 What facilities would you like to have to aid the maintenance of the knowledge/knowledge-based system ?

Go to 5.25

5.24.3 If known, please explain why no facilities have been included in the system to aid the maintenance of the knowledge.

5.25 Is it necessary to include new knowledge or modify the existing knowledge in the knowledge-based system ?

Yes No - Go to 5.26

5.25.1 How is the need to modify the knowledge-base identified ?

5.25.2 What steps been taken to include this new knowledge ?

5.25.3 Who is responsible for the formalisation of the new knowledge ?

5.25.4 Who is responsible for the verification and validation of the new knowledge?

5.25.5 Who is responsible for the process of incorporating the new knowledge into the knowledge-based system ?

5.25.6 Who is responsible for testing the updated/modified knowledge-based system ?

5.25.7 What methods are employed to verify,validate and test the updated knowledge-based system ?

5.25.8 How effective are these methods ?

5.26 Do the operating procedures within the domain alter over a period of time ?

Yes No - Go to 5.27

5.26.1 How frequently do the procedures alter ? (1 = Never, 2 = Infrequently, 3=Frequently, 4 = Very Frequently, 5 = Continuously) ?

5.27 Do you think the functionality of the system is flexible enough to cope with alterations to operating procedures within the domain ?

Yes - Go to 5.28 No

5.27.1 Why do you think the system is not flexible enough to cope with alterations to the domain task ?

5.28 Does the knowledge-based system account for any alteration to the domain task over a period of time ?

Yes No - Go to 5.30

5.29 Is there a mechanism by which the knowledge-based system can cope with the alteration to the domain task ?

Yes No - Go to 5.30

5.29.1 Please describe how the knowledge-based system copes with changes to the domain task.

5.29.2 Do you think there are more suitable methods for the knowledge-based system to cope with alterations to the domain / domain task ?

Yes No - Go to section 6

5.29.3 Please describe the facilities and/or methods that should be used to help the knowledge-based system cope with alterations to the domain / domain task.

5.30 How do you think the inability to cope with alterations to the domain task will affect the use of the knowledge-based system ?

SECTION 6. ENVIRONMENTAL CONSIDERATIONS

6.1 Is the knowledge-based system currently being used ?

Yes No - Go to 6.3

6.1.1 Is the knowledge-based system being used in the anticipated environment (e.g. shopfloor, office, 'field location') ?

Yes - Go to 6.1.4 No Don't Know

6.1.2 If known, what environment is the system being used in ?6.1.3 Why has the knowledge-based system been used in this environment ?

6.1.4 How effectively is the knowledge-based system operating in this environment ?

6.1.5 For what task(s) is the knowledge-based system being used ?

6.1.6 Is the knowledge-based system being used in its anticipated role, i.e. advice system rather than tutor system ?

Yes - Go to 6.1.9 No

6.1.7 Why is the knowledge-based system not being used it its anticipated role ?

6.1.8 In what role is the knowledge-based system currently being used ?

6.1.9 How effective is the knowledge-based system in this role ?

6.1.10 Is the knowledge-based system being used in the anticipated mode, i.e. single user, team based ?

Yes No - Go to 6.1.13 Don't Know

6.1.11 What mode is the knowledge-based system being used in ?6.1.12How effective do you believe the knowledge-based system is when operating in this mode ?

Go to 6.2

6.1.13 Why is the knowledge-based system not being used in the anticipated mode ?

6.1.14 Do you think the system would be more effective if it were being used in its anticipated mode ?

Yes No Don't Know

6.2 Is the use of the knowledge-based system restricted to certain personnel ?

Yes No Don't Know

6.2.1 If so, who are they and who controls the access ?

Personnel	Access control

6.2.2 Is the access control effective or can anyone use it ?

Go to 6.4

6.3 Why is the knowledge-based system not being used ?

6.3.1 What needs to occur for the knowledge-based system to be used ?

6.4 Does the actual physical environment in which the knowledge-based system is used, affect how you use the system ?

Yes No - Go to section 7 Don't Know

6.4.1 How do the following physical conditions affect the use of the knowledge-based system ?

Condition	Effect
Light	
Sound	
Temperature	
Space	
Location	
Position, i.e. keyboard to screen	
Other - please specify	

SECTION 7. IDENTIFICATION OF COST/BENEFITS OF THE SYSTEM

7.1 What were the anticipated benefits from your viewpoint from the introduction of the knowledge-based system.?

7.1.1 How do the anticipated benefits compare to the actual benefits ?

7.2 What were the anticipated costs from your viewpoint from the introduction of the knowledge-based system

7.2.1 How do they compare with the actual costs ?7.3 Did the demand for a knowledge-based system come from a higher level ?

Yes No - Go to 7.5

7.4 If known, who was responsible for this demand ?

7.5 Are there any measures of performance to indicate whether the quality of the output from the domain task has been improved as a result of using the knowledge-based system ?

Yes No - Go to 7.6Don't Know - Go to 7.6

7.5.1 Please indicate the measures of performance

7.5.2 Please indicate how the domain task has been improved

7.6 If you (the user) don't know any of this information, who would ?

APPENDIX B - Parameter/Parameter Lookup Table

Introduction

This appendix contains the parameter/parameter lookup table which was used to identify relationships between parameters before the selection of the relationships we wished to evaluate in greater detail during our experimental work.

This table has been constructed using a form of QFD. The relationships identified have been established from the work carried out in developing our model of utilisation (described in chapter 2) and the results of practical examination of KBS described in chapter 4. This table represents a comprehensive examination of the relationships that can exist between the factors we have identified. In order to allow experimental work to be performed it was necessary to reduce the number of relationships which we examined. The process by which we selected the relationships we wished to test is described in chapter 5. To aid readability, this table has been nominally divided into sections that reflect those used in the case study. The sections are defined by thick lines.

Relationships		
Strong	●	9
Medium	○	3
Weak	○	1
None		

READ

Parameter

Parameter ◄

No.	Parameter	Use of general computer systems	User likes/dislikes	Time required to become familiar	Training in conventional systems	Role of system	Demand for system	Familiarity with domain task	Involvement in domain task	Utilisation of KBS	Familiarity with system (proficiency	Willingness to use system	Necessity to use system	Manager attitudes	Colleagues attitudes	User's role	Training in the use of the system	Effectiveness of training	Type and quality of training	Duration of training	Reasons for no training	Fit with user requirements	Functionality	Provision of system help	Provision of explanation	Response time	Security features	Need for robust system	How was it established ?	User view on robustness	Error reporting	Passing comments	Effect of maintenance	Method of displaying information	Features user likes/dislikes	Method of selecting options	Need for methodology	Factors affecting user confidence	Method of increasing confidence	Breadth of knowledge	Depth of knowledge	How information is used by user	Agreement of user on advice	Identification of system maintainer	Maintenance features	Maintenance procedure	Alteration to operating procedures	Flexibility to cope with changes	Environment KBS used in	Effectiveness of KBS	Mode of operation	Access control	Physical environment	Benefits from use	Cost of use	Measures of performance
1	Use of general computer systems						○							○																																										
2	User likes/dislikes																																																							
3	Time required to become familiar	○																																																						
4	Training in conventional systems	●					○										○																																							
5	Role of system									●				⊙	⊙	⊙			⊙			●	●	●	●			⊙												●	●								○	○						
6	Demand for system									●			●				●				●									●				●						⊙	⊙									●				●	●	
7	Familiarity with domain task					⊙	●		●	●			●		⊙	⊙									●																	●	●					○									
8	Involvement in domain task					⊙	⊙	●		●		●			⊙	⊙																										●	●					○									
9	Utilisation of KBS										●																	●		●			●	●	○	○	○		●	●	●						○	○	○	●		○		●	●	
10	Familiarity with system (proficiency									●		⊙		●	⊙		●							●																										○		○				
11	Willingness to use system									●																		●		●					○	○	⊙	⊙		⊙	⊙							○								
12	Necessity to use system						●			●	●	⊙			⊙																						⊙	⊙																		
13	Manager attitudes	⊙								⊙	●	⊙	⊙		●						●						●	⊙									○			⊙	⊙						⊙	⊙		●				●	●	
14	Colleagues attitudes									○		○	⊙															⊙									○	⊙		⊙	⊙									●		○		●		
15	User's role							⊙	⊙			⊙			⊙									⊙	⊙				○								○																			
16	Training in the use of the system						⊙			⊙	●	●			⊙	⊙																						⊙	⊙																	
17	Effectiveness of training										●						●		●																			⊙																		
18	Type and quality of training	⊙									●						●	●		⊙																		●		⊙	⊙															
19	Duration of training	⊙									⊙						●	●	○																																					
20	Reasons for no training										⊙																																								○				●	●	
21	Fit with user requirements		⊙				●			●		⊙	⊙		●												●	●		⊙				●	⊙	⊙		●		●	●															
22	Functionality					⊙	●			●					●		●		⊙			●		●	●	●	⊙																		⊙			●								
23	Provision of system help		○								⊙						●				○	●	●											⊙				⊙	⊙																	
24	Provision of explanation																●					⊙	●											⊙				⊙	⊙	●	●															
25	Response time																					⊙	⊙													○																				
26	Security features												●									○	●																											○						
27	Need for robust system								●				⊙	⊙								●																●												●						
28	How was it established ?														⊙																						⊙																		
29	User view on robustness											⊙																																					○						
30	Error reporting																											⊙	⊙		●							⊙												⊙						
31	Passing comments																												⊙	●																				○						
32	Effect of maintenance																																																						
33	Method of displaying information	⊙	⊙			●				●					⊙		⊙					●	●												⊙			●																		
34	Features user likes/dislikes														⊙																			⊙				⊙																		
35	Method of selecting options	⊙	⊙							●					⊙		⊙					●	●															●																		
36	Need for methodology									○																												○																		
37	Factors affecting user confidence																											⊙								○																			
38	Method of increasing confidence																																																						
39	Breadth of knowledge					●				●					⊙							●		●	⊙													●									○									
40	Depth of knowledge					●				●					⊙							●		●	⊙													●									○									
41	How information is used by user					●																	⊙																															
42	Agreement of user on advice														⊙																			●		○	⊙	●		●	●															
43	Identification of system maintainer																																					⊙								○			○							
44	Maintenance features								⊙													●																																	
45	Maintenance procedure																													●	⊙												○				○								
46	Alteration to operating procedures												⊙	●																														○										●	
47	Flexibility to cope with changes													○																														●	⊙										
48	Environment KBS used in												⊙			⊙																											○												
49	Effectiveness of KBS									●		⊙	⊙		●												○	●	⊙	⊙	⊙	⊙	●	⊙	⊙	⊙	⊙	⊙		●	●				⊙			⊙			○			●		
50	Mode of operation																					○				⊙			⊙								⊙														⊙				
51	Access control																									⊙																								⊙					
52	Physical environment																																																						
53	Benefits from use						●																					⊙									⊙	●		⊙	⊙				⊙		●			●		○				
54	Cost of use						●																								⊙													⊙			●			⊙						
55	Measures of performance																																																						

APPENDIX C - Experiment Results

C.1 Introduction

In this appendix we present the results of the experiments. Each of the hypotheses contains a description of the hypothesis, the approach adopted to test it, the initial findings as well as the sample size present. Any problems that were encountered when performing the experiments are also discussed. It must be noted that the lines drawn between segments in the polar graphs used to depict some of the results obtained does not imply a relationship between segments, rather it is a means of more clearly displaying the data obtained.

C.2 Findings

The following sections contain the results from the experiments that were performed.

C.2.1 Familiarity with domain task -> Role of system

It is proposed that a user's familiarity with the domain task will impact on his view as to the most effective role a system will perform. For the purpose of this exercise, it is assumed that system can fulfil up to three main roles. These roles are described in table C.1.

System Role	Definition
Advisor	A system that is able to provide the user with suggestions as to the most appropriate action to be taken given a set of conditions.
Assistant	A system that provides the user with support during the performance of his everyday task.
Tutor	A system that is able to act as a teacher.

Table C.1: System Roles

In order to test this hypothesis it was necessary to determine the level of expertise a user possessed, and their view as to the effectiveness of a system's ability to perform a given role. As described in the previous chapter a mock framework was used to give each user a similar experience of the use of a system. By using a framework and structured questionnaire to record results (as well as obtaining details of each subjects occupation and expertise), it is possible to obtain accurate results as to the beliefs of users as to the effectiveness of a system in performing a given role. It provides a repeatable framework from which various subjects can be assessed against. The experiment sample size for this hypothesis was four consultants, two engineers and four graduate engineers.

From the results obtained the following graphs were constructed. Figure C.1 depicts the assessment of the consultants as to the effectiveness of System A. Figure C.2 depicts the results of the assessment made by senior engineers and engineers. Figure C.3 shows the results obtained from graduate engineers.

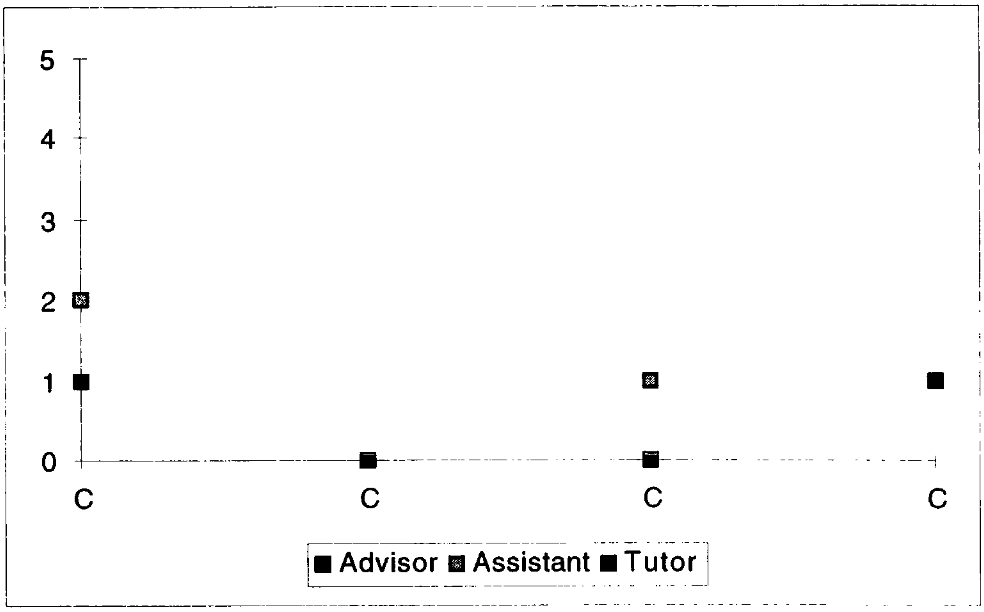


Figure C.1: Effectiveness of the system A rated by consultants

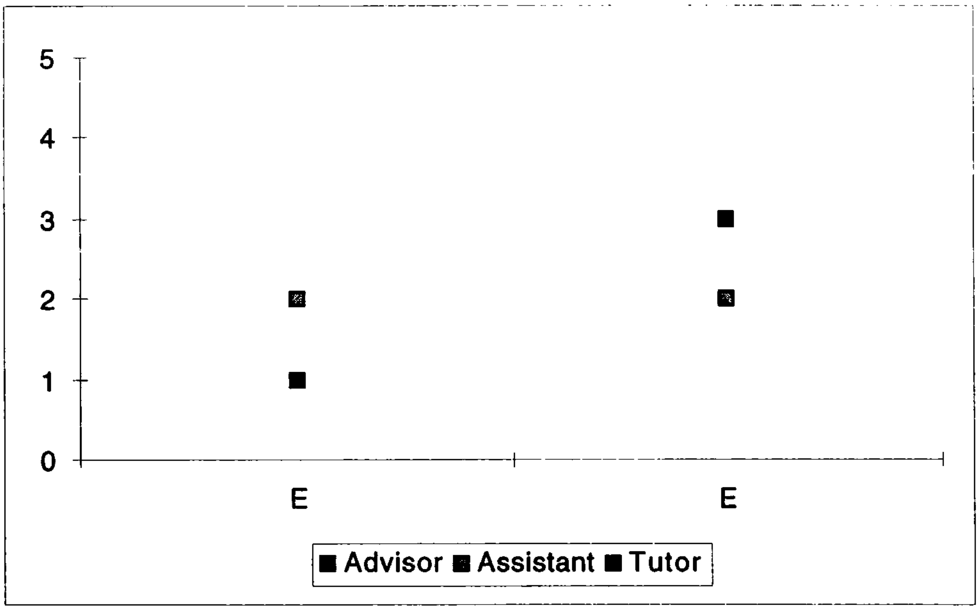


Figure C.2: Effectiveness of the system A rated by engineers

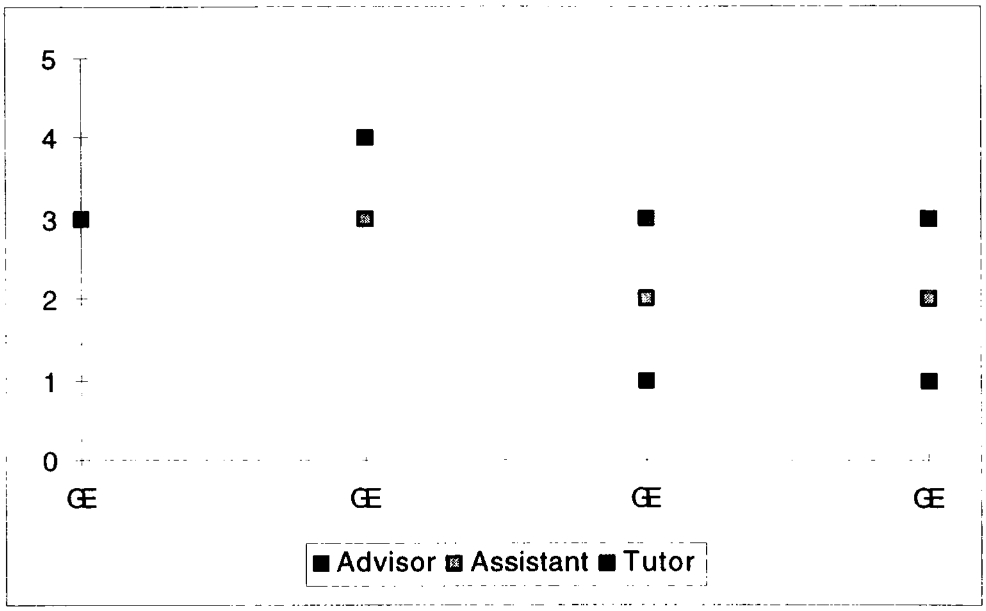


Figure C.3: Effectiveness of the system A rated by graduate engineers

This hypothesis was evaluated as there appeared to be a relationship between the uptake of a system and the relative expertise of a user. This seems to be born out with the results we have obtained. In assessing this hypothesis, a number of problems were encountered, a major problem was the availability of suitable subjects. This lend to the omission of results for the group senior engineers, and the limited number of engineers who performed the experiments.

C.2.2 Functionality -> Fit with requirements (usefulness)

A major part of a system is its functionality. It is proposed that the functionality offered by a system will affect the usefulness of that system. In order to test this hypothesis, it is necessary to determine the functionality that is available in a system and of that, the functionality that can be easily evaluated. To carry out the experimental work, a structured framework was used to provide a set of exercises which required the user to explore a predefined number of system functions in order to complete a task. The results of the subjects views on the functions used were then recorded in the results questionnaire. Two systems were used as it was accepted that they offered more diverse functionality that was present in any one of them. The experiment sample size was three consultants, three senior engineer, one engineer and four graduate engineers for system A. For system B, there were four consultants and the same number of senior engineers, engineers and graduates engineers as for system A.

In the case of the system A only 27% of subjects found that the functionality actually met with their requirements, 36% believed that the functionality required major enhancements, and 37% believed functionality required some enhancements. The general consensus was that all aspects of the system A's functionality required improvement. From figure C.4, it is evident that all the consultants believed system A did not meet their requirements.

In the case of system B 67% of subjects found the functionality met with their requirements, 33% believed that the system required minor enhancements. Areas for system improvement included system returning to a logical place after user completes a task rather than 'just hanging' waiting for input, prioritise possible control systems. In general system B has a higher functionality score than that of system A.

The functionality of a system affects the ability of a system to meet user requirements (as would be expected). If a system has a negative functionality score this indicates that the system does not provide basic functionality to make the system usable.

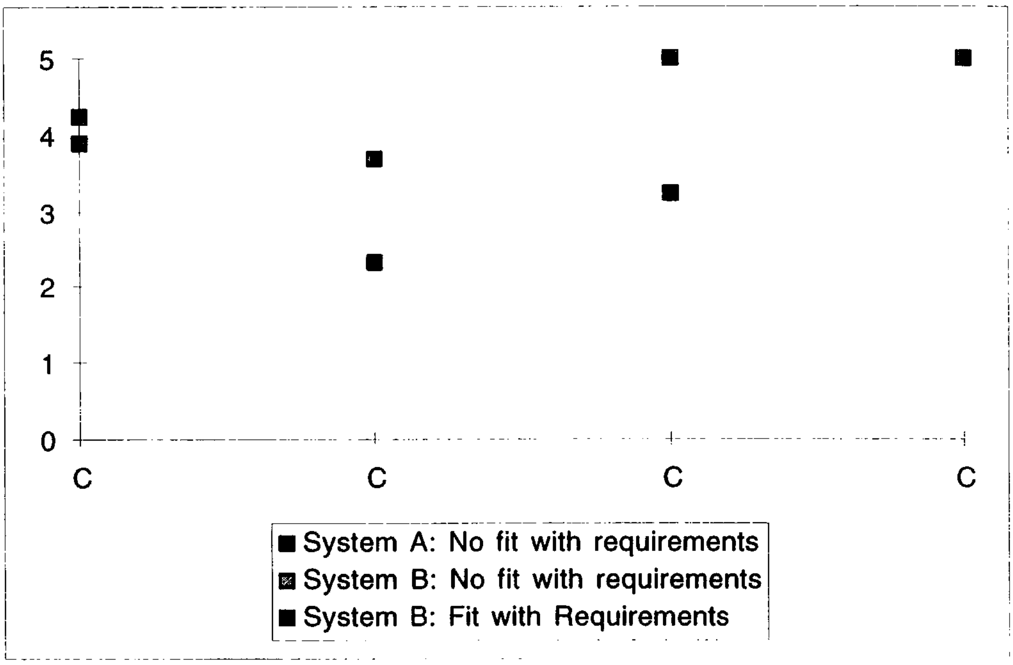


Figure C.4: Fit with requirements (Consultant)

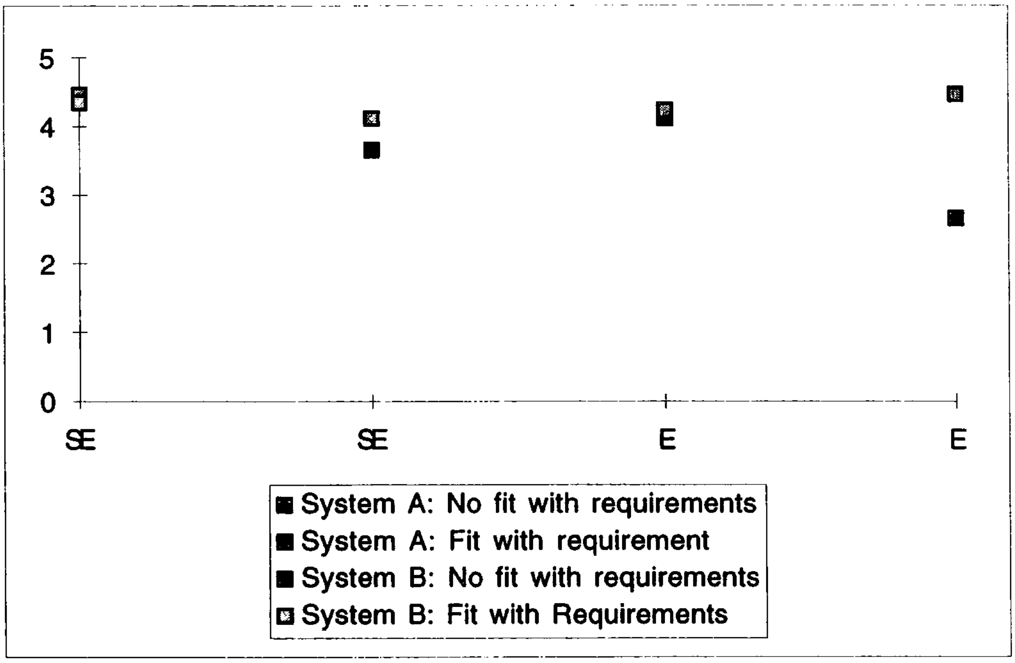


Figure C.5: Fit with requirements (Senior Engineer & Engineer)

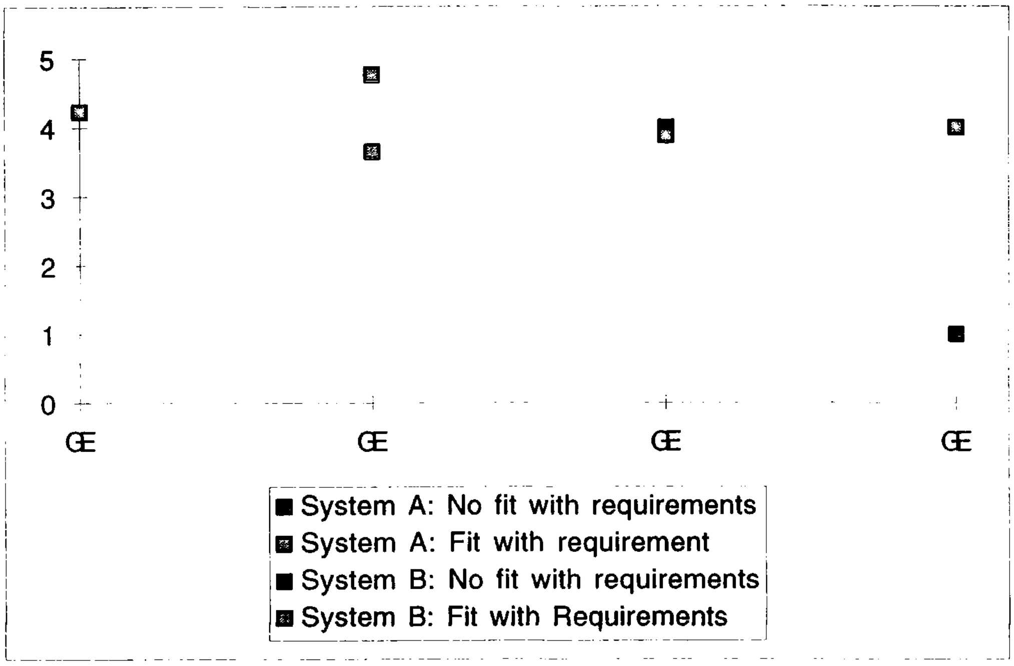


Figure C.6: Fit with requirements (Graduate Engineer)

C.2.3 Provision of help -> Increased fit with requirements (usefulness)

It is proposed that there is a relationship between a system's ability to help a user perform his task and the user's view of the system. As with the previous hypothesis a set of mock tasks were used to give each of the subjects the same experience of the system. A results questionnaire was used to record the subjects view (after completing the mock tasks) as to the affect help facilities had on their view of a system. As with the previous experiment two systems were used to provide sufficient scope for testing the hypothesis. A sample size of three consultants, three senior engineers, one engineer and four graduate engineers carried out this experiment with system A. For system B, four consultants, four senior engineers, two engineers and four graduate engineers performed the experiment.

The following tables represents the results obtained. The subjects tended to agree on the need for a help facility, but were unable to specify the most acceptable format this facility should take. It can be seen that for System A, over 73% of the subjects believed that the system required some form of help facility. For system B, 71% believed that the system required a help facility.

Subject	System Fit with Requirements	Requires Help Facility
C		
C		X
C		X
SE	X	X
SE		
SE		X
E		X
GE	X	X
GE	X	X
GE		
GE		X

Table C.2: Fit with requirements with respect to (wrt) provision of help for system A

Subject	System Fit with Requirements	Requires Help Facility
C		
C		
C	X	X
C	X	X
SE		X
SE	X	X
SE	X	X
SE	X	X
E	X	
E	X	
GE	X	X
GE	X	X
GE	X	X
GE	X	X

Table C.3: Fit with requirements wrt provision of help for system B

From the subjects answers it can be seen that a form of help is necessary for the system to fit with their(users) requirements. However, in a number of cases, the need for a help facility does not bring about a fit with user requirements. This indicates (for those particular subjects) that there are additional features of the system that impact on their view as to the system's effectiveness. From the actual responses in the results questionnaire (not reported here) the subjects reported that the help facility needs to be easily accessible, but more importantly, it needs to direct the user in the task he is performing rather than simply explaining what a specific function does.

C.2.4 Provision of help -> Improved functionality

This hypothesis is closely linked to the previous one. It is our assertion that there is a link with the provision of help facilities and a general improvement in the functionality offered by a system . In order to evaluate this hypothesis, we used two systems to provide sufficient scope of functionality. A set of structured tasks were used to ensure that all subjects had the same exposure to the particular system they were to use during the experiment. The results obtained were again recorded in a detailed questionnaire after the completion of the structured tasks. For system A, a sample size of three consultants, three senior engineers, one engineer and four graduate engineers carried out the experiment. For system B, four consultants, four senior engineers, two engineers and four graduate engineers performed the experiment.

In order to represent the functionality scores recorded by each subject and the need for a help facility, the following tables have been used. The functionality scores indicate the subjects view as to the amount of facilities offered by the system answers were in the range of Very Useful, Useful, Adequate, Inadequate and Very poor.

Subject	Functionality Score	Requires Help Facility
C	Very useful	
C	Inadequate	X
C	Adequate	X
SE	Useful	X
SE	Useful	
SE	Useful	X
E	Adequate	X
GE	Useful	X
GE	Useful	X
GE	Useful	
GE	Very poor	X

Table C.4: Functionality score wrt provision of help for system A

Subject	Functionality Score	Requires Help Facility
C	Useful	
C	Useful	
C	Very useful	X
C	Very useful	X
SE	Adequate	X
SE	Useful	X
SE	Adequate	X
SE	Useful	X
E	Useful	
E	Useful	
GE	Useful	X
GE	Very useful	X
GE	Useful	X
GE	Useful	X

Table C.5: Functionality score wrt provision of help for system B

In the case of System A it can be seen that there is no general consensus of opinion as to the functionality score (roughly 50% of the subjects found the system's functionality to be useful). From the results obtained, there does not appear to be a relationship between the need for a help facility and the functionality of a system. Although there is a general opinion as to the need for help facilities, this is not matched with a general view as to the functionality score of the system. It appears (in the case of system A) that there is no relationship between functionality and provision of a help facility. In the case of system B, it can be seen that the subjects generally found the system to be useful (86%), however, they still expressed a need to have a help facility. This result implies that although the system is seen as useful, there is still areas where improvements need to be carried out (i.e. provision of a help facility).

These results provide some indication that there is a potential relationship between help facilities and improved functionality. However, as they stand, there is insufficient data to make a full evaluation of the hypothesis. In order to fully validate the hypothesis it would be necessary to carry out major alterations to the systems to implement the help features that the subjects identified as being required. Due to time and resource limitation, these alterations could not be carried out.

C.2.5 Provision of explanation -> Improved functionality

This hypothesis is linked to the previous one. We believe that there is a link with the provision of explanation facilities and a general improvement in the functionality offered by a system. To evaluate this hypothesis, we used two systems to provide sufficient scope of functionality. A set of structured tasks were used to ensure that all subjects had the same exposure to the particular system they were to use during the experiment. A structured questionnaire was then used to record their findings after they had completed the structured tasks. For system A, a sample size of three consultants, three senior engineers, one engineers and four graduate engineers carried out the experiment. For system B, four consultants, four senior engineers, two engineers and four graduate engineers performed the experiment.

In order to represent the functionality scores recorded by each subject and the need for a help facility, the following tables have been used. The functionality scores indicate the subjects view as to the amount of facilities offered by the system answers were in the range of Very Useful, Useful, Adequate, Inadequate and Very poor.

Subject	Functionality Score	Provision of explanation facility
C	Very useful	X
C	Inadequate	X
C	Adequate	X
SE	Useful	X
SE	Useful	X
SE	Useful	X
E	Adequate	X
GE	Useful	
GE	Useful	
GE	Useful	
GE	Very poor	

Table C.6: Functionality score wrt provision of explanation facilities for system A

Subject	**Functionality Score**	**Provision of explanation facility**
C	Useful	X
C	Useful	X
C	Very useful	X
C	Very useful	X
SE	Adequate	X
SE	Useful	X
SE	Adequate	X
SE	Useful	X
E	Useful	X
E	Useful	X
GE	Useful	X
GE	Very useful	X
GE	Useful	X
GE	Useful	X

Table C.7: Functionality score wrt provision of explanation facilities for system B

From the subjects answers, 64% believed that system A required some form of explanation facility. As with the previous hypothesis, there is no real consensus of opinion as to the functionality of the system. It appears that the provision of explanation facilities is desirable, but the results obtained do not provide sufficient information in order to validate the hypothesis (in the case of system A). From the results obtained for system B, it can be seen (as in the previous hypothesis) that although the system is generally seen as useful, there is still need for improvement through the addition of an explanation facility.

These results provide some indication that there is a potential relationship between explanation facilities and improved functionality. However, as they stand, there is insufficient data to make a full evaluation of the hypothesis. To fully test this hypothesis, it would be necessary to implement major alterations to the systems in order to provide the necessary explanation facilities. However due to time and resource limitations, these alterations could not be carried out.

C.2.6 Security features -> Improved functionality

It is our hypothesis that the presence of security features will impact on the functionality of a system To test this hypothesis, we used two systems to provide the necessary functionality required, as well as a set of mock tasks to allow the subjects to have the same exposure to the systems. A structured questionnaire was used to record the results. A sample size of three consultants, three senior engineers, one engineer and four graduate engineers carried out this experiment with system A. For system B, four consultants, four senior engineers, two engineers and four graduate engineers performed the experiment.

From the results obtained, only 36% of the subjects who used system A believed that security features were necessary. It can be seen from the table that these subjects found the system to be a least adequate (wrt functionality). For system B, 57% of subjects expressed a need that the system should have some form of security features.

Subject	Functionality Score	Provision of security features
C	Very useful	X
C	Inadequate	
C	Adequate	X
SE	Useful	X
SE	Useful	X
SE	Useful	
E	Adequate	
GE	Useful	
GE	Useful	
GE	Useful	
GE	Very poor	

Table C.8: Functionality score wrt provision of security facilities for system A

Subject	Functionality Score	Provision of security features
C	Useful	X
C	Useful	X
C	Very useful	X
C	Very useful	X
SE	Adequate	
SE	Useful	X
SE	Adequate	
SE	Useful	X
E	Useful	X
E	Useful	X
GE	Useful	
GE	Very useful	
GE	Useful	
GE	Useful	

Table C.9: Functionality score wrt provision of security facilities for system B

From the results obtained, it appears that there is a relationship between the provision of the security features and the functionality of the system. However, as they stand, there is insufficient data to make a full evaluation of the hypothesis. In order to achieve this, major alteration to system functionality would be required in order to implement the security features that the subjects expressed as being necessary. Due to time constraints and resource issues, these alterations could not be carried out.

C.2.7 Human-Computer Interface -> Role of system

In this hypothesis we wish to try and determine if there is a relationship between the method by which information is displayed to a user and the user's view as to the role of the system. To be able to test this hypothesis, two systems with associated mock tasks were used. The two systems selected provided the user with information in two formats, namely blocks of text, or in a graphical tree representation. The results of the subjects views on the role of the system and the effectiveness of the display were recorded in a structured questionnaire. For system A, a sample size of five consultants, three senior engineers, one engineer and four graduate engineers carried out the experiment. For system B, four consultants, three senior engineers, two engineers and four graduate engineers performed the experiment.

It can be seen from the following graphs, that there appears to be no relationship between the role of the system and the means by which information is displayed to the user. However, there is evidence to support the view that there are additional factors that impact on the effectiveness of a system to perform a given role. This is evident from the fact that the role scores are different.

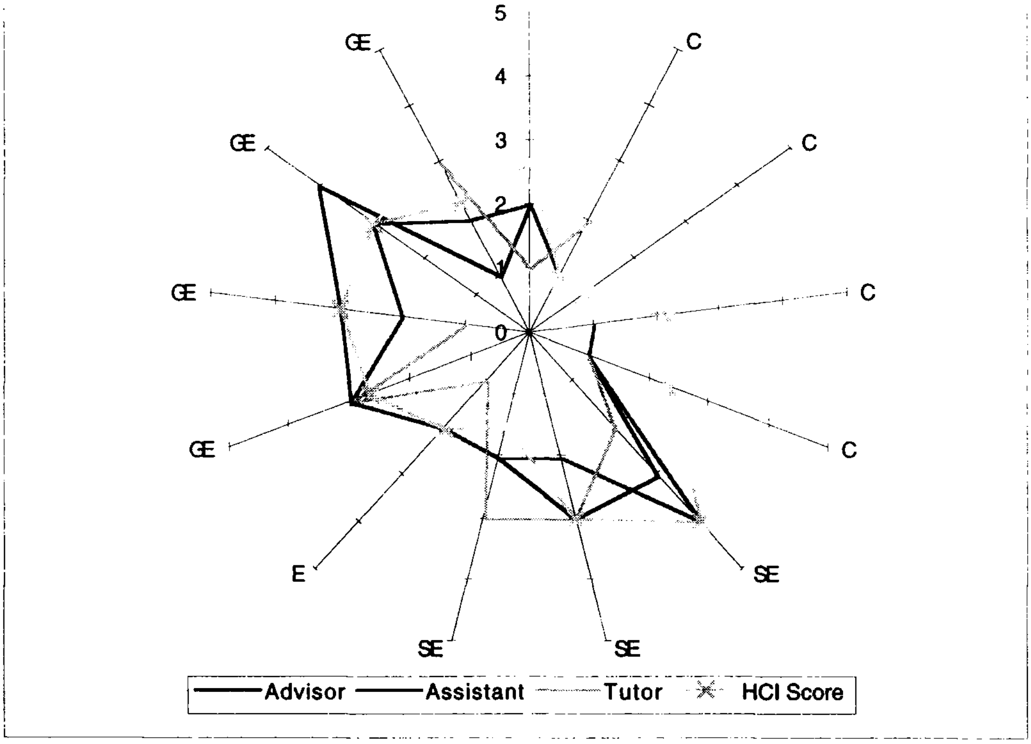


Figure C.7: Impact of the HCI on the role of system A

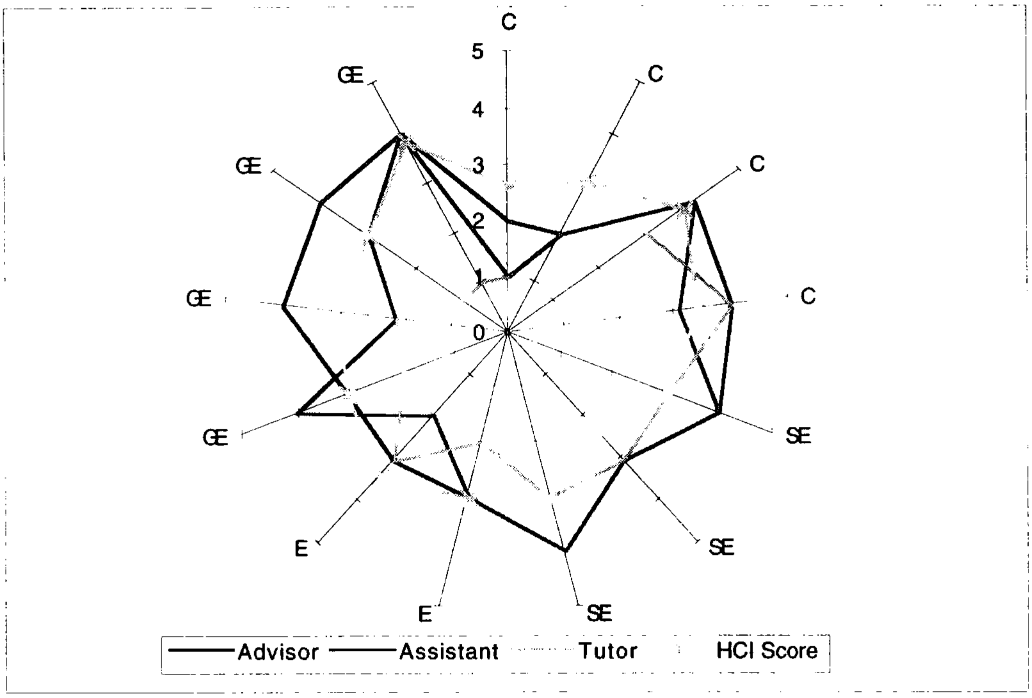


Figure C.8: Impact of the HCI on the role of system B

From the results we have obtained, we can make a preliminary conclusion that the method of displaying information in the case of system A does play some function in the role of a system. It can be seen that if a subject rated the system was relatively highly in the role of an advisor or assistant, then there was a corresponding high rating of the HCI. It must be noted that although there was a relatively high score for the HCI (approximately 2), this is only seen as lying somewhere between an inappropriate interface and an appropriate one. Therefore, the relationship that is seen may imply that a more appropriate interface will result in a more effective system that can perform a given role.

In the case of system B, a similar relationship between HCI score and the role of advisor and assistant can be seen. However, in this case, the general interface score is higher, as well as the scores for the role of the system. Furthermore, the system's ability to act as a tutor is more apparent. These results do suggest that the HCI does have an impact on the role a system can perform.

The results obtained highlight a relationship between the HCI of a system and the ability of a system to perform a given role. However, the lack of agreement by subjects as to the role of a system does imply that there are other issues that influence the system's ability to perform a given role (in the case of system A, that of a tutor). In order to fully test this hypothesis, further work needs to be carried out by providing subjects with a variety of HCI configurations. This work has not been performed due to time and resource limitations.

Due to time restrictions and limitations with the systems used for the experimental work, it has become necessary to group the following four hypotheses in order to present meaningful results. This grouping has allowed for easier representation and analysis of the results obtained. A full discussion of the problems encountered, that has forced this grouping is provided in the following chapter.

C.2.8 Method of displaying information -> Fit with requirements (usefulness)

C.2.9 Method of selecting options -> Fit with requirements (usefulness)

The two hypotheses represent the view that the Human-Computer Interface has an affect on the ability of a system to fit with user requirements. To test both hypothesis, a set of mock tasks in conjunction with two knowledge-based systems were used with a structured questionnaire to record the results obtained. For system A, five consultants, three senior engineers, one engineer and four graduate engineers were involved in the experiment. The system B experiment was performed by four consultants, four senior engineers, two engineers and four graduate engineers.

It is our assertion that the HCI will have an impact on a system's ability to fit with user requirements (the ability of a system to perform the tasks required by the user). From the results obtained the following graphs have been plotted.

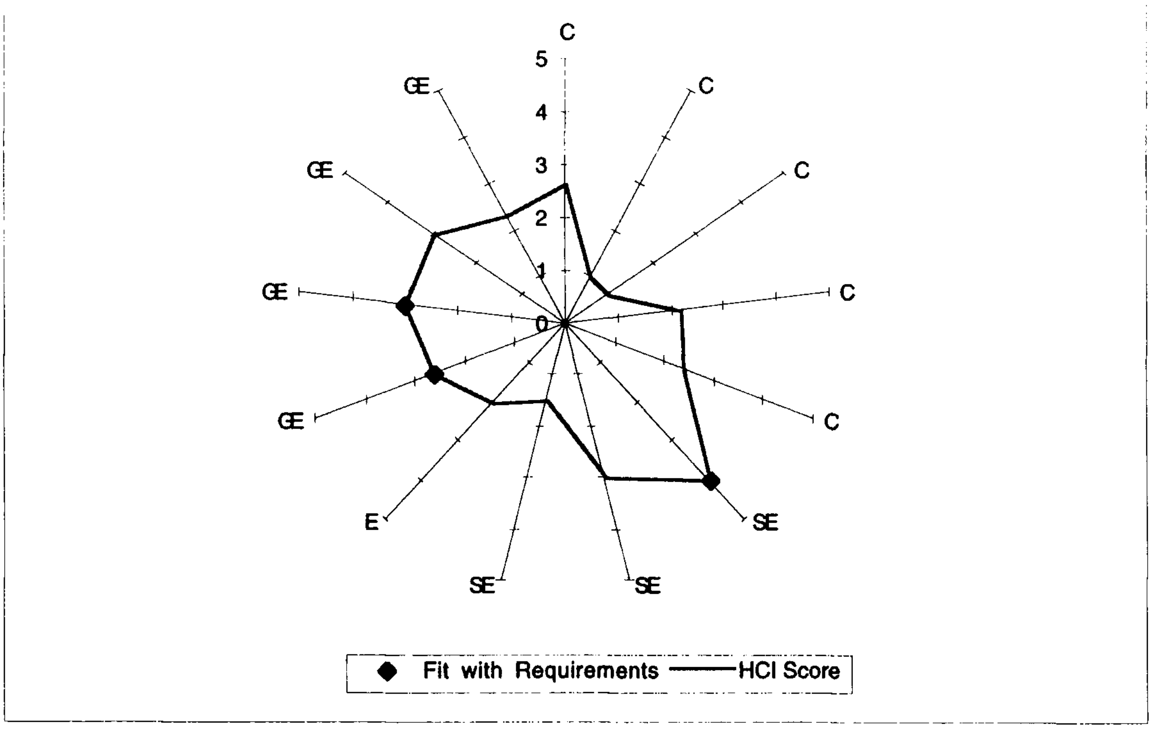


Figure C.9: Fit with requirement for System A's HCI

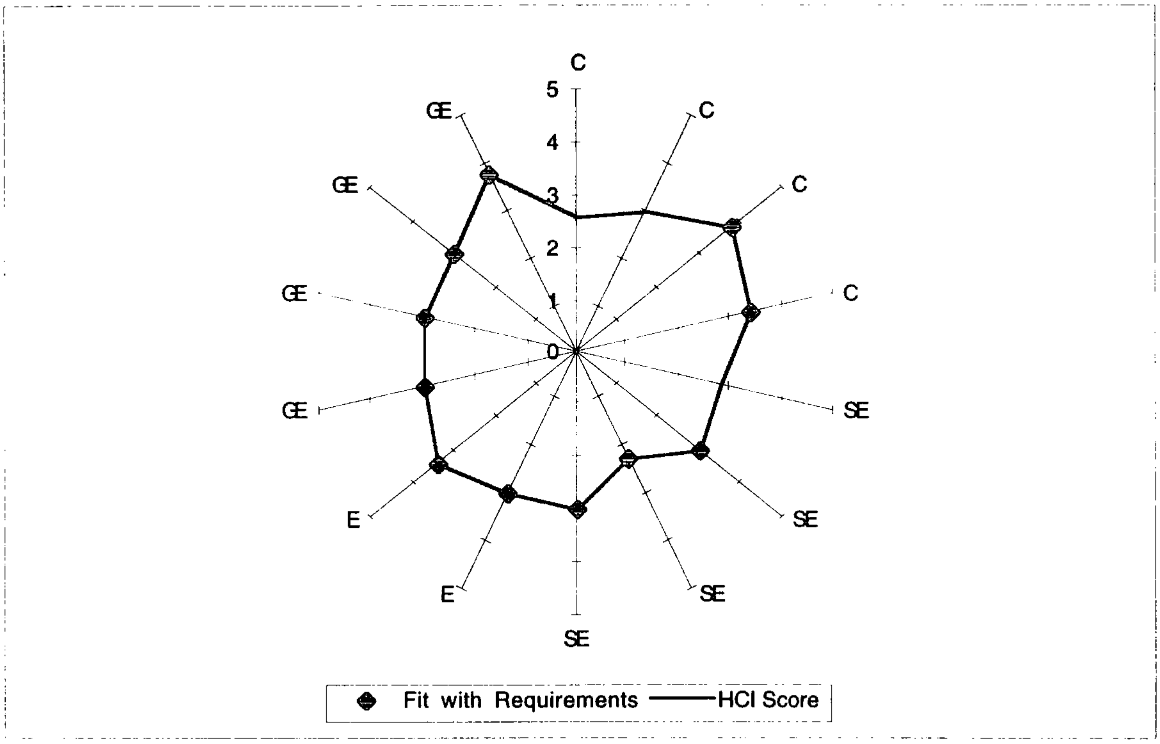


Figure C.10: Fit with requirement for System B's HCI

From the subjects consulted, 23% (3 out of 13 subjects) believed that the HCI for system A would fit with their requirements (an average HCI score of 2), this compares to 69% (9 out of 13) for the system B (average HCI score of 3). In the case of system B, a more even score for the HCI is visible compared to that of system A. The irregularity of scoring for system A implies that there are additional factors that influence the subjects rating of the HCI. This is further supported by the low number of subjects who state the system fits with their requirements.

The method of displaying information can be seen to have an affect on a systems ability to meet user requirements. The more appropriate the HCI, the more likely the system is to meet user requirements (as would be expected). In order to fully explore the issues relating to why the HCI scores for system A are so irregular, further experimentation would be required. This work has not been carried out due to time and resource restrictions.

C.2.10 Method of displaying information -> Functionality
C.2.11 Method of selecting options -> Functionality

In these hypothesis we wish to determine whether there is a relationship between the HCI and the functionality of a system. In order to determine if such a relationship does exists, two systems were used to provide suitably diverse HCI and functionality. A set of subjects performed a series of tasks and recorded there views of the systems in a detailed questionnaire. For system A, five consultants, three senior engineers, one engineer and four graduate engineers performed the experiment. In the case of system B, four consultants, four senior engineers, two engineers and four graduate engineers performed the experiment.

From the results obtained (shown in figure C.11 and C.12) it can be seen that there is a relationship between the functionality of a system and it's HCI. In both systems, the HCI score is less that of the functionality score, although the two are closely matched. Only in the case of a graduate engineer using system A does the functionality score of the system fall below that of the HCI. Generally speaking it can be said, that if there is a relatively high functionality score, then there is a correspondingly high score for the HCI.

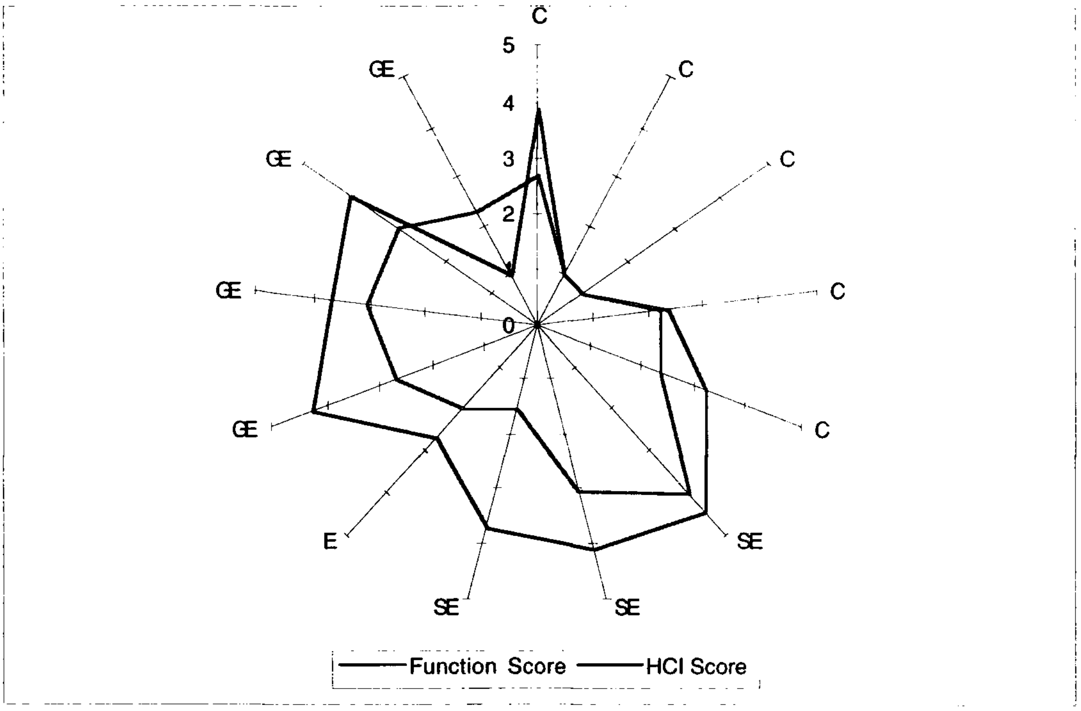


Figure C.11: Relationship between System A's HCI and functionality

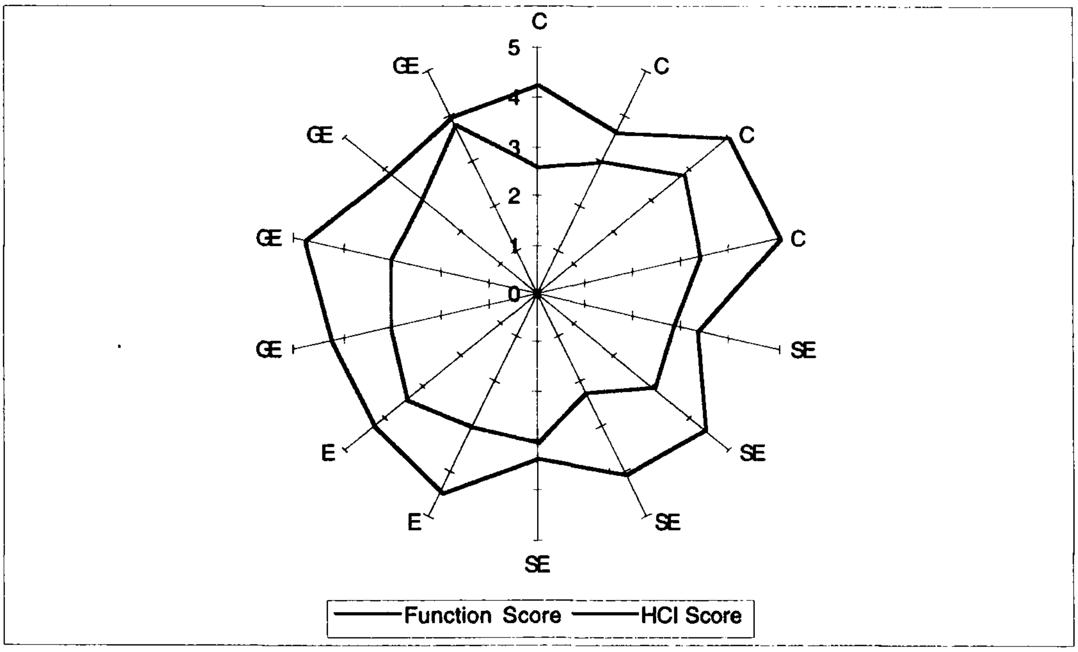


Figure C.12: Relationship between System B's HCI and functionality

The results obtained indicate that there is a relationship between the functionality of a system and the HCI. This relationship seems to imply that high functionality score will result in a relatively high HCI score. However, the results obtained do not provide sufficient information to determine whether the relationship identified is consistent across more subjects and systems. To test these hypotheses fully, it would be necessary to perform more detailed experiments using more subjects as well as different systems offering a range of HCI and functionality.

C.2.12 Breadth of knowledge -> Role of system

It is our hypothesis that there is a relationship between the breadth of knowledge held in a system and the role that system can perform. To be able to tests this hypothesis, two systems have been used in conjunction with a set of mock tasks and a detailed questionnaire to record a subject's views on the systems. In total, four consultants, three senior engineers, one engineer and four graduate engineers performed the experiment using system A. For system B, four consultants, three senior engineers, two engineers and four graduate engineers took part in the experiment.

Due to the limited number of subjects who rated both the breadth of knowledge and system role for system A, no definite conclusions can be drawn on our hypothesis. Where breadth of knowledge has been defined, it was generally seen as appropriate, although there is a wide distribution of results. It appears that the breadth of knowledge does not have any influence on the role of the system. From the graph, it is apparent that the subjects can not gain a consensus of opinion as to the effectiveness of the system in performing a given role. It would be expected that if the breadth of knowledge does influence the role of the system, then if breadth increases, then we would see a corresponding increase in the score for a role.

In the case of system B, a larger proportion of the subjects were able to determine the breadth of knowledge and role of the system. Again, no consensus of opinion as to the breadth of knowledge or system role can be seen.

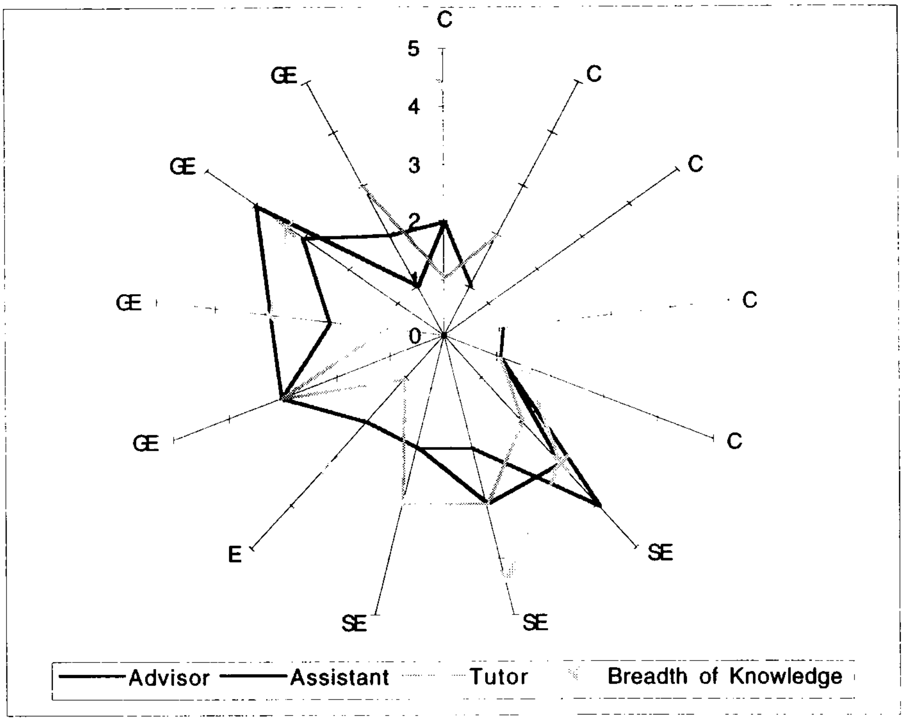


Figure C.13: Relationship between breadth of knowledge and system role for System A

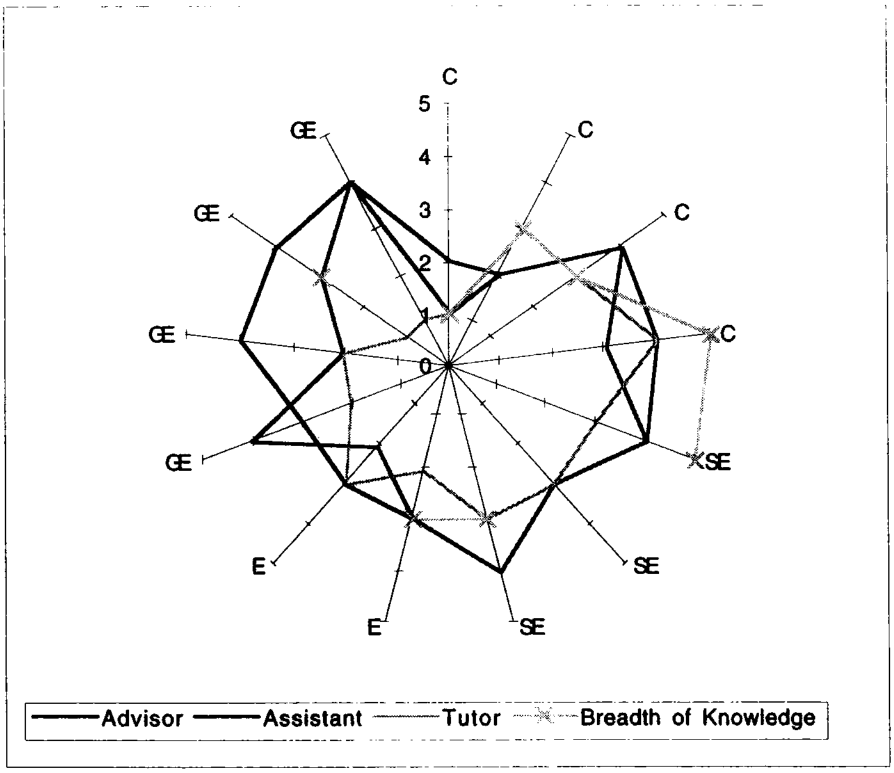


Figure C.14: Relationship between breadth of knowledge and system role for System B

Problems have been encountered in assessing the breadth of knowledge held within both systems. This stems from a number of factors which include, subjects domain knowledge (a subject may not be fully conversant with the domain information held in each system), limited exposure to the system due to the structured task, misinterpretation of the questionnaire used to record results of the experiment. A full discussion of these issues will be carried out in the next chapter. In order to fully test our hypothesis, it would be necessary to perform a more extensive set of experiments using a wider number of subjects with varying domain knowledge as well as a more detailed structured task and results questionnaire. Due to time and resource constraints it was not possible to perform this work.

C.2.13 Breadth of knowledge -> Fit with requirements (usefulness)

In this hypothesis we wish to establish whether there is a relationship between the breadth of knowledge held in a system and the ability of that system to meet user requirements. In order to test this hypothesis two system have been used in conjunction with a structured tasks and questionnaire. In total, five consultants, four senior engineers, two engineers and four graduate engineers performed the experiment using system A. For system B, five graduate engineers, two engineers, four senior engineers and four consultants took part in the experiment.

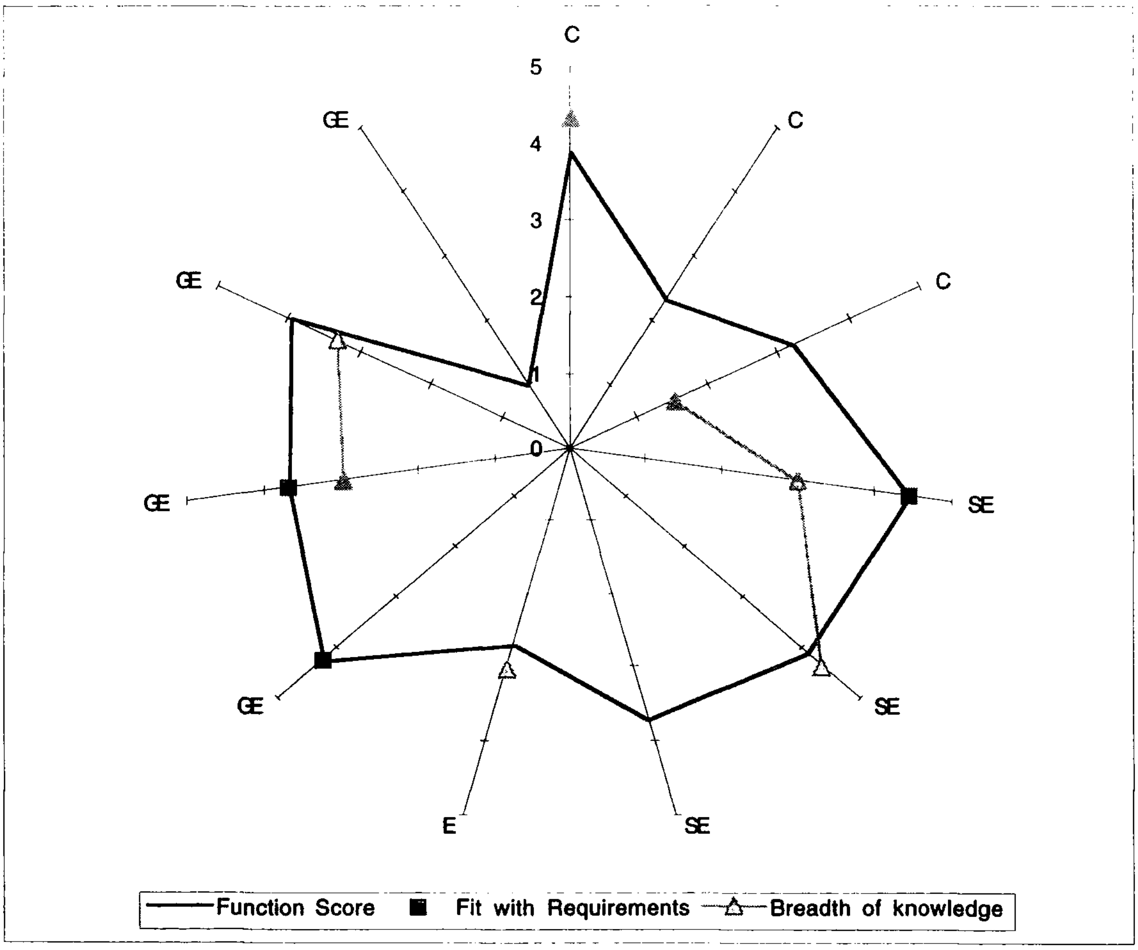


Figure C.15: Relationship between breadth of knowledge and ability of system A to fit with user requirements

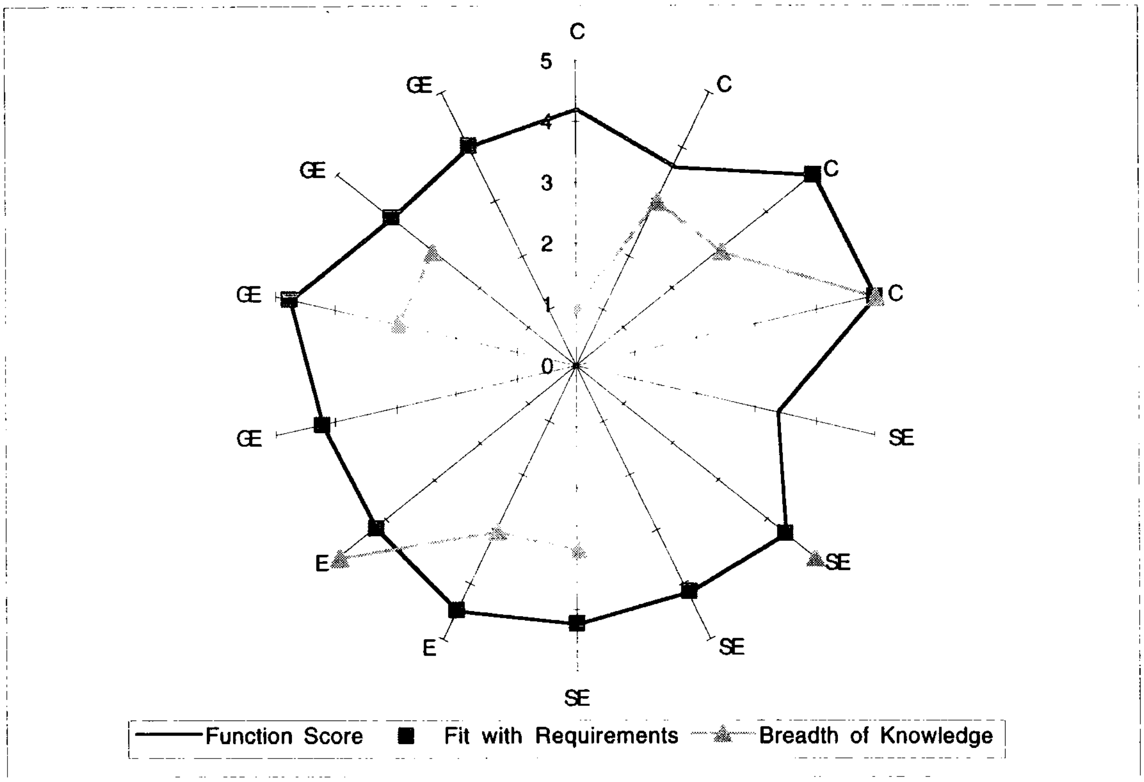


Figure C.16: Relationship between breadth of knowledge and ability of system B to fit with user requirements

For both systems there does not appear to be a significant relationship between the perceived breadth of knowledge and the ability of a system to meet user requirements. In the case of system A (where answered) most subjects saw the breadth of knowledge ranging from general to adequate with a corresponding usefulness of limited to useful (even though the breadth of knowledge in the system is constant and the same for all subjects). If there is a relationship present, then we would expect to see the breadth of knowledge scores in-line of the scores for 'fit with requirements'. This does not appear to occur. Similarly, for the system B there is a greater range of answers. The breadth of knowledge is seen as general to comprehensive, however, there are more scores for 'fit with requirements', but these scores are not consistent with the scores given for the breadth of knowledge.

The lack of a discernible relationship may be attributed to some extent to the limitations of the experiments that have been performed, i.e. limited sample size, structure of tasks, structure of the results questionnaire and the knowledge-based systems used to perform the experiments. In order to fully test this hypothesis it would be necessary to increase the sample size ensuring that the subjects have sufficient domain knowledge to determine the knowledge content of each system. Due to resource and time limitations this repeat experiment could not be performed.

C.2.14 Breadth of knowledge -> Provision of explanation

In this hypothesis we intend to determine if there is a relationship between the breadth of knowledge held in a system and the ability of a system to provide explanation facilities. In order to test this hypothesis, we used two knowledge-based systems in conjunction with a set of tasks and a questionnaire to record subjects findings of the systems. In total, three consultants, three senior engineers, an engineer and four graduate engineers performed this experiment with system A. Four consultants, four senior engineers, two engineers and four graduate engineers carried out this experiment with system B.

From the results obtained it is evident that explanation facilities are seen as essential for system A (82% of subjects expressed the need for explanation facilities). In the case of system B, all subjects agreed for the need for explanation facilities. However, it both systems, there does not seem to be a relationship between the breadth of knowledge held within a system and the need for explanation facilities.

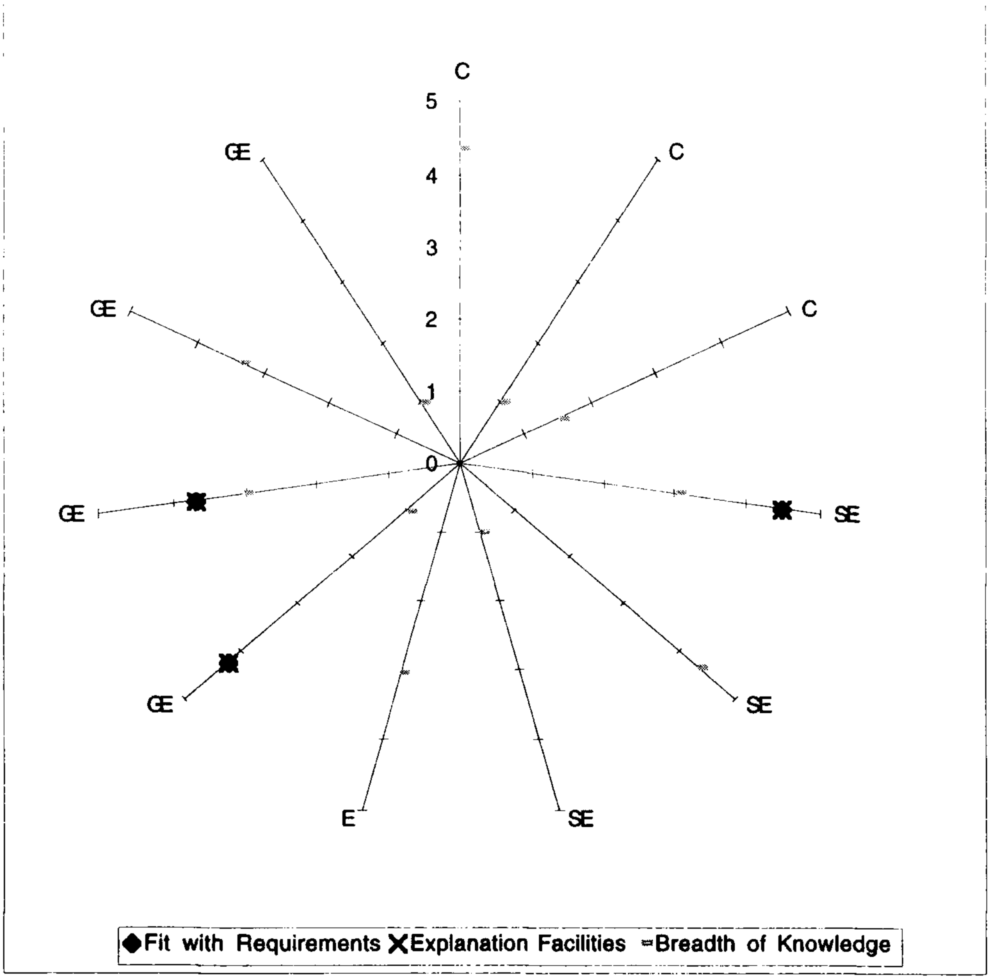


Figure C.17: Link between breadth of knowledge and explanation facilities for system A

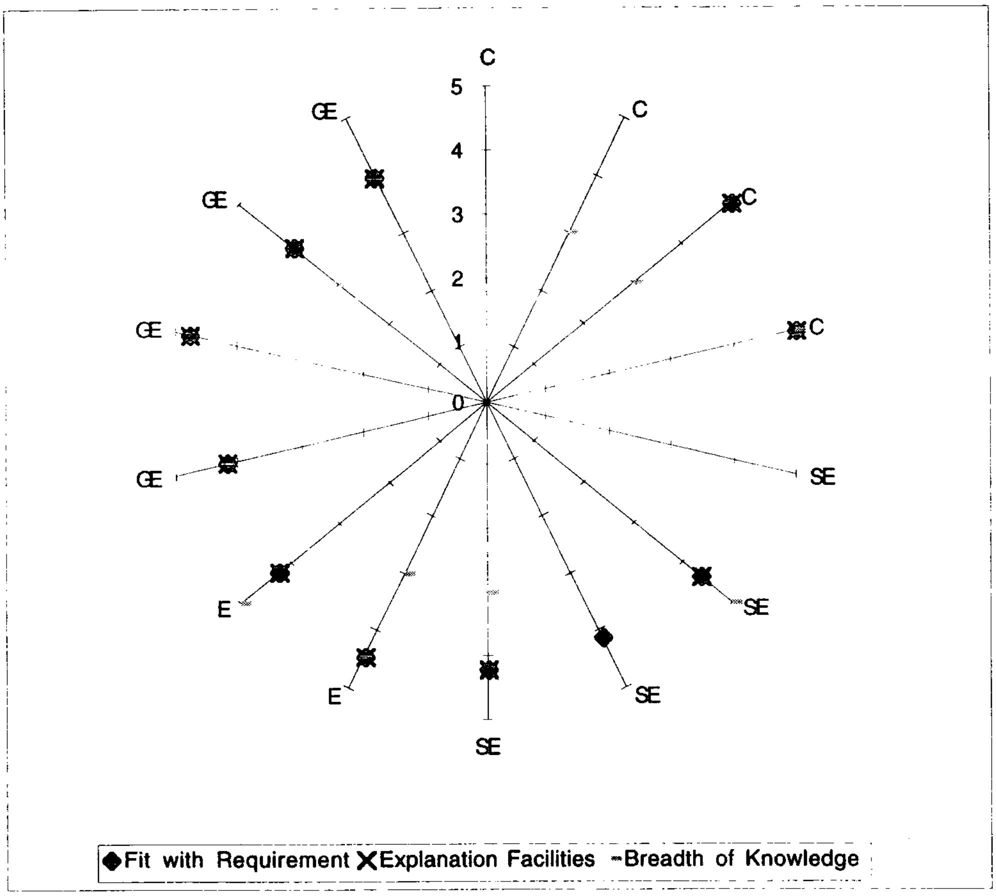


Figure C.18: Link between breadth of knowledge and explanation facilities for system B

As with the previous hypothesis this lack of relationship may stem from the form of experimental work carried out as well as the limited sample size and the systems used as the basis for the experimental work. In order to fully test this hypothesis it would be necessary to increase the sample of subjects, provide a more rigidly defined set of tasks and results recording method and finally use alternative systems that rely more heavily on explanation of its decision making process.

C.2.15 Depth of knowledge -> Role of system

It is our hypothesis that as we believe there is a relationship between breadth of knowledge and the role of the system there is a similar relationship between the depth of knowledge and system role. In order to test this hypothesis a structured framework was used in conjunction with two knowledge-based systems. For the experimental using system A, five consultants, three senior engineers, one engineer and four graduate engineers formed our sample set. For the experimental work using system B, four consultants, three senior engineers, two engineers and four graduate engineers carried out the experiments.

From figure C.19, it can be seen that in the case of system A, there does not appear to be a clear relationship between the role of the system and the depth of knowledge. However, if the system is used as an advisor , then in a number of cases it does appear that there may be a relationship, i.e. the greater the depth of knowledge, the more useful the system acts as an advisor. Furthermore, it appears that no consensus of opinion concerning the depth of knowledge is present, the range is from inappropriate to appropriate. The subjects appear to find the system least useful in the role of tutor.

System B, can be seen to have a more useful role as both an advisor and assistant. Again, the system is seen to be least effective in the role of tutor. As with system A, there does not appear to be a clear relationship between the role of the system and the depth of knowledge. However, a similar relationship seems to be present between the depth of knowledge and the system acting as an advisor.

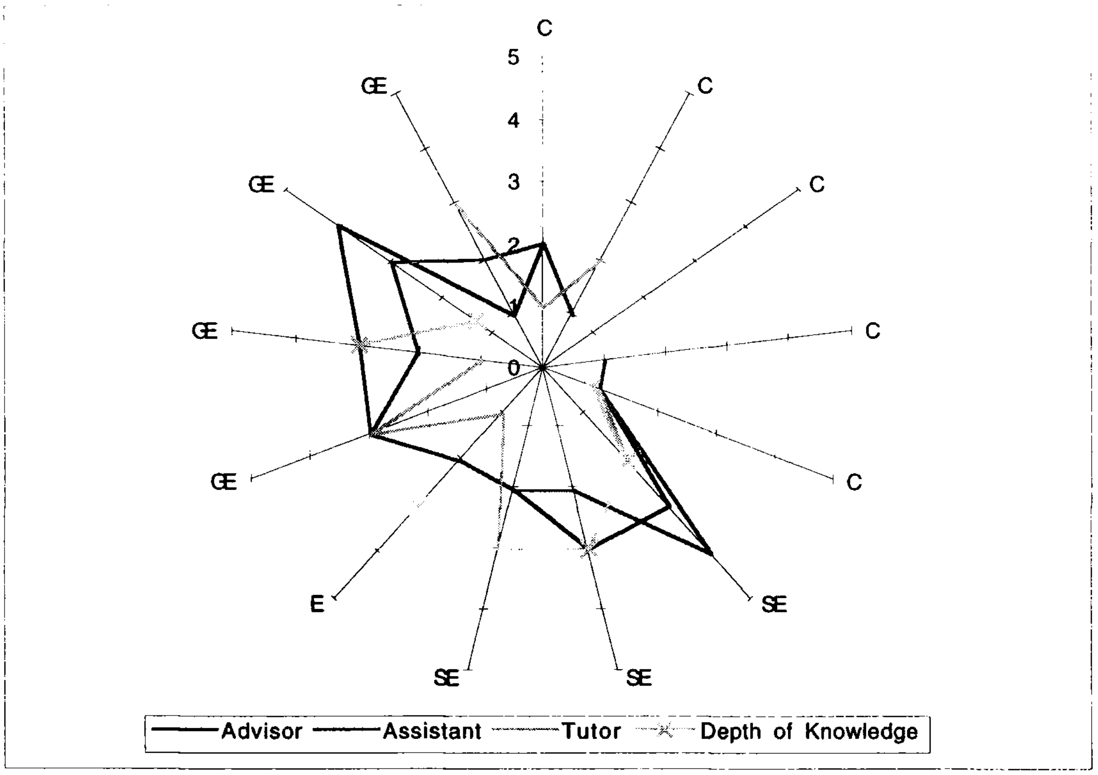


Figure C.19: Relationship between role of system and depth of knowledge for system A

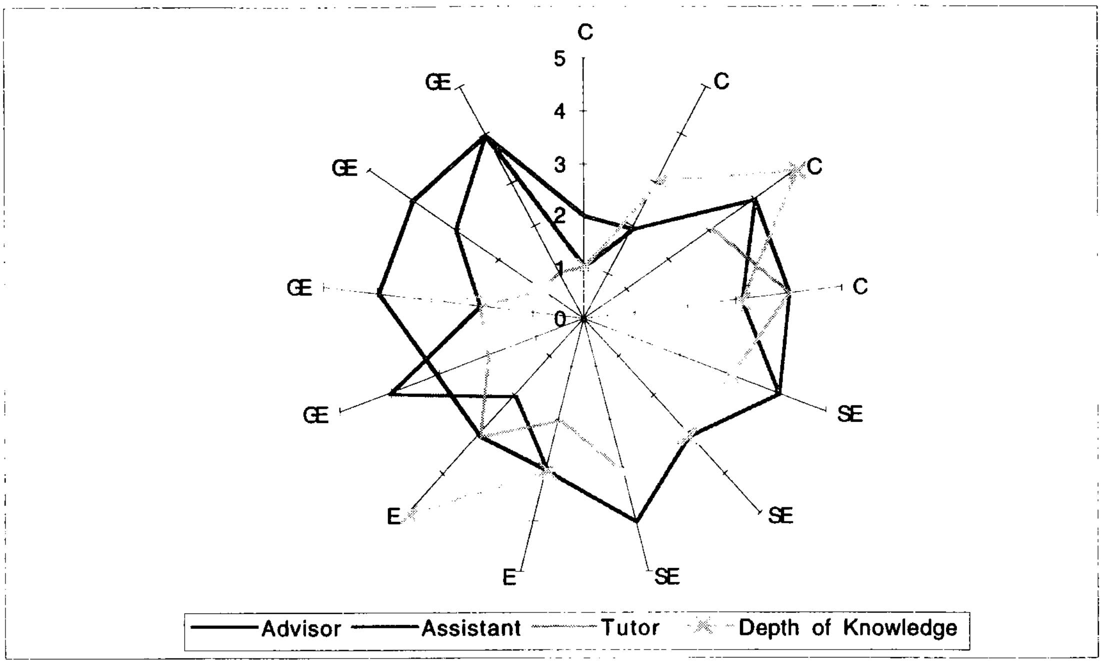


Figure C.20: Relationship between role of system and depth of knowledge for system B

From the results obtained no conclusive evidence exists to suggest that there is a firm relationship between the role of the system and the depth of the knowledge held within that system. Again, this may be due to the experimental conditions and the number and expertise of the subjects who participated in the experiments. If time and resources permitted, further experimental work using more subjects and detailed tasks to evaluate this hypothesis would be necessary.

C.2.16 Depth of knowledge -> Fit with requirements (usefulness)

In this hypothesis we intend to determine whether the depth of knowledge held in a system will affect the ability of the system to meet with user requirements. As with the other hypothesis, a set of tasks and two knowledge-based systems were used. In total, three consultants, three senior engineers, an engineer and four graduate engineers performed the experiments for system A. In the case of system B, four consultants, four senior engineers, two engineers and four graduate engineers took part.

From figure C.21, no conclusion can be drawn as to the affect of the depth of knowledge on the ability of the system to fit with user requirements. In a number of cases, the subjects were unable to determine the depth of knowledge in the system or to express whether the system would meet their requirements. An initial observation would suggest that for system A, there is no relationship present, further experimental work would be required in order to fully investigate this hypothesis.

In figure C.22, system B does appear in a number of cases to show that a relationship does exist between the depth of knowledge and the ability of the system to meet user requirements (this can be seen from the high scores as to the depth of knowledge and a corresponding high score for the fit with requirements). However, this relationship may be due to other factors that are present when the subject is using the system, e.g. human-computer interface.

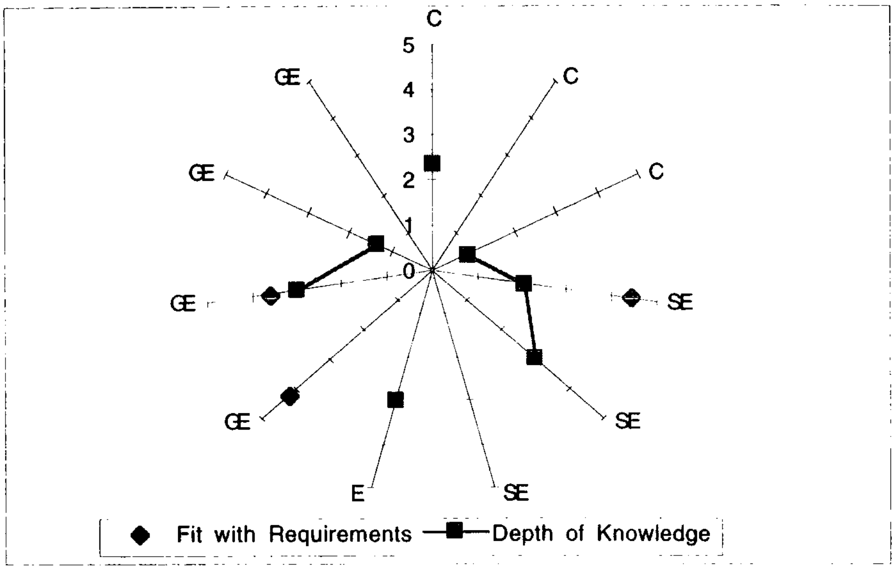


Figure C.21: Affect of the depth of knowledge on fit with requirements for system A

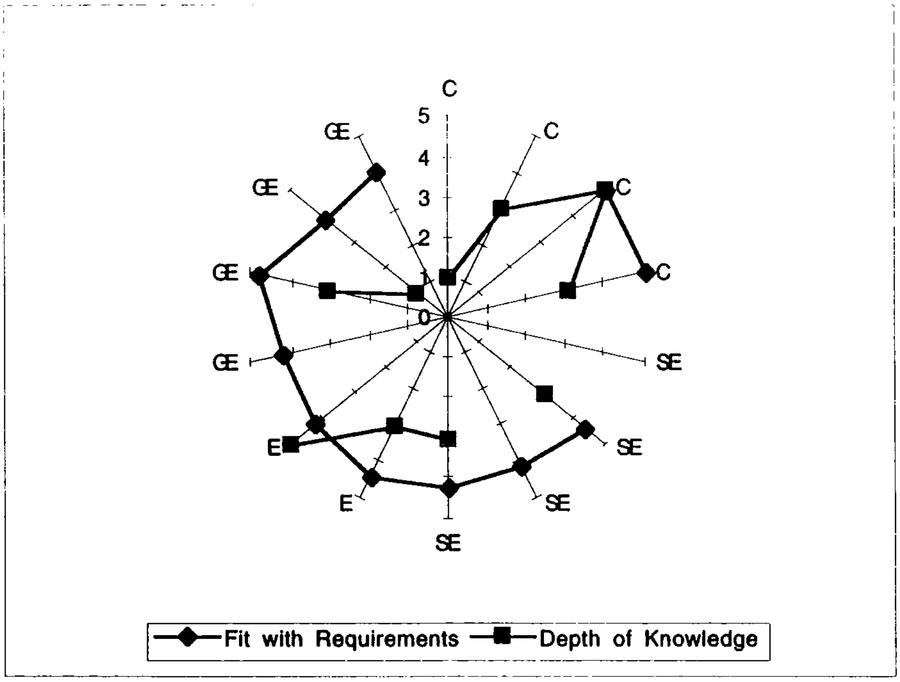


Figure C.22: Affect of the depth of knowledge on fit with requirements for system B

In order to conclusively determine whether there is a relationship between depth of knowledge and the ability of the system to meet user requirements, it would be necessary to perform further experimental work. Again, a greater sample size would be required than that shown here. Furthermore, the experiments would need to be redesigned to take into account the impact of other factors, such as the HCI in order to test the relationship.

C.2.17 Depth of knowledge -> Provision of explanation

Here we wish to determine if there is a relationship between the depth of knowledge and the ability of a system to provide explanation facilities. To test this hypothesis, two systems were used in conjunction with a set of detailed tasks and a results questionnaire. Three consultants, three senior engineers, an engineer and four graduate engineers performed the experiment using system A. For system B, four consultants, four senior engineers, two engineers and four graduate engineers participated in the experiment.

As in hypothesis 14 (C.2.14), due to the lack of evidence no conclusions can be drawn as to the relationship between the depth of knowledge held in a system and explanation for system A. The results obtained are shown in figure C.23. In the case of system B (results shown in figure C.24), although the subjects stated that there is a need for explanation facilities, the depth of knowledge does not seem to influence this requirement (evident from results where depth of knowledge is classed as ranging from none to very detailed; each subject still expressed the need for explanation facilities).

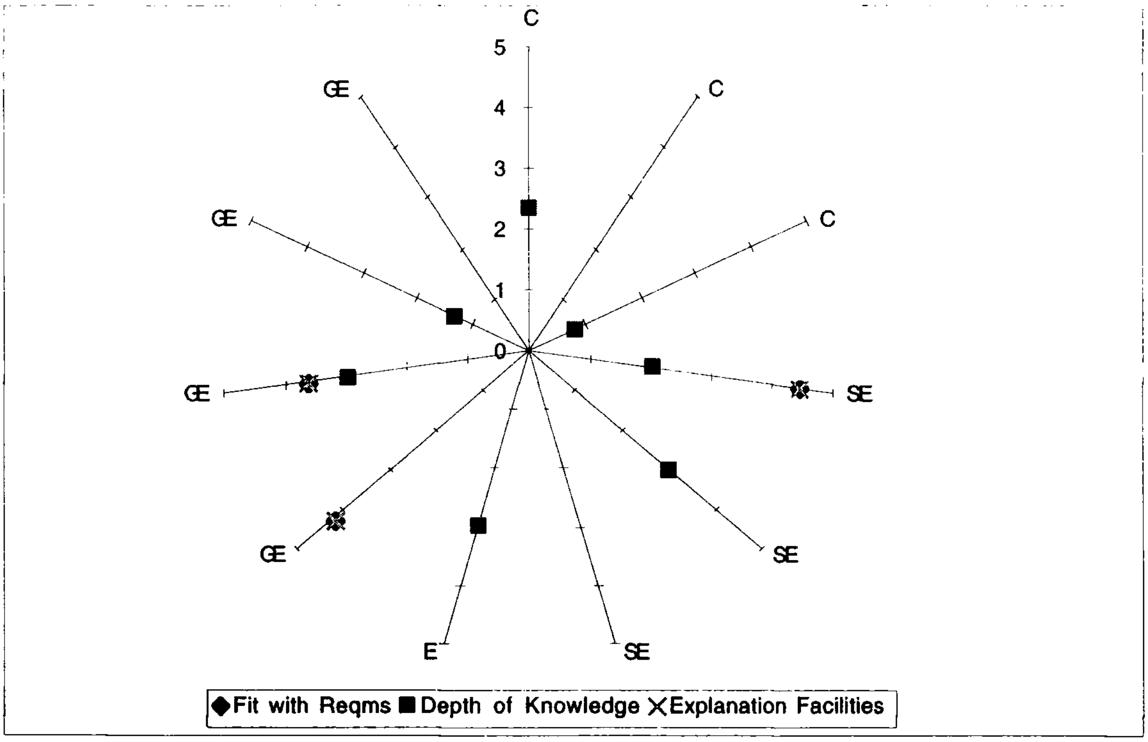


Figure C.23: Link between depth of knowledge and explanation facilities for system A

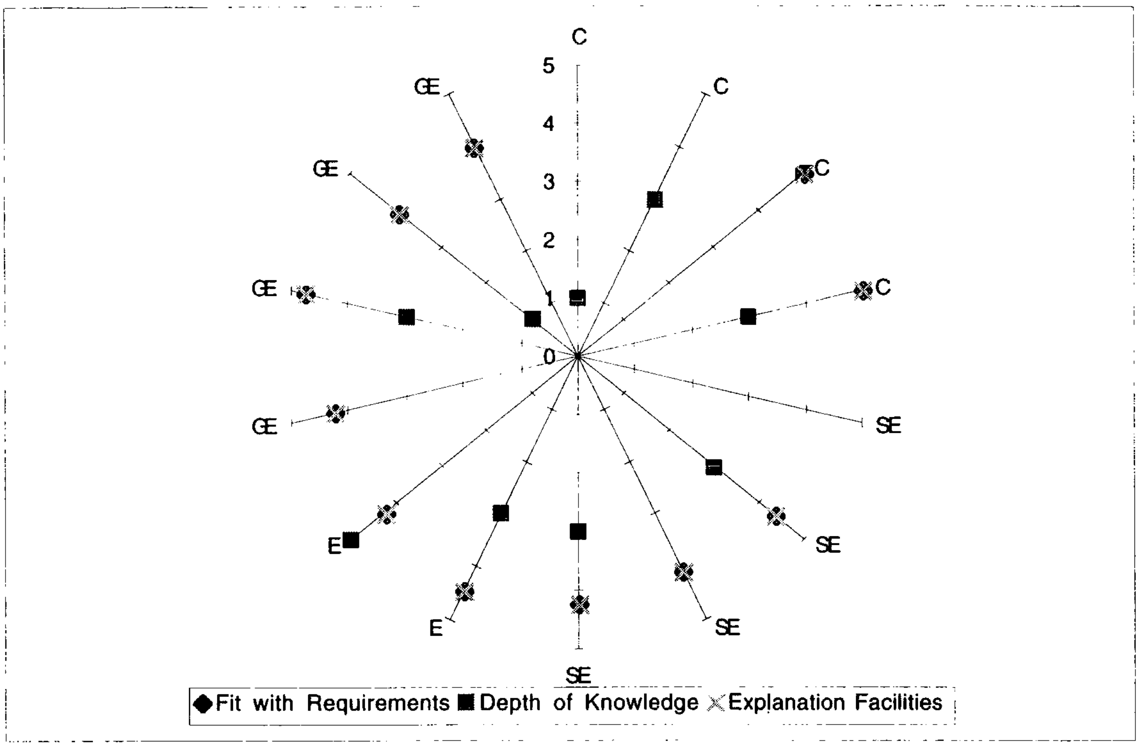


Figure C.24: Link between depth of knowledge and explanation facilities for system B

In order to fully test this hypothesis it would be necessary to carry out further experimental work using a larger sample size. In addition, the experiments would need to be redesigned to take into account the impact of other factors, such as the HCI in order to test the relationship.

C.2.18 Maintenance procedure -> Error reporting

In this hypothesis we wished to determine the impact maintenance procedures will have on error reporting. However, due to resource limitations we were unable to test this hypothesis. In order to fully evaluate the hypothesis it would have been necessary to perform experimental work on system that had been in service for a sufficient period of time to allow maintenance activities to be performed as well as requiring a reporting mechanism. Although no experimental work was carried out to test this hypothesis, subjects were asked as to the effect of maintenance procedures on error reporting, 93% of subjects stated that maintenance procedures would be required and that error reporting would form part of these procedures. The impact of the error reporting mechanism on daily use of a system would be negligible and would be outweighed by the benefits provided by the system.