AN EXPERT SYSTEM FOR THE DEVELOPMENT OF A HEALTH AND SAFETY POLICY/RISK ASSESSMENT IN THE PLASTICS INDUSTRY

AbdelKrim Bensiali

Doctor of Philosophy

THE UNIVERSITY OF ASTON IN BIRMINGHAM

March 1988

SUMMARY

An Expert System for the Development of a Health and Safety Policy/Risk Assessment in the Plastics Industry.

AbdelKrim Bensiali, PhD Thesis, University of Aston in Birmingham, 1988.

Health and safety policies may be regarded as the cornerstone for positive prevention of occupational accidents and diseases. The Health and Safety at Work, etc Act 1974 makes it a legal duty for employers to prepare and revise a written statement of a general policy with respect to the health and safety at work of employees as well as the organisation and arrangements for carrying out that policy.

Despite their importance and the legal requirement to prepare them, health and safety policies have been found, in a large number of plastics processing companies (particularly small companies), to be poorly prepared, inadequately implemented and monitored. An important cause of these inadequacies is a lack of necessary health and safety knowledge and expertise to prepare, implement and monitor policies.

One possible way of remedying this problem is to investigate the feasibility of using computers to develop expert system programs to simulate the health and safety (HS) experts' task of preparing the policies and assisting companies implement and monitor them. Such programs use artificial intelligence (AI) techniques to solve this sort of problem which are heuristic in nature and require symbolic reasoning. Expert systems have been used successfully in a variety of fields such as medicine and engineering. An important phase in the feasibility of development of such systems is the engineering of knowledge which consists of identifying the knowledge required, eliciting, structuring and representing it in an appropriate computer programming language.

Key words: Artificial intelligence, expert systems, health and safety policies, knowledge engineering, plastics processing, problem solving.

To
My Mother and Father

ACKNOWLEDGEMENTS

I would like to express my appreciation and gratitude to my supervisors Professor Richard Booth and Dr Ian Glendon who helped me through the various phases of this project by giving me valuable guidance and support.

I am also indebted to the following:

Professor Andrew Hale (TH Delft) for giving valuable advice on many occasions and commenting the frameworks developed and at various stages of the program.

Mr Lawrence Bamber (AMI Ltd) and Mr Alex Kendray (Employers' Federation) for accepting to be interviewed and be observed while carrying out safety audits.

Dr Peter Waterhouse (ICI), Mr Alan St John Holt (E St John Holt & Associates) and Mr Les Beaumont (HSE) for taking part in the workshop on knowledge elicitation and providing essential information on health and safety problem-solving.

The Plastics Processing Industry Training Board, in particular Ms Diana Warren and Mr Steve Penhale, for providing data and contacts and assisting in this project.

The staff of HASTAM Ltd (Aston Science Park) who hosted the proceedings of the workshop on knowledge elicitation.

Mr Peter Ward (HSE) for commenting on the project and accepting to be interviewed.

The IOSH Midland Branch members for discussing the project and providing useful advice.

The British Plastics Federation staff, particularly Ms Dorothy Nesbitt, for providing useful information and contacts in the PPI.

My sponsors the Algerian Ministry of Higher Education for their financial support and my employers l'INES de mecanique of Batna.

Mr Gordon Rich of Lucas Electricals for commenting on the program at various stages and for hosting a team of experts who were observed solving various health and safety problems.

Mr Les Carter of BXL Liverpool for commenting on the project and providing valuable information on the health and safety in the PPI.

All the managers, health and safety advisers, officers and other personnel in the various plastics processing companies who provided valuable information during the different knowledge elicitation and engineering phases.

I am also indebted to my colleagues in the Health and Safety Unit and I thank Ms Diane Stretton for helping me to put the thesis into shape.

I would particularly like to acknowledge the patience, valuable comments and feedback given to me by Mr M Khandwalla.

Finally I wish to record my appreciation of the help, encouragement and endurance of my wife during the period of the project and offer my apologies to my family and friends whose encouragement and support at all times has been invaluable, but who have only been rewarded by my absence.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

Introduction

1.1 Research Background

This research project forms part of the occupational health and safety research programme undertaken by the Health and Safety Unit at Aston University. The work is concerned with the development of computer-aided safety management program for the plastics processing industry.

Health and safety policy statements are considered to be the cornerstone for effective management of health and safety. The Robens Report (1972) stressed their importance and the Health and Safety Commission and Executive have repeatedly emphasised the need for them. The Plastics Processing Industry Training Board (PPITB), recognising their importance prepared guidelines for the preparation of health and safety policies (PPITB 1976). The PPITB is a national body providing training facilities for the plastics processing industry (PPI) which, in 1986, employed more than 120, 000 people (PPITB 1986), more than half of whom are in relatively small companies (see Tables 4.1 and 4.2).

The PPITB confirmed its interest in health and safety when, in February 1980, its sub-committee on health and safety (chaired by Professor RT Booth) conducted a survey of health safety policy statements. The 18-month survey studied health and safety policy statements from 121 companies (Warren & Orchard 1982). Its main objective was to identify training needs for those who prepare health and safety policy statements. This led the study team to consider other aspects of safety policies such as their preparation, implementation and monitoring. The survey findings were published and later presented at the Second International Conference on Health and Safety organised by the Plastics and Rubber Institute (PRI 1984). Many shortcomings and weaknesses (Table 3.3) were identified in the 121 policy statements that were studied not only regarding the training aspects but also relative to the preparation, implementation and monitoring of those policies (PPITB 1982). This survey and other studies (HSE 1980, Leopold & Beaumont 1982) point to the same problems faced particularly by small establishments where staff often did not know where to get information for hazard identification and control or were unaware of substantial quantities of information and advice on health and safety matters made available. Moreover the same studies reveal that even when these establishments had the information supplied to them (e.g. by management, enforcing authorities, expert bodies or others) relevant staff did not know how to use it.

This problem is certainly made worse by the large number of small companies which may still have the full range of hazards encountered in larger companies. Table 4.2 shows that more than 4/5 of plastics processing establishments employ less than 150 people (PPITB 1985). Moreover, these companies generally do not have access to advice from a health and safety specialist who would help them to manage their health and safety properly. Table 4.4 shows the positions of the people in charge of the health and safety function.

The Chairman of the Health and Safety Commission's Small Firm Working Group has stated that there is worrying evidence from reported incidents that people working in small manufacturing firms run a much higher risk (perhaps 50% higher) of suffering a serious accident compared with those who work in large establishments (The Safety Practitioner May 1987 p.4). Health and safety management is crucial to achieve high health and safety standards. There is thus a need to develop ways of getting health and safety information and advice to these small companies and enabling them to understand that information and to implement appropriate recommendations for the control of hazards at work and the management of health and safety. One promising avenue which is worth looking into is to try to find whether computers can be used to assist these companies in the management of health and safety and to what extent.

Until recently, computers have been used for repetitive tasks -handling numbers and following well defined algorithms. However, there is an increasing use of computers to solve problems which require human intelligence and problem-solving skills. This area of computer science is called artificial intelligence (AI). AI techniques and applications have been used in special programs called expert systems which can emulate human experts in narrow domains of expertise where experts are unavailable.

1.2 Objectives of the research

The main objectives of this research are therefore to answer the questions:

- What are the characteristics of health and safety expertise and the distinctive features of health and safety problems in the PPI?

- How do health and safety experts solve problems and prepare policies?

- What is the value of artificial intelligence (AI) techniques and applications (which have been used to solve problems requiring human intelligence in various fields), in health and safety ?

- Can health and safety domain experts be simulated using AI/ES techniques and computer programs to solve health and safety problems and what are the particular problems for the implementation of such programs?

Answers to such questions should be useful to a better understanding of the decision-making and problem-solving processes of health and safety experts. They should also be useful in determining the amenability of health and safety problem areas to the development of expert systems in health and safety. Another outcome of the research should be a better understanding of the knowledge (ie training requirements) required by and problem-solving skills necessary for health and safety trainees and practitioners. This should also permit a better understanding of the acquisition of health and safety knowledge and problem-solving skills.

1.3 Scope of the Research

Complete answers to the questions above are beyond the scope of one thesis and one expert system. Therefore, the scope of the system was reduced to a manageable size by confining the study to the PPI and to certain aspects of a health and safety policy preparation. Three areas, namely machinery guarding, maintenance and health and safety organisation, were chosen to test the practicability of expert system application.

1.4 Structure of the thesis

The thesis is divided into ten chapters:

Chapter 1 (of which this sub-section is a part) outlines the historical development of the project and details the objectives of the thesis.

Chapter 2 begins by discussing the literature relating to expert systems. It gives an overview of this AI sub-area, the requirements for the development of expert systems and how knowledge is engineered ie acquired and knowledge represented in expert systems. It also gives some examples of successful systems developed in various fields and the purposes to which they have been put. It describes the system MYCIN and reviews analogies between problems dealt with by health and safety and medical experts.

Chapter 3 reviews legal requirements of health and safety policies and their importance for the prevention of occupational accidents and ill-health. Sub-sections cover the structure of such policies and phases in their preparation.

Chapter 4 introduces the target industry on which the research activities are based and that is the plastics processing industry (PPI). The main activities and hazards encountered in nine plastics processing plants visited in the course of the research. Findings from a major survey on health and safety policies in the plastics industry are reviewed - culminating in formulation of the research problem in Chapter 5.

Chapter 5 develops the problem to be investigated by discussing shortcomings reported in the PPITB survey, characteristics of the health and safety expertise, problem-solving in health and safety and the value of expert systems in health and safety. This chapter also describes the tools used by health and safety experts in the assessment of health and safety performance and progress.

Chapter 6 describes details of the research method and strategies used to investigate the problem ie defining the health and safety knowledge required for the development of expert systems, identifying the knowledge sources and determining how the ways and tools to elicit that knowledge. Five methods were used to investigate the problem namely industrial visits, questionnaires, interviews, expert observation and knowledge elicitation workshop. This is an important part of the thesis as it describes in detail the different phases of knowledge engineering relevant to the new task of building an expert system for the management of health and safety.

Chapter 7 describes the approaches and frameworks for structuring the elicited health and safety knowledge and the concepts needed before expert systems for the management of health and safety can be developed.

The major analytical tools which the research strategies revealed were a risk assessment framework SHATER (Situation, Hazard, Arrangements, Testing, Recommendation), a problem-solving strategy ERIM (Existence, Required, Implementation, Monitoring) and a diagnostic framework called SECT (Symptoms, Effect, Causes and Treatments). These tools are described in detail in terms of their necessity and suitability for developing expert systems to investigate problems and manage health and safety.

Chapter 8 describes three modules of the health and safety management program (HASMAP) developed. It reviews the phases of knowledge acquisition, structuring and representation for each module. It points to the various knowledge representation schemes used in each module.

Chapter 9 lists conclusions and discusses them first in terms of the objectives of the research and their implications for the field of occupational health and safety when personal computers are becoming more accessible and more powerful.

Chapter 10 discusses possible avenues for further research in the field of expert systems in health and safety, problem-solving, knowledge representation and on the use of computers in general.

CHAPTER TWO

Building an Expert System

2.1 Introduction

Expert systems are a sub-class of Artificial Intelligence. They are a means of recording and accessing human knowledge in a particular specialist field. An expert system is a computer program that provides expert-level solutions to important problems and is:

– heuristic: eg reasons with judgemental or formal knowledge,

– transparent: explains its reasoning and answers questions,

– flexible: new knowledge can be incrementally lodged in it.

Feigenbaum (1982), a pioneer in expert systems, states that an expert system is an intelligent program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution.

2.2 How an expert system works

2.2.1 Basic architecture

There are three essential interlinked components of an expert system. Despite the range of terminology used in this field, it is commonly agreed that these components (shown in Figure 2.1) are:

– knowledge base,

– inference engine,

– user interface.

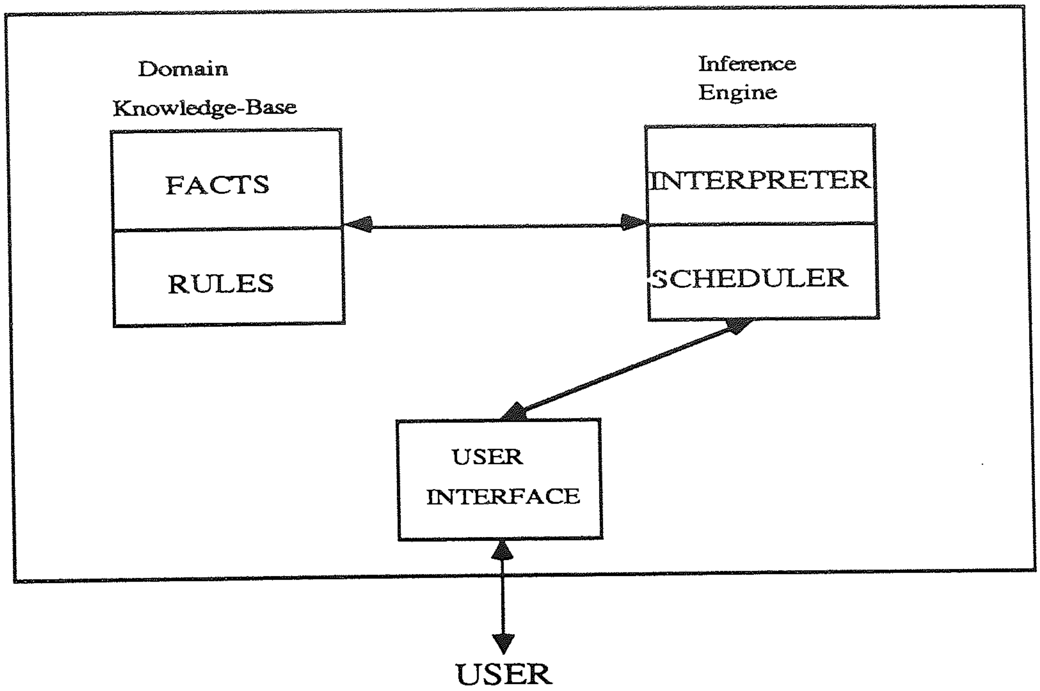


Figure 2.1 Elements of an expert system

2.2.2 Expert systems and conventional programming

Conventional computer programs use fixed routines to speed up repetitive processes and routine work. They have been widely used for various tasks such as spreadsheets, word processing packages and data bases. They are pre-written by programmers to manipulate data supplied by users. They are not transparent and the user receives only the final product. This may be satisfactory at times when only speed is important but it may be worthless if a reasoned decision is required. Computing of this sort cannot be expected to support users involved in making judgements or decisions. The essential difference therefore is that expert systems manipulate knowledge while conventional programs manipulate data. Table 2.1 summarises the differences.

Table 2.1 Comparison of Expert Systems and Conventional Programming		
Criterion	**Conventional Programming**	**ES Symbolic Programming**
Reasoning	Algorithms	Heuristics
Use of data	Numerically addressed data base	Symbolically structured KB in a global working memory
Orientation	Towards numerical processing	Towards symbolic processing
Processing	Sequential, batch	Highly interactive processing
Transparency	Mid-run explanation impossible	Mid-run explanation easy

Table adapted from Harmon et al (1985)

Unlike those of conventional programs, an expert system knowledge base contains judgemental and qualititative knowledge which is needed to reach reasoned decisions.

2.2.3 Characteristics of an expert system

Expert system performance is evaluated by considering the accuracy, speed and cost-effectiveness of its information gathering techniques (Cravetto et al 1985). Expert systems are also typified by other properties, most of which are usually taken for granted in human experts, namely:

- ability to explain and justify answers, either on the basis of theory or by citing relevant heuristic rules, or by appeal to case studies,

- closeness of reasoning procedures to those used by human experts,

- ability to deal with uncertain or incomplete information about the current problem,

- ability to summarise and point out features of the problem that were most important in leading to an answer, including information about which other factors might still have an effect if they were to become known,

- the ability to grow gradually by adding new knowledge increments. These qualities make expert systems more effective as consultants since there is some way of backing up answers and of building confidence in the system's abilities.

Figure 2.2 illustrates the characteristics of a problem which determine whether it may be tackled by an expert system.

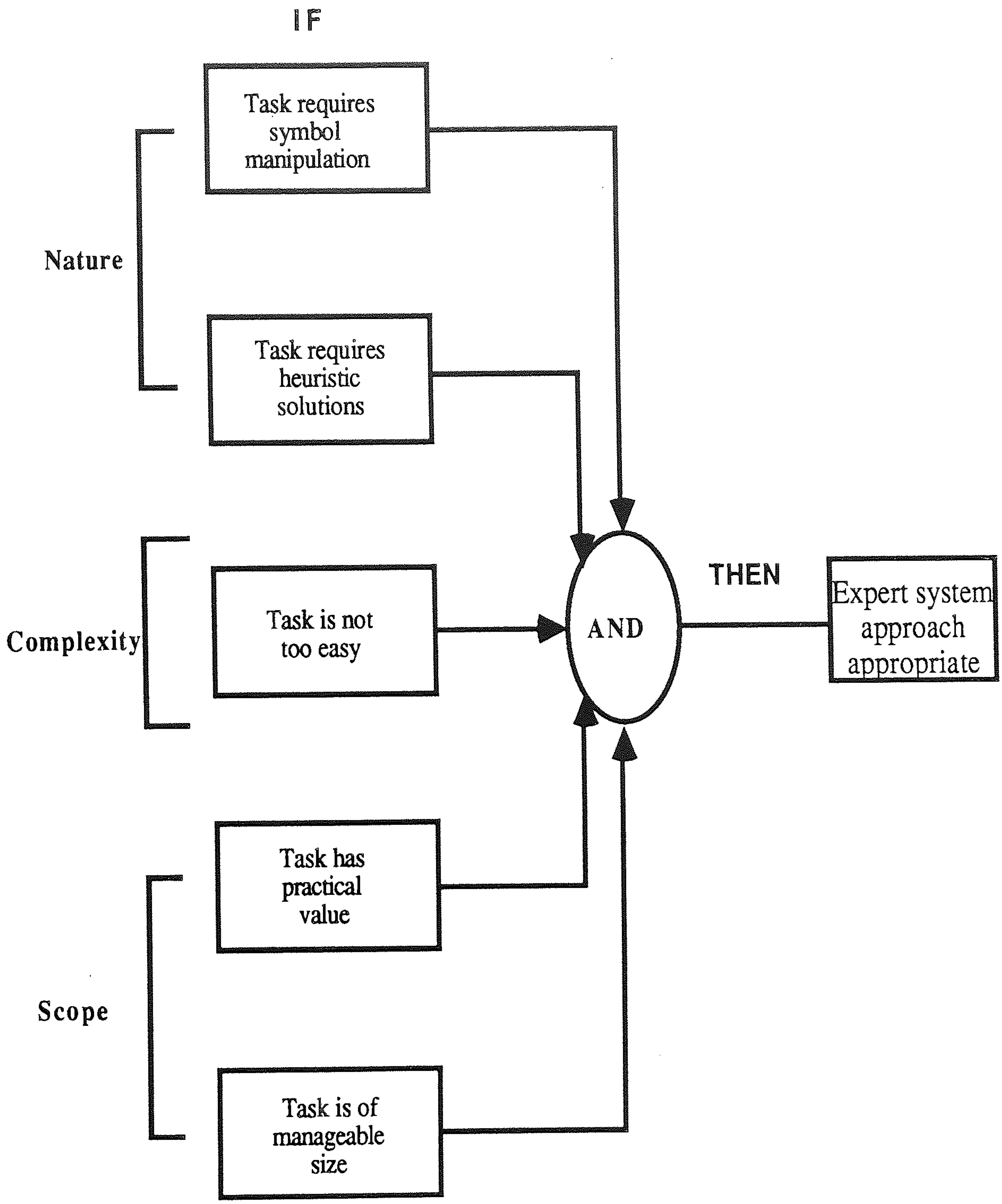


Figure 2.2 Characteristics that make the use of expert systems appropriate
Adapted from Waterman 1986

2.3 Application of expert systems

Expert systems have been developed and used to perform tasks ordinarily requiring a well-trained specialist for a given domain. There is a considerable momentum within this new field for many reasons:

- unavailability of human experts who are not easily available when needed to solve problems requiring knowledge and expertise. They are in great demand and in short supply,

- experts are expensive,

- improvement in the understanding of human intelligence and reasoning,

- widening the dissemination of knowledge and expertise.

An expert system can in theory capture practical experimental knowledge which a human expert has acquired over many years. The experimental practical knowledge of the human expert in any field is hard to pin down and may be difficult to extract from textbooks. Therefore, the most difficult task in expert system design is the elicitation of this knowledge from human experts. This issue is dealt with in Chapter 5.

Considering the vast number of fields where expertise is required potential applications for expert systems abound. Since 1970 a number of expert systems have been developed to solve a range of practical problems. Actual applications have so far been developed in a number of industries including steel, textiles, plastics and agriculture. Waterman (1986) compiled a list of major areas where expert systems have been developed (Table 2.2).

The first expert system DENDRAL was developed in the field of chemistry in 1970 and is used to infer the molecular structure of unknown compounds from mass spectral and nuclear magnetic response data. Amongst the developed systems so far , this system is the most widely used and it uses a special algorithm to enumerate systematically all possible molecular structures. Chemical expertise is then used to prune this list of possibilities to a manageable size.

Table 2.2

Application areas for expert systems

Agriculture	Manufacturing
Chemistry	Mathematics
Computer Systems	Medicine
Electronics	Meteorology
Engineering	Military Science
Geology	Physics
Information Management	Process Control
Law	Space Technology

In medicine, the development and use of expert systems is becoming increasingly important with the growth of specialisation. Many expert systems exist in this field and have been developed around the well-known system MYCIN. MYCIN was developed by ShorTliffe (1976) and is a program for medical diagnosis and therapy. It diagnoses bacteremia, blood infections, and meningitis and assists physicians in the selection of appropriate anti-microbial therapies for treating those infections.

PROSPECTOR was developed in the field of geology in 1983, after about nine years of research. This system acts as a consultant to assist field geologists in the search for ore deposits. In oil exploration, there is a shortage of expert well-log analysts and PROSPECTOR was developed to assist in the interpretation of field data of a geological region as to the likelihood of finding particular types of mineral deposits.

While expert systems have been devised to solve many different types of problems in many fields, their basic activities are usually grouped according to the task and problem they have been devised for (Waterman 1986). There are seven broad performance categories for expert systems:

- control,
- debugging,
- design,
- diagnosis,
- interpretation,
- monitoring,
- prediction.

These are considered in turn.

2.3.1. Control systems

This type of expert system adaptively governs the overall behaviour of a system. It repeatedly interprets a given situation, predicts the future, diagnoses the causes of anticipated problems, formulates a remedial plan and monitors its execution to ensure success. Examples of the use of such systems include air traffic control and business management.

2.3.2 Debugging systems

These systems prescribe remedies for malfunctions which are detected by a diagnosis component.

2.3.3 Design systems

These systems develop configurations of objects that satisfy the constraints of the design problem such as circuit layout, building design and budgeting.

2.3.4 Diagnosis systems

These infer systems malfunctions from observed data and behavioural irregularities. One method usually used is to relate behaviours to diagnosis. Another method is to combine the knowledge of system design with the knowledge of potential flaws in design, implementation or components to generate candidate malfunctions consistent with observations. MYCIN is an example where diagnosis is used to determine the type of infection from symptoms observed in patients. Other examples of diagnosis include finding faults in electronic, electrical, mechanical and software systems or finding defective components in the coolant systems of nuclear reactors.

2.3.5 Interpretation systems

These systems infer situation descriptions from observable data. This category includes signal interpretation, image analysis, surveillance and chemical structure analysis. Such systems explain observed data by assigning symbolic meanings to describe the situation accounting for the data.

2.3.6 Monitoring systems

These compare observations of system behaviour to features that seem crucial to successful plan outcomes. They identify vulnerabilities which correspond to potential flaws in a plan. The vulnerability may correspond to an assumed condition whose violation would nullify the plan's rationale or to some potential effect of the plan violating a planning constraint. Examples of such systems are used in the monitoring of hazardous plant such as nuclear reactors to detect accident conditions or in assisting patients in intensive care units by analysing data from instruments and equipment.

2.3.7 Predictive systems

Such systems infer likely consequences from given situations. This category includes weather forecasting, demographic predictions, traffic predictions, crop estimations and military forecasting.

There are no distinct boundaries between the different categories and a system may be developed to perform many tasks that can be simultaneously described, for example as diagnosis, prediction and monitoring. The system described in Chapter 5 bears this hallmark as it can be considered to be a diagnostic tool as well as an interpretation and design system. It takes in the data, interprets it, uses it to diagnose certain problems and helps in the development of a health and safety policy.

2.4 Requirements for expert system development

Expert systems can in principle be developed to assist in any field. However, there are some fields which are more amenable than others to the development of expert systems and there are pre-requisites for the success of such systems. Brady et al. (1984) point out that:

> "the pre-requisites for the success of a knowledge based expert system are:
>
> - there must be one human expert acknowledged to perform the task well,
> - the primary source of the expert's exceptional performance must be special knowledge, judgement and experience,
> - the expert must be able to explain the special knowledge, experience and the methods used t apply them to particular problems,
> - the task must have a well-bounded domain of applications".

Figure 2.3 illustrates the necessary requirements for expert system development.

Figure 2.3 Necessary requirements for expert system development (Waterman 198

2.5 Expert system development phases

Building an expert system involves, as for developing any product, several phases of which the major ones are shown in Figure 2.4. As will be seen, these phases are by no means distinct or even independent. The whole activity is a protracted iterative process.

Experts in this field have described five such phases which will be taken in turn below and which are:

- identification,
- conceptualisation,
- formalisation,
- implementation,
- testing.

2.5.1 Identification: involves the human expert and the knowledge engineer who is to extract the expertise. In this phase they work together to identify the:

- problem area, its type and scope,
- important features of the problem eg the participants in the development process,
- required resources eg time, computing facilities,
- goals and objectives of building the expert system.

Figure 2.4 Development phases for expert system building (Waterman 1986)

Table 2.3

Generic types of problem solving

Type	Description
Interpretation	Inferring situation descriptions
Prediction	Inferring likely consequences of given situations
Diagnosis	Inferring system malfunctions from observables
Design	Configuring objects under constraints
Planning	Designing actions
Monitoring	Comparing observations to plan vulnerabilities
Debugging	Prescribing remedies for malfunctions
Repair	Executing a plan to administer a prescribed remedy
Instruction	Diagnosing, debugging, and training
Control	Interpreting, predicting, repairing, and monitoring system behaviour

Adapted from Hayes-Roth et al (1983)

2.5.2 **Conceptualisation**: during this stage the knowledge engineer and expert decide what concepts, relations and control mechanisms are needed to describe problem-solving within the domain. The tasks, subtasks, strategies and constraints related to the problem-solving activity are also explored. At this stage the problem of 'granularity' is addressed ie to consider at what level of detail the knowledge should be represented. It is advisable that a system developer should not try to produce a complete problem analysis before beginning program implementation (Waterman 1986).

2.5.3 **Formalisation**: involves expressing the key concepts and relations in some formal way usually dictated by the expert system building tool or language. The knowledge engineer selects the knowledge or building tool and with the help of the domain expert gathers expertise and represents its basic concepts and relations. There are many ways of formalising the expertise as will be seen in the section on knowledge engineering.

2.5.4 Implementation: the knowledge engineer turns knowledge into a computer program. This process of going from the formalised expertise to the resulting working computer program requires content, form and integration:

- content: comes from the domain knowledge made explicit during the previous phase - data structures, inference rules and control strategies necessary used in the problem solving mechanism,

- form: specified by the language chosen for the development of the system,

- integration: involves combining and re-organising the various pieces and modules of the system to eliminate any likely mismatches between the different parts such as data structures, rules or control specifications.

2.5.5 Testing: involves evaluating the performance of the prototype program and revising it to meet the requirements for the performance defined by the domain experts.

2.6 Amenability of the problem to expert system development

Before beginning to build an expert system, one has to investigate whether the domain is suitable given:

- the current state of-the-art of both the technology of knowledge engineering, and

- the art of acquiring knowledge.

However, it is important at the design stage to ascertain the nature of the human expert's expertise. There is a circularity in trying to do this as there is a need to talk to experts and to discuss the types of expertise before deciding on the nature of the expertise itself. Although any given domain such as medicine, engineering, etc has many different intellectual tasks, a given expert may practice only a sub-set of them. This is the fundamental reason for not relying on one expert when identifying an expert's task and selecting that task which the computer system is to simulate (Mittal 1984).

A difficult task faced by scientists is that concerning the domain problem itself and whether it is amenable to the development of an expert system. It is a difficult decision to make but studies have shown that Artificial Intelligence scientists seem to be better at commenting on specific problems rather than at describing in general terms the characteristics that make a problem amenable to the development of expert systems (Waterman 1986). On this same aspect, Waterman (from whose works this section has been drawn heavily) states:

> 'Often the right question is not "will expert systems work for my problem area?" but rather "what aspect of my problem area lends itself to expert system development? " '.

Offering some guidelines on this, he wrote:

> 'Consider expert systems only if expert system development is possible, justified and appropriate'.

So considering the objectives of this project, are these three requirements (eg whether an expert system is possible, justifiable and appropriate) met for an expert system to be developed in the field of health and safety.

As was the case for other expert systems, it is quite difficult to test those requirements in a field which is still developing. What is certain is that developing an expert system in a domain involves understanding that field well, how the experts in it solve problems and formulate solutions. Whatever the adequacy of a system, a very useful part will be the better understanding of the expertise involved and the reasoning of the human experts. It should be interesting investigating the feasibility of an expert system in health and safety.

Knowledge engineering is the second phase in expert system development after problem or domain identification. It involves working on the domain expertise to make it representable and in a usable form. It has been defined by Feingenbhaum (1977) as being the art of building complex programs that represent and reason with knowledge of the world.

During this phase, the knowledge engineer has to find the source of expertise, extract that expertise, structure that expertise in a usable form, input the represented expertise into the computer before being able to see it used. As an introduction to the problem, the following sections give a brief description of the ingredients necessary for the development of an expert system for the management of health and safety. Two important ingredients can be identified:

– The domain knowledge and expertise, and
– Knowledge engineering techniques and tools.

2.7 Domain expertise

In order to develop an expert system, there are three important pre-requisites which are related to the domain experts and their expertise namely:

- finding genuine domain experts who are significantly better than novices at solving domain problems. An expert system should incorporate the problem-solving skills and heuristics of a human expert otherwise it might just be a sophisticated program or data base,

- there should be agreement amongst experts concerning the solutions in the problem domain. This facilitates and makes the task of validating the system's performance possible,

- an expert must be available and able to devote time willing to have his/her expertise elicited.

2.7.1 Experts

The requirements regarding the expert's task and expertise are:

- the expert's task must be cognitive and not require physical activities that are learned through practice,

- the task must not take weeks or days but rather hours or (less) and expertise must not be extremely difficult nor necessitate on-the-job experience such as measuring pollutants in the environment with monitoring instruments,

- the task must not be new or poorly understood.

2.7.2 Expertise

Expertise is knowledge built-up over years of experience and which is used to make informed and wise decisions that have proved to work and be viable. Some of that knowledge which has come through particular experience is not found in textbooks nor is it a set of procedural rules. Decisions that human experts arrive at are often based on intuition. The expert may have never stated how a judgement is made or decisions arrived at and is often not consciously aware of the process of decision-making. This is one of the problems the knowledge engineer faces in the elicitation of expertise which is diffuse in the expert's head. It is believed that the more expert human experts become the less able to describe their expertise they are. Consequently, expertise is often less apparent to knowledge engineers and is more difficult to elicit. Waterman (1986) points to two important characteristics regarding the nature of knowledge:

- the knowledge should not be changing frequently,

- the knowledge must not include a significant amount of common sense.

So in order to acquire knowledge and elicit expertise - from domain experts - for the development of an expert system, knowledge engineers must identify:

- the source of expertise,
- the nature of the expertise sought, and
- availability of the domain expert.

Determining the expertise is the prime activity of the knowledge engineer in the identification phase. This is the domain in which the expert proficiently carries out the task which would take non-experts more time and effort to achieve similar results.

Expertise is therefore what first needs to be defined if a system is ever to be developed. The next requirement is finding a domain expert or experts who are willing to be observed, questioned about their expertise and tasks they perform.

Expertise and knowledge are often used interchangeably but should always be used in relation to a domain expert. Figure 2.5 shows a model of how expertise, knowledge and domain experts are related.

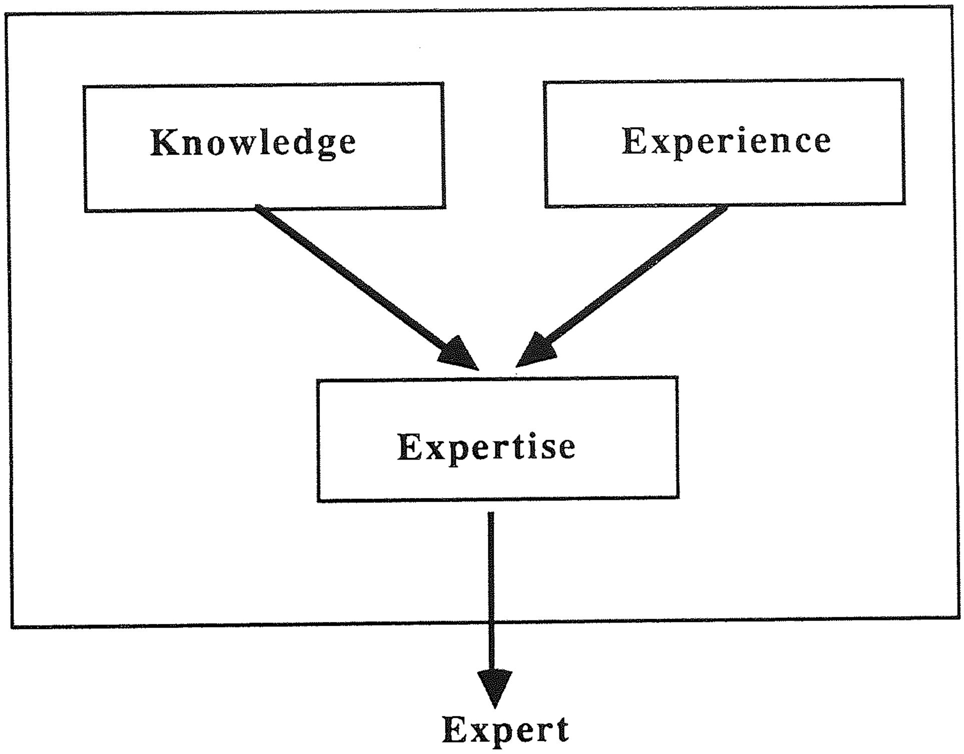


Figure 2.5 Knowledge and expertise

Expertise itself is intangible and can only be described in relation to a given expert who has knowledge about a certain problem and has the know-how to apply that knowledge to solve that problem.

Knowledge is accumulated and gleaned over many years from a number of sources such as literature, films, training. Besides the formal acquisition of their knowledge, domain experts learn by experience how to use sets of rules of thumbs to solve problems and reach conclusions about problems much faster than novices. Their know-how consists therefore of knowledge and sets of hunches, heuristics and methods which they have used over the years.

People often like to think of expertise as some notion with boundaries but unlike machine expertise, human expertise has ill-defined boundaries. This very difference is important in avoiding serious consequences and makes human experts' performance degrade more gracefully than machines' when it comes to drawing from their large pool of experiences.

2.8 Knowledge engineering

Knowledge engineering is a fundamental activity in expert system development. Feigenbaum (1977) defines knowledge engineering as:

> 'The knowledge engineer practices the art of bringing the principles and tools of AI research to bear on difficult applications problems requiring experts' knowledge for their solution. The technical issues of acquiring this knowledge, representing it, and using it appropriately to construct and explain lines-of-reasoning, are important problems in the design of knowledge-based systems .... The art of constructing intelligent agents is both part of and an extension of the programming art. It is the art of building complex computer programs that represent and reason with knowledge of the world.'

Building on this definition, knowledge engineering can be considered under two angles:

- the components of knowledge engineering, and
- how the activity is carried out and those tools are used to engineer and process knowledge for its use in an expert system.

The following are the components of knowledge engineering:

- the knowledge engineer,
- the domain expert, and

- the various tools used to engineer knowledge.

The activities of knowledge engineering can also be summarised as consisting of:

- knowledge elicitation and acquisition,
- knowledge organisation, and
- knowledge representation.

2.8.1 The knowledge engineer (KE)

A knowledge engineer is concerned with with identifying the specific knowledge that an expert uses in solving a problem (Harmon et al 1985). The KE studies a human expert and determines what knowledge (facts and rules of thumb) the expert uses. Then the KE determines a strategy for using the elicited expertise in problem-solving situations before developing a computer program which uses that strategy to simulate a human expert's problem solving skills.

2.8.2 The domain expert

An expert is not merely someone who knows lots of facts but is also capable of high-quality performance. Brachman et al (1983) commented on the question of expertise, its characteristics and the intuition features of being an expert. They pointed to the following two aspects:

- the quality of the behaviour to be addressed e.g. how the expected judgement, diagnosis, etc. compares with the observed or actual result, and

- the speed at which a decision is reached. This is an important factor which determines the acceptability of the recommendation and hence the expertise.

It is important to note that Brackman et al (1983) have taken those two characteristics to be the goals to be attained in expert systems and not necessarily in humans. Hart (1986) expresses a contrasting view which seems to indicate that human beings are experts in one field or another. She wrote:

> 'It is very easy to make a list of people who might be thought of as experts. Such a list might include specific names of individuals, or professions of people who, by virtue of their status, would be expected to be experts. ... In short, we assume they know what they are talking about!' p.14

2.9 Knowledge engineering tools

These are general tools used by knowledge engineers to represent a knowledge domain and expertise in a computer program to solve problems. There are two main types of tools required to simulate a domain expert: the hardware or computer type and the software or programs used or developed to run on them.

Although the physical machine on which the software runs is as important, this project is concerned more about the software and program development. This will be addressed in more detail in Chapter 7 when describing the development of a program prototype - a Health And Safety Management Program (HASMAP).

There is a continuum of language-tools used to develop AI applications and expert systems. Programming environments, knowledge representation languages and shells (discussed below) are collectively referred to as tools (Harmon et al 1985). As shown in Figure 2.6, these tools range from high level languages to a multitude of tools which can be used even by non-programmers to develop small knowledge systems (Harmon et al 1985) and each type presents advantages and disadvantages and the choice of a tool is dependent on such factors as task features, experience of the knowledge engineer(s), performance and future proposed or possible expansions of the system.

Figure 2.6 The language-tool continuum
(Harmon et al 1985)

Programming environments or languages are one obvious strategy for starting from scratch. These are the standard high level programming languages such as LISP and PROLOG both of which are considered to be the AI languages and are described below with some other tools that are used in this field.

2.9.1 AI languages

LISP and PROLOG are the two most widely used languages in AI and are therefore often referred to as Artificial Intelligence programming languages.

PROLOG (for PROgramming in LOGic) - invented in Marseilles, France and polished in Edinburgh - hardly saw any breakthroughs until the Japanese chose it for their fifth generation project as the language of interaction between the logic processing hardware they aim to develop(in this project) and the software that implements the various problem-solving strategies.

LISP (for LISt Processing) - the older of the two languages - has been tested and used for a much larger number of working systems, the most famous of which is MYCIN which is referred to in subsequent sections. Besides being a tested language, LISP can be used for several other reasons which Barstow et al (1983) identified as:

– oriented towards symbolic computation,

– conveniently manipulates symbols and their relations,

– interactiveness greatly facilitates the evolutionary development so essential to knowledge engineering,

– does not differentiate between data and control programs, and hence other LISP programs can be used as data,

– more higher-level functions can easily be built with the basic LISP functions - called "Primitives".

AI scientists have discussed the merits and demerits of each language. When this project was undertaken in 1984, there were no doubts LISP had been successfully used while speculations were being made as to the viability of PROLOG which needed major changes before it could be successfully used (Forsyth 1984). In fact, one eminent AI scientist Feigenbaum (1984) wrote the following when commenting on what is wrong with the Japanese 5th Generation Project and the limitations of PROLOG:

> '... Finally, from a viewpoint of the AI specialist, skepticism and criticism have focused on two elements of the plan: the priority given to the high-speed logic processor (do we really need all those millions of LIPS? e.g. Logical Inferences Per Second) and the choice of PROLOG as the machine language of the logic processor.'

There are several dialects of LISP which differ primarily in the features of their programming environments, the most common being INTERLISP and MACLISP. Recently there have been several moves to standardise LISP for commercial purposes and saw the development of COMMON LISP (Harmon et al 1985). Figure 2.7 shows the LISP family to which Golden COMMON LISP (GCLISP) - a version of COMMON LISP used in this project- has just been added and which came on to the market in 1984.

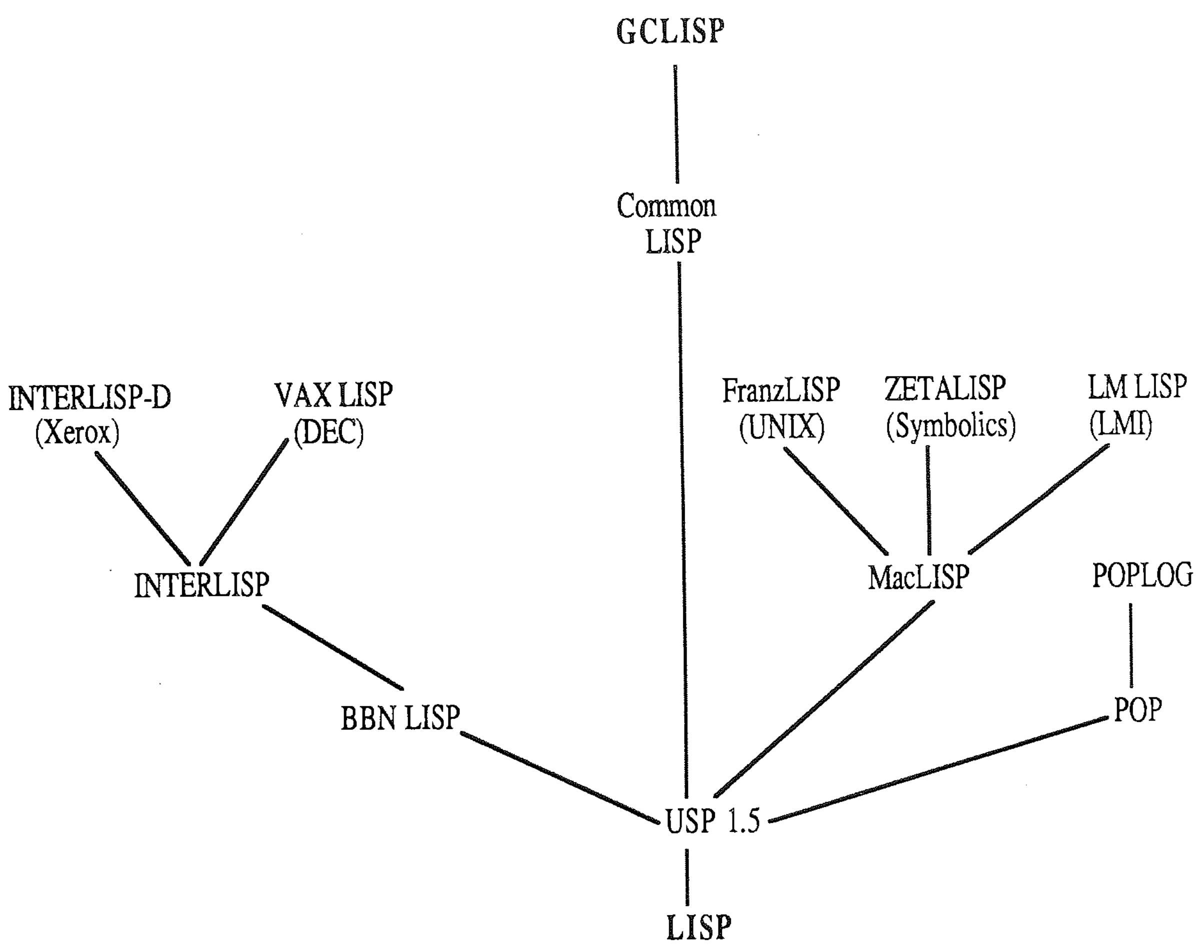


Figure 2.7 The LISP tree
adapted from Harmon et al (1985)

2.9.2 Other tools

The word tool is a generic name for a wide variety of knowledge engineering languages and shells. As in most fields, it is sometimes difficult to set up clear categories. For example, some observers would call PROLOG and OPS5 (languages) tools (Harmon et al 1985). These two are much less flexible than LISP but not nearly as constrained or as highly focused as tools such as M.1 or EXPERT (Weiss 1985); hence they are probably best classified as environments.

Knowledge representation languages embed one or more knowledge representation schemes referred to in Section 2.12. ROSIE (Fain et al 1982), RLL (Greiner and Lenat 1980), HEARSAY-III (Erman et al 1981), OPS (Forgy et al 1977), OWL (Szolovits et al 1977), KRL (Bobrow et al 1977) and KRYPTON (Brachman et al 1983) are notable examples of knowledge representation languages.

KEE is a hybrid tool. It can be used to represent knowledge in several different ways. Another alternative to programming from scratch is to use what is called an expert system shell which is a skeletal or empty system. This is a generalisation of an expert system emptied from its domain specific knowledge and other facilities to the framework for building some other domains. Examples of these shells include EMYCIN or the Empty MYCIN (van Melle 1979), KAS (Reboh 1983) and EXPERT (Weiss and Kulikowski 1979) derived respectively from the famous systems MYCIN, PROSPECTOR and CASNET. Table 2.4 shows various tools and environments.

Some techniques are strongly associated with particular paradigms. Specific types of problems require certain tools which are built up with a certain set of representation, inference, and control techniques. While this can be a serious limitation for new domains, it can prove very useful in reducing system development time.

Source: Harmon et al (1985)
* Indicates that the tool is good at the consultation

2.9.3 Shells

It was pointed out at the beginning of this chapter that, unlike traditional computer programs, expert systems have a key feature and that is the separation of the knowledge and data base from the reasoning or inference engine. This difference has had profound consequences and has assisted the development of new systems using knowledge-based emptied systems. This idea of 'empty' systems is to make use of a standard framework or shell. An increasing number of shells has been developed since the first empty shell derived from MYCIN and was called EMYCIN for Empty MYCIN.

Despite their limitations, shells have proved to be of potential value and have been successfully used. Emycin has been used to develop a number of expert systems in the medical field such as PUFF, ONCOCIN and HEADMED and in engineering such as SACON (Buchanan et al 1985).

Other examples of well-known shells include Micro Expert which was based on PROSPECTOR (Cox 1984) and those issued by the National Computer Centre in its Alvey pack (NCC 1985) namely: ES/P Advisor, Expert Ease, Micro Expert and Micro Synics.

The great advantage of using shells is the reduction in effort and time of development. As Feighenbaum (1985) points out, the development time taken to reach a working system based on the analysis of some 250 test cases was less than 10 person-weeks of effort by knowledge engineers with less than 50 hours of interaction with the subject experts. However, there are serious disadvantages to using shells, notably the restriction which they impose on content and direction and their relative inflexibility. This is translated by the difficulty to fit the problem under study to the architecture of the shell. One of the pre-occupying limitations of shells is the user interface over which the shell user has no control. It is all set and the user has to express the problem in the form the shell was built for. Choosing a shell is a crucial decision users of shells have to make before opting for one or another such tools as it may prove to be, halfway, unsuitable for the problem.

There are many instances where users were disappointed after having gone a long way. An example is the bitter experience a Plessey AI research team underwent. That AI team admitted, after 18 months of controversy, that despite their usefulness, expert system shells were just too restricting to be practical (Johnston 1985).

2.10 Conventional and AI languages

Conventional languages are essentially designed to handle numerical operations following a set algorithm. AI languages are well suited to handle symbols and for solving problems where rules-of-thumb are used and no definite algorithm is used.

From the programming side, one of the advantages of AI languages is that they have built-in features that make them easier for constructing expert systems.

2.11 Knowledge acquisition/elicitation

This is the transfer and transformation of problem-solving expertise from some source to a computer program. The sources are various and include:

– human experts who can be interviewed and observed,

– case studies,

– text books,

– data bases.

It is the most important and complex of the three knowledge engineering phases. This transfer and transformation is often referred to as knowledge acquisition when in fact it may be more precise to call it expertise elicitation. A distinction between knowledge and expertise is described above and illustrated in Figure 2.5. Human experts (domain experts) are the most important source because the knowledge engineer can see the sort of knowledge and observe these experts' behaviours during problem-solving. An expert may ask questions, take measurements, observe the surroundings/environment which can all be observed and noted. The knowledge engineer's task is finding the cognitive skills involved in the problem-solving which lie below an expert's observed behaviour, to find out the expert's mental models, cognitive strategies and rules-of-thumb used when dealing with a task and deciding what to do in a particular situation. It is therefore essential to carry out a task analysis of the domain expert's behaviour.

Because of the unavailability of domain experts (too busy to devote time to knowledge engineers), their unwillingness to be examined, their inability to verbalize about their cognitive processes etc, makes this important phase of expert system development a real test for AI scientists and systems developers. In fact knowledge acquisition is considered to be a bottleneck in the construction of expert systems (Buchanan et al 1983). Knowledge acquisition usually goes hand in hand with knowledge representation - an important expert system development phase discussed in Section 2.12-. There are various stages of this phase:

- the knowledge engineer getting to know the domain,

- the KE getting to know the expert and matching the expert and the problems. The KE ascertains the nature of the expert's expertise. There is a circularity in trying to answer this question in a satisfactory manner (Mittal et al 1984).

- before a task or problem area is selected, the KE must have expert(s) he/she can question about the domain in which the task belongs.

It is recognised that any given domain such as medicine, engineering or health and safety has many different intellectual tasks but a given domain expert may practice only a subset of them (this point about health and safety intellectual tasks is dealt with in more detail in Chapters 6 and 7). Mittal et al (1984) refer to this potential mismatch as a key reason for not relying on a single expert (or some small group of them) in selecting expert systems' tasks.

The difficulties in acquiring knowledge mentioned above and faced by both domain expert and knowledge engineer, are made worse (particularly at the initial stages of expert system construction) by the fact that experts find it difficult to identify and articulate the most appropriate aspects of their problem-solving behaviour (Mittal 1984) and because of limits on the current technology for developing expert systems.

Communication problems can seriously impede the process of expertise transfer from expert to engineer. The knowledge engineer's hardest task is structuring the domain expertise, as well as identifying and formalising concepts. This task is laborious and takes time to work over the versions of the elicited knowledge during the transfer and updating phases. To remedy these problems of knowledge acquisition, researchers have been trying to automate this knowledge elicitation via an induction program (Lenat 1983) which should be more effective in coping with inconsistencies that are experienced during the updating of the system. Figures 2.8a - 2.8c show ways in which knowledge can be engineered.

Figure 2.8c Induction-data to Knowledge base via an induction program (Hayes-Roth 1984)

2.12 Knowledge representation

Knowledge in an expert system can have a number of different forms such as facts about the domain, heuristics, global strategies, fundamental knowledge in the domain and meta-knowledge eg knowledge about knowledge. Knowledge representation is how to represent the knowledge of a domain as data structures in the memory of the computer in a manner in which they can be conveniently accessed for problem-solving (Feigenbaum and McCorduck 1984). Representing knowledge consists of two important steps:

- devising a conceptual framework for thinking about the world -symbolically or numerically, statically or dynamically, centered around objects or around processes etc. (Buchanan and Shortliffe 1984), and

- choosing conventions within a computer tool for implementing those concepts.

Section 2.11 dealt with eliciting knowledge whereas this deals with the structuring and classification of knowledge in categories to be represented in the software comprising an expert system.

As it was discussed in Section 2.2 and as shown in Figure 2.1, a knowledge-based expert system consists of three main parts each may be requiring different representation paradigm (eg representation scheme). Choosing the right tool to develop a system component is important for the success of a project and the flexibility of representation depends on the schemes the tool offers. Of the tools, programming environments do not constrain in any way expert systems designers whereas knowledge representation languages, and particularly shells, do (Keravnou and Johnson 1986). An example of how serious this can be is the experience of Plessey whose AI scientists had realised 18 months after a project was launched that the shell selected for developing an expert system was inadequate (Johnston 1985).

Moreover, after the selection of a language or a shell, the KE's most difficult task is then to help the expert to structure the domain knowledge, to identify and formalise the domain concepts (Buchanan et al 1983 :128).

Each representation scheme has its strengths and weaknesses and it often takes experimentations to find out what scheme is most suitable for what problem domain such as medicine or health and safety (Buchanan et al 1983 :391). Whatever the representation scheme chosen, there are three basic requirements for a representation scheme in an expert system (Buchanan and Duda 1983):

- extendability eg flexible enough to allow extensions to the knowledge base without forcing substantial revisions,

- simplicity: this is very much linked to the flexibility mentioned above and requires simplicity and uniformity so that access routines can be written. This is vitally important particularly in explanation when the system is asked to justify why a question is asked or to explain how a conclusion is reached. Simplicity also comes from using the same terminology used by the domain experts, and

- explicitness: explicitness of the knowledge represented in the system. Although the explicitness makes the knowledge base appear simple, whether it is or not, it is certainly very useful for inspecting and debugging the knowledge base to determine any inconsistencies.

To achieve these three requirements, there is a need to construct expert systems using one or more standard representation frameworks such as production rules, frames, networks etc. Here a brief description of these three main representation schemes, often used, is given.

2.12.1 Semantic Networks

Semantic networks represent objects and their relations by the use of nodes and links (usually called arcs) respectively. Meaning is ascribed to the nodes and links and links through an accompanying description. There are two important advantages for using semantic networks:

- allow for the building of large taxonomies, and

- possess the property of class inheritance e.g. the ability of one node to inherit characteristics of other nodes that are related to it by relationships such as 'is-a' and 'has-a'.

2.12.2 Frames

A frame is one popular way used to represent declarative knowledge. The notion of frames was developed in the early seventies and was proposed as a model of human thought (Minsky 1975). It is a description of an object which includes properties (called slots) which store values (default values), demons (eg procedures for computing values needed) and pointers to other frames. Through the use of slots and pointers, inheritance properties can be established. This framework is a generalisation of semantic nets (Brachman 1977) where knowledge is organised in objects and classes of objects linked together and programming with this framework is sometimes called object-centred programming (Buchanan and Duda 1983).

2.12.3 Rules

The most popular scheme in expert systems is the production rule paradigm. A production rule has a Situation-Action format which is also referred to as IF <condition>

THEN <action> or IF <antecedent> THEN <action> and generally as the LHS (left hand side) and RHS (right hand side) of the rule.

The LHS or condition part of a rule consists of some pattern that can be matched against the contents of a data base. If a match is found, the action is triggered and this can be any arbitrary procedure such as causing new data to be entered in the data base, or altering old or adding new facts there. Rules can be classified into different categories depending on the 'task' they are assigned to perform. Examples of types of rules as classified by (Shortliffe 1983) in the medical field include:

- definitional rules used to eliminate gender-specific diseases once a patient's sex is known,

- cause-to-effect rules and effect-to-cause rules establish links and their directions between antecedents and actions,

- associational rules establish only the antecedent and action related, and

- self-referencing rules which update parameter values based on previous values.

2.13 Reasoning strategies

The knowledge engineering tools described in the previous sections are used to develop expert systems. Expert systems comprise a variety of programs representing human experts' reasoning strategies. They reach conclusions on the basis of information supplied by the user about the current situation and the knowledge contained in the knowledge base. The reasoning is performed by different parts of the system's control structure.

2.13.1 System search

In an expert system, the inference engine uses the knowledge in the knowledge base to solve problems by emulating the reasoning of a human expert. This problem-solving consists of searching a solution from a search space. There are two types of searches:

- depth-first search where the inference engine focuses to produce a goal and digging deeper and deeper into the details. Most expert systems use this type of search.
- breadth-first search where the inference engine sweeps across all the premises of a rule before 'deciding' to investigate a sub-goal.

A search can be exhaustive or unexhaustive. It is called exhaustive when all the states (eg all premises of a rule) are investigated and unexhaustive if the search is suspended when a value (eg a goal or sub-goal) is obtained.

However, both strategies have their shortcomings namely:

- the depth-first search may take time particularly if the search space is large, and
- the breadth-first search presents a problem of focusing the problem-solving strategy.

To avoid these shortcomings, heuristics are elicited from human experts and used in expert systems to search through search spaces. Heuristics are rules-of-thumb and hunches human experts have acquired as a result of years of experience to solve problems more quickly and effectively than others.

2.13.2 Backward and forward-chaining

To solve problems, expert systems use human expertise embedded in the knowledge base rules. Rules are used in two important ways:

- forward-chaining, and
- backward-chaining.

Forward-chaining systems also called 'data-driven' systems are characterised by the fact that the reasoning proceeds from data or symptoms to hypotheses. This reasoning is described as 'recognise-act' where the inference engine uses the given data to reach conclusions.

Backward-chaining systems, the reasoning proceeds from hypothesis to data. The inference engine first selects a hypothesis or problem area to be tested then investigates it by seeking the data to test that hypothesis.

2.13.3 Matching

In either of these reasonings, a process of matching is used. This process consists of matching the data in the working data base with the premises of rules to determine whether they are true or not.

2.14 Discussion - Health and safety and expert systems

Expert systems can perform a range of activities such as diagnosis, planning, and control. Their usefulness in a variety of fields has already been highlighted and it should be a contribution if they can be used in HS. Many computer packages,such as word processors, spreadsheets and other specialised programs (HSIB 1986, ACGIH 1987), using conventional programming techniques, were and are being introduced and used by HS practitioners. However, despite their usefulness, there is a need to develop more sophisticated programs which use AI techniques to solve HS problems that are heuristic in nature and lend themselves to symbolic reasoning such as managing health and safety.

Expert systems developed in HS, should contribute to a better organisation of the HS knowledge and expertise. They could be used to enhance the user's skills of solving HS problems and they can be considered as training tools.

As in any other field, HS experts are not readily available and their services are usually expensive. Expert systems could be used (as in medicine) to assist HS practitioners in solving problems and carrying out complex tasks such as safety auditing and investigating accidents.

Like other domain experts, HS experts find difficulties explaining their reasoning when it is essential to understand how decisions are made and conclusions reached. Better understanding of experts' problem-solving strategies is important in more than respect as described below.

There will be better understanding of the HS experts' decision-making and problem-solving processes when assessing risks eg how hypotheses are formulated, decisions made and assumptions made. Understanding these processes should permit better and more accurate assessments of risk and controversies to be avoided. For example, the Canvey Island risk assessment is just one instance of how important it is to understand the problem-solving and reasoning strategies of HS experts. In that case, two separate reports highlight the difference between the estimations of risks by about a factor of ten

(HSE 1978 and 1981). Other benefits from developing expert systems for the management of health and safety include:

- understanding how HS experts solve problems will help determining what HS trainees need to be taught.

- experts are too busy with important issues and therefore rely heavily on memory joggers (such as checklists) which can be incomplete and inappropriate and computers perform well where memory is required,

- once aggregated in an expert system, the wealth of knowledge and expertise can be shared for the benefit of a plant, a company, or an industry,

- expertise of an organisation' HS experts is also saved in suitable forms before these experts retire or pass away.

- as it is common practice in medicine where the medical community insists on questioning the medical diagnosis of its experts (for better understanding of expert problem solving, for analysis of consistency of medical diagnosis, etc.), there is a need to study health and safety experts reasoning and problem solving to be able to simulate it using computers,

- experts have their own biases, particularly when under pressure. A HS expert system can be used in all sorts of environments (eg at times when human experts may not be available such as at week ends, at different work shifts), is not affected by stresses and can provide the user with readily available justifications for the course of actions it recommends.

2.15 Conclusion

Developing an expert system for the management of health and safety, such as preparing health and safety policies, should be a major contribution to understanding the HS expertise and above all assisting health and safety practitioners and industry in their tasks of preventing occupational accidents and ill- health. It is therefore important to investigate whether the development of such a system is justifiable, appropriate, and most importantly whether it is possible. Considering the requirements for developing an expert system - described in the previous sections-, it is important to determine the boundaries of the problem (such as the tasks of the system, the target industry and processes), understand the nature of the expertise and identify its sources. Each of these requirement is dealt with in the following chapters.

CHAPTER THREE

Health and Safety Policies

3.1 Introduction

Problems associated with health and safety at work are changing more rapidly now than in the past. As the Robens Committee (1982) pointed out, there is a need to keep up with these changes and to ensure that changes to and improvements in health and safety are both harmonious and acceptable. The Committee identified three pre-requisites for progress in health and safety at the individual firm level such as plastics processing plants:

- awareness by top management of the importance of health and safety. That is, if directors and managers take positive interest in and show positive attitudes towards health and safety, this should trigger a remarkable degree of awareness throughout the firm,

- health and safety ought to be a normal function of management just like production, marketing, etc.,

- a need for methodical assessment e.g. identification, evaluation and control of health and safety problems, making use of diagnostic and predictive techniques and the adoption of a systematic approach to accident prevention.

3.2 Background

The Robens Committee recognised the need for employers to adopt more comprehensive systems of accident and ill-health prevention than simply to rely on ad hoc patching up of deficiencies which were brought to light only after the occurrence of accident injuries. It was also made explicit that management policy objectives should be stated in writing and that individual responsibilities should be clearly defined. The Committee proposed the following changes in law and administration relating to occupational health and safety.

(a) The introduction of an enabling Act to place broad general duties on employers, manufacturers of industrial products, employees, the self-employed and occupiers of buildings where people work. The old principal statutes dealt with a considerable range of topics in varying degrees of detail, had no consistent pattern of dealing with those topics and as a result employers and others found it very difficult to form a comprehensive picture of the requirements of concern to them. The enabling Act which resulted from the Robens Committee was both general in scope and at the same time precise in defining the duties of each category in industry e.g. employers, employees, manufacturers, suppliers, etc. However, there is still an explosion of statutes and regulations which people find difficult to keep up with and to follow. So the Committee identified what people should do but left open how they would do it. In a way this can be stimulating and leaves the ball in the employers' court in areas where legislation has not yet provided definitive guidance: ie where they have to do something. It became clear to them that it is an absolute duty for those who create hazards to control them. The chemical industry is an example of how hard an industry can be hit. Manufacturers have to carry out a battery of tests before deciding whether it is likely to be cost-beneficial to put a product on the market.

(b) The broad general requirements of the Act would be supported by more detailed provisions of statutory regulations, approved and voluntary codes of practice and standards. The Committee stressed that more use should be made of these voluntary codes and standards.

(c) The amalgamation of the previous inspectorates into one unified inspectorate – the Health and Safety Executive (HSE). This and other Robens' Committee recommendations were designed to produce a framework for stimulating and encouraging self-regulation by industry. Thus, the function of the HSE was seen as the provision of advice and assistance towards progressively better standards. However, the Report also made it clear that offences should be dealt with quickly and effectively within this framework. The Report concisely summarised the new and important role that the HSE was to play. It stated,

> '... we are not arguing in favour of a much more discriminating and efficient approach, constructive where appropriate, rigorous when necessary'.

(d) The conferment of wider, more effective accident prevention powers upon HSE inspectors namely:

– improvement notices, and
– prohibition notices.

(e) The establishment of a new policy making body, the Health and Safety Commission (HSC), consisting of employers' and workers' organisations representatives as well as representation from local authorities and educational establishments. The HSC would submit proposals forming the basis of new regulations to the Secretary of State for Employment who would lay them before Parliament. The HSC was formed as a recommendation of the Committee for a unified administration.

(f) Less statutory regulation, encouragement of self-regulation and more voluntary participation by management and workers. Regulations such as the Safety Representatives and Safety Committees Regulations (1977) was an example of empowering union-appointed safety representatives from the workforce to carry out inspections of the workplace with a view to identifying and/or monitoring workplace hazards and making recommendations to management.

3.3 The Health and Safety at Work etc. Act 1974 (HSWA) and Health and safety policies

The Health and Safety at Work etc. Act 1974 implemented most of the proposals of the Robens Committee Report on Safety and health at work (Robens Committee 1972, HSWA 1974). The HSWA was the culmination of a long process concerning the legal treatment of health and safety at work.

The HSWA has solved many of the problems that previous legislation created (Robens Committee 1972) and was not spatially limited e.g. to 'factory', 'mine', 'office', etc. but included within its ambit virtually the whole working population and the public with respect to hazards arising from the activities of persons at work.

3.3.1 General Duties

The HSWA places general duties upon five separate classes of persons:

- employees,
- employers,
- manufacturers and suppliers of industrial products,
- self-employed,
- occupiers of buildings in which persons other than one's own employees work.

As this project intends to consider health and safety in plastics processing plants, the HSWA affects the processors as employers, manufacturers and occupiers of the premises where contractors may work and also affects employees and the self-employed (directors). As an employer, a plastics processor has the duty, so far as is reasonably practicable, to ensure the health, safety and welfare at work of all his employees (Section 2(1)).

3.3.2 Duties of employers

In paragraph 128, and in the light of the previous legislation which was too fragmented and specific, the Robens Report recommended:

> '...that the Act should begin by enunciating the basic and overriding responsibilities of employers and employees'.

This general statement is now enacted in sections 2 - 9 of the HSWA. The Committee believed that this general statement would encourage both employers and workpeople to take a less narrow and more rounded view of their roles and responsibilities. It also believed that this statement would provide guidance to the courts in their work of statutory interpretation and encourage inspectors to look at the workplace as a whole rather than at particular details which had been made the subject of regulations. Section 2 states the duties of employers. This portmanteau duty is owed to all employees at work. This section consists of seven sub-sections which will be referred to later but reviewing sub-section 2 and concentrating mainly on sub-section 3 which deals with the duty to prepare a written health and safety policy.

Section 2(2) specifies five general duties, all of which use the test of reasonable practicability:

(a) Provision and maintenance of plant and systems of work which are safe and without risks to health – section 2.2a;

(b) Arrangements for ensuring safety and absence of health risks in connection with the use, handling, storage and transport of articles and substances – section 2.2b;

(c) Provision of such information, instruction, training and supervision as is necessary to ensure the health and safety at work of his employees – section 2.2.c;

(d) Maintenance of any place of work under the employer's control in a condition that is safe and without risks to health and the provision and maintenance of means of access and egress to and from such place of work which are safe and without such risks – section 2.2.d, and

(e) Provision and maintenance of a working environment for his employees that is safe, without risks to health and with adequate facilities and arrangements for the employees' welfare at work – section 2.2.e.

3.4 Health and safety policies

The cornerstone of the philosophy of the Robens Committee is that of 'self-regulation'. This became so because the Committee was determined to avoid falling into the traditional pre-occupation of past official inquiries on the subject of health and safety at work, namely with details of the relevant legislation and of the arrangements for enforcing compliance with statutory requirements. It kept in view an important issue which did not seem to have been much explored by previous investigations. There were essentially two important issues namely:

- how much can and should be looked for through the medium of legislation and state intervention? and

- how much through the voluntary efforts of employers and work people?

By recommending self-regulation in preference to imposed regulation through enforcement by external agencies, the Robens Committee had to look for ways to make this happen. That was the intention of section 2(3). As the Committee pointed out, the best managements are in no need of persuasion or pressure. The intention behind passing subsection 2(3) was to remedy to this problem and to enable managements in all types of companies (large or small) to raise their standards of health and safety and to see that the general level of interest be raised to the standards of the best firms.

3.4.1 Section 2(3) of the HSWA 1974

The HSWA made it a legal requirement for employers to prepare a safety policy and gave some guidance as to the elements of the policy and left it, as part of the 'self-regulation' philosophy, to the employer to decide precisely what should go into the policy. The duty to prepare a policy is made clear in Section 2(3) of the Act:

> 'Except in such cases as may be prescribed, it shall be the duty of every employer to prepare and as often as may be appropriate revise a written statement of his general policy with respect to the health and safety at work of his employees and the organisation and arrangements for the time being in force for carrying out that policy, and to bring the statement and any revision of it to the notice of all of his employees'.

Despite being a legal requirement, health and safety policies are not always available and are sometimes written with motives other than compliance with the law. Examples of such motives include:

- to obtain public acceptance of notoriously hazardous activities,
- demonstrating safety consciousness to official bodies for contracts to be granted,

- financial - for effective loss control programmes,

- planning for better health and safety activities.

3.5 Importance of health and safety policies

The importance of health and safety policies was recognised well before the HSWA made it a legal requirement. Lippert (1947) pointed out in his book 'Accident prevention administration':

> '...A statement of policy concerning the company's stand on accident prevention is desirable because it informs management, supervision and workers of the company's intent and serves as a definite foundation on which to build an operating procedure'.

Lippert has identified and discussed safety policies and their importance to safety planning within an organisation. The proposal Lippert put forward started taking shape as that importance became clearer and in 1966 the American National Safety Council expressed the following view in its Industrial Safety Data Sheet 545 (NSC 1966):

> 'A company or plant which attempts to stop accidents without a definite guiding policy - one which is planned, publicised and promoted - will find itself continuously "fighting fires"...'

In its report, the Robens Committee recognised two essential ingredients for better management performance in the field of health and safety namely:

- explicit policy objectives, and
- effective organisation in which individual responsibilities are defined clearly.

Commenting on the recommendation of these elements the Committee stated the importance of policy statements as follows:

> 'they provide a frame of reference for positive safety and health within the firm, and a stimulus to interst and participation by all personnel'.

The health and safety policy is indeed the starting point for all the activities in a safety programme (Petersen 1978). Besides enabling management to put clearly and in writing the course of action it intends to take, it is a way of letting the workforce know that management is concerned about their health, safety and welfare. It enables management to think of and manage safety as they do other functions such production and marketing. It was found that successful managements have ceased seeing accident prevention as some vague kind of separate activity to be evaluated and attribute their success to their health and safety policy and the communication of that policy to all their employees and key managers (Robens Committee 1972, Lancianese 1985).

The success of a health and safety policy, unlike other policies, depends very much on dissemination and publicity so that everybody in the organisation knows exactly when, how and what part they have to play in the success of the health and safety programme. It is in no way the business of the management alone nor of the safety practitioner or supervisor, but depends very much on the effort each individual makes to observe the rules, to work safely, to be alert and to feel as if they are a building block or a piece of a complex jig-saw.

Despite the legal requirement to prepare and the importance of a health and safety policy, some companies, notably the small ones, have not still got a clear picture as to the purpose of preparing such a document as shown on Table 3.1.

Aston University

Source: (Warren & Orchard 1982)

3.6 Elements of a health and safety policy

A health and safety policy is a document that should enable management to relate the organisation's work to its objectives. Studies have shown that such documents vary a great deal in size and content (Warren & Orchard 1982). These policies' contents range from mere expression of a management intention to providing health and safety conditions, to very detailed documents including detailed safety rules, procedures, organisation and arrangements to ensure that the company's activities are carried carried out safely and without health risks.

In that Plastics Processing Industry Training Board (PPITB) study, the length of a policy was found to be independent of its quality.

The Act requires that a health and safety policy should contain three main elements.

(a) A written statement of general policy with respect to health and safety at work. This statement of intent should outline the company's commitment to health and safety.

(b) The organisation for the time being in force for the carrying out of that policy. This part should clearly specify the responsibilities , duties and accountabilities of people within the company. An organisational structure is useful and should demonstrate clearly such things as:

- how accountabilities are fixed,
- how policy implementation is to be monitored,
- how safety committee(s) and safety representatives are to function,
- how individual job descriptions should reflect health and safety responsibilities and associated accountabilities.

(c) The arrangements for the time being in force for the implementation of that policy.

There are HSE guidelines (HSE 1983) for the preparation of health and safety policies. They suggest a checklist that can be used for reference and encourages employers to consider the sort of items that should go into the arrangements. Items in the checklist are classified under the 15 headings in Table 3.2 below:

Source: HSE(1983b)

This is can be regarded as a test for the suitability of the Robens' philosophy of self-regulation. This test is: how can a balance be achieved between two important issues:

- how, on the one hand, can regulations be passed which lay down precise methods of compliance because of their intrinsic rigidity? and

- how, on the other hand, can legislation be passed that is general, lacks precision and creates uncertainty?

The problem with the first approach is that legislation may need to be repealed more often as it may be overtaken by events. This is less so with the second approach.

A dilemma which the Robens Committee had to face was how to reconcile flexibility with precision. The difficulties were due to a number of factors and were related to how the proposed legislation was to be complied with.Some of these difficulties are shown in Table 3.3.

Source: Warren & Orchard (1982).

The Robens Committee did not, however, envisage the sort of effects a change of government policy and attitude towards health and safety would have on the system they proposed. As an example, there are two different attitudes on the criterion for the preparation of a health and safety policy. In 1972, the Committee recommended that firms employing 10 employees need to prepare one. In fact, that exception referred to in Section 2(3) of the HSWA is in the Employer's Health and Safety Policy Statements (Exception) Regulations 1975. These regulations except from the provisions of Section 2(3) any employer of less than 5 employees. In 1986, the Department of Employment had a different attitude and considered that some of the health and safety legal requirements might be hindering industry and consequently intervened to try to 'lift the burden' of workplace health and safety law on businesses - particularly on small enterprises by commissioning a study carried out by the Department's Enterprise and Deregulation Unit. That study had the following terms of reference (GMBATU 1986):

> '... To identify difficulties caused to employers by the law on health and safety and its administration by Her Majesty Factory Inspectorate and local authorities; and to make recommendations to the Secretary of State and the Chairman of the HSC'.

At the same time, the General, Municipal, Boilermakers and Allied industries Trade Union (GMBATU 1986) carried out a survey which presented the effects of such attitudes on the number of accidents in the workplace as shown in Table 3.4

Table 3.4

Summary of the findings of the GMBATU survey
(GMBATU 1986)

	1981	1982	1983	1984	Change % 1981 - 84
Factory Inspectors	950	886	852	825	-13
No of visits made(000)	267	258	248	245	-8
Incidents* investigated	17200	18800	13800	11400	-34
Notices served by HMFI	5258	5272	5078	5127	-2.5
More infringements					
Informations laid by HMFI	1604	2134	1989	1855	+16
Increased deaths/ disability					
Deaths/Major Injuries**:					
Manufacturing	70	74	79	87	+24
Construction	164	204	221	233	+42

* by all HSE inspectors
** Incidence rates per 100,000 employees

Source: GMBATU (1986)

The Committee proposed a system which relied on self-regulation and self-accountability but left it to the employers, the courts and others concerned to provide for the tools, understanding and all that is necessary for its implementation. It could be argued that the Robens Committee did not set any guidance for the interpretation of the proposed legislation. As a result, fifteen years later, individual companies -particularly small ones which, although they can have potential hazards, have on the other hand poor resources to manage health and safety adequately - are finding difficulties living up to the Committee's high expectations.

3.7 Self-regulation or self-accountability?

The Robens' Committee placed high hopes on the concept of self-regulation and sought ways for the new legal obligations to make a constructive contribution towards promoting and sustaining active interest in health and safety at work.

The major task the Committee set itself was to achieve a balance between two bewildering issues concerning the style of the new legislation referred to in page 60. These issues taken again here and which the Robens' Committee faced were:

- Having learnt a lesson from the previous legislation, how to avoid recommending general and broad legislation which would quickly become obsolete and overtaken by rapid technological developments, and

- How, on the other hand, to avoid passing legislation that is so general that it lacks precision and creates uncertainty. The Committee had to reconcile these two problems by recommending that specific regulations should be passed under the new legislation and made it the duty of those who create hazards to control them. That duty is also left as a general one and it is up to the courts to decide on the test of 'reasonable practicability'.

The qualifying phrase 'so far as is reasonably practicable' in fact occurs on some eighty different occasions in the HSWA. However, this phrase is not defined in the Act but its meaning was judicially determined in the leading case of Edwards v. National Coal Board in 1949 and subsequently approved in another case Marshall v. Gotham Ltd in 1954.

However, it is not too apparent that either of the objectives sought (eg less specific legislation and a new approach for self regulation) is being achieved.

The basic implementation problems that were experienced can be summarised as follows:

- the new legislation is not to provide the solution to every situation but should stimulate industry to start thinking about its problems itself and to take the necessary steps to ensure that working conditions are healthy and safe,

- industry was not expected to wait for external enforcing agencies but should deal with more of its own problems. Examples were given in the Robens' report of the ways to achieve such results. More use of the voluntary codes and standards developed by independent bodies and organisations such as the British Standards Institute was an example. The course the Committee followed was undoubtedly a noble one but was it achievable in the time available?

The Committee was seeking to introduce the concept of self-regulation but what it aimed at was greater self-accountability which is more diffuse, complex and not easily achieved.

A significant shift away from the concept of self-regulation occurred - from 1980 to 1986- from a position where the HSE was expected to monitor and enforce the new legislation to a situation where it started prescribing what needed to be done. In some cases, over 60% of employers did not have a health and safety policy (GMBATU 1986) and it is situations like this that drove the HSE to prepare and sell ready-made health and safety policies (HSE 1986) when it had been categorically against such practices (HSE 1980) stating categorically that:

> 'the document can not be bought or borrowed, nor can it be written by outside consultants or inspectors' (HSE 1980).

This raises some questions as to the adequacy of the Robens Committee's philosophy of self-regulation and the introduction of a new and different system (a unified legislation and a unified administration) which will boost health and safety at work. As an example, the political and social environment can be a significant determinant of the success of this philosophy. The impacts of a change of government were discussed above. However, the Committee's work triggered some important social changes as the HSE reports:

> '... There is increasing pressure from employees, trade unions and some sections of the public for improved working conditions' (HSE 1983 p.4).

This notion of pressure indicates the extremes to which employees and employers usually go to in respectively worrying least and worrying most about health and safety in the workplace. In the same report, the HSE (HSE 1983 (b) p.3).points to some of the worries of employers:

> '... a workable policy ... should not become a straightjacket to deny change or inhibit local initiative, adaptability or ingenuity by or within the organisation.'

A normative set-up should involve not only employers and employees but should also involve the public, scientists and the enforcing authorities. Such a set-up ensures harmonious representation and participation in the debate for effective health and safety management. It should involve:

- the public - who benefit from the activities and services of industry,

- scientists - who should identify the requirements necessary for carrying out those activities safely and without risk to health of those who may be affected (e.g. workers, consumers, ...), and

- the government who will enforce the agreed requirements. Table 3.2 illustrates the important items HSE recommends to be considered when preparing a health and safety policy and which the authorities (ie its factory inspectors) will enforce by ensuring that both employer and employee comply.

3.8 How effective are health and safety policies?

By recommending the new system, the Robens Committee was hoping that the general level of interest throughout industry would be raised to the level of the best firms and that small pressures in the right direction to natural development of good practice would be initiated. As the evidence showed, making the preparation of a health and safety policy a legal obligation was thought to be a crucial element for the promotion of good practice. But was this intention enough? Questions need to be asked as to:

- how was this to work in practice?
- how would the safety policy be prepared?
- how would it be implemented?
- how effective if at all would it be?

Some employers have taken pains to formulate their health and safety policies only subsequently to find out that HSE inspectors are not satisfied with them (Hamilton 1979). This is one of the tests the Robens philosophy was to undergo. Some employers failed in their interpretation of Section 2(3) which requires the preparation of a written heath and safety policy. A number of employers thought that all that was necessary was for them to model their policies closely after those of some successful companies (Heath 1985).

Some employers felt that HSE should provide a model of health and safety policies, a 'fill-in-the blanks' model. The HSE inspectorates expressed a great deal of disquiet about their findings that firms had merely written statements without detailing how they would put those into action (HSE 1976).

Health and safety policies were found to be inadequate because:

(a) information about specific hazards was omitted,

(b) procedures for carrying out hazardous jobs were omitted,

(c) there was an over-emphasis on employees' responsibility laid down in Section 2(2) (a-e),

(d) managers responsible for safety had no clearly defined limits to that responsibility,

(e) some organisations had simply copied other policies with no thought to their applicability in different circumstances.

3.9 Conclusions

The problem is that health and safety policies are needed for adequate management of health and safety. There is a legal requirement for employers to prepare health and safety policy statement.

Indicators and pointers show that despite the need for better health and safety management and the legal requirements what is done is not the solution and is not enough. Where are the root causes of the problem? A risk assessment approach is applied in the next chapter to examine one particular industry with the intention of looking for the root causes of the problem, evaluate how big it is and propose a method to solve it. Because of the historical background referred to in the introduction, the plastics processing industry is therefore considered.

Small companies need more assistance with the preparartion of, implementation and monitoring of their health and safety policies. Health and safety knowledge needs to be made more available and most important of all to ensure that the health and safety knowledge is adequately used.

CHAPTER FOUR

Plastics Processing Industry and Occupational Health and Safety

4.1 Introduction

In the previous chapter, the importance of health and safety policy statements for an effective management of health and safety was reviewed. In this chapter, health and safety in the plastics processing industry (PPI) will be considered to identify problems and to ascertain how health and safety policy statements can improve the management of occupational hazards.

Laws and regulations have been and still are being introduced to provide improved health, safety and working conditions throughout a wide range of industries. As discussed in Chapter 3, the HSWA had a major impact on this improvement and unlike previous legislation, it applies not only to all manufacturing and processing industries (amongst which is the PPI) but also to such activities and places as the education sectors and hospitals.

4.2 The plastics processing industry (PPI)

The plastics processing industry (PPI) has been growing rapidly because of the many applications of its products which are of an exceptional adaptability (Milby 1973). Plastics take many forms and are capable of undergoing many processes to meet widely divergent requirements and have consequently been increasingly widely used (Tables 4.1- 4.4) .

Table 4.1

Size of PPI per year
(Jordan 1987)

Size of industry	1980	1981	1982	1983	1984
Enterprises	2851	2865	2844	2913	3891
Establishments	3191	3202	3164	3228	4185
Employees ('000)	153.7	139.4	129.3	129.1	134.5

Table 4.2

Classification of establishments and entreprises for 1984
(Jordan 1987)

Size group	Establishments	Entreprises	Employees (000)
1 - 9	2451	2420	8.8)
10 - 19	659	646	9.1)
20 - 49	486	482	16.1)
50 - 99	257	245	17.9)
100 - 199	181	164	24.8
200 - 299	77	66	18.7
300 - 399	27	26	9.1
400 - 499	19	16	8.3
500 - 749	17	16	9.9
750 - 999	5	5	4.2
1000 and more	6	6	7.4
Total	4185	3891	134.3

Table 4.3 Consumption of plastics raw materials in Europe ('ooo tonnes) (Jordan 1987)					
Country	**1982**	**1983**	**1984**	**1985**	**Growth (% p.a.)**
UK	2101	2310	2412	2586	+7.1
West Germany	5677	6243	6541	6681	+5.6
France	2666	2753	2744	2806	+1.7
Italy	2360	2520	2660	2775	+5.5

Table 4.4

Estimated UK consumption of Plastics raw materials
('000 tonnes) (Jordan 1987)

Material		**1983**	**1984**	**1985**	**1986**
LDPE(*):	LDPE	480-485	450	500	510
	L/LDPE	20-25	58	80	100
HDPE		195	210	250	275
PP		268	297	330	370
PVC		444	444	450	484
PS		140	147	148	156
XPS		31	31	30	33
ABS		51	53	55	58
Polyamides		17	19	22	23
Acetals		7.5	10	11	12
T/P Polyester (non film)		28	37	41	45
Acrylics		25.5	27	28	29
Polyester film		21	23	24	24
Phenolics		48	49	50	49
Aminos		115	122	125	131
T/S Polyester		45	50	51	53
Epoxies		16	17	18	19
Urethanes		88	91	94	100
Others		270	280	295	265
Total		2315	2415	2602	2736

* LDPE: Low density polyethylene

Plastics are very flexible and with a combination of chemical processes many products can be obtained from a single type. As an example epoxy can be modified for use as a flexible adhesive, altered for encapsulating electric coils or converted to provide a rigid resin for a moulded gear or can form the structure of a laminated boat combined with fibre glass and even can be used on roads if mixed with asphalt.

The variety of their characteristics allowed plastics to be extensively manufactured and used. These varieties of characteristics and products are obtained by a multitude of chemical combinations and processes potentially many of which are hazardous. Each process involves a variety of machinery and equipment and similarly each product comprises a mixture of chemical substances e.g. stabilisers, fillers, dyes and pigments, flame retardants, plasticisers and blowing agents.

4.2.1 Types of Plastics

Plastics are composed of polymers and additives. Polymers are long chain molecules formed by polymerisation of different monomers which are the basic building blocks. Monomers are organic materials whose molecular composition always include atoms of carbon. Other atoms in typical monomers include hydrogen, nitrogen, oxygen, fluorine, silicon, sulphur and chlorine.

The vast range of plastics is obtained by using additives with polymers. Plastic materials are usually classified according to their characteristics after the processing stage. There are two major categories: thermoplastics and thermosets.

Thermoplastics are resins that can be remoulded several times. They soften when heated and harden when cooled.

Thermosets, once they have undergone chemical change during processing become permanently insoluble, hard and relatively unaffected. The polymerisation of the thermoset polymer is completed in two stages:

- the first is done by the material primary manufacturer,
- the second stage is done by the moulder during the process of moulding the material into the desired shape.

4.3 Plastics material

4.3.1 Forms

Each type of plastic can be made in several forms. However, not all types are produced in every form and thus there are restrictions in the way in which any particular polymer may be processed. Many of the health and safety problems can be determined if the form of the plastic and the processes used are known. There are three forms:

- liquid resins - used for adhesives and for the processes of coating, laminating, casting and foam manufacture,
- powder - thermoset resins for moulding are usually supplied in powder form,
- pellets - thermoplastics are supplied as pellets in cubic, spherical and cylindrical shapes.

4.3.2 Plastics processing

Plastics can be processed on a variety of machines and products are obtained in a number of forms such as films, sheets, rods, tubes, profile shapes, fibres, foam, or laminates. Table 4.5 shows the main activities within the plastics processing industry.

Table 4.5

Analysis of activities and employment in the PPI for 1985
(PPITB 1985)

Main activity	Establishments	Employees
Blow moulding	55	7659
Compression moulding	61	4391
Injection moulding	597	39051
Rotational moulding	22	627
Sheet and section Extrusion	120	8397
Vacuum forming, Thermoforming	118	5936
Film making, conversion	113	7732
Coating	53	4191
High Frequency welding	71	2861
Hot air welding	14	164
Rigid foam	9	433
Adhesives	4	1158
Buttons	8	292
Glass reinforced plastics(GRP)	151	3713
Plastics sign making	37	518
Floor covering	7	1101
Roller (printers) covering	4	40
Tool making	9	79
Fabricating	96	2136
Reprocessing, colouring, compounding	45	1335
Laminating (non GRP)	13	525
Decorating, screen printing	12	384
Foam conversion	17	1023
Styrene foam packaging moulding	14	839
Machining of plastics	41	1582
Components assembly	23	2943
Writing instruments manufacture	3	914
Roofing felt manufacture	9	1456
Other, miscellaneous	160	10083
Total	1886	111563

Not all shapes can be obtained on all processes and with all materials. The process is selected according to the type of material and the desired shape of the product see Tables 4.6 and 4.7.

Table 4.6

Suitability of decorating methods for particular plastics

Material\Process	Painting	Hot Stamping	Electro plating	Vacuum Metalising	Printing
ABS	+	+	+	+	+
Acetal			+		
Acrylic	+	+		+	+
Aminos					
Cellulosics	+				
EVA					
Fluroplastics	+*				
Phenolics	+				
Polyamides	+				
Polycarbonate	+		+	+	
Polyester (unsat)					
Polyethylene	+*	+			+*
PPO			+		
Polypropylene	+*		+		+*
Polystyrene	+	+		+	
Polysulphone					
PVC		+			+
SAN	+				

* Special surface treatment needed

4.4 Plastics processes

4.4.1 Principal processes

Processing of plastics refers to the method of fabricating and converting the liquid or solid substance into a product. Most of the resins are processed by a variety of processes, of which the main ones are shown in Table 4.7. The variety of materials and processes used is a source of a variety of hazards a sample of which is shown in Appendix 3 hazards in the plastics processing industry.

Table 4.7

Major plastics processes
Calendering
Casting
Coating
Extrusion
Moulding - blow, compression, injection, rotational or transfer
Thermo/vacuum forming

The choice of a particular processing method is dictated by many other factors besides the economic one. Such factors may include: technical feasibility, capital expenditure, production cost, tool costs and length of the run. Plastics processors use their expertise to select the appropriate processes for different materials.

Calendering

This is a method used, like extrusion, to produce plastic film and sheets but mainly in the production of PVC sheet. In this process, a plastic formulation is being passed between three nips of heated rolls.

Casting

This processing method differs from the others in that it does not involve pressure and the initial feedstock is liquid rather than granules or powder. Liquid plastic material is poured into moulds to obtain products.

Extrusion

After injection moulding, this is the next most important processing method and accounts for a large percentage of the tonnage of plastic processed in the world. It is used to produce continuous lengths of sheet, pipe, rod and profiles. This method is sufficiently versatile to be adapted for the production of single items such as bottles. During extrusion, plastic material is forced more or less continuously through a die to shape it into uniform cross-section to produce those shapes. The plastic granules are transported along the heated barrel by a rotating screw which permits a uniform melt and mixing. The melt is pressurised by decreasing the channel depth and at the end of the screw, the plastic passes through a filter and eventually through a changeable die to form the desired shape. There are many hazards associated with this process and which may result in injury. The injuries are mainly from pinch points in equipment, hot machinery and electric shock. Health hazards are mainly due to toxic fumes and dusts given off during processing.

Injection moulding

Of all moulding processes (e.g. blow, compression, reaction and transfer) injection moulding is the most widely used and consequently injection moulding machines represent the greatest proportion of machinery in the industry. Injection moulding is basically a simple process in which granular or powdered material is fed through a hopper, is melted in a barrel and then injected into a cooled closed mould.

This process presents a range of dangers related to the machinery and to the materials used. In such an expanding industry, moulding techniques have changed very rapidly to meet the demands of processing.

With the introduction of the Health and Safety at Work etc., Act 1974 (HSWA), a positive move was made by the British Plastics Federation (BPF) when they published a voluntary code of practice for the safeguarding of horizontal injection moulding machines (BPF 1978). These machines are rated according to their size and clamping force which relate respectively to the amount of material to be processed and the pressure force available on the machine to keep the mould closed during injection of the melted material. Another characteristic of these machines is cycle time. Materials require fast cycle and there is always pressure to sacrifice safety for speed. Harmful fumes and gases are given off when injection moulding is carried out at temperatures high enough to degrade materials in the barrel.

Thermo/vacuum forming

In this process, a thermoplastic sheet is heat softened and then formed into an open mould using pressure or suction. It is mainly used in the packaging industry but can also be used for large structural items such as boat hulls and baths. Products are obtained by holding a plastic sheet over an open mould where it is heated until soft. By sucking the air out, the sheet takes the shape of the mould then cold air is used to cool the plastic.

4.4.2 Ancillary processes

The processed product may require some machining or other treatment before it is put on the market. Such ancillary processes may include printing, welding, machining and assembling. The main hazards are described in Appendix 3 for some of the activities or/and machinery used.

4.5 Health and safety in the Plastics Processing Industry (PPI)

In Britain, manufacturing industry has one of the highest accident rates compared with other industries as pointed out by the HSE annual statistics. In 1980 it reported the following:

> 'Just over half of all the reported accidents and over a quarter of all fatal accidents occurred in manufacturing' (HSE 1982a).

The plastics processing industry operations used to be rated by insurance companies as 'extremely hazardous' (Plastics Design & Processing June 1970). The injection moulding process is widely used and is the most hazardous because dangerous reciprocating screw machines are used. Operators, fitters, and other employees can be seriously injured if they trapped between the reciprocating mould parts. Table 4.8 shows the results of a survey carried by the American National Safety Council concerning the dangers of these machines and others as rated by plastics processors. The size of the sample of respondents was not revealed.

Table 4.8

How do managers rate processing machinery as to relative degree of hazards? (Modern Plastics May 1969).

	1st, %	2nd %	3rd, %	4th,%	5,%
Injection moulding	66.5	33.3	0.05	0.05	0.05
Extrusion	13.7	61.5	12.4	12.4	-
Thermoset moulding	-	33.3	33.3	33.3	-
Compression and transfer moulding	10.6	45.4	27.2	18.2	-
Blow moulding	33.3	33.3	-	33.3	-
Thermoforming	16.7	33.3	33.3	16.7	-
Rotomoulding	-	66.6	33.4	-	-
Clendering, casting and coating	57.1	14.3	14.3	-	14.3
Laminating	34.9	50.7	14.4	-	-
Foam moulding	19.5	40.5	19.5	-	19.5
Hot stamping	88.9	11.1	-	-	-
Machining & general fabrication	32.6	67.4	-	-	-
Tool & die making	100	-	-	-	-

This industry is comparatively recent and science-based but has grown and is still growing very fast and as a consequence there are direct effects upon plant safety. As space requirements increase there is a tendency to crowd the place with machinery, equipment and materials and this results in less than satisfactory standards of health and safety. Coupled with this is the constant introduction of new technology and the recruitment of new operators while the effort to provide safer and healthier places of work do not match the requirements.

In Britain, the plastics industry's history of accidents and ill health does not seem to be an alarming one, and as the HSE reports, this has been due more to the maintenance of reasonably good standards of control than to an absence of potential mishaps (HSE 1982b).

This statement was forwarded with the efforts deployed by the British Plastics Federation in mind. However, detailed studies have shown that if the picture does not look alarming, things are not well under control and as the HSE report points out, there was too much emphasis on mechanical safety - which is undoubtedly a deadly area. Similarly there was an overemphasis on safety standards many of which covered minor matters such as specifying the exact placement of fire extinguishers (Plastics Technology 1979) and it is only recently that there has been a shift of some regulatory agencies towards a more comprehensive approach and consideration of less tractable issues such as occupational health and hygiene.

Because of the objective of the project, which is to explore and evaluate the existing situation for the possibility of developing a simulation program, it is important to concentrate on the acute health and safety problems but refer to the importance of health hazards which should be catered for if a systematic and comprehensive control approach is adopted as there is no fine delimitation between the health and safety arrangements in a well managed organisation.

4.5.1 Accidents in the PPI

When it was set up, the NIG responsible for the PPI (HSE 1983a), concentrated its efforts on machinery accidents. This was because of the high number of serious machinery accidents - about 30,000 machinery accidents have been notified annually to HMFI in recent years- representing about 15% of the annual total of notified accidents in all factory processes under the Factories Act. Table 4.9 lists typical machinery used in the plastics processing industry for principal and ancillary processes, where the majority must meet the Woodworking Machinery Regulations requirements such as drilling and milling machines.

Table 4.9

Principal machinery used in PPI

Principal processes	Ancillary processes
Compression moulding machines	Printing machines
Granulating machines	Drilling machines
Rotational moulding machines	Milling machines
Horizontal injection moulding machines	Mixers
Expanded polystyrene machines	Ovens
Blow moulding machines	Blending machines
Extruders	Welding machines etc, ...
Vacuum forming machines	
Plastic converting machines	
Haul-off units etc,...	
Plant	
Conveyors	
Fork lift truck	
Boilers	
Lifting tackle	
Vehicles etc,...	

A study carried out by the National Safety Council (1979) revealed that small companies are at a very much higher risk than large corporations. The study revealed that plants with:

- more than 500 employees had 46% of the total number of workers in the USA but only 32% of the reportable accidental injuries,

- 25 to 99 employees had 16% of the workers and 21% of the injuries.

The study showed that the frequency and severity rates of the smallest plants were about triple those of the larger plants. The risks or hazards may be more concealed in the smaller plants than in the larger ones, but they are likely to be even more menacing.

In a recent study, the HSE (1983a) reported that 3421 accidents were notified including 102 which resulted in major injuries. Table 4.10 shows the distributions of accidents by agent of injury and the severity by agent of injury.

Table 4.10

Distribution of accidents by agent of injury in the PPI in 1981

Agent of injury	Number of Accidents Reported (NA)	%	Number of Major injuries (MI)	Severity MI/NA x 100
Machinery	477	14.0	32	6.7
Working surfaces	464	13.6	21	4.5
Hand tools	333	9.8	3	0.9
Industrial vehicles	136	4.0	9	6.6
Road Transport	41	1.2	2	4.8
Excavations	8	0.2	1	12.5
Scaffolds	5	0.1	0	0.0
Fire/Explosion	4	0.1	1	25.0
Trailers	4	0.1	0	0.0
Gases, Vapours	3	0.1	0	0.0
Other Plant	1502	30.6	16	0.0
Others	894	26.2	17	1.9
Total	3421	100.0	102	

Source: HSE 1983a

Table 4.11 shows the distribution of major injuries by accident type that were reported to Her Majesty's Factory Inspectorate (HMFI) and the incidence of accidents by type.

Table 4.11

Distribution of accidents by accident type in the PPI during 1981

Type of accident	Number of accidents	%	Number of Major injuries	%
Struck	1327	38.8	31	30.4
Over exertion	713	21.0	3	2.9
Trip	457	13.4	19	18.6
Trapped	409	12.0	18	17.6
Falls	214	6.3	19	18.6
Electricity	98	2.8	6	5.9
Inhalation	24	0.7	2	2.0
Vehicle collision	10	0.2	1	1.0
Exposure/Contact	10	0.2	2	2.0
Asphyxiation	1	0.0	0	0.0
Other	158	4.6	1	1.0
Total	3421	100.0	102	100.0

Source: HSE 1983a

The report HSE (1983a) gives no detail about the working population in the PPI where 3421 accidents occurred. However, the number of employees is useful to calculate the incidence rate and compare this industry with other manufacturing industries and can be determined bearing in mind that up to the begining of the 1980s, the PPI was a specialised industry - this means that all workers processing plastics were working in the PPI unlike now plastics have become widely used and processed by and are an integral part of other industries such as the motor car and food industries.

Consequently, an estimate of the number of employees at risk can be derived from the annual reports of the PPITB (1984 & 1985) which give details about the number and categories of employees - about 128,000 employees. This gives an accident injury incidence rate of about 2752 making the PPI one of the medium incidence industries. However, this incidence rate is higher than for all other manufacturing industries combined (Table 4.12) showing the meagre efforts for health and safety while this industry is rapidly expanding - and so its associated hazards. Similar situation was noted in the USA when a study by the National Safety Council (1969) showed that on-the-job accident rate in the PPI was almost 50% higher than for all manufacturing industries combined.

Table 4.12

Injuries to employees in Great Britain 1981
(Social Trend 1984)

Industry	Agriculture	Mining	Manufacturing	Construction	Transport	Other
Injuries						
All injuries	8172	44344	151954	45868	20549	163905
Fatal & Major	197	1088	4206	1795	609	4875
Fatal	32	62	109	105	45	98
Incidence						
All injuries	2310	13240	2560	4190	1450	
Fatal & Major	55.6	324.9	70.6	164	43.1	
Fatal	9.0	18.5	1.8	9.6	3.2	

4.5.2 Occupational health and hygiene in the PPI

Occupational health hazards are generally less obvious than safety or physical hazards such as machinery problems, fire hazards and their associated acute effects. This is particularly true for occupational diseases such as cancers, often referred to as silent killers, which have long latency periods of up to 25 years or more (eg time it takes a disease to manifest itself). These occupational diseases are caused by physical, chemical, biological environmental pollutants to which employees may be exposed. In the PPI, practically all plastics are inert and are not harmful when completely reacted and in their final application (Society of the Plastics Industry 1970). However, health hazards associated with the manufacture and processing of plastics relate to the basic plastic itself - or resin - and to the wide range of additives used (Table 4.13). There are about 2-3000 different substances used in plastics products with about 200 new ones introduced each year (BPF 1982).

Table 4.13

Additives used in the PPI

Antimicrobials	Flame retardants
Antioxidants	Heat stabilizers
Antistatic agents	Impact modifiers
Blowing agents	Lubricants
Catalysts	Plasticisers
Colorants	Release agents
Fillers	

Health hazards may be dusts generated when handling materials, toxic fumes given off as a result of inadequate processing conditions such high temperatures, or some other toxic substances like solvent vapours and aerosols as shown in Table 4.14.

Table 4.14

Some toxic substances in PPI

Substance	Main Source
Vapours	Emanating from solvents
Hydrogen chloride	PVC
Styrene	Polystyrene
Nitrogen-compounds	Nylons and acrylonitrile polymers
Fluorine compounds from	Polytetrafluoroethylene (PTFE)
Amines	Thermosetting resins (corrosive)
Peroxides	
Isocyanates	

There are thousands of materials used in the PPI and only a small percentage have been studied in detail. Effects of these substances range from irritations (to the eyes, nose, throat, dizziness and headaches), sensitisation, to just being a nuisance. There is a variety of control measures adopted such as those shown in Table 4.15.

Although plastics processing operations used to be rated (particularly by insurance companies) as very hazardous, studies have shown that there was no conclusive evidence that this is so (Plastics Design 1970). An example of that concern about hazards in the PPI, a guidance note EH15/79 was published by the HSE to alter the threshold limit value (TLV) for styrene from 100ppm to 50ppm (HSE (1983a) and PRI (1984)). The new limit value became an issue and the proposal had to be rejected as the medical evidence used was challenged by the industry. However, a guidance note was prepared on occupational health and hygiene problems in the plastics processing industry explaining what needs to be done to control them (BPF 1982). The BPF has also provided a specimen of a typical data sheet for substances used in the PPI (Appendix 2).

Table 4.15

Possible preventive measures to control health hazards
Substitution of safer chemicals for dangerous ones
Isolation
Enclosure of dangerous chemicals/processes
Ventilation - local exhaust ventilation
Dilution ventilation
Changing processes and procedures
Handling techniques
Good housekeeping
Controlling the temperature of processes
Training and education of workers
Minimising exposure of workers
Supervising the work
Provision of better information to those handling and exposed to chemicals
Welfare facilities
Protective equipment
Personal protection eg skin cream, ...
Monitoring of the workplace
Provision of a health monitoring system e.g. recording system ...

So because of the nature of health hazards described above, and the fact that health problems are not alarming, reference will be more to the safety hazards. However, health problems and arrangements to control them will be referred to.

A list of the main and ancillary processes with their related hazards is given in Appendix 1. The list suggests the sorts of actions that need to be taken to control those hazards.

4.6 Health and safety policies for the PPI

The rubber and plastics processing industry (PPI) can be regarded as one of the successful industries which have taken a responsible attitude towards safety. In 1976, the Plastics Processing Industry Training Board (PPITB) published some guidelines for the preparation of health and safety policies (RPPITB 1976). In 1974, the British Plastics Federation (BPF) formed a health and safety committee to prepare technical guidance in health and safety and in conjunction with other professional bodies (namely HSE, the Confederation of British Industries, and the Engineering Employers Federation) published a variety of codes of practice such as that illustrating methods of safeguarding horizontal injection moulding machines, or for safety in the construction and use of granulators, the safeguarding of compression moulding machines etc.

Despite these efforts, a survey undertaken by the Plastics Processing Industry Training Board (PPITB) in 1982 suggests that health and safety is still not adequately managed confirming results of a study carried out about three years earlier by the HSE (HSE 1980). In that survey, health and safety policy statements from 121 plastics processing companies were analysed and the results revealed serious defects and shortcomings listed already in Table 3.3.

An important finding of that survey was that, besides their style and content, the policy statements often gave little or no detail as to the arrangements necessary for the implementation of the policies. Table 4.16 summarises those findings.

4.7 Conclusion

Although efforts have been deployed to control health and safety hazards in the PPI, action is needed for an adequate management of health and safety. Small plastics processing companies (employing three quarters of the PPI workforce and using hazardous materials and processes) often have not got access to health and safety expertise and consequently are exposing their employees to a greater risk.

It should be worthwhile investigating the possibility of using computers and software developments to make health and safety advice more accessible to such companies. This is the research problem investigated in the next chapter.

CHAPTER FIVE

The Research Problem

Expert Systems in Health and Safety and Problem Solving

5.1 Introduction

The previous three chapters have set the scene, described the background to the research and examined three major areas where the research has taken its roots from namely:

- expert systems,
- health and safety and health and safety policy statements, and
- the plastics processing industry.

Although some background of the areas have been given, it is necessary to define precisely the problem the research proposed to investigate, the strategy for investigation and the outcome of that investigation. This chapter first determines the boundaries of the problem by reviewing the justification for and appropriateness of developing an expert system in health and safety – or in the AI terminology, the identification and conceptualisation phases described in Chapter 2. It then focuses on the possibility of developing such a system by investigating aspects such as characteristics of health and safety knowledge and expertise, strategies in health and safety, and problem–solving.

5.2 Value of AI techniques and expert systems in health and safety

5.2.1 Is expert system development justified?

The answer to this question stems from all the findings, referred to in Chapters 4 and 5, of the studies, investigations undertaken by the Robens Committee, the HSE and the PPITB. Those findings stress the need for more positive actions to reduce accidents and better management of health and safety. The problem is more acute particularly in small companies handling hazardous materials and processes while lacking, as it was pointed out in the previous chapter, adequate health and safety knowledge and training. Expertise is often expensive and not readily available. To cope with such difficulties even large manufacturing companies have started exploring development of expert systems for a wide range of purposes even when they have access to specialist advice. For example British Steel developed a system for the diagnosis of certain engineering problems to cope with breakdowns when their human experts were not available – during night shifts and holidays – (The Chemical Engineer 1985). Moreover, by developing such systems, companies would have saved a wealth of knowledge and expertise before their domain experts retire, change jobs or pass away. Writing about this, Kletz (1985) pointed out to the importance of saving health and safety (and other) knowledge and expertise acquired by an organisation over many years of experience. Else (1980) also pointed out the need to share the experience, skills and knowledge within an organisation and amongst organisations of the same company, companies, industries and countries. Health and safety data bases have already been set up and are useful in retrieving information about a wide range of topics such as dangerous substances, professional organisations, etc. However, the data and information retrieved often require health and safety knowledge for its interpretation and expertise for using it in the management of health and safety. This double problem of data and its interpretation is better dealt with using expert systems which not only provide the data but also explain how the data is used to solve the problems investigated.

As studies have shown (see Chapter 4), even when small companies have access to health and safety information, they often do not know how to use it.

5.2.2 Appropriateness of system development

Three key factors, already introduced in Chapter 2, need to be investigated determine whether the development of an expert system namely the nature, complexity, and scope of the problem to be solved.

Nature of the problem

The problem was defined at the outset of this project consists is the preparation of health and safety policy statements. As it was pointed out in Chapter 3, ready–made health and safety polices can be obtained (purchased, written) but a policy can only be effective if implemented and monitored properly. Thus the preparation of an adequate policy does not only require knowledge of health and safety but should also involve consideration of a wide range of parameters such as the structure of the organisation where it is going to be implemented and how it is going to be monitored. This task is primarily heuristic in nature – requiring the use of rules of thumb -- and is often carried out by specialists with years of experience about a variety of industries.

Complexity of task

Preparing a health and safety policy is not an easy task and bears the hallmark of the complexity and multi–faceted nature of health and safety problems. However, the

PPITB's survey revealed that health and safety policies were poorly prepared, implemented and monitored. The survey revealed also that in 50% of the policies, there was no mention of almost 2/3 of the arrangements analysed (Table 4.16).

Scope

The success of an expert system is determined by its scope. Since there is no existing expert system in health and safety management, it was one of the objectives of this project to determine what components make up a policy and investigate whether these components are areas amenable to expert system development and what is it required for them to be.

As a document, a health and safety policy consists of three principal parts which may vary in length from a single sheet to many manuals but it is the organisation's activities, structure and style that determine the components of a policy and hence the scope of the problem ie policy preparation. For example a plant employing 5 workers and involved in mechanical assembling of plastic components may have a significantly different health and safety policy than a much larger company of 300 or more people and using a variety of hazardous materials and processes and employing. There differences in the activities carried out, the ingredients used, the organisation structure and hence the need for appropriate physical and organisational arrangements for an effective management of health, safety and welfare at work.

The problem is complex and to in order to be made practical and more manageable (Waterman 1986), the research concentrated on small plastics processing companies. So by the nature of the problem (or task) and the PPI, any expert system that might be developed should be modular and have as many modules as policy components. These three issues are dealt with in the sections below.

5.2.3 Possibility of system development

While traditional computer programs have been used more efficiently than people for particularly strenuous and repetitive jobs, they have proved (up till now) not to be suitable for tasks requiring human intelligence. It is therefore important to explore the possibility and requirement for using AI techniques and constructing an expert system to advise small plastics processing companies in preparing, implementing and monitoring their health and safety policy statements. In pursuing this task, the underlying model of competence of a health and safety expert who would have prepared such a policy needs to be captured and ways to simulate such an expert, using computers, investigated.
And so addressing the issues of whether it is possible to capture health and safety experts' competence and simulate them would amount to:

- analysing the task and problem–solving strategies of health and safety experts,
- tools and techniques used to carry out the problem–solving tasks,
- determining what framework and other tools are needed to develop a computer program (eg expert system) that simulates such experts,
- identifying the areas amenable to the development of expert systems.

In order to analyse HS experts' task of preparing a health and safety policy and develop their model of competence, there is a need to acquire first the knowledge these experts use, structure it and eventually represent it in a suitable programmable form. However, before we start let us see what are the major strategies which HS experts adopt and what framework is best suited for the simulation of these experts.

5.3 Tasks and strategies of health and safety experts

Health and safety experts adopt three main approaches/strategies, or their combinations, in solving problems:

- pre–accident (planning) strategy,
- during accident (preventive) strategy, and
- post–accident (palliative) strategy.

Although health and safety practitioners adopt the three strategies, ideally they need to concentrate on the first one to prevent accidents and ill–health and their recurrence. Each strategy involves solving problems which consist of identifying problem areas and determining deficiencies which might result in occupational accidents or diseases (Table 5.1). HS experts' task is therefore predominently diagnostic and involves using knowledge and expertise gleaned over years of training, industrial practice and experience.

Table 5.1

Health and safety strategies and tasks

Strategy	Task
Pre–accident	Accident prevention
During accident	Consequence mitigation
Post accident	Accident/cause investigation

Here is an example of how these strategies or their combinations are used in tackling a health and safety problem such as high noise levels from a granulator used for recycling waste plastic materials.

Adopting the first strategy, a HS expert would have eliminated or mitigated the problem by analysing the reclaiming activity, identifying the hazards – dust, injury, vibration, noise– and determining the necessary precautions to control them. This strategy is a planning srategy and would have prevented creating the problem (hazards) altogether. Here the expert has a variety of options when health and safety measures could have been integrated before the machine design, construction and/or installation.

While adopting this strategy, an example of HS experts' problem–solving tasks would be to consider the control measures before the purchase/acquisition of new plant, equipment, material or recruitment of personnel, in order to avoid creating any situation which might give rise to problem areas.

If for whatever reason the granulator is installed and there are high levels of noise, HS experts called to solve this problem would adopt the second strategy of mitigating the consequences – since the problem has already been created. Here the potential of danger exists but may not have manifested itself and the expert's task is to evaluate the possible consequences should the danger manifest itself and take the necessary control measures. Such measures may include engineering control of noise (such as toughened plastic blades), isolating the activity, providing ear muffs to operators and reducing their exposure time.

The third strategy may be adopted if it is feared that occupational deafness has resulted from exposure to noise in order to determine the cause of deafness (ie source, type and level of noise). Ideally this strategy can be adopted simultaneously as the first two. It would permit the monitoring of implemented existing control measures and their efficacy.Other examples of arrangements considered when this strategy is adopted include first aid facilities, fire fighting systems and security systems.

Whatever strategy is chosen, HS experts are constantly assessing risks eg before accidents/diseases manifest themselves to prevent any incidence, during accident/disease to mitigate the consequences and after incidents to investigate the causes and monitor performance of control measures.

5.4 Health and safety expertise/knowledge

For whatever diagnostic task, the HS expert's knowledge can be viewed under the classes of knowledge as shown in Figure 5.1 and which can be equated with the structural forms of knowledge that are required for expert systems and AI programs (Addis 1987). Knowledge and expertise are often used interchangeably where in fact knowledge is the factual hard knowledge and expertise is that knowledge and the wealth of know–how.

Health and safety professionals, like medical specialists, exercise over a wide range of domains and are often called in to deal with a variety of problems which not only require a scientist or an engineer but ideally would require both these specialists as well as others such as a behavioural scientist, a management professional etc. The multidisciplinary nature of health and safety makes it difficult to define the boundaries of health and safety knowledge and expertise. One definition of this expertise can be extracted from Johnson (1980) who wrote:

> 'Technical expertise in the industry is the primary responsibility of engineers and scientists. The safety professional may be the expert on the hazards of a technology'.

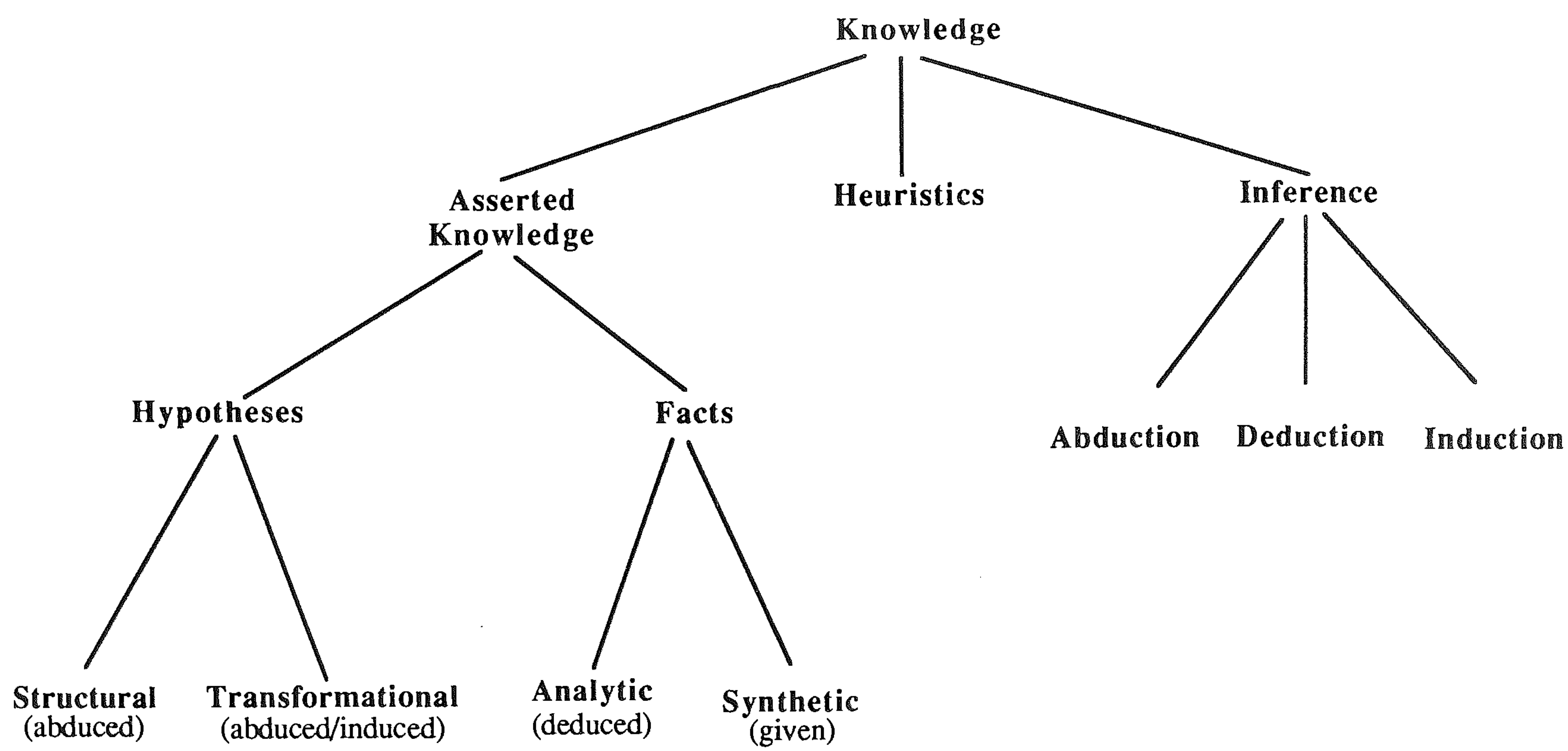


Figure 5.1 Types of knowledge
Source: Keravnou (1986)

This remark emphasises the importance of problem–solving skills in health and safety and, as it was recognised in medicine, the need to study, develop and structure those skills (Cutler 1979). There is a parallel between health and safety and medicine in that they both use a wide range of sciences and technologies such as physics, chemistry, metallurgy. The diversity of backgrounds of health and safety experts is also shown in a list of professionals recommended by the Canadian Centre for Occupational Safety and Health. The list includes about 200 different titles of these experts (CCOHS 1987).

5.4.1 Health and safety experts

From what was described of HS expertise, one critical skill of the safety professional is the capacity to enlist full participation of a myriad of specialised competencies throughout the organisation. The American Society of Safety Engineers (American Society of Safety Engineers, Scope and Functions of the Professional Safety Position, 1972) briefly lists the broad knowledge and skill areas just described and concludes with the following statement:

> 'The safety professional of the future will need a unique and diversified type of education and training if he is to meet the challenges of the future... The increasing complexities of man's everyday life will create many problems and extend the safety professional's creativity to its maximum if he is to successfully provide the knowledge and leadership to conserve life, health and property'.

Commenting on the HS professional's skills or expertise, the Society pointed to major components thought to be necessary and sufficient namely:

1 – Knowledge of technical and behavioural elements of safety.

2 – Skills in designing, implementing, and measuring methods and systems which enhance safety and performance.

3 – Managerial and organisational skills.

4 – Ethical and performance goals to motivate improve merits.

5 – Vigour in planning a pace of improvement adequate for the challenges of the present and future.

Because of the multi–disciplinary character of health and safety, as referred to above, it is difficult to define expertise and competence in this field. Experts are competent professionals who are called in to solve specific problems. An example of how the courts have defined an expert witness was given in a law case Bratt et al v. Western Air Lines (1946) as follows:

> 'A witness is an expert and is qualified to give expert testimony if the judge finds that to perceive, know, or understand the matter concerning which the witness is to testify, requires special knowledge, skill, experience, or training and that the witness has the requisite special knowledge, skill, experience, or training, whether a witness called to testify to any matter of opinion has such qualifications and knowledge as to make his testimony admissible is a preliminary question for the judge presiding at the trial, and his decision of it is conclusive unless clearly shown to be erroneous as a matter of law'.

Moreover, considering comments by McCormick (1945) on a law court expert witness, such an expert can be described as:

- qualified to testify because he/she has the first–hand knowledge which the jury does not have of the situation or transaction at issue, and

- having something different to contribute ie the power to draw inferences from the facts which the jury would not be competent to show. The subject of the inference must be so distinctly related to some science, profession, business or occupation as to be beyond the ken of average laymen.

5.5 Problem–solving in health and safety

The tasks undertaken by HS experts depend on the strategy (described in Section 5.3) adopted. For whatever strategy, the task can be described as being a diagnostic task where the expert is involved in identifying what can go wrong (ie pre–accident strategy), controlling what has gone wrong and/or investigating what has gone wrong.

When solving health and safety problems, HS experts call on their expertise which is sought to be elicited and acquired for developing artificial inteligence programs whose objective is to simulate the performance of those experts. Observations revealed ((Bensiali. 1987) and Appendix 5) that, like other experts such as physicians, HS specialists start their problem–solving by making – even with very little information– an initial guess as to the nature of the problem (Elstein et al 1978).

As problem solvers, HS experts have the a–priori knowledge of inference since without this ability, there could be no interpretation of the facts through hypotheses and there could be no new knowledge. Their diagnostic inquiries should follow three forms of inference which most problem solvers are seen to follow as illustrated on Figure 5.2 (Addis (1987), Peirce (1878)).

- abduction,
- deduction,
- induction.

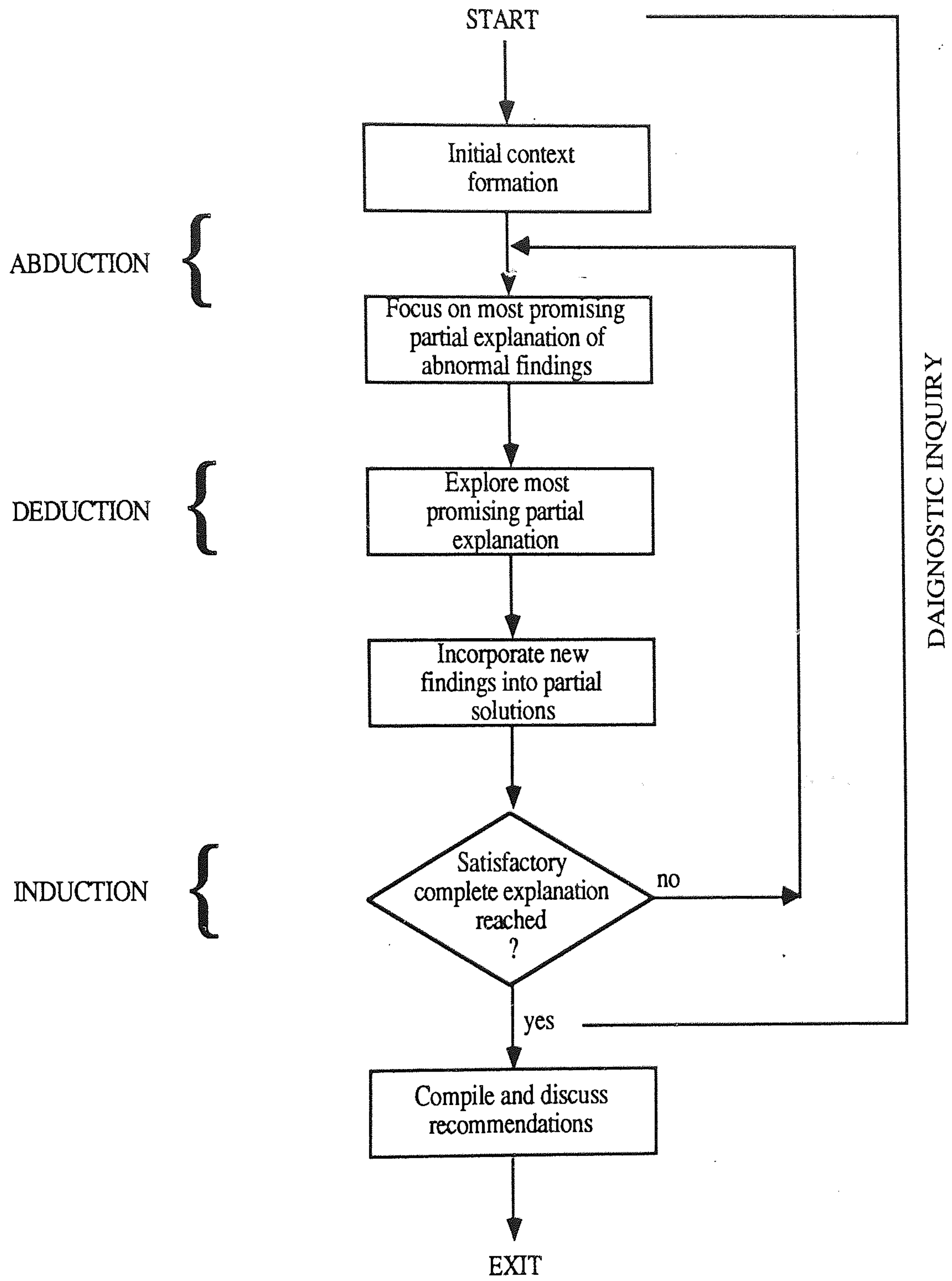


Figure 5.2 Reasoning cycles of diagnostic inquiries
(adapted from Keravnou et al 1986)

5.5.1 Abduction

This is the act of insight by which a hypothesis is arrived at and which explains its occurrence, ie generating hypotheses (new knowledge) when presented with puzzling phenomena (see Expert Observation transcript in Appendix 5 for examples. The expert can be observed asking the question and supplying the answer as he would expect it to be, and that is confirmed or otherwise by the client.). Abductive diagnostic steps usually take place at the begining of a diagnostic process when initial problem contexts are formed. At this stage a situation is looked at globally and the hypothesis is a general one which explains the possible deviation of a system under study. The data for pointing to the causes (or their non-existence) are usually easily obtained and the abduced hypotheses point to (or exclude) problem areas rather than specific causes.

In an abductive diagnostic process, a problem solver adopts two types of moves:

1 contextual abductive moves, and

2 non–contextual abductive moves.

The two types of abductive diagnostic steps are summarised in Figure 5.3

A contextual abductive move is said to occur when a hypothesis is generated in the context defined by another hypothesis whereas the non–contextual takes place at the begining of a diagnostic process. Table 5.2 gives a comparison between the two sorts of contextual abductive moves in a diagnostic process.

Aston University

Content has been removed due to copyright restrictions

Table 5.2

Contextual abductive moves in diagnostic processes

Type of move	Reason for use	When they occur
Traversal moves (taxonomic)		
–generalisation	to broaden range of explanations	at initial stage
–refinement	to constrain range	at subsequent stages
Lateral moves		
–opponents	findings expected on opponent hypothesis	Hypotheses share expectations
–complementary	problem better pointed to by more than one hypothesis	Hypotheses related via association

Adapted from Keravnou et al (1986)

5.5.2 Deduction

Deduction is a truth maintaining mechanism where the conclusions must follow from the premises. An example of deduction is a set of rules which are triggered in a forward chaining process and which come to a certain conclusion which is called a deduction. HS experts use deductive reasoning of which examples can be found in transcripts of Expert Observation (Appendix 5) and Workshop (Bensiali (1987). A deduced fact may be regarded as 'new' knowledge which is made available (not new to humans as it is a tautology but new to the reasoning system). An example of deduction is illustrated in the noise–rule in Table 5.3 where a HS expert can deduce that a noise survey/measurement was carried out if noise levels are known.

Table 5.3	
	A typical rule for a module on noise control
If	Noise levels are known to be >=95dB(A)
Then	Noise measurement was done.

5.5.3 Induction

This inference process is used to assess the truth, the utility or the viability of a hypothesis. Induction therefore deals with the decision of whether an explanation of the deficiency has been reached. An inductive diagnostic process can be illustrated by the example of a non–working air sampling pump. A satisfactory explanation for the problem is when all the abnormal findings are accounted for by the concluded hypotheses e.g. a satisfactory explanation of the problem would indicate a set of new batteries as being poorly connected. If after connecting them the pump still does not work then the given explanation is not correct and the hypothesis (test) that 'the problem is poor connection' should be rejected. These inferences are discussed again in the sections on knowledge acquisition.

5.6 Diagnostic tools used by experts in the management of health and safety

There is a wide variety of tools used by health and safety experts to identify health and safety management weaknesses and health and safety needs. Basically the experts are assessing the risks to health and safety and deciding on what measures need to be in place to control those risks. In so doing a variety of analytical techniques, summarised in Table 5.4, are used.

Table 5.4

Risk evaluation techniques	
Gretener Method	evaluates fire hazards in industrial trades and public buildings. It incorporates evaluation of fire and explosion damage to buildings and personnel.
Dow Index	is very widely used and was originally meant to serve as a guide to the selection of fire protection methods. To determine this index, a certain number of factors such as the materials used (ie energy potential of materials used, their reactivity, flammability etc), the units of the plant, the operating conditions, eg pressure, temperature etc.
Mond Fire,Explosion & Toxicity index	is a direct development of the Dow Index but allows more indices to be calculated and toxicity, internal explosion, fire load. These may be considered to give an overall index.
IFAL (Instantaneous Fractional Annual Loss)	The primary aim of this technique is to provide a measure of the hazards of an operation through quantifying the loss in terms of property, human life or production. It incorporates three factors: the process factor **p** (inherent hazards of process), the engineering factor **e** (effect of engineering design) and management factor (**m**). IFAL = **p x e x m**
Hazard and Operability Analysis (HAZOP)	HAZOP is a systematic method of assessing the ways in which a system can deviate from its planned method of operation
Fault Tree Analysis (FTA)	Requires the construction of a logic diagram (fault tree) which traces from an undesirable event all that can lead to the event
Event Tree Analysis (ETA)	An event tree is similar to a fault tree but explores the consequences of an undesirable event
Failure Mode & Effect Analysis (FMEA)	FMEA gives a comprehensive assessment of the whole sequence of events from initial cause, which may be a component failure, through to the ultimate consequent of the event. FMEA usually produces the results in the form of tables.
Cause–Consequence Analysis	In many ways, cause consequence analysis is a combination of fault and event tree analysis. It presents the sequence of events in the form of a logic diagram and can present a quantification of the risks of a system.
Random Number Simulation	This method is also called the Monte Carlo Method. This is a more refined version of fault tree or cause consequence analysis. Instead of using a single value for the probablty of failure, it uses a range of probabilities. Consequently it presents outcomes as a range of possibility.
Techniques for Predicting Human Error (THERP)	This is really a sub–routine of the other techniques as it is a way of determining the allowance that should be made for human error in the other techniques.

Source: Bensiali (1985),

As for the diagnostic tools, health and safety professionals use three of them comprising:

- checklists,
- health and safety audits,
- accident investigation.

5.6.1 Inspection checklists

Many diagnostic checklists, ranging from simple to very complex ones, are found in the health and safety management literature (Stevenson 1980; HSE 1983; ILCI 1984). In most cases, consultants using these checklists use simple heuristics to evaluate the responses and attributes to the questions. Questions answered 'NO' are often viewed as red flags and could signal inadequacies in arrangements such as adequate documentation, written records or inadequacies in the responsibilities assignments, communication systems, etc.

The lack of diagnostic rules and minimal documentation of the reasons for pursuing a certain line of thinking, asking specific questions limits the use of this type of tools in building expert systems.

A typical example of a checklist is a diagnostic tool developed by the HSE–APAU (HSE 1983b) for evaluating the safety effort, or CHASE developed (HASTAM 1987) for identifying management weaknesses. These checklists can fall in one of two broad categories: simple checklists and audits.

The HSE prepared also a checklist which was meant to assist its users to prepare health and safety policies (HSE 1985b).

Below is a brief description of three of these checklists.

1. HSE–APAU checklist

This is a checklist which was prepared in 1980 and meant to highlight the important areas that need to be considered in the preparation of adequate health and safety policy statements. This publication gives examples of successful firms and tries to support the Health and Safet Executive's Accident Prevention Advisory Unit's (APAU) view that the success of those firms was due to planned safety programmes represented in their safety policy statements.

It provides a suggested checklist guide of 103 questions to probe the applicability, strengths and weaknesses of existing policy documents.

The checklist consists of three parts:

– the policy statement,

– the organisation for health and safety, and

– arrangements for health and safety.

Most of the checklist is about arrangements for health and safety which are considered under 14 headings shown in Table 5.5

Table 5.5
Arrangements for health and safety
Dust,
Emergency procedures,
Environmental control,
Fire,
Internal communication,
Machinery and plant,
Medical facilities and welfare,
Monitoring at the workplace,
Noise,
Radiation,
Safe place of work,
Safe systems of work,
Toxic materials,
Training,

Source: HSE (1980, 1983)

2. AMI Checklist

Table 5.6 shows the checklist used by AMI health and safety consultants to carry out a safety inspections and audits on industrial sites. The checklist consists of a number of arrangements which AMI consultants expect to find and believe to be the minimum requirements for an adequate management of health and safety at an industrial site. This checklist is referred to in Chapter 7 and Appendix 5 illustrates how an observed expert has used it.

Aston University

Content has been removed due to copyright restrictions

3. Project checklist

This checklist was developed earlier in the project and which was meant to be used on site in two stages: office–checklist and physical inspection checklist.

This checklist is in the form of a questionnaire (see Appendix 2) specifically adapted for inspection and auditing of plastics processing plants. The questionnaire serves as a guide and is organised in topics each considered in turn. It was developed after visits to four plastics companies but was hardly used because of the unwillingness of the companies in the PPI (sensitivity of the questions asked) and for other reasons taken again in Chapter 7 when dealing with knowledge acquisition. As a checklist, it can be used to systematically review various aspects in a plant and form a picture about those aspects which can then be compared with other plants or other parts of departments of the same plant.

5.6.2 Safety audit

Safety audits are specific checklists used as diagnostic tools in the management of health and safety. The objective in conducting health and safety audits is to reduce the number of hazards and thereby reduce the number of occupational accidents and diseases. These tools differ in style and content depending on the purpose of their use. Examples of safety audits prepared by three different organisations are reviewed below.

1. HSE-Monitoring audit

This is a set of schemes published by HSE 1985b) and devised by a number of firms from different industries (eg construction, civil engineering, and chemical) and meant for different levels (eg plant, works, and divisional levels). Extracts from that publication are in Appendix 3.

2. CHASE

This is health and safety management audit which is in 12 sections (see Table 5.7) below each dealing with a specific aspect of the management of health and safety. Each section is made up of one or more questions which requires a 'yes' or 'no' answer. Unlike certain audits such as the ones below, branching is used in CHASE.

3. International Rating System

The package of this system consists of two parts:

- a guide for inspections of physical conditions and
- a rating system e.g. a scoring safety audit.

(a) Physical Conditions Guide for Inspections

The guide was designed as an aid for sampling physical conditions in a workplace. It is an aid to prepare for and make good general inspections and physical condition audits of plants and premises. This guide can be used with or independent of the rating system which is described below. It comprises the following six sections which are described briefly here:

Section 1. The General Inspection Review: consists of important factors to keep in mind when making a general inspection,

Section 2. General Workplace Conditions: is an abbreviated checklist which deals with what to look for. It consists of 8 major categories namely:

A General workplace conditions

B Facilities

C Materials

D Equipment

E Hazard controls

F Emergency systems

G Other

H Protective equipment compliance

Table 5.5 shows more details of the 39 aspects that an inspector using the guide should look for to assess their adequacy.

Table 5.8

General Workplace Conditions
'What to look for'

1 Aisleways and passageways	21 Machine tools and guarding
2 Chemical and fuels	22 Materials handling equipment
3 Color coding	23 Materials labeling
4 Compressed gases	24 Mechanical power systems
5 Conveyors	25 Mobile equipment
6 Electrical power systems	26 Noise exposure
7 Ergonomic factors	27 Personal protective equipment
8 Emergency instructions	28 Platforms/scaffolding
9 Emergency rescue equipment	29 Pneumatic power systems
10 Exit/egress	30 Pressure vessels
11 Eye bath and showers	31 Roadways
12 Fire protection	32 Signs and tags
13 First aid kits/stations/equipment	33 Stacking and storage
14 Floors (walking & working surfaces)	34 Stairs
15 Hydraulic power systems	35 Valves and mechanical controls
16 Hand and portable tools	36 Ventilation and extraction
17 Ladders	37 Warning systems
18 Lifting gear/equipment	38 Waste disposal
19 Lighting	39 Other conditions
20 Lock–out systems	

Source: ILCI (1984)

Section 3. Physical Conditions Evaluation: this is a pullout section which may be used together with Section 2 or separately for the purpose of the management audits. It may be used for random sampling or for full comprehensive physical conditions audits. This type of audit is usually carried out by a team of multidisciplinary personnel within the local organisation.

At the end of a tour, the percentage of compliance can be computed for each sub–group listed above A–G. Very broad guidelines are given to the user as to how this audit is to be used and how scores are attributed. For example, the manual (ILCI 1984) describes that:

'Value factors for each group should be assigned, reflecting that area's relative importance from a safety and health/loss control standpoint. These values must add up to 100'.

However, it gives no details as to how to assign a score to the elements of each sub–group nor how one score affects the final score of the inspection.

The value factors assigned to the 7 categories (the last category H is not scored as they are not considered physical conditions in themselves), do not show the priority/ importance borne in mind by the designers of the audit. An example of that is that Facilities, Hazard controls and Emergency systems have all been assigned a value factor of 15.

Section 4. Substandard Conditions Summary: is a pullout form used for highlighting critical items e.g. list of conditions and corrective action.

Section 5. Occupational Hygiene Summary: is a reminder for the guide user of the importance of adequate controls for a list of certain substances such as Acetone, Formaldehyde or other items such as noise.

Section 6. Back Page: for the inspector to draw the inspection area layout and route which should be helpful reference and future inspections.

(b) International Safety Rating:

This is a safety rating or safety audit system also developed by the International Loss Control Institute (1984) to be used with the inspection guide described above. It is used for the evaluation of the management of health and safety of an organisation by attributing stars which are awarded according to the set criteria. There are two broad categories of programme: standard and advanced programmes. Depending on the type of programme (or award) sought, different criteria are used. The criteria are basically the number of questions asked, the elements required to be rated, and the award sought.
So how an audit is to be carried out depends on:

- type of programme (standard or advanced),
- type of award sought (1 to 5 stars).

Once the choice has been made, that determines the elements required to be rated and the number of questions to be asked and which can be up to 579 questions if the user of the audit aims for a 5–star award for an advanced programme.

The audit consists of 20 elements (Table 5.6) about which questions are asked, rated and scored. The star then depends on:

- the minimum average score obtained,
- the minimum on any of the list elements ,
- the minimum physical conditions score.

Table 5.9

Elements required to be rated	
1 Leadership and administration	11 Personal protective equipment
2 Management training	12 Health control and services
3 Planned inspections	13 Program evaluation system
4 Job/task analysis and procedures	14 Purchasing and engineering controls
5 Accident/incident investigations	15 Personal communications
6 Job/task observations	16 Group meetings
7 Emergency preparedness	17 General promotion
8 Organisational rules	18 Hiring and placement
9 Accident/incident analaysis	19 Records and reports
10 Employee training	20 Off–the–job safety

Source: ILCI (1984)

The above checklists and audits have their limitations and can not be used as widely as it is usually hoped because not only they are specialised, they can be used effectively only by health and safety professionals. Non health and safety users will find it hard to monitor or/and evaluate the management of health and safety using these tools.
Similar problems were highlighted by Power (1985) who wrote that the lack of diagnostic rules and minimal documentation of the reasons for asking specific questions limits the use of such tools particularly in building expert systems.

5.6.3 Accident investigation

Accident investigations are important to consider to see what strategies health and safety experts adopt when trying to determine accident cause(s). Such investigations help prevent future accidents by controlling hazardous situations and activities which could lead to similar accidents. However, although accident investigation is a tool widely used in solving problems, it has its limitations which will become clearer after this activity is investigated.

Denton (1983) described accident investigation as follows:

'... accident investigation is at best an educated guess that may or may not prevent accidents.'

So how does health and safety experts investigate accidents and how suitable is accident investigation as a strategy for the construction of this system?

HS professionals (Denton 1983, Kletz 1985) agree that the process of accident investigation consists of 4 basic steps namely:

1 investigate accident,

2 analyse information and events surrounding accidents,

3 suggest possible causes,

4 make recommendations for possible action.

The accident investigator looks for cause(s) and explanations for the occurrence of an accident and this approach overlooks many other contributory causes which are not so straightforward. This approach can be described as a top–down approach where the top event has occurred and the investigator is working retrospectively to find out what caused it, going back to the terminal nodes. It is adopted in Johnson's management oversight risk tree (MORT) technique which is widely used by investigators (Johnson 1980) and where a top event is selected and traced down a tree back to the root cause(s).

Although it is cost–effective, this approacn overlooks many possible causes and accident investigator certainly have serious constraints, particularly time pressures to identify the causes of the accident and to complete the investigation. The 1987 King Cross underground fire showed the pressures on the investigation team to determine the cause(s) of the fire before more disasters happen in other stations. As accident investigators, HS experts use structured checklists and techniques such as MORT to go through an activity systematically and identify hazards which can lead to accidents. However useful these tools may be, they have their drawbacks ie while the checklist user has thoroughly investigated a system, those aspects which are not on the checklist might easily go unnoticed.

In an accident investigation, there is no logical reason to believe that accidents can be prevented and/or their number reduced in the long–term because, despite an investigation, the real causes of the accident may not be determined and accident investigation experts may be under pressure to find any explanation (cause(s)).
Accidents ususally have more than one cause. Causes can be categorised as primary, secondary, tertiary etc., depending on their degree and weight in producing accidents either in isolation or when combining with other contributory factors.

Another drawback in using accident investigation is that the investigator is motivated to find the cause or causes. That motivation may degrade rapidly as soon as the first cause(s) has been determined and be even weaker in the case of a no–loss incident. It can be reasonably accepted that such an attitude is held if investigators have resources constraints.

Moreover accident investigations techniques are usually devised for specific types of accidents and changes to be used outside the field for which they have been designed. For example aviation accidents have long had intensive investigation, rooted essentially in the system characteristics of aviation. Although the organisation, methods, checklists and search for causes were excellent, generic methods were difficult to perceive, transfer and apply for less well defined systems (Johnson 1980).

5.7 Accident investigation and problem–solving skills

Accident investigation techniques can be applied in a variety of fields. However, they need to be adapted to the domain where they are to be applied and investigators learn, through training and practice, and how to effectively use them and improve their problem–solving skills. Accident investigation, like medical diagnosis, involves a spectrum of domains and expertise can only be developed on specialised areas. It is therefore important to note this aspect in training problem–solving skills to accident investigators. This aspect of specialisation was emphasised by the HSE(1985b) when considering safety auditing. It stated:

> '.... all the schemes vary for two basic reasons – the first is that each company is unique and the second that the management of each company views its needs in a different way.'

So training problem–solving skills to accident investigators can only be effective if it is based on a specific domain ie industry. And even when this is so, the trainee acquires the principles and will take some time to digest those principles before transfering them to his/her field of interest and then applying them. It will take some more time, after applying them, to see how effective they are. This situation can be illustrated by some work pioneered by the American National Transportation Safety Board (ANTSB) for improving generic accident investigation principles to transportation. However, these principles and generic methods took on the characteristics of the industry and were obscured by subject matter which led the ANTSB to develop its own techniques of event and causal sequence (ANTSB 1971).

Another shortcoming in accident investigation as a problem solving strategy results from constraints on the scope of the investigation. Investigators need to define well this scope and hence are often led to consider only the most obvious activities or events that happen to exist at the time of an accident. Consequently only the most obvious causes of accidents/diseases such as guarding, toxic substances and unsafe conditions are tackled. Even when those causes, often self evident and easy to identify, have been eliminated, the more subtle ones may still remain in existence. This was termed 'reasoning by sign' i.e. signs of poor attitudes, training and ineffective procedures and therefore these must contribute to the accident (Denton 1983). This type of reasoning is not to be abandoned because it is often the only tool when resources are limited e.g. time and personnel.

In some cases the causes are so subtle that investigators may, in frustration, call them 'acts of God'. Such statements and many of the accident investigation outcomes can not establish a sound cause–effect relationship if that cannot be rigorously checked and consistent results obtained over and over again such as for empirical laboratory experiments. For example the success of corrective measures implemented, as a result of an accident investigation recommendation, may be due to many factors and it is important to determine how true and accurate is the measure(cause) – accident(effect) relationship (Menckel & Carter 1985). This difficulty is illustrated by improvements following a safety training programme. They may be due to the fact that the trainer was addressing a receptive group of employees or that the group might be trying to please the instructor rather than changing their attitude.

There is a need therefore to study in more detail how health and safety experts solve problems to determine deficiencies and problem areas in a given undertaking. It is important that the multi–causality phenomenon of occupational health and safety problems is recognised. Their problem–solving can be termed as diagnosis.
Problem–solving analyses are usually carried out before expert systems in a field are developed. Such analyses were for example extensively carried out in medicine where there are standard books for differential diagnosis (Gale and Marsden 1983) and for organisations where researchers have reviewed measures of individual and organisational effectiveness (Campbell 1977; Cameron 1978; Price 1968; Steers 1977).

In medicine as in the analysis of organisations, there are reviews and textbooks which provide lists of symptoms and indicators associated respectively with diseases and organisational problems. However, there are no measures, standards, or norms for interpreting those symptoms/indicators nor are they well defined (Steers 1975).

Luckily a great deal more is being done in Medicine where not only lists of indicators and symptoms have been devised but much attention is still being paid to the diagnostic processes themselves and the problem–solving. Indeed Cutler (1979) points vigorously to this aspect and its importance by stating that:

> 'There is no more important field in medicine than diagnosis. Without it, we are charlatans or witch doctors treating in the dark with potions and prayers. Yet there is no field more difficult to teach. Strange that this art and science has not attracted innumerable theorists to make it more teachable! Thousands are studying membrane transfer, yet few strive to make a science of diagnosis'.

5.8 Conclusion

Accident investigations are palliative measures carried out after the occurrence of accidents. Important though accident investigations may be, they can only be regarded as tools used in the prevention of future accidents e.g. by using the investigations results.
In this respect, they are not 'positive' diagnostic tools but are rather used only after accidents have occurred.

It is therefore essential to adopt more positive approaches and determine what frameworks health and safety experts (e.g. accident investigators and other practitioners) use to carry out diagnoses to uncover deficiencies – which are the real causes– before accidents happen. These frameworks are hardly referred to and are not crisply defined.

Because of the difficulty experienced in adopting generic problem–solving techniques, it is necessary – for the purpose of this project – to develop a new approach for the prevention of occupational accidents and ill health. New frameworks need also to be spelt out and used, in the development of a health and safety management expert system.

It is also important to tailor the generic accident investigation and the other problem–solving principles before applying them to the target industry (the PPI) and to any of its activities. The PPI has been introduced in Chapter 4 and examples of activities are given in Appendix 4 and in the remaining chapters. There is therefore a need to analyse how health and safety experts diagnose and solve problems, and to devise better frameworks which can be adopted for developing expert systems for the management of health and safety.

CHAPTER SIX

Research Strategies I
Project strategies

6.1 Introduction

This chapter deals with the research strategies used to investigate thoroughly the problem and determining how the framework, approach and tests described in the previous chapters are used by experts and how the knowledge can be elicited for the construction of a Health and Safety Management Program (HASMAP).

This chapter has two aims and some criteria are set for the knowledge acquisition. The two aims of the chapter are:

- to add increased clarity, specificity, and breadth to current descriptions of the diagnostic thinking process in HS, and
- to identify problem areas HS experts tackle and to see what questions are asked and the spectrum of expertise subjects.

The criteria set for the case studies considered in this chapter were that they should:

1 relate to the experiences of HS experts,
2 produce a developmental picture,
3 test the methodology developed and used in the expert system HASMAP, and
4 yield pragmatic solutions to the problems posed.

To achieve those aims, five different but complementary research methods were developed over the research period. These methods are:

1 industrial visits,
2 questionnaire,

3 interviews,
4 expert observation, and
5 a knowledge elicitation workshop.

6.2 Industrial visits

Visits were carried out to a dozen plastics processing plants where a variety of processes, ancillary processes and other activities took place. A summary of the main activities, hazards and health and safety arrangements in some of the plants visited is given in Appendix 4 and below are tables of accidents which have occurred in some of them. Tables 6.1 – 6.11 show the sorts of accidents and injuries occurring in the PPI. These visits were particularly useful in discussing the project with health and safety and other managers and assess the need for such work and to find out what pitfalls should be avoided so as to cater for the acceptance of such a program (and its modules) by users whose needs should be understood.

Table 6.1

Accidents by department
Company A 1983

Department	Accidents	%
Conversion	52	27.7
Extrusion	38	20.2
Engineering	38	20.2
Reclaim	35	18.6
Print	12	6.4
Warehouse	7	3.7
Elsewhere (e.g. canteen)	6	3.2
Total	188	100.0

Table 6.2

Accidents by site of injury
Company A 1983

Site of injury	Accidents	%
Hands	109	58.0
Arms	19	10.1
Back	13	7.0
Legs	11	5.8
Feet	11	5.8
Head	11	5.8
Eyes	08	4.3
Trunk	06	3.2
Total	188	100.0

Table 6.3

Accidents over an eight-year period
Company A 1978–1985

Year	Hours lost due to accidents	Total Number of all recorded accidents	Number of reportable accidents (> 3 days)	Average N^{O} of employees
1978	–	366	37	398
1979	–	394	32	376
1980	992	307	6	332
1981	644	225	5	303
1982	1250	210	8	330
1983	628	188	5	321
1984	608	12	4	319
1985	744	190	5	35

Table 6.4

Number and type of injuries
Company B 1984

Injury types	Accidents	%
Cuts	58	35.8
Bruises	25	15.4
Burns	11	6.8
Irritat.	10	6.2
Sprain	8	5.0
Laceration	4	2.4
Rash	2	1.2
Others	44	27.2
Total	162	100.0

Table 6.5

Distribution of accident by department
Company B 1984

Department	Accidents	%
Moulding	49	30.2
Extrusion	19	11.8
Tool Room	14	8.6
Finishing	14	8.6
Maintenance	11	6.8
Compounding	10	6.2
Packaging	7	4.3
Material reception	5	3.1
Printing	2	1.2
Inspection	0	0.0
Other	31	19.2
Total	162	100.0

Table 6.6 (a)

Distribution of accidents by department and type of injury
Company C 1985

Department / Injury	Materials in	Compounding	Extrusion	Moulding	Maintenance	Total
Cuts	2	3	5	23	5	38
Bruises	0	0	3	5	0	8
Laceration	0	2	0	1	0	3
Burns	0	0	3	5	0	8
Rash	0	0	0	1	1	2
Irritation	1	2	0	3	1	7
Sprain	0	1	1	1	1	4
Others	2	2	7	10	3	24
Total	5	10	19	49	11	94

Table 6.6 (b)

Distribution of accidents by department and type of injury
Company C 1985

Dept. / Injury	Tool Room	Finishing	Packaging	Inspecion	Printing	Other	Total
Cuts	6	5	2	0	0	7	20
Bruises	4	3	2	0	2	6	17
Lacerations	0	0	0	0	0	1	1
Burns	0	0	0	0	0	3	3
Rash	0	0	0	0	0	0	0
Irritation	1	0	0	0	0	2	3
Sprain	0	3	0	0	0	1	4
Others	3	3	3	0	0	11	20
Total	14	14	7	0	2	31	68

Table 6.7

Number of accidents by contributory cause Company D 1985

Year	1985		1986	
	Accidents	Days lost	Accidents	Days lost
Traping between objects or machines	25	21	14	75
Lifting, reaching, pushing	24	75	23	96
Slipping due to surface	20	41	10	23
Banging into or against	7	102	13	0
Cut with Stanley knives	5	4	6	12
Tripping or stumbling	5	32	7	10
Scalds or burns	5	0	5	7
Splashing of liquids	5	5	1	0
Falling	3	0	1	7
Dropped or falling items	3	48	13	47
Electric Shock	0	0	1	18
All other causes	19	1	14	35
Total	131	509	108	330

Table 6.8

Distribution of accidents by type of injury over 3 months at Company D 1986

	January	February	March
Cuts	20	18	25
Sprains	4	4	6
Falls	3	4	1
Burns	3	3	3
Miscellaneous	2	6	5
Rash	2	2	1
Splinters	2	1	1
FB	1	1	2
Total	37	39	44

Table 6.9

Distribution of accidents by department over 3 months at Company D 1986

Department	January	February	March
Moulding	18	15	9
Warehouse	4	4	7
Toolroom	3	1	2
Assembly	2	1	4
Maintenance	2	6	4
Rail wrapping	1	2	1
Celuka	1	1	5
Extrusion	1	1	4
Transport	1	1	0
Staff	1	1	4
Cleaners	1	2	0
Coton Farm	0	1	3
Stores	0	2	1
Canteen	0	1	0
Others	2	0	0
Total	37	39	44

Table 6.10

Accidents at plastics processing plants
National Plastics accidents (NIG 1986)

Accidents	Number	Type of accident*
Anoxia	1	9
Collapse	6	8
Explosion	4	12
Exposure	21	10
Fall	5	7+
Fire	4	11
Handling	83	5
High Fall	10	7 (high fall)
Low Fall	26	7 (low fall)
Machinery	147	1
Other	14	15
Struck By	91	2
Transport	18	3
Trip	49	6
Volt	6	13
Walk Into	26	4
Total	511	

* – i.e. numbers below relate to boxes
on Form F2508 – Section E (see Appendix 6)
+ on same level

The industrial visits, although extremely useful, had their limitations in that it was not possible to cover all the industry or learn about all the hazards and arrangements that are usually implemented in the PPI. And so there was a need to see the set up of the plastics industry, and its organisation and how health and safety arrangements determined by experts are put into practice, how those experts determine the organisation that is neeeded to implement and monitor those arrangements. Consequently there was a need to devise a questionnaire which would cope with those difficulties.

6.3 The questionnaire

The questionnaire was designed to analyse plastics processes, activities, hazards and arrangements. It was to be administered to firms in the PPI to cover a wide range of processes eg moulding, extrusion, laminating, vacuum forming etc. There are two main reasons that this method had to be abandoned:

(a) There was a limited number of firms we could send the questionnaire to and only two out of four firms to whom the questionnaire was sent to seemed to be willing to answer the questions asked (see Appendix 2 for the questionnaire and companies' reactions to it).

(b) Although questionnaires can be very useful, they require efforts and resources to prepare and put them into shape. They are also not the best method for eliciting knowledge and would have been an unsatisfactory way of collecting facts or opinions from the PPI (Parkin 1980). Parkin pointed out to the sorts of difficulties in using questionnaires in such situations as this case where the data needed is a combination of both hard facts and the heuristics HS experts use in solving problems and making decisions. Moreover, questionnaires do not cope and do not reveal the sort of information needed because of the following failings listed by Parkin (1980):

- low response may mean unrepresentative sample,

- reliability is often untested or untestable e.g. will the same person give the same answer on two different occasions?

- validity is often untested or untestable e.g. will the question asked elicit the intended information?

- questions asked in this case need deep thinking from the respondents (e.g. the health and safety expert) and would take a long time to write down what he/she thinks,

- the limitations of written questioning may therefore lead to a shallow question being asked or a shallow answer being supplied. An incomplete question leads to an incomplete answer,

- people may be prejudiced against questionnaires e.g. they receive too many, they mistrust the method, they are sceptical of the use that will be made of them, they might feel the data supplied is sensitive, and as a result ignore them or complete them rashly, misleadingly or untruthfully.

6.4 Interviews

Because of the many limitations of the first strategy, another method that was followed is that of interviewing health and safety experts and practitioners.

The second research method was a form of introspective account gathering by interviewing HS experts with different backgrounds and exercising in various fields using audio recording.

This method was particularly useful at the outset particularly to:

- review the problem areas HS experts deal with,

– determine and identify difficulties in the development of an ES in HS,

– probe the parts of expertise of HS experts, and

– set up the scene for a methodology for analysing HS problem–solving.

The interviews were carried out with pre–selected experts who basically agreed to be interviewed. There were 5 types of experts who agreed to be and who were interviewed:

– academic scientists,

– experts from industry,

– enforcing authorities experts,

– professional organisation experts,

– independent consultants.

6.4.1 Objectives of the interviews

The main objectives of the interviews were three–fold:

- interviewing the experts to inform us about the PPI and how it can be structured in terms of activities, hazards, etc.

- interviewing experts to identify health and safety concepts around which diagnosis is usually carried out,

- interviewing the experts to see whether this can reveal some guidance on how they solve problems.

6.4.2 Difficulties

Although interviews were carried out, it was difficult to characterise them as interviews but as special meetings. During these meetings, there was a need to explain extensively what the project was about to highlight to the interviewee the importance of the exercise, the need to define the problem domain and to identify a framework on which to base the expert system.

Difficulties related to interviewing the expert can be summarised as follows:

- interviewee unable to articulate their expertise and their problem solving strategies,
- experts' scepticism regarding the utility of expert systems in health and safety,
- as with other AI projects, it was not easy to interview experts who sometimes felt threatened by the exercise to see their expertise reduced to manageable heuristics represented on paper (Feigenbaum (1984) p. 115),
- interviewees (HS experts) are often busy and therefore unable to devote enough time for interviews and consequently the interactions were not detailed, accurate, developed and refined. To do so, there was a need of going more than once over to experts (when possible) about the same concepts and interactions to develop them,
- misunderstanding and confusion may result (Gilbert (1980), Feigenbaum and McCorduck (1984)) about the objectives of the interview and about what the expert would wish to contribute.

6.4.3 Methodology

There were two types of interviews carried out for the purpose of this project:

- interviews carried out by the researcher eg interviewing HS experts, and
- interviews carried out by HS experts eg while they are working on a problem such as safety auditing.

The interviews were arranged either by post or by telephone and were fairly unstructured and intended to discover details about what expertise HS experts have, whether they are willing to participate in the knowledge elicitation, and to identify patterns in their problem–solving.

When a HS expert has agreed to participate, he/she was asked to 'think aloud' and describe how problem areas are being selected, on what basis (criteria used) when selecting a problem area and how shifts from one problem area to the next is done.

Twelve experts were interviewed in the course of the research and lists of questions were prepared for interviews. The roles of both the interviewer and interviewee are formulated at the begining of each interview. Gilbert (1980) points out that the tacit knowledge needed to formulate roles cannot be learnt effectively from books or from any other source than direct experience and that this difficulty accounts for the frequently heard comment that qualitative 'field' methods are impossible to teach. Eliciting and representing knowledge may be just one way of getting round such difficulties much encountered in health and safety e.g. safety audits are prepared but still need expert opinion to answer questions and attribute scores.

Every interview required some degree of relearning, practice and re–adaptation to the role. This is mainly due to the need for a conception of the interviewee's role which needs to be reformulated depending on who is being interviewed.

6.4.4 Interview analysis

It turned out that generally experts identify problem areas and then select sub–problems before focusing on each sub–problem, solving it using a variety of approaches described in the section on problem solving in health and safety and adopting a strategy summarised in the proposed framework SECT (see Chapter 7 below). As Gilbert (1980) put it, scientists are not used to being interviewed but like all other academics, they are used to discussing science with colleagues and especially with students. He wrote:

> '...It seemed at the begining of the interview they cast me into the role of an interested student'.

Similar difficulties were experienced particularly with resident and external experts. Suggestive evidence can be drawn from a number of apparently trivial details of the way in which they set up the interviews, reacted to initial questions and interpretation of my comments. Careful control of dialogue are necessary in this sort of situation (ie during an interview) to avoid misunderstanding and confusion.

The interviews were very useful for identifying pitfalls that need to be avoided in developing health and safety expert systems (eg concentrate on cognitive tasks, defining tightly the problem, etc) and problem areas but were not an adequate means by which one would undertand how the expert's mind works in problem–solving. The inadequacy was particularly so because of different reasons including that experts were:

- not easily available,

- were not willing to be questioned in great detail about how they reached a certain conclusion,

- were not able to articulate out-loud the problem–solving process. Sometimes they were not even conscious of the problem–solving process they went through and only realise it once they told about it,

- do not like being interrupted eg to preserve their train of thought,

- experts found it difficult solving fictitious problems where a lot of assumptions had to be made to define the boundaries of the problem.

Despite the usefulness of interviews in permitting to see what facets (eg problem areas, hypotheses, deductions) experts take into account when faced with a problem, they had their limitations because the experts shift their concentration from finding the solution(s) to defining the problem instead.

The limitations of interviews led to search for better means and that is seeing experts in action – solving problems or reaching decisions – so that they could be questioned in their reasoning process. This was the next strategy of the research.

6.5 Expert observation

This method was particularly useful to understand how experts arrive at the conclusions they arrive at and make the decisions they make. This need was felt particularly as interviewed experts found it difficult to explain and elaborate on problem areas they were set to solve and to think aloud while solving them. There were two case studies where this strategy was adopted.

In the first, four health and safety experts were invited to visit a plastics processing plant and were set the task of evaluating three problem areas eg machinery guarding, maintenance and HS organisation, and determining the imminent factors which may lead to accidents and/or ill–health.

In the second case study a health and safety expert was observed identifying the health and safety problem areas for a client and recommending the sort of arrangements necessary to control those problems. This case study was more successful as there was only one expert to observe and over a whole day (instead of an hour or so for each expert in the first case study).

However useful the strategy was, its shortcomings were that it was not possible to question the experts about, and follow, their strategies and problem–solving processes. The shortcomings were principally due to the limited time experts had at their disposal and the need to finish the task – in the second case study the expert was called in by a client. This led to search for another strategy which should enable health and safety problem–solving to be understood better and hypotheses about health and safety problem–solving, formulated up till now, to be tested.

6.5.1 Analysis of observation

The following are the problem areas the observed expert (the second case study) considered in his audit and assessment of health and safety at the plant visited. The transcript of the Expert observation session (see Appendix 5) (between the clients and the HS expert) reveals the strategies adopted by this expert. These consists of adopting an approach, considering the arrangement using framework and investigating each arrangement by applying tests to it. These approaches, frameworks and tests are described in detail in Chapter 7. Table 6.11 shows a summary of the Expert observation of the case study.

Table 6.11

Expert observation analysis

Problem area	**Topic of Question**
Company HS Policy	Does it exist? Responsibilities
Health and safety person	Title of safety person How does he get advice? Responsibility of safety person
Safety Representative	Exist Elected Number Distribution Union Training Safety Committee
Safety Committee	Chairman/title Members Meeting frequency Formality Task

Hazards	Layout settings Hazard reporting Documentation/log book
Organisation	Formality

Checklist

HS Management	Responsibilities
Safety Advice	Responsibilities

Checklist

Safety Training	First Aid
First Aiders	Where is it available? Who are the first aiders? First aiders training Task/responsibility Reporting BI 510/accident form
Reported Cases	How many? Nature of cases (acc., illnessses)

Accident Statistics	Categories of accident Categories of department Recording system
Computerisation of Accidents	Who deals with this system Types of problem areas
Expert sources of information	Questionnaire/interview he asks He is told He infers
Problems with Accident Investigation	
Medical complaints	Recording Over what time span? Analysis of records
Safety training	Previous knowledge of company (see below)
General safety	Dealt with throughout survey
Training	Induction of new recruits

Induction	How undertaken? YTS Safety film
Training	Training for managers Training for supervisors Since when training done? Recording of training on computer Recording training undertaken
Computer	Training about use (ergonomics aspect) How do people use them (eg sitting, glare)?
The expert did not follow the audit checklist as shown in Table 5.6. He let the discussion flow and only later (when the discussion was on) did he refer to the checklist.	

Checklist

Visitors	Badge system Who is responsible for them?

Checklist

Hazardous operations	Dust, fumes, chemicals Ozone risk from photocopiers Cleaning chemicals Fire extinguishing system PCF halon Gas cylinders Solvents and toners for photocopier Ammonia based copiers
Hazard data sheets	Existence of system
Noise	Does it exist? Level Monitoring
Normal handling	What are the tasks? Kinetic Training course exist Written system

Checklist

VDUs	Anti–glare Position
Air conditioning	Treatment Equipment

Water treatment	Biocides Knowledge of chemicals

Checklist

Fire safety	Wardens (on each floor) Fire drills frequency Type of evacuation (eg full extent) Disabled personnel
Alarm system	When tested (frequency of test)

Checklist: This refers to the fact that the expert observed referred to the checklist instead of chaining the next question to the previous one.

Such expert observation studies are useful to:

- identify the sorts of questions experts ask

- see how the information they gather is used, and

- appreciate the sorts of questions that need to be asked in an acceptable user–interface (eg questions a health and safety expert asks, help facilities). Thus an important consideration in expert system development for health and safety management is defining the user of such systems.

The questions experts ask to elicit findings (eg symptoms), test results, and to get to know plant history, are from a standard list (Expert Observation Appendix 5, and Table 5.6) and are as important as the answer which is obtained. It is those answers that determine what questions to ask next. The list of questions is also a memory jogger, reminding the expert of problem areas considered and of those needing to be considered, but the actual problem–solving is done around each problem area. It is not an isolated exercise but a complex network where problem areas are profusely interrelated.

6.6 Workshop for knowledge elicitation

6.6.1 Introduction

Problem–solving is a critical function performed by all experts, yet the processes that underlie this intellectual achievement are poorly understood (Kassirer & Gorry 1985). So far no or very little attempt has been made to explain the components of the diagnostic process of health and safety experts which is one of the key elements of health and safety problem–solving. A lot has been written on what needs to be done and sometimes how to do it but nothing on how those recommendations have been arrived at. Carrying out such work is necessary to develop frameworks within which a comprehension of the decision–making tasks of the profession can be developed. These frameworks should enable better scrutiny of the problem solving processes of health and safety experts who also need to understand what problem–solving skills their students need instead of relying on their abilities to deduce from observation what an experienced health and safety professional practices but is unable to articulate.

Investigating the diagnostic process is difficult because of the wide scope encompassed by the subject material and the uncertainties inherent in health and safety data (eg accident data, disease causation).

6.6.2 Background

The workshop was meant to explore how health and safety experts solve problems, arrive at decisions and formulate their judgements. Because health and safety experts practice in many fields, the purpose of the workshop was to invite as many experts as practicably possible (eg they are scarce and busy) and from various organisations. It was difficult to decide on what basis to judge who would participate and the following were the criteria we have set:

- Experts who are known to the professional bodies such as IOSH,
- Experts who are articulate and can explain their thinking process,
- Experts who are willing to be asked detailed questions about the process of their reasoning,
- The experts have dealt with accident investigations before and have cases which are ready and can be presented,
- Experts who will be willing to work in the presence of other experts.

The experts who agreed to take part in the one-day workshop on knowledge elicitation were asked to present a case of an accident which they have investigated and found either interesting or presenting some sort of importance when it was investigated. This workshop was designed on lines similar to those in the medical field. The New England Journal of Medicine publishes weekly clinical cases which have been discussed in what is called Clinico-Pathological Conferences (CPC).

6.6.3 Description

The workshop (Bensiali 1987) consisted of the protocol analysis of recording and analysis of HS experts' diagnostic problem–solving (The transcript of the workshop was excluded from the thesis on the grounds of its length). There was then an introspection (combined with those from previous interviews) to obtain an analysis of the strategies that health and safety experts use.

The health and safety experts taking part in the workshop are accustomed to dealing with difficult problems and were selected on the assumption that they have experience in accident investigation which characterises health and safety problem–solving. Detailed examination of these experts has yielded important principles underlying the process of unstructured information gathering they used. They have adopted the following two main approaches:

- gather data and analyse it to see how it can be used, and

- define a problem and then seek to find information to support formulated hypotheses.

The benefits of a deeper, more explicit understanding of this process are undeniable. An accurate delineation of principles and strategies:

- should improve the process of developing health and safety reasoning in young practitioners,

- could be used in the development of better measures of the quality of health and safety decision–making and could therefore aid health and safety efforts,

- should provide for better understanding of HS problem–solving.

6.6.4 Objective

The study was designed to identify some of the specific tactics and general strategies constituting the problem–solving behaviour of experienced health and safety experts as they are engaged gathering information about given cases. Many elements other than those associated with diagnostic problem solving contribute to the interaction between client and expert (in Expert Observation case studies above), and between case presenter and panel (in Workshop case study) during the information gathering process. The two exercises differ in that in the first case there was a more formal interaction whereas in the workshop the members of the panel knew each other and this led to some degree of intimacy and informality. Consequently the proceedings in the two situations went in different ways. Nevertheless, factors such as effective communication between interlocutors, the psychological importance of the interaction and the expert's evaluation of the accuracy of indicators reported, by the client or case presenter, are all common and equally important in both situations.

The purpose of the workshop and Expert observations was to capture data about methods of health and safety cognition and not to test diagnostic skills (eg to identify the ingredients of the process of decison–making rather than how the case presenter carried out the investigation. This would be investigating the experts' expertise).

6.6.5 Selection of experimental subjects

Three health and safety experts took part in the workshop and all were members of the Institution of Occupational Safety and Health (IOSH): two consultants and an HSE inspector of factories. Moreover, they all have substantial experience in investigating accidents.

6.6.6 Obtaining the protocol

In the workshop, experts were asked to present an accident case (an accident which they have investigated and that is special and interesting as defined by the criteria in the next section). Before presenting his case, each expert was given the following guidelines:

- to describe the circumstances where the accident occurred,
- to give as little detail as possible and only give information when it is requested eg only the information they themselves had initially available to them before the investigation,
- to provide the reason for asking a specific question,
- to think aloud while manipulating the information elicited so that we can see where and how it was used and what inference/conclusions were drawn using it,
- to summarise his diagnostic impressions when reaching a final diagnosis of what they think was the cause(s) of the accident.

The experts had no difficulty following these instructions but because of the nature of the exercise and its novelty, it was difficult at times to determine in what detail a presenter should describe the case which would meet the objectives of the exercise and keep it lively. The other difficulty was breaking the experts' chains of reasoning to ask them to provide explanations for asking questions. It was therefore necessary to infer that by tracking the line of reasoning and determining what conclusions or use the expert has made with the information elicited. The experts agreed with most inferences.

Another difficulty was to follow one expert's reasoning from start to finish so that his reasoning can be analysed. This difficulty was experienced in a second Expert Observation case study.

6.6.7 Selection of case material

In the Expert Observation cases, it was a question of availability of experts (previous trials to accompany safety audit teams were not successful eg Appendix 7). Besides the 'availability of experts' criterion, cases were selected to conform with the following criteria:

- one which has happened and not a fictitious case which would require assumptions to be made,

- it was left to the participants to choose their cases which they know well and so can provide any information the panel can possibly ask for,

- the case is a tricky one where the investigator(s) took a long time, or were at first misled.

6.6.8 Analysis of the protocols

Detailed analysis of the protocols of the participating experts shows that they tried various hypotheses as explanations of the accident occurrence. The Expert Observation cases differed in that the accident had not yet occurred. This is the preventive approach referred to in sections on HS problem–solving. The hypotheses formulated by experts fit more or less well the problem at hand.

Experts have also gathered the evidence for or against competing hypotheses until one hypothesis seemed plausible. When findings seemed inconsistent with a hypothesis, they searched for an explanation for the inconsistency or they rejected the hypothesis in question.

Analysing the protocols leads to an examination of the elements of health and safety experts' problem solving process which are:

- hypothesis activation,
- hypothesis evaluation, and
- information gathering.

(i) Hypothesis generation

There is a fundamental difference here between the expert observation case (Bamber's case) and the workshop cases:

- in Bamber's case (eg second Expert Observation case in Appendix 5) there was initially no problem and the expert was trying to foresee a possibility of one occurring and therefore had a pre–set list of hypotheses he was trying to test,

- in the workshop, the problem had occurred and experts were relying more on abductive reasoning.

Despite that difference, experts very quickly focus their problem–solving behaviour. Every time a problem area is considered, the experts were observed to zoom in deeply to investigate it as a separate entity and as part of the system being investigated.

Hypotheses are often triggered by indicators and symptoms as they are introduced in the descriptions of a case presenter or the client. However, sometimes the investigating expert ignores these indicators despite them being supplied. This may have one or more of three possible explanations:

- the expert was thinking about other hypotheses,

- the expert was shifting laterally or transversly on diagnostic levels eg validating a hypothesis which was generated,

- did not think for the time being it was a potential problem indicator.

An example of that was information supplied by the client (in the expert observation) to the health and safety expert about crowding and lack of space which the expert seemed not to have considered (in second Expert Observation (T1S1–Exp–Obs2 p.16)) Experts also generate hypotheses when there is a notable discrepancy between new information obtained from the presenter/client and an already existing hypothesis and this forces them to shift from one hypothesis to another. Hypotheses were generated either by observation or from information given by the case presenter or client.

In the workshop, the process of hypothesis activation dominated the early part of the diagnostic session as the experts searched for some explanation of the findings (ie the facts that they were given about each accident) and for a context from and in which to proceed. Later in the session, the emphasis was on hypothesis evaluation. Table 6.12 illustrates the relation between hypothesis generation and hypothesis evaluation.

Identifying a context through the process of hypothesis activation appears to be one of the critical features of the diagnostic and problem–solving processes in health and safety . When activating a context (eg supervision is inadequate), the health and safety expert seemed to use this context as a model with which to evaluate new data from the client/presenter. In the second Expert Observation case (Appendix 5), the expert tests the data gathered against an imaginery ideal model (whose details are acquired through years of experience) of the context. Such a model provides a basis for expectation when mental simulations are run by the expert. This shows the ability of HS experts to carry out cognitive tasks which are a function of both their grasp of the problem–solving methods and of the extent of their knowledge of problem entities.

(ii) Hypothesis evaluation

In both of the two different settings described above, experts used a common approach to evaluate the generated hypotheses. The process of evaluation and information gathering were being carried out simultaneously. The information gathered (dealt with below) acts like pointers indicating the directions along which the expert needs to move. The hypotheses generated are refined, rejected and discriminated.

Table 6.12
Relationship between hypothesis generation and hypothesis evaluation.
– select a problem area, – identify the causes of the problem area, – consider one cause at a time taking it as a context, – activate hypotheses (eg hypothesis generation), – search for evidence for its occurrence (eg hypothesis evaluation) – move to the next cause (context), – move to the next problem area.

(iii) *Hypothesis refinement*

Refining a hypothesis consists of incorporating new information into existing hypotheses to modify or eliminate them. An example of such refinement process is when, the HS expert (see Expert Observation Appendix 5 and Table 7.5), the expert asked whether the visitor had a badge. He then asked more questions about whether the visitor was given a badge or whether he lost it etc.

Each question was intended to refine the hypothesis or problem area 'dealing with visitors'.

In this case hypothesis refinement is straightforward but can be quite a complex problem requiring the assessment of the number of findings (eg symptoms, indicators) of a given problem are present and the number of signs indicating its absence. Taking the example given about assessing the adequacy of the 'visitors arrangements', how can it be ascertained that this case was an odd one and not a deficiency in the system? The expert had to refine this hypothesis to confirm it by asking more questions relating to the existence of arrangements to deal with visitors, the adequacy of implementation and monitoring of those arrangements.

(iv) Hypothesis elimination

In this elimination strategy, questions are asked about observations that are so often associated with given problem areas. Health and safety experts adopt this strategy to eliminate any uncertainty about the existence of a problem area and this is highlighted by their use of typical phrases such as 'just to be on the safe side' meaning that it is unlikely there is a problem but just to make sure it is not there. An illustration of this elimination strategy can be found in Expert Observation (Appendix 5) when the expert said:

> 'we will go into the office and leave no stone unturned'.

and said also:

> 'I know there are inspections carried out because you told me there were inspection reports; but just to check, who carries out these inspections?'

(v) Hypothesis discrimination

This strategy is used to distinguish between two competing hypotheses. Examples are numerous where experts use 'reasoning by the absurd' (eg present the opposite view to that which is there and try to test whether it is true or not. If it is not true then the opposite is true. This means that if we have tried to prove a clause and failed then the negation of the clause is true.) to ask questions whose answers would negate or confirm the presence of a given problem area. One such example is in the 3rd accident case presented in the workshop on knowledge elicitation by ASH. In that case, experts were trying to determine the cause(s) of the accident and at a certain point of the investigation, there was more than one hypothesis: adequacy of supervision at the site and existence/adequacy of system of work (ie as possible causes which led to the accident). Consequently, there was a need for hypothesis discrimination in order to decide which one of the competing hypotheses to investigate.

(vi) Information gathering:

– Purpose of information gathering

It is important to understand the HS experts' strategies and processes for gathering information during the various stages of problem–solving eg problem definition, hypothesis generation, ... Information is gathered for one of the following reasons:

- construct a plausible hypothesis(ses) of what might go wrong,
- to identify the possible hazards existing or likely to exist in the future,
- to characterise/quantify the possible consequences,
- to assess the type of arrangement required,
- to assess the organisational set up of the plant/company,
- to evaluate who is to implement/monitor arrangement,

In the Bamber case, broad categories of problem areas/hypotheses are written down and each is considered in turn. In the other cases (Expert Observation or workshop), the experts used no checklist to gather information but instead relied on their intuition, experience and practice.

– Questions in information gathering

In the study cases, the experts gathered a large amount of information in different ways such as observations (a walk through the plant, examination of photographs, drawings etc), and asking questions. Tables in the Appendix 8 show samples of the questions HS experts asked to elicit information and the sequences in which they asked them.

Analysing the sorts of questions HS experts ask and why they ask them should be an important step in understanding better HS cognitive processes and expert performance. It would also be important to establish lists of relationships between symptoms and problem areas, as used by HS experts in their diagnoses. This approach is discussed in more detail in the next Chapter under SECT (Symptoms, Effect, Causes, Treatment). In most of the case studies, experts relied on their intuitions in gathering information and consequently it is difficult to classify the questions they asked without verifying the classification system. However, the questions asked can be categorised according to their objective as follows:

- finding questions eg asked to set up the scene. Any question that does not fall in the categories below should fall here indicating that the expert asks it to have an idea of the activities. Examples of this category include questions like:

  'Is the machine guarded?',

  'Did the tea–boy know where the key was?'

- temporal questions are asked to determine whether the problem is a logical result or is just an odd occasion (eg the instance where the expert was asking a visitor about the badge in the Expert Observation case),

- functional questions eg ask questions which elicit information about indicators whether arrangements are implemented and are working. An example of such questions is:

'Is the guard to BPF standards?'

- symptomatic questions eg questions intended to reveal what symptoms exist which indicate a problem area. An example of questions is:

  'Is the time taken by the fitter to repair machines reasonable?'

- implementation questions are asked to determine the context where the control measures which have been or are going to be implemented. Examples of such questions include questions about the organisation and the resources,

- responsibility questions are asked to determine the personnel involved in the running of a system and its monitoring.

These questions asked follow the scope of a framework discussed in Chapter 7 – SHATER .

(vii) Expert witness concept

In surveys, as it was noted (in the section above), health and safety experts gather a great amount of information – by asking questions, looking at past and present records, etc. – so that reasoned judgements can be made and the risk of omitting unexplored problem areas minimised. One other important strategy is the expert witness concept used by experts to minimise this risk of omission is to rely on other experts' reports and judgements. This enables them to validate/confirm their diagnostic hypotheses and also to evaluate the recommended arrangements, their quality, and how and whether they were implemented. This evaluation enables the expert to decide on the best arrangement needed in the light of the performances of previous arrangements. Examples of such strategies are shown on Tables 6.13 where the expert is asking whether any competent person or organisation has already considered the fire safety aspects.

The availability of an expert witness is, however, only one part of the strategy. The quality of the witness is also crucial. When adopting this strategy of expert witness, HS experts ask two types of questions meant to identify:

– who the expert was, his/her status, his/her domain of expertise, and

– what judgement was made etc.

Examples of the second type includes questions like:

'who carried out the investigation?'

'what caused the problem did they conclude?'

'what arrangements did they recommend?'

'what did they say?'

In the workshop, the expert witness concept was less apparent because there was more than one expert and the validation process was therefore done simultaneously. This comes out very clearly in the first Expert Observation case study where an expert used this concept by referring to Lucas as being a company renowned for its high health and safety standards. This reference can be formulated in the following rule of thumb:

If it is Lucas (eg Lucas renowned by its high HS standards)

Then health and safety standards should be good

Another example of using this concept is found in the workshop proceedings (3rd Case W/S–Tape3–S1 p.14) where an expert asked another about his reply to a firm which was asking for consultancy services. He asked: 'And what did you say (to them)?' i.e. 'what was your reaction in this situation?'.

6.7 Discussion

In any of the case studies in knowledge elicitation strategies, the HS experts have used highly directed information gathering methods. The style, however, varied. For example in the first Expert Observation case study (carried out at Lucas and in which four experts took part), although the experts were asking questions, it was difficult to see what inferences they were making, and what conclusions they were arriving at. The difficulty was mainly due to the fact that it was a relaxed exercise whose end product (the diagnosis and recommendations the experts will make) was not to be evaluated, nor implemented by the client – the company where the safety audit was carried out and was therefore open–ended.

In the second Expert Observation case (Appendix 5), the expert had a well defined task (identify and control health and safety problems in a plant) and consequently focussed on obtaining pertinent information regarding the activities, hazards, and the arrangements in place following a framework described in the next Chapter –SHATER. In this second case the expert was carrying out a real–life task for which he was accountable to more than one party. A precise diagnosis as well as recommendations had to be made and consequently he was using an extended and precise series of questions, to assess the presence of symptoms for problem areas.

In carrying out this task, the expert had well defined hypotheses, of which only a small number of active ones was maintained, and dealing thoroughly with each hypothesis before moving on to the next. This activity is similar to an event tree where all possible deviations (eg deviations from what a system is supposed to do) likely to occur are investigated. This can be particularly difficult because of the combinatorial explosion of the possible deviations.

In the one–day workshop the experts adopted a more relaxed approach. They viewed the exercise more as a 'toy' problem than a real–life experience which would have been more challenging, exciting and motivating. The exercise is more like the fault–tree technique where the problem (ie the accident) has occurred and the experts were trying to trace it back to its roots (ie causes).

In all cases, the experts asked more or less similar questions but the pattern of questioning was not as directed and focussed as it was for the second Expert Obsrvation case referred to above. In some cases the experts tended to explore the symptoms which might exist and which are indicators of existing or possible problem areas. In other cases, they took it as an opportunity for comparing their problem–solving skills with that of other experts or learn when the concept is outside their area of expertise.

At times experts reverted to reviewing the case under study to refresh their memories and to decide what direction (eg problem area) they should tackle next. The choice of the next problem area is made either arbitrarily or is dictated by the unexplored information previously supplied to the expert.

On problem–solving, studies have generally been few in numbers and limited in scope (Kassirer and Gorry 1985). In HS, problem–solving is still in its embryonic state and should be looked into more using the techniques and methods identified and referred to above such as information acquisition/gathering, hypothesis generation.

6.8 Conclusion

The research methods were complementary and each contributed to a better understanding of HS experts' problem–solving strategies and processes. This should facilitate the simulation of these experts using computer programs despite the difficulties presented by the richness of verbal data and which require protocol analysis to be used.

Experts performed diagnoses within and outside their domain of expertise. Within their domain (ie using their special knowledge and expertise such as chemical engineering, construction, behaviour science etc.) experts showed efficient problem–solving whereas outside they resorted more to methodical search and problem–solving. It is necessary to investigate in more detail how HS experts solve problems and develop frameworks which can be used in computer systems for emulating human problem–solving.

CHAPTER SEVEN

Research Strategies II
Approach, Framework and Tools

7.1 Introduction

Developing a health and safety management program is a novel idea and involves many facets as described in earlier chapters. Three fundamental issues need to be addressed when building an expert system:

- programmning tools,
- the knowledge the system will comprise, and
- the concepts and frameworks to embody the knowledge and expertise elicited.

The first issue of programming tools has already been introduced in Chapter 2 and will be reviewed again below in the context of this project.

The second issue concerning knowledge, expertise, and the representation schemes of the system eg rules, triplets, frames etc, have already been dealt with and will be addressed again in the context of this research, in Chapter 8, when each of HASMAP's modules is considered.

The third issue is the basis for and important in expert system development. It needs to be addressed so that the tools can be used effectively to represent the knowledge and expertise captured. This chapter deals with this issue and with the need for a new approach, framework and models to emulate HS experts. It attempts to investigate HS experts' reasoning strategies and domain knowledge structures and to formulate their model of competence needed for the development of an expert system for the management of health and safety.

7.2 The need for a preventive approach

The shortcomings of accident investigations as a diagnostic approach were reviewed in the last chapter. Accident investigation techniques were developed to be used to investigate accidents which have occurred and are therefore not preventive in nature although their results are used in the prevention of future accidents. Therefore in developing a health and safety management program, a suitable preventive approach should be adopted to diagnose deficiencies and problem areas before they result in any kind of loss.

HS experts were observed, in the various knowledge elicitation methods, solving problems in order to prevent accidents and ill–health from happening. The approach adopted consists of tasks similar to those in accident investigation but, in order to be implemented in an expert system, it should be carried out in reverse order and should involve:

1 collecting all problem information eg about the work environment, employee,

2 examinining and interpreting those data,

3 isolating the causes of the problems,

4 verifying causes by setting up prevention programmes eg to analyse cause–effect relationships,

5 evaluating the programme effectiveness.

Unlike in the accident investigation approach, here the examination of the data is different. The data collected is analysed to find anything that is unique to a particular accident or group of accidents eg analysis of data concerning condition or activity, for example in a maintenance workshop, which may lead to an accident. There must be an on–going analysis of information to identify possible problem–causing conditions instead of the usual procedure of waiting for an accident to occur and then to collect any available information though limited it may be. Once the data have been collected, they should be examined to see if indicators/symptoms and patterns specific to some safety problem can be isolated.

7.3 Emulation of HS experts

Throughout their brief history, expert systems have been loosely modelled on the behavior of human experts. Since HASMAP is intended to assist in the management of health and safety, results from the knowledge elicitation studies should permit the modelling of HS expert thinking.

The emulation principle can be used in different ways as illustrated by the following two quotes:

> 'Cognitive emulation is an expert system design strategy that attempts to model system performance on human (expert) thinking'. (Slatter 1985 p. 28)

> 'Cognitive emulation means building systems in such a way that they process information in ways that resemble how users process information.' (Fox 1983 p.8)

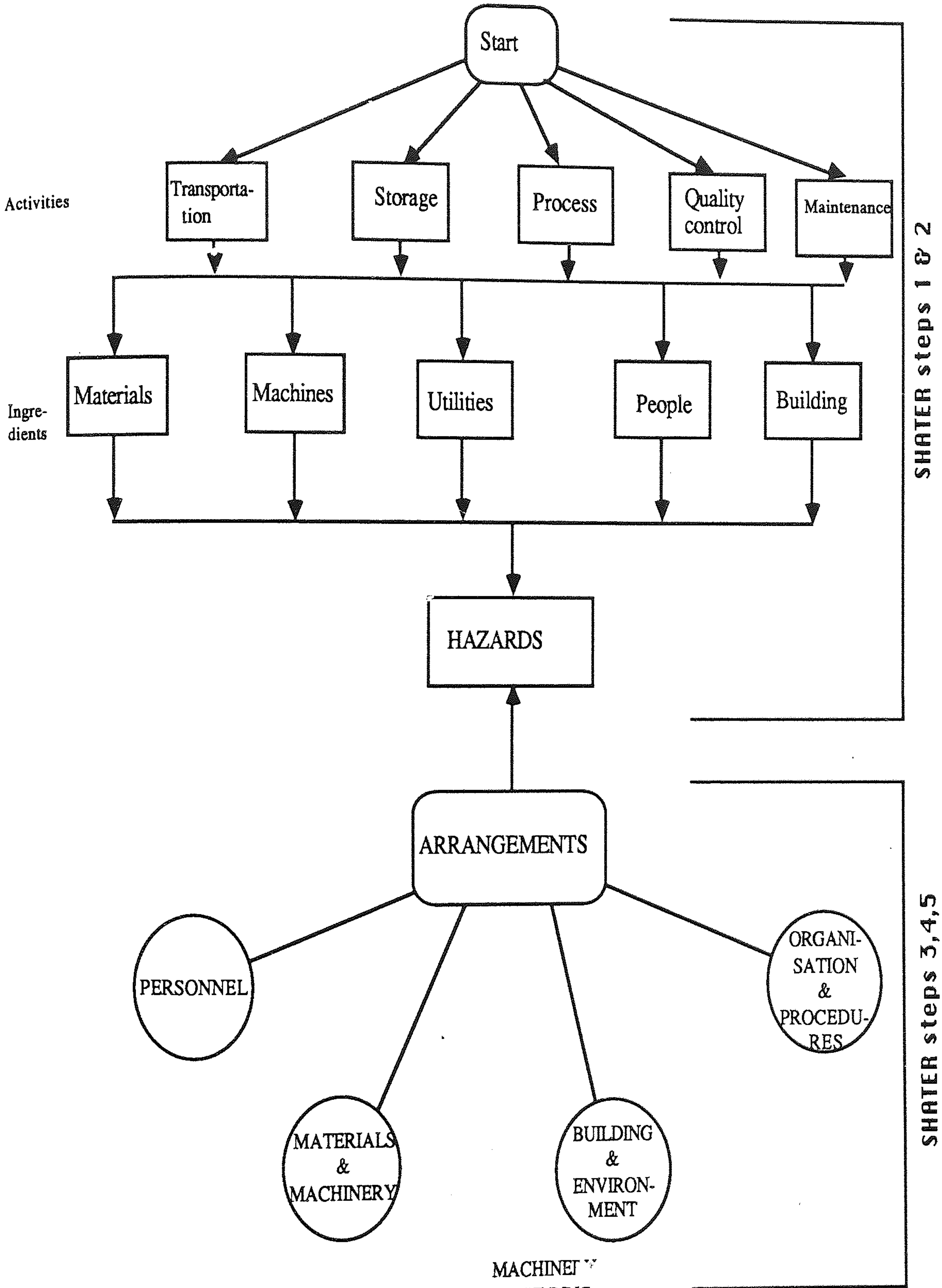
In order to simulate HS expert thinking, the rest of this chapter will analyse health and safety (domain) expertise and health and safety experts' tasks. Frameworks to emulate HS experts will be developed seeking to capture what is typical about the organisation of knowledge and problem solving. There is a relation between experts, and their knowledge and expertise as already pointed out in Chapter 2.

7.4 Expertise/Problem solving framework - SHATER

Different techniques were used in this project – and described in Chapter 6 – to elicit different types of knowledge. Health and safety experts were observed carrying out different cognitive tasks at various levels of generality. At the highest level, a general framework can be identified where HS experts analysed problems by first determining broad abstract domains, categories, concepts and expectancies which help direct the gathering of information. They then refine those concepts and domains by identifying more sub–domains before focusing on each sub–domain and its relations with other elements of the system under study. An example of such a system can be a plastics processing company, site, or a plant.

In order for the computer to emulate a HS expert, it needs to be told (programmed) explicitly how the tasks of a HS expert are done. Emulating HS experts, preparing health and safety policies in the PPI, would require an analysis of the various steps at each of the levels referred to.

From interviews and observations, it was noticed that, at the top level of their problem–solving task, HS experts followed a 5–step scenario – called by the acronym SHATER – which consists of breaking down the task into small components (sub–tasks) and then running the same scenario again and again for each activity in an undertaking as shown in Figure 7.1.



MACHINEI
&BUILDING

Figure 7.1 Problem-solving levels of health and safety experts while using SHATER

7.4.1 The Five–Step Scenario SHATER:

A health and safety policy should enable management to monitor its health and safety progress and performance and hence effectively manage health and safety. To prepare a policy, a HS expert's task involves the following basic steps as summaried in the SHATER framework:

1– knowing the Situation,

2– Hazard identification,

3– Arrangement(s) required,

4– TEsting existing arrangements,

5– Recommendation of measure to be taken if any.

Each of step of the framework SHATER is described below as a task undertaken by a HS expert to prepare a policy.

(a) Knowing the Situation

HS experts get to know the undertaking by identifying all activities undertaken –one by one– and all the ingredients necessary for each activity to be carried out. They get to know the setting and about the activities on a site in different ways such as:

- observations as they inspect the place,
- asking questions like those in the questionnaire in Appendix 2,
- being informed/told by client about problem areas and existing situations.

This enables them to identify any hazardous activities or conditions.

(b) Hazard identification

While learning about the situation, HS experts are constantly looking for hazards (existing or which are likely to be created as a result of a new activity, personnel, materials etc.). In an undertaking, expert assess the risks to determine what control measures are needed.

(c) Arrangement determination

Once hazards have been identified, experts rely on their knowledge to determine the sort of arrangements necessary to control those hazards. Their experience (eg from other industries, plants, activities) and knowledge enables them to appreciate quickly the adequacy of the control measures provided if any and decide on the aspects requiring control measures or classes of measures. There are four categories of arrangements related to people, materials and machinery, environment, and organisation and procedures.

(d) Testing arrangements:

The HS experts' appreciation just referred to, which is a set of observations, expectancies, knowledge about the structure of the organisation etc., often enables them to decide whether those measures require any testing and how extensive should those tests be. That appreciation is a form of sampling and is widely used by HS experts such as factory inspectors and private consultants in their inspections and audits.
HS experts use criteria against which the existing arrangements are assessed. Those criteria are mainly expectancies developed through years of experience and are used as a

basis in the evaluation of arrangements. This is the second level of generality in a HS expert's problem solving task where refinement is needed.

Experts usually focus further on an arrangement to test it. This test has been given the acronym ERIM test and is dealt with in more detail in Section 7.5.

(e) Recommended Solution:

In this last phase of their problem–solving task, HS experts determine the measure(s) which should adequately control the identified hazards . It is this phase that really distinguishes experts from novices because it is important not only to determine the problem and its size but to recommend the necessary practical control measures whether physical arrangement(s), organisational, (e.g. who does what), procedural (eg. how the arrangement should be implemented) or other.

For a computer program, the 5 steps in the framework SHATER can be represented as a flowchart where the levels of decision making can be cleary stated. That flowchart is shown on Figure 7.2.

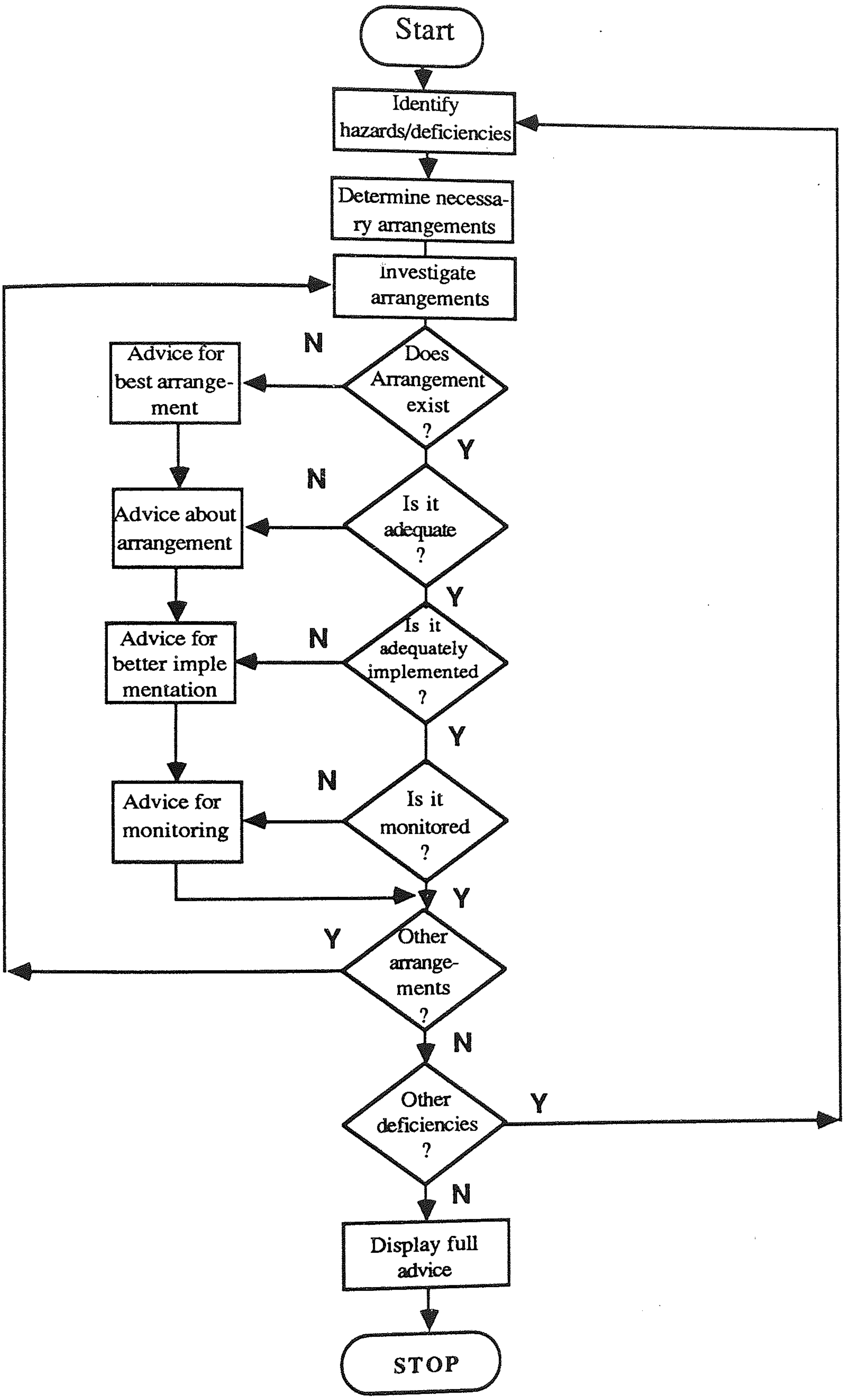


Figure 7.2 Flowchart illustrating the problem-solving tasks carried out by HS experts adopting the framework SHATER.

7.4.2 Using SHATER

The following are some examples of how Health and Safety experts were using the SHATER scenario to solve problems.

In the workshop and in the expert observation, it was noticed that all experts were following this approach. They go very quickly through the first three steps of SHATER (ie getting to know the situation, identifying the hazards, determining the required arrangements) and spend most of their problem–solving time (70% or more) on steps 4 and 5 e.g. about testing the arrangement(s) and determining what recommendations to propose to the client. As an estimate Table 5.6 below shows some of the timing as recorded while experts were dealing with each of the three cases described in the workshop (Bensiali 1987).

Table 7.1

Distribution of time used by HS experts over the 5 steps of SHATER*

	Presentation of problem (steps 1,2,3)	Steps 4 & 5 of SHATER	Time for case
Expert I	18' (30)	42' (70)	60'
Expert II	15' (23)	50'(77)	65'
Expert III	12'(20)	48'(80)	60'

* Numbers in brackets are percentages of time.

Although the time spent depends on many factors such as the expert's experience in the particular industry or company, it was clear from the evidence that, when considering Figure 7.1 above, experts move quickly to the arrangements. In the case of the workshop, experts went quickly to looking for the cause(s) of the accidents which can be described as deficient arrangements. In the Expert Observation case study, the HS expert quickly went on to test the arrangements and took a few more days analysing the findings before formulating the recommendations.

The real problem–solving task of HS experts is done for the last steps of SHATER. Here is an example where the 5 steps of SHATER appear clearly and where the HS expert's problem–solving task consists mainly of the last two steps.

In Case II of the workshop, the panel of experts knew the situation, identified the hazards and decided that one of the arrangements that was necessary was a permit–to–work system (PTW). This was concluded from the presentation of the case as shown in the Table 7.2 below

Table 7.2 **Illustration of how SHATER is used**
LB I am concerned about the permit obviously. We have a multi–permit system? **PW** The PTW system at Billingham contains what everybody else thinks of PTW, it is all contained within itself.

Source: Workshop T2S1 p.12

At this point, experts seem to agree that one principal cause of the accident was the deficiency in one arrangement: the PTW system. Having identified the PTW system as being a problem area, experts carried on their investigation following the last two steps in SHATER ie., testing and recommendations.

The testing of arrangements is the next important level in the problem–solving task of a HS expert.

7.5 The E R I M Test

HS experts possess series of ideal situations they use to assess the existing arrangements. The assessment is done by matching their expectancies with their findings. That assessment consists of a series of tests, summarised in the acronym ERIM, whereby every arrangement is subjected to a thorough investigation. The investigation is geared to determine the arrangement:

- Existence,
- Requirement (ie intrinsic adequacy),
- Implementation, and
- Monitoring.

The ERIM test, graphically represented in Figure 7.3, is devised to answer the following four questions:

(a) Does the arrangement exist?

(b) Is it adequate?

(c) Is it adequately implemented?

(d) Is it properly monitored?

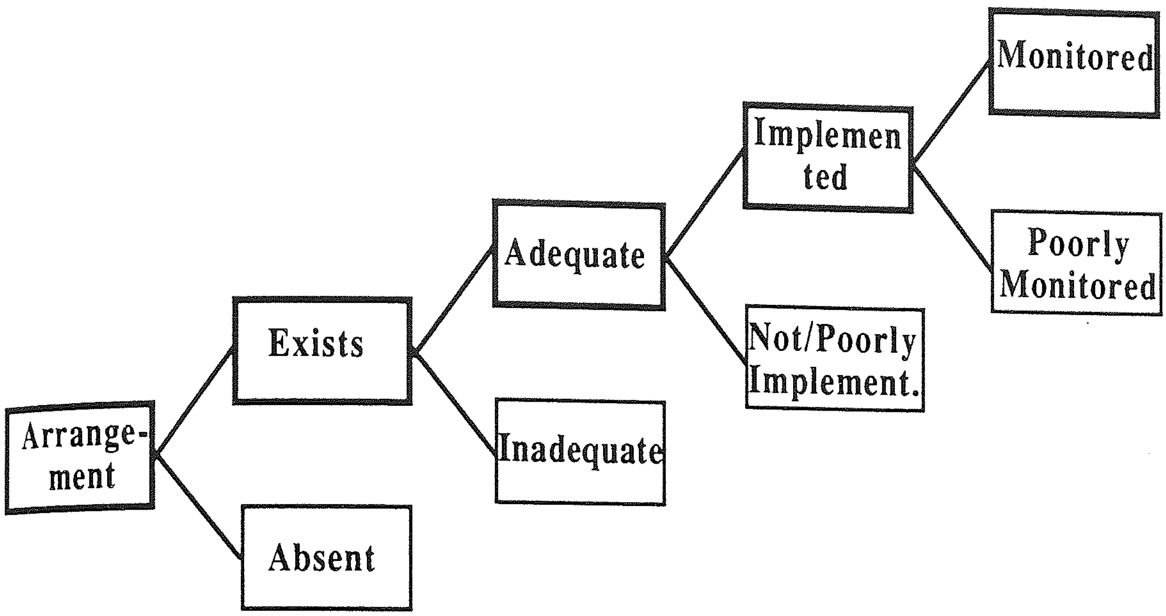


Figure 7.3 Health and safety problem solving: the ERIM test

7.5.1 Existence

This is the simplest and easist of the tests. It is usually determined with a 'yes/no' question. A computer program such as HASMAP relies solely on the user's input as it can not do any physical checking. Future systems could be integrated in or linked to industrial settings to detect the existence or absence of such arrangements. An example would be an expert system to evaluate the organisation and administrative system in a computerised company. Such a system could plan the maintenance in a workshop and would alert the company if the maintenance of a particular plant has not been carried out (or has not been or improperly logged in).

7.5.2 Adequacy of control

This is usually the most difficult test which requires HS diagnostic skills and expertise. The diagnosis often requires physical observation and hence it is this part of test which expert systems are not good at. Expert systems are suited for cognitive tasks rather than physical ones. In certain areas for example where constant monitoring is needed, they can be integrated to interpret data and send commands to control devices such as in the expert system Ventilator Manager (VM) used in Medicine (Fagan 1979). The Ventilator Manager provides diagnostic and therapeutic suggestions about post–surgical patients in an intensive care unit (ICU). The VM is linked to an ICU monitoring system from which it reads data about a patient's state and history, and interprets quantitative measurements such as heart rate, blood pressure, and data regarding a mechanical ventilator which assists the patient with breathing.

The 'adequacy of control' test involves carrying out operability tests. For example, it is relatively easier to test whether a guard's interlocking system is adequate than to test whether a respirator for a particular job is adequate. The results from the former test are immediate whereas the latter test requires more elaborate procedures such as consulting the manufacturer's literature, determining the airborne contaminants (eg is it mist, respirable dust , fibres?).

This test is even more difficult to assess the adequacy of a recommendation for an organisational change or work method. Here HS experts rely very much their experience of situations they have encountered to recommend this type of arrangements. These arrangements (eg organisational changes etc) are difficult to monitor because of the time it may take to evaluate the change and the complexity of the causal network (described in Section 7.7) which shows that a recorded effect usually has more than one cause (hence the difficulty to relate precisely a change of performance to just one change agent).

In case II of the workshop, the experts were judging the adequacy of the PTW system by considering its content and whether it covers the sorts of work the burner has to deal with. Their line of reasoning is summarised by the question and answers in Table 7.3 below.

Table 7.3

Example of how the second step of ERIM test is used by experts

LB

I am concerned about the permit obviously. We have a multi–permit system?

PW

The PTW system at Billingham contains what everybody else thinks of PTW. It is all contained within itself.

LB

And it has got 'radioactive', it has got 'entry into confined space' in terms of entrance certificate ... it has got 'hot work' permit, 'electrical isolation' system, 'blanking connection and isolation ...and he (the process supervisor) which is appropriate?'

Source W/S T2S1 p.12

Because the workshop involved HS experts who know each other (ie they have relied on the assessment of the case presenter who believes that the PTW was adequate), this test was quickly gone through. The experts actually saw the PTW and judged it was adequate, well prepared and comprehensive. Table 7.3 illustrates how one expert described it: 'it is all contained within itself'.

To judge the adequacy of the PTW system, Health and Safety experts rely on models they have acquired over years of experience and with which they work. Those models seem to consist of certain standards of reference in relation to which experts judge situations they encounter using sets of criteria of acceptability. With these models, HS experts seem to be very good at knowing what to expect in a system under study. This ability is often referred to as the expert having an accurate internal model (Veldhyzen & Strassen 1976) which enables him/her to predict how a system will function. The events are then compared, as they happen (eg during an inspection or an audit), with this prediction/expectancies to identify whether anything unusual has occurred. Such ability shown by HS experts has also been characterised as 'Routine Model' (Kraft & Launderweend 1974).

7.5.3 Implementation

This is the third test applied by HS experts. The fundamental questions asked are about the quality of implementation of the arrangement ie is it in place and serving the purpose of its use. In the example of the PTW system, the test was to find out whether the PTW is put adequately into practice. This entails considering the implementation over three phases:

(i) Before the task

This really consists of determining how the PTW is acquired, how it is issued eg who issues it, when, to whom, signatures

(ii) During task

Here experts consider how the task is carried out using the permit ie how it is used, who uses it (burner & supervisor...), and

(iii) After task

This is a sort of verification and evaluation of the system having gone through the tests (i) and (ii) above. It is ascertaining whether work has been completed and whether it has been safely done. This is the real test of the adequacy of the system, and of its implementation. The results of this test are usually taken into consideration when monitoring/revising such an arrangement.

In practice, this part of the ERIM test is generally to concentrate on identifying the people on whom the onus rests and to see how they are accountable for the duties the system has placed on them. This is shown in the workshop where experts have not followed this pattern of pre, during and post–task, as it is an informal situation and as there is no harm in going back and forth between different problem areas as data become available and as the case unfolds. To evaluate the PTW system implementation, experts have asked the types of questions shown in Table 7.4.

Table 7.4

Typical questions asked by HS experts when evaluating the adequacy of implementation of an arrangement applying the ERIM test

- Who issues PTW?
- How is it issued eg. counter–signed?
- How competent/trained is person issuing PTW system?
- Are standard instructions followed?
- Do standard instructions require an inspection of the job?

To evaluate the implementaiton of an arrangement HS experts often need to carry out, where practicable, physical inspections of the arrangement (eg safeguards, PPE). In cases where it is not practicable, they ask questions and run all sorts of simulations to reach a conclusion about the adequacy of implementation of arrangements. Examples of simulations are many and Tables 7.5 and 7.6 give an illustration.

Table 7.5

A simulation used by a HS expert when investigating the 'Arrangements for Visitors'

LB
(Addressing KB) Have you got your badge?

KB
No.

LB
Has it dropped off?

KB
No. I was not given one.

LB
So you walked in. (Addressing his client JC) So you only get a visitor's badge when you come by car?!

JC
No, you can one when you walk in.

Source: Expert Observation T1S2–Exp/Obs p.3 (Appendix 5)

Table 7.6

Simulations used by HS experts

LB

Had the vessel been in plant rather than being taken out and it is deemed necessary to do hot work on it, would anything different have been done?

Source: W/S–T2S1 p.16 (Bensiali 1987)

7.5.4 Monitoring

Evaluating the monitoring of an arrangement is usually carried out only when the other tests (eg existence, adequacy, implementation) are passed. This last test is applied to ensure that arrangements are being maintained to the standards they were initally installed for and that other arrangements (mainly organisational) exist to ensure that the arrangements under study will be continuously monitored. Monitoring should detect any deficiency such as those which may be created as a result of changes.

Change can take many forms (eg changes of processes, procedures and personnel) and often results in the major contributory causes of catastrophies. Examples of the consequences of such changes are the accidents experienced at the chemical Flixborough Works of Nypro (DOE 1975) and at Brent Cross (HMSO 1965). The changes in both situations were technical changes. In the Flixborough disaster, a change was the design and installation of an inadequately supported by–pass assembly instead of a reactor . In the Brent Cross crane accident, the change was the mis–manufacture of a gate not as designed.

Change can be one or a combination of new situations such as changes in the four categories of arrangements:

- organisation of procedures or software eg new system of work
- liveware eg new personnel
- hardware eg new material, machinery, plant
- environment eg new building.

In order to apply the monitoring test to the PTW system in the workshop, the experts asked a variety of questions a sample of which is shown in Table 7.7. Apart for the first test about the existence of an arrangement, experts asked questions, made observations, inferred conclusions etc. to reach a conclusion at the end of each test. It is important to note that, all along their problem–solving task, they were constantly looking for indicators and symptoms of deficiencies and tracing back the root causes of any observed deficiency or symptom. This adopted strategy, called SECT, is dealt with in more detail in Section 7.7.

Table 7.7 Sample of questions asked to evaluate the monitoring of a PTW system
– Has anybody checked the permit?
– Is a sample check on permits carried out to show that standard instructions are being followed?
– And is there a little section called: MONITORING?
– Does anybody monitor the PTW system?

Source: W/S T2S1 (Bensiali 1987)

7.6 A new framework:Symptoms, Effects, Causes and Treatments (SECT)

The need for a comprehensive and new approach for better prevention has been felt for a long time because of the weaknesses and limitations in existing health and safety management techniques (Kjellen 1984). These are well illustrated by the limitations in risk assessment in Table 7.8

Table 7.8 **Limitations of Risk Assessment techniques** (Bensiali 1986)
i) Inaccuracy of mathematical models used which describe ideal situations which are different from what would occur in reality. Uncertainty in the supporting data has also limited its efficacy.
ii) Incompleteness in the analysis: although carrying out risk assessment usually involve relying on systematic methods, there is no guarantee that the assessment is thorough and complete.
iii) Complexity: Risk assessment consists of complex and laborious techniques which require considerable expertise. Studies like that of the Canvey Island, the Reactor Safety Study WASH–1400 and the Rijnmond are examples of this.
iv) Such complexity activities require high levels of expertise, are time consuming and very costly. The WASH–1400 took three years and cost millions of dollars compared with the other studies of Canvey and Rijnmond which cost £1/2 million each.
v) Criteria of acceptability: there are difficulties in setting and meeting criteria.

Analyses of the problem–solving tasks of HS experts revealed that their diagnostic skills can be represented in a new framework SECT which should improve the prevention of occupational accidents and ill health and could make the development of expert systems for the management of health and safety possible. SECT is an acronym which summarises another level of the problem–solving task of HS experts.

In the sections above there was reterence to HS experts' need to select problem areas by sampling procedures before focusing and devoting resources to a particular problem area. The selection of the problem areas is dictated by the indicators HS experts encounter, observe, and/or infer while in an industrial undertaking.

SECT formalises the HS experts' diagnostic task. It is closely related to SHATER and to the ERIM test as illustrated by Figure 7.4. SECT can be regarded as a strategy adopted, in connection with the ERIM test, by experts.

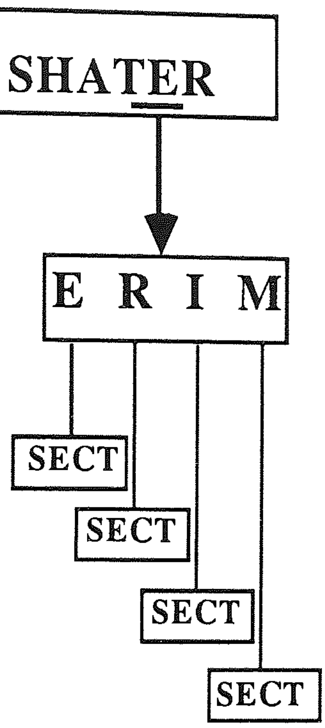


Figure 7.4 Graphical representation of the relationship between SHATER, the ERIM test and the diagnostic framework SECT

7.7 Using SECT

SECT is adopted every time the ERIM test is being applied to an arrangement which has been selected. Table 7.9 illustrates how SECT should be used in connection with the ERIM test to diagnose deficiencies and problem areas.

Formalising SECT should be an important step in the development of health and safety management expert systems. It should be the answer to the limitations in using the existing health and safety management diagnostic procedures and tools which were described in Chapter 6 and in Table 7.8. The task of building an expert system is made even more difficult because of the multi–disciplinary aspect of health and safety.

Table 7.9

Use of the strategy SECT when applying the ERIM test to an arrangement.

ERIM / SECT	EXISTENCE	REQUIRED/ ADEQUACY	IMPLEMEN–TATION	MONITORING
Symptoms	Indicators of non-existence	Indicators of inadequacy	Indicators of poor/ inadequate implemen–tation	Indicators of poor/no monitoring
Effect	Consequences if non-existent	Consequences if inadequate	Consequences if poor/ not implemented	Consequences if poorly/inadequately monitored
Cause	Why non-existent?	Why inadequate?	Why not/properly implemented?	Why not/properly monitored?
Treatment	What action is needed?	What action is needed?	What action is needed?	What action is needed?

The three formalisms SHATER, ERIM and SECT were all derived in the attempt to determine how health and safety management knowledge can be structured for expert systems that support diagnostic reasoning. Besides its usefulness in structuring HS knowledge and expertise for the management program HASMAP, this diagnostic reasoning framework should be particularly useful in:

- understanding the structure of the diagnostic reasoning, and
- drawing appropriate analogies to other fields where similar approaches have been used such as in medical diagnosis.

Exploring the possibilities of reconceptualising health and safety management using the SECT framework involves re–organising HS experts' knowledge about problem domains, symptoms and treatments and using it in a more logical manner which is required for an acceptance of a computer program such as asking questions and triggering contexts logically.

SECT provides the wealth of knowledge needed for the development of a health and safety management expert system, consisting of the problem–solving skills and strategies of HS experts. Chapter 6 described the difficulties in eliciting HS experts' knowledge and skills and those were particularly at this level of problem–solving where even the experts themselves could not clearly appreciate – introspectively– their problem solving process. The major difficulty was unraveling the heuristics and decision rules – discussed in more detail in Section 7.10 they used.

SECT is mainly used once an ERIM test has been triggered however, experts look also for symptoms which would them to select problem areas (eg dust, cough may tell the investigator that the problem area to investigate is the ventilation system, or PPE or system of work). Tables 7.10 and 7.11 illustrate with three examples how HS experts adopt SHATER to select arrangements for investigation, apply ERIM test to a selected arrangement and use SECT to reach conclusions.

Table 7.10

Examples of how HS experts use SHATER to select arrangements to which ERIM and SECT are then applied

Case	Activity	Main Ingredient	Arrangement
1	Filling operation	Asbestos material	Ventilation
2	Injection moulding	IM machine	Guards Inspection
3	Welding	Steel vessel	PTW system

Table 7.11

Examples of how ERIM and the SECT can be used

Case	Arrangement	Symptoms	Effects	Causes	Treatments
1	Ventilation	Dust, cough	Emphysema	Asbestos fibres	PPE, Ventilation
2	Guards Inspection	No inspec–tion records	Poor guards, Injuries..	No inspection system	Establish Inspection system
3	PTW	PTW system unknown to welder	Fires, burns.	Poor commu–nication	Communication system.

These three examples illustrate, on a very narrow domain, how HS experts use SECT in connection with SHATER and ERIM. For example, Case1 shows that the expert decided to investigate the activity Filling, determined the hazards arising from the use of Asbestos as a filler, and found symptoms (which were quite evident in this case) which point to a problem area: ventilation. This problem area is an arrangement and is taken as a context and the task of problem–solving begins. The ERIM test is applied to establish the ventilation's:

- existence,
- adequacy,
- implementation ie adequately installed by competent personnel,
- monitoring ie inspected, maintained.

For every ERIM test applied, the HS expert looks for symptoms or evidence which confirms the adequacy, or otherwise, of the expected action for each test. For example dusts are a good symptom of the inadequacy of the ventilation system. If a ventilation system exists, the expert goes on to determine what the symptoms can be attributed to ie determining the cause(s).

HS experts can start their investigation of an undertaking, activities, ingredients etc. at various levels. They often have a wealth of information at their disposal and which requires great skills to process. This is another feature of their expertise. However, the HS domain expertise and knowledge need to be structured for the development of expert systems.

7.8 Knowledge categories for a HASMAP

In order to use the diagnostic reasoning framework SECT in an expert system for the management of health and safety, it is necessary to structure the HS knowledge needed. From the analyses of the interviews, the literature, industrial visits etc., five broad categories of knowledge can be identified:

1 Health and safety management problem areas,

2 Setting factors,

3 Symptoms and indicators,

4 Arrangements and interventions,

5 Decision rules.

7.8.1 Health and safety management problem areas:

Examples from case studies referred to throughout the thesis (eg Appendix 5, (Bensiali 1987) etc.) illustrate how HS experts solve problems. They usually start by defining the problem area(s) (ie scope of the problem) and hence the importance of identifying the gross health and safety problem domains.

Considering the multi–faceted nature of health and safety problems, it is a complex task to attempt to structure the knowledge of such a field. However, bearing in mind the purpose of this project, which is to assess the feasibility of building a health and safety management expert system, health and safety problems in a given plant can be classified and categorised according to the activities during which they are created. The model of an undertaking was introduced in Figure 7.1 of Section 7.4 which shows three important levels at which HS experts work and use their knowledge and expertise:

- the activities and ingredients level eg they identify the activities carried out and the ingredients of those activities,

- the hazards level eg identify the hazards resulting from the activity and ingredients,

- the arrangements level eg four types of arrangements are usually dealt with.

Occupational hazards are bound to result from the activities in an undertaking such as a plastics processing plant. No activity is risk–free and the existence and quality of arrangements (eg to control those risks) play an important role in the acceptance of those risks.

Figure 7.1 illustrates the four types of arrangements that are ideally required and which represent the major problem domains that HS experts usually investigate. Examples of these four major problem domains are given in Table 7.12 and are related to:

(a) hardware or physical/material,
(b) liveware or personnel,
(c) software or procedures and organisation, and
(d) work environment.

Each of these problem domains is considered below.

(a) Hardware or physical/material problem domains,

These problem domains attract most of the attention of organisations as they are related to the first arrangements usually put in place. These problem domains are relatively easier to identify and the effects of putting them right can be quickly seen. Examples of these problem domains include inadequacy of fire fighting equipments, machinery safeguards, electrical isolation, personal protective equipment, and portable tools,...

(b) Liveware or personnel problem domains

Every employee in an undertaking may be associated with the 'individual behaviour' problem domain. Specific problems associated with individuals and their behaviour may include unsatisfactory selection, inadequate supervision, lack of motivation, inadequate training for a particular task, inadequate information/instruction conflict or ambiguity about an assigned role (inadequate job description), or a person/job mismatch (Table 7.12). Accident investigation experts tend to fall back on these problem domains particularly when investigating difficult cases.

(c) Software or organisation/procedural problems

As with the other three types of problem domains, software problem domains cannot be considered in isolation but need to be considered in a context ie in connection with activities. Without a context it is very difficult to even set a task to an expert. It was shown in Chapters 5 and 6 that when solving problerms, HS experts start by defining the boundaries of the problem they are to investigate ie defining the context in which they call on their knowledge and expertise otherwise it is an open–ended task. This was shown by the early interviews carried out as part of this project.

The software problem domains can be considered under two classes namely procedural and organisational problem domains.

- Procedural problem domains involve all types procedures that should be in place so that activities are carried out safely and without risk to health. Examples of these procedural (ie software) problem domains are inadequate systems of work, lack of/poor permit to work (PTW) systems, or an inadequate communication system.

- Organisational problem domains include all the structural set up in an organisation which may contribute to poor/unsatisfactory health and safety. Examples of organisational problems are a poorly managed health and safety committee, a poorly run occupational health/hygiene service, health and safety climate malaise, tense industrial relations.

(d) Work environment problem domains,

Success of a health and safety programme depends also on how safe and how healthy is the environment. Environmental problem domains are related to the internal and external environment:

- internal environment problems are those related to the confines of the workplace and the problem areas are numerous such as: unsafe buildings, hazardous work atmosphere, unhygienic water, inadequate lighting, inadequate ergonomic layout of the plant, unbalanced air temperature/humidity, and conditions of work.

- external environment problems are those which might affect the consumer of the products of an undertaking, the public nearby, or which might pollute the air/water/land as a consequence of the undertaking's activities such as waste disposal, transportation of dangerous substances, undetected leakages.

Table 7.12

Problem domains for the four arrangement levels

1 PEOPLE

First Aid
Information
Medical examination
PPE
Selection
Supervision
Recruitment
Training

2 ORGANISATION

Accountabilities
Communications
Policies (regarding people, machinery/materials, environment)
Procedures for work
Responsibilities
Supportive services (medical, finance, stores..)

3.1 MACHINERY/PLANT

Purchase Purchase
Design
Testing
Installation/setting
Usage
Maintenance
Modification
Decommissioning

3.2 MATERIALS

Transportation
Usage
Handling
Processing
Monitoring/control
Waste

4 ENVIRONMENT

Design
Construction
Commissioning
Use
Maintenance
Alterations
Decommissioning

7.8.2 Setting factors

When assessing the health and safety risks in an industrial plant, HS experts consider the characteristics of the organisation under study, eg style of management, number of employees. These characteristics, referred to as setting factors need also to be taken into consideration when recommending arrangements for improvement, implementation and/or monitoring of existing arrangements. They form the essential information gathered by experts for making decisions and should therefore be the raw material a health and safety management expert system starts asking the user about. Besides forming the bulk of the working data base, setting factors are also incorporated in the production rules in the knowledge base of such systems. In each of the four gross problem domains (eg hardware, liveware, software, environment problem domains) different setting factor data are needed. For example when investigating the problem domain 'Selection of fitters' in an undertaking, a management expert system such as HASMAP would ask the user about a number of relevant setting factor data including a number of facts like age, length of service, job title, and skill proficiency.

The setting factors needed when considering a plastics processing plant can be grouped into three categories:

(i) activities and ingredients,
(ii) hazards, shortcomings and deficiencies,
(iii) arrangements and provisions to control hazards/deficiencies.

(i) Activities and ingredients in the PPI

Tables 4.5 – 4.7 (in Chapter 4) illustrate the major classes of activities and ingredients encountered in the plastics industry most of which are also found in the manufacturing industry. The processes in the PPI are dealt with in Chapter 4.

(ii) Hazards and deficiencies

The type of hazards and deficiencies vary depending on the activities carried out and the quality of the organisational arrangements. Lists of the physical hazards were compiled when visits to various plastics processing plants were carried out as illustrated in Appendix 4.

(iii) Arrangements

The arrangements necessary to control hazards also vary and consequently can only be considered when risks from a specific activity and its specific ingredients are assessed. This should determine what and how hazards can happen and therefore determine what arrangements are necessary. They can however be categorised according to levels at which they are administered. Table 7.12 illustrates those levels at which intervention should be done.

The arrangements necessary are dictated by their feasibility, the resources available, the ability to implement and monitor those arrangements.

7.8.3 Symptoms and indicators

The starting point in a diagnostic reasoning framework is the identification of symptoms. Symptoms are manifestations indicating organisational malfunctioning. For example, high accident rates, absenteeism, high employee turnover, are all symptoms or indicators of situations which can result in health and safety problems. Groups of symptoms may also be identified as indicators of specific problems in a given domain. Tables 7.10 and 7.11 illustrate how symptoms can be used to identify which problem areas need to be investigated.

It is a complex exercise trying to establish a causal network of symptoms and problem areas. This is laborious because of the multi–causality inherent to health and safety problems. Figure 7.5 is an attempt to show how a causal network of the domain knowledge can be developed. It illustrates how symptoms relate to problem areas, which in turn are investigated and other symptoms from that area relate other problem areas etc. For example when considering the activity injection moulding, the fitter is one of the ingredients in this system. Problem areas related to fitters include their selection, training, motivation, PPE and information. Focusing on the problem area of training, HS experts would look for symptoms indicating inadequacy of training before deciding whether to investigate it. Symptoms of poor training include time taken to diagnose faults, job necessitates to be re–done, frequent breakdown of machines etc. The multi–causality phenomenon appears in each of these symptoms and HS experts have to decide about the sensitivity of their symptoms. For example the reason for fitters taking excessive time to diagnose faults may be that they are not well supervised or that the machinery is new, or poor industrial relations.

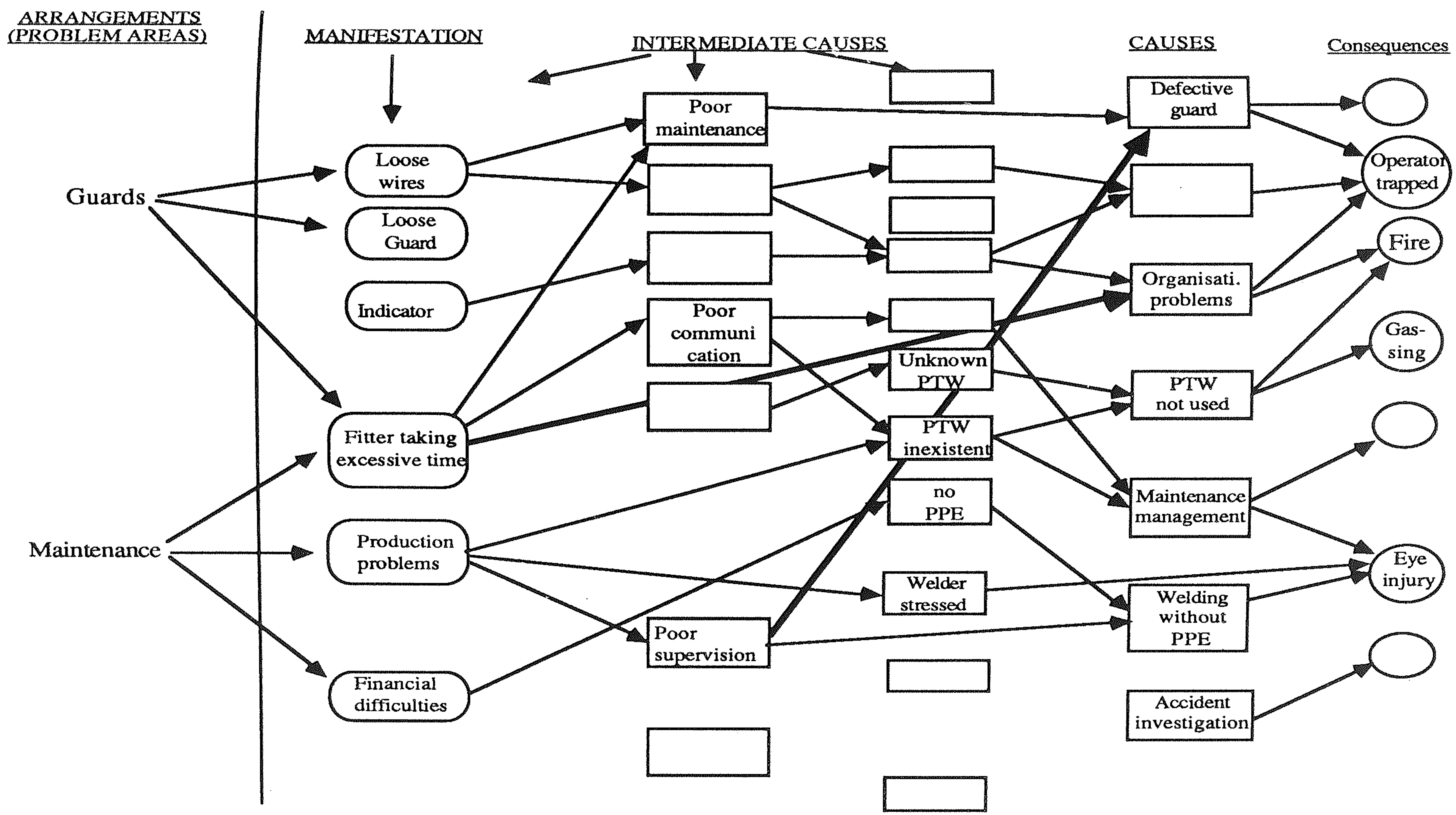


Figure 7.5 Causal network of domain knowledge.

In order to use SECT in health and safety management programs, it is important to develop lists of symptoms and establish relations between symptoms and problem areas. The state of current knowledge about symptoms may be one major limitation for using SECT. Symptoms of health and safety problems can be classified under four major categories which are along the lines of the ERIM test and are related to the organisation:

- knowledge of health and safety,
- attitude towards HS and its other activities,
- resources, and
- monitoring of its preventive activities.

(i) knowledge about health and safety

Knowledge (of health and safety and other technical aspects) is essential and any inadequacy may result in problems. This category of symptoms and indicators determine at what level are problems likely to occur. Examples of such symptoms are HS training of people at various levels:

- all management levels eg top, middle, line, first–line management.

- those in charge of health and safety activities if any eg HS person, hygienists, medical staff, first aiders.

- employees' representatives, eg shop stewards, safety representatives.

- employees on high risk – and specific – activities eg abrasive wheels, solvents users, maintenance personnel, storekeepers.

Indicators of HS knowledge inadequacy at any of these levels can be attributed to one or more problem areas which can then be investigated.

(ii) attitude towards HS and other activities,

The ideal situation is to integrate health and safety in every activity of an undertaking. HS should be managed and regarded as important as other activities like production, maintenance and transport. Attitudes are not be easily defined and are shaped by factors such as training, industrial traditions and relations, company incentive schemes etc. An example of symptoms of an organisation's attitude towards health and safety is whether all its employees HS performance is appraised in one way or another. Negative or passive attitudes at any of these levels are clear indicators of possible health and safety problems. For example a line manager – a production department manager– may create hazardous conditions by installing a new plant/machine without adequate assessment of the risks. The potential for an accident exists but the accident may not occur for some time because of other lines of defense (such as precautions taken by supervisors, fitters, operators) which can interrupt the causation chain. If similar attitudes prevail from the top management to the shop floor then these conditions will soon result in an accident.

Measures of individual and collective employee behaviour are good indicators of problems. For example absenteeism, negative verbal and physical behaviours, on– and off–the–job behaviour can be good symptoms and indicators of problems which might exist in an organisation and reflects the organisation members' commitments to health and safety.

(iii) resources

This is another problem area to which a category of symptoms may be linked. Taking the example given in (ii) about the acquired new equipment, an assessment of risks may be carried out and control measures were recommended. Those measures may not be adequate or not properly installed and monitored if the resources are not adequate . For example, if there no spare parts in stock a production/maintenance manager may decide to manufacture and fit a part which results in an accident. Similar situations might arise for personnel where, for some reason, an unqualified fitter may be called in to deal with a highly sophisticated equipment.

(iv) monitoring

This group of symptoms indicates that there is no, or inadequate monitoring of health and safety activities. For example the lack of accident records is a good indicator of lack of monitoring. The non-existence of tools for environmental monitoring are all symptoms of problems waiting to manifest themselves.

7.8.4 Arrangements and treatments

When dealing with treatments (ie arrangements) there are two broad categories of arrangements and treatments:

- arrangements to prevent hazardous situations from being created, and
- treatments to control hazardous situations already created.

Specific arrangements and treatments can be related to the four gross health and safety management problem domains identified in Section 7.8.1 eg hardware, liveware, software, and environment problems arrangements.

An important aspect concerning the arrangements that can apply to an organisation's problems depends very much on the type of problem, the resources needed for the acquisition, implementation and monitoring of control measures.

A strategy can be adopted in the selection of arrangements to control hazards. For example in dealing with a physical or chemical hazard (which can be categorised as an element/ingredient (see Figure 7.1), the strategy to adopt is to select one or more control measures from the following list arranged from the best to the least suitable:

- radically eliminate the hazard if possible by changing/mechanising the process,
- substitute the hazardous substances, equipement,
- control the danger eg substances, at source,
- isolate the danger by eg enclosure,
- provide protective equipment to personnel exposed to danger.

This example illustrates the importance of the selection of the right measure. There should be more emphasis on:

- radically treating the problem rather than its symptoms,
- considering the practicability of the control measure(s),
- considering the resources and capabilities for adequate implementation and monitoring of control measure(s).

The third factor needing emphasis (eg resources for implementation and monitoring) includes problem areas such as selection, training, information, instruction, supervision, motivation. It is also important to note that these arrangements and factors need to be considered in a context like a unit in an organisation (eg department, service) and can not be generically determined: an arrangement is selected according to the conditions set up in that context.

7.8.5 Decision rules

The key to linking the information between activities, ingredients, hazards and arangements is to develop heuristic or production rules which are then used by a HS management expert system. Some sort of pattern matching has to be done by the system for controlling information gathering, drawing inferences and reaching conclusions. At least five categories of rules need to be developed for health and safety management expert systems. These rule categories relate to:

- starting a session, an investigation,
- information gathering,
- tentative diagnosis,
- conflict resolution,
- recommendations.

(i) starting a session/investigation rules

These rules are needed to suggest starting points for a session, for search in restricted spaces or when there are more than one possible starting point. The selection of problem areas where to start can be determined by facts (ie symptoms). After having gathered the standard information regarding a new session (eg name of user, activities of user, etc.) the system then selects a problem area for investigation. For example, an expert system such as HASMAP may select to investigate maintenance as a problem area and will have as subtasks to investigate problem areas related to maintenance. The 1985 HSE's report on accidents which occurred during maintenance activities can serve as one starting rule. Table 7.13 shows the relationship between accidents causes and maintenance activities. Those causes can be taken as problem areas and investigated in the order shown in that table to determine if those defieciencies exist in an organisation. To decide which target group needs to be investigated, the same report provides some guidance on where the investigation may be started as illustrated in Table 7.14.

Table 7.13

Relationship between accident causes and maintenance activities

(Agricultural, Factory and Mines and Quarries Inspectorates 1980–1982)

Accident cause	Number of cases	%
System of work	178	24.0
Unsafe Plant/equipmt/workplace	157	21.0
Management organisation/supervision	100	13.5
Safety equipment or guards	95	13.0
Information/instruction/training	68	9.0
Human error	68	9.0
Unforeseeable event or not known	32	4.5
Unauthorised activity	25	3.5
Communication failures	12	1.0
Defective design of plant or equipment	10	1.0
Adverse weather	3	0.5
Total	748	100.0

Source: HSE (1985b)

Table 7.14

Personnel killed during maintenance work
(Agricultural, Factory and Mines and Quarries Inspectorates 1980–1982)

Occupation	Number killed	%
Mechanical engineering fitter	64	19.8
Roof worker	34	10.5
Process operator	33	10.2
Painter	30	9.3
Labourer	24	7.4
Window or indutstrial cleaner	18	5.6
Farmer or farm worker	17	5.2
Manager or supervisor	13	4.0
Jobbing builder or handyman	12	3.7
Bricklayer/stonemason/steeplejack	10	3.1
Electrician or electrical engineer	10	3.1
Driver	9	2.8
Plumber or pipe fitter	8	2.5
Scaffolder	6	1.9
Service or inspection engineer	6	1.9
Linesman (electric power)	5	1.5
Road repair man	4	1.2
Carpenter	4	1.2
Greaser or oiler	4	1.2
Welder	3	0.9
Others	10	3.1
Total	324	100.0

Source: HSE (1985b)

(ii) information gathering rules

Rules are needed to determine the sort of symptomatic information needing to be elicited and the logical order in which it should be elicited. Both backward and forward chaining or reasoning systems require such rules for information gathering. An example of such a rule is:

Table 7.15		
	Rule 221	
If		Maintenance fitter takes excessive time
Then		Fitter's training is inadequate (likely)

Such facts (ie indicators) suggest triggering the investigation of relevant problem areas such as that of 'TRAINING'.

(iii) tentative diagnosis rules

During the information gathering process, information must be aggregated by rules to test a particular hypothesis the system has 'thought of'. Example of that is the following rule:

Table 7.16		
	Rule 231	
If		Fitter fits wrong components
	and	Fitter takes excessive time
Then		Test the hypothesis that the fitter has not been properly selected

This rule therefore triggers the rule about FITTER-SELECTION to assess how adequate selection has been triggering the following rule:

Table 7.17		
		Rule 232
If		Fitter has had medical examination
	and	Fitter passed trainability test
	and	Fitter passed selection test
	and	Selectors are competent
Then		Fitter has been properly selected

(iv) conflict resolution rules

Once information is aggregated, it is used to test and compare competing diagnostic hypotheses. Differential diagnostic rules, cutoff scores and other mechanisms need to be developed.

(v) Recommendation rules

These rules are used in a program which considers the possible control arrangements and decides which arrangement(s) are best suited and need(s) to be recommended knowing the resources and capabilities of the organisation under study.

7.9 Statistical models

There are however other models which experts use in other fields such as medicine and which should be attempted to be used in health and safety. Such statistical models are predictive probabilistic models based on Bayes' theorem. It is unfortunate not to use such a model with the amounts of data gathered each year by all health and safety organisations and professionals.

The HSE's report shows causes of accidents whereas in fact those are only symptoms which were reported. The real causes were not investigated and were not described. Taking the cause 'SYSTEM OF WORK', this accounts for 24% of all causes. But had the HSE applied the ERIM test to this arrangement (system of work), then the real causes would have been discovered. The non-existence or inadequacy of systems of work might have been due to:

– lack of training,

– lack of resources, or/and

– negative attitudes.

This probabilistic model can be used to determine the probability of occurence of one cause (which leads to an accident) given certain indicators. This can be represented in a computer program using the same framework SECT suggested for HASMAP. This model should make use of the indicators used in HASMAP but combining them with accidents and ill–health data gathered over the years. It should be much easier for occupational health where such models have already been used.

The model works on the basis that given certain symptoms, the probability of existing problem areas is calculated and consequently the most likely ones investigated.

This approach is very useful but the collection and analysis of accident statistics needs first to be standardised. This can be done more easily in a company or industry and careful follow up is needed to draw conclusions which may be valid only for that company or industry.

The approach should work as follows:

Assuming there are three main causes of maintenance accidents:

- lack of knowledge,
- lack of resources,
- negative attitudes.

And assuming that the original probability (derived from accident investigations) of these causes are:

lack of knowledge	= 0.43,
lack of resources	= 0.25,
negative attitudes	= 0.32.

The probability of a symptom given a problem area can be provided by practicing HS experts. Examples would be as follows:

Table 7.18

Data which can be obtained from HS experts on the relationship between symptoms and problem areas

Problem area / Symptom	Lack of Knowledge (LK)	Lack of resources (LR)	Negative attitudes (NA)
SOW/PTW	0.65	0.12	0.23
Unsafe plant	0.29	0.58	0.13
Inadequate management	0.26	0.15	0.59
Safety equipment/guard	0.11	0.71	0.18
Information/Instruction/ training	0.08	0.23	0.69
Human error	0.23	0.06	0.71
Unforseeable event	0.58	0.04	0.38
Unauthorised activity	0.34	0.49	0.17
Communication failures	0.20	0.16	0.64
Defective design of plant/equipment	0.69	0.21	0.10
Adverse weather	0.57	0.23	0.20

Examples with hypothetical probabilities illustrating the conditional probabilities of having different symptoms given three problem areas.

The probability of a symptom given a problem area needs to be established (ie the probability of 'LACK OF HS KNOWLEDGE' given that there is no 'SYSTEM OF WORK' could be established from accident investigation reports for certain activities (eg maintenance) in a particular industry or company.

With such assumptions, using the Bayes' theorem technique , the probability of a problem area existing given a symptom can be calculated. Tables like 7.18 can be established for linking different symptoms with problem areas.

For example, a system can use this approach whereby it asks questions considering symptoms to determine the most likely occuring problem area on which to advise the system user. The symptoms together affect the probability of a problem area existing. For example if there is a symptom S1 no permit to work is used by welder then the probability that 'LACK OF KNOWLEDGE' about PTW systems is possible and can be calculated using Bayes Theorem:

- the initial probability for 'LACK OF KNOWLEDGE' = 0.43
- the conditional probability that there is 'no PTW' because of 'LACK OF KNOWLEDGE' = 0.65
- The probability that there is 'LACK OF KNOWLEDGE' given the symptom 'no PTW' can be computed using the Bayes' Theorem formula:

$$Pr\,(PA/S) = \frac{Pr\,(S/PA) \times Pr\,(PA)}{Pr\,(S)}$$

Where: Pr – Probability,
PA – Problem Area,
S – Symptom.

Bayes' theorem gives the probability that there is a lack of knowledge (LK) given that there is the symptom 'no PTW' is:

$$Pr\ (LK/PTW) = \frac{Pr\ (PTW/LK) \times Pr\ (LK)}{Pr\ (PTW)}$$

Pr (PTW/LK) = 0.65 (from Table 7.18)

Pr (LK) = 0.43 (initial probability for lack of knowledge (LK).

Pr (PTW) = Pr (PTW/LK) x Pr (LK) + Pr (PTW/LR) x Pr (LR) + Pr (PTW/NA) x Pr (NA)

(using the Theorem of Total Probability: $Pr\ (S) = \Sigma^{3}_{i=1}\ P(S/PA) \times P\ (PA)$)

Pr (PTW) = ((0.65 x 0.43) + (0.12 x 0.25) + (0.23 x 0.32)) = 0.38

$$Pr\ (LK/PTW) = \frac{0.65 \times 0.43}{0.38} = 0.73$$

This probability for the problem area changes depending on the answers the user supplies. At the end of a set of questions the computer calculates the probabilities assigned to the different problem areas and will give recommendations on the most problem areas which have scored high. Table 7.19 illustrates how maintenance accidents can be categorised and can serve as a prototype for developing symptoms–problem areas relationships.

Table 7.19

Causes of Maintenance accidents

Maintenance as an arrangement	Maintenance as an activity
ie Maintenance of plants, machinery, equipment such as below:	ie Accidents occuring during maintenance activities to staff and others such as below:
Production services: water, gas, electricity systems FLT, cranes, lifts, Process Machinery, Ancillary machinery, Buildings floor, exits, Ventilation system,	Fitters Setters Supervisors Operators Drivers
Contributory Causes	**Contributory causes**
Organisation/managerial problems Engineering difficulties Resources problems men, finance Reporting system Supervision Communication Resources inadequate Bad organisation of maintenance eg records analysis Monitoring of maitenance work	Permit–To–Work systems Resources, inadequate tools Human error Defective design Resources problem eg PPE Communication problems Management safety commitment Personnel problems eg information instruction, training Reporting systems Supervision Fitness of maintenance staff

Source: Adapted from (HSE 1985b)

7.10 Discussion of health and safety problem–solving

Health and safety problem–solving is as complex as the field of health and safety itself. As seen in the previous sections (particularly in Expert Observation Appendix 5 and Workshop) there are four important aspects of health and safety problem–solving:

1– Researching the problem not the solution: in this kind of situation the problem–solver might be looking for the cause but not the treatment (e.g. arrangements) that needs to be implemented (Else 1983) eg it is easy to tackle side issues instead of the main ones.

2– Symptoms are not causes: section 7.9 pointed to the fact that there is a confusion in using terms interchangeably. There are symptoms, causes and effects and each one should be distinct from the other. For example the HSE reported 326 maintenance accidents which occurred over the 3–year period (1980–1982) attributed to 11 sorts of causes. One of these causes is the system of work. Actually the deficiency reported (lack or unsafe, inadequate, not maintained or used system of work) is not the real cause. The investigators should have dug deeper to determine the real causes of this deficiency. This deficiency can be regarded as a symptom which has manifested itself which is linked to root causes.

3– There is a need that health and safety experts set criteria of acceptability on which to select the control measures they recommend. Booth (1976) sets the scene for this requirement for criteria which he lists for the type of guard required on dangerous parts of machinery. The recommendation of a type of guard takes into consideration the risk and the frequency of the need of access to the zone of danger.

4– Health and safety experts should aim not to strain people (when possible) but instead their recommendations should include as many hardware solutions as possible. Recommendations for health and safety arrangements are also more accepted (although not necessarily easily implemented) if they are hardware arrangements. The field studies showed that industrial clients are more likely to implement recommended control measures when presented with hardware recommendations. Tables 7.19 and 7.20 are extracts from the workshop and Expert Observation proceedings and illustrate examples of clients explicitely asking consultants for hardware arrangements to be recommended.

The clients' eagerness is a sign that they are willing to devote resources and implement the arrangements recommended if they are convinced how those arrangements can control risks. For example, a survey has shown that plastics processors place more emphasis on control measures which control acute problems. They are however less motivated for software measures Table 7.21.

Table 7.21

Component items of plastics processors' safety programmes

Item	Use (%)
Machinery and equipment guards	83.6
Fire extinguishers	82.1
Goggles	76.1
Electrical safeguards	71.6
Warning signs	67.2
Machine lockouts	55.2
Instructional signs	49.3
Operating manuals	41.9
Hard toe shoes	29.8
Safety manuals	23.7
Hard hats	10.4
Safety committees	2.9
Ear plugs	1.6
Job safety analysis	1.5
Daily plant inspection	1.4

Source: (Modern Plastics 1969)

5- Health and safety experts need to take into consideration the resources, attitudes and aptitudes of their clients when recommending control measures. Their clients' participation in the selection of the right arrangement is a key factor which affects the adequacy of its implementation and monitoring.

7.11 Tools

The programming tools used for building expert systems have been dealt with in Chapter 2. GCLISP, a LISP dialect was chosen as the programming language to represent the elicited knowledge. This dialect was chosen because of the flexibility it affords for representing knowledge. It is time consuming programming in languages like LISP or PROLOG but the novelty of the project (eg in conceptualising and structuring the HS knowledge) dictated the choice. It was difficult to risk opting for a shell when not knowing what format would the HS knowledge take.

However, besides the numerous advantages the LISP family offers (see Chapter 2), there are three fundamental reasons for using GCLISP:

1 portability of the end–product was considered crucial if small plastics processing companies are to benefit from this experience (ie GCLISP was available on IBM PCs and other compatibles), and
2 GCLISP was acquired by the Chemical engineering department and was used by two other members of the research school, and
3 the problem domain was complex and there was no previous expert systems developed in the field of health and safety to judge whether an existing tool could be used and hence the need for a flexible tool which would enable relatively any representation.

7.12 Conclusion

Those observations revealed that when presented with or in possession of certain key findings, HS experts rapidly establish hypotheses or contexts from which they start investigating problems. The problem solving–strategies can be strcutured in better formats to be used in expert systems. There is however a need for a better reporting, recording and analysis of health and safety data such as accidents data. The frameworks developed in this chapter can be used in constructing health and safety expert systems. Examples of how to use those frameworks are found in the next chapter where three HASMAP modules are described.

CHAPTER EIGHT

Building the system HASMAP

8.1 Introduction

In the previous chapters, all the basic information was gathered and the requirements for building an expert system were reviewed. As it was pointed out the major bottleneck in building an expert system is the acquisition of knowledge and its engineering. The reasons for that bottleneck are mainly the unavailability of experts (eg the source of expertise) and the difficulty to engineer that knowledge once it is acquired. That difficulty is two–fold:

– how to structure knowledge, and

– how to represent it using GCLISP.

The pilot system, a health and safety management program (HASMAP), has been designed to evaluate the feasibility of an expert system for the management of health and safety. HASMAP's architecture and knowledge representation are described in this chapter and so are three of its modules.

Each of those modules will be focused on in turn and each time the three phases of knowledge acquisition, structuring, and representation will be described.

8.2 Knowledge engineering

Three important steps of knowledge engineering were described in Chapter 2. They are reviewed again here in the context of the project.

8.2.1 Knowledge acquisition

The sources of knowledge can be numerous and each of the five phases of system development (eg identification, conceptualisation, formalisation, implementation and testing) requires a certain type of knowledge. The first three phases were dealt with in the previous chapters not under the same categorisation but their objective is to define the boundaries of the problem, identify the concepts and devise a framework to express those concepts and relations in a formal way. Chapters 6 and 7 were an account of health and safety expertise and knowledge and how that was elicited. In this chapter, knowledge acquisition is about the knowledge for the pilot system ie it is specific knowledge of health and safety for the three modules supported so far by HASMAP.

8.2.2 Knowledge structuring

Again this is specific to the three modules supported and how the knowledge and expertise were structured after elicitation before being represented within HASMAP. The frameworks developed and discussed previously should apply to all aspects of health and safety when preparing a policy. For example the SHATER, and SECT frameworks and the ERIM test should apply to any aspect when preparing a HS policy. They will be taken later to show how they have been used in HASMAP.

8.2.3 Knowledge representation

After the knowledge was elicited and structured, it was represented in a computer using the dialect GCLISP. The characteristics of this language were described in Chapters 2 and 7 have proved adequate for representing HS knowledge, concepts and frameworks. Different data representations and paradigms such as rules, frames, triplets (property values) were tested and used to represent health and safety knowledge.

8.3 Overview of HASMAP

HASMAP was designed in modules and so far consists of three modules which are aimed to test the applicability of AI techniques in the management of health and safety. The approaches described in earlier chapters were developed so that the huge task of HS policy preparation can be reduced to manageable models which can then be translated into computer programs which will be run to simulate human experts. HASMAP consists so far of three modules: guarding, maintenance and organisation.

Before describing its construction, it is essential to define some important factors which will facilitate its evaluation and results validation. The important factors that should be dealt with are:

– the objectives of HASMAP, and

– its scope.

8.3.1 Objectives

The objectives of HASMAP are those of this project ie the assessment of the feasibility of using AI techniques to solve health and safety problems such as preparing a health and safety policy using personal computers. This objective would be met by structuring the problem and showing whether it is possible to design an expert system for better management of health and safety.

8.3.2 Scope of HASMAP

Researching this problem revealed that what is needed is to structure and reduce the problem to a model whose components can be looked at each in turn. Visits to industry and discussion with field experts confirmed that the project is very ambitious and would require, like any other AI project, many man–years and would require the development and linking of many expert systems to produce a health and safety policy.

However, given the time allocated, it is only possible to investigate the aspects and problems associated with the development of such a system. One of the requirements of developing an expert system is to select a narrow area of expertise because of the amount of computing involved and of avoiding problems with memory particularly as HASMAP was intended to be constructed on a personal computer.

So showing the feasibility of building an expert system in health and safety would therefore open the way to using AI techniques in health and safety and assist small companies manage better the prevention of occupational accidents and ill–health.

HASMAP was therefore designed to show this feasibility. Suggestions and recommendations are described in the last chapter which would enable future researches to be taken further.

The overall task of HASMAP consists of the following four steps:

- Determining if there is a health and safety problem,
- Determining if there is an adequate arrangement in place,
- Assessing the efficiency of the existing control measure, if any, and consequently
- Recommending the appropriate action to be taken given the hazards and the organisation under study.

8.4 Working of HASMAP

HASMAP consists of modules described below under the section *Architecture*. HASMAP starts with an introduction module which describes the system, its components, and how it is used. A user manual (to be prepared) explains in more detail how to use the system.

HASMAP consists basically of two major parts: a diagnostic and a consultation part. After the introduction module, the user is asked whether to run a diagnostic session or a consultation session to get information about different health and safety aspects.

(a) the consultation session

The consultation session enables the user to get more information about certain important features of health and safety in a workplace and which apply generally equally to plastics processing or other plants. The information is organised in modules about:

- Specific hazards which might exist in the workplace,
- Specific arrangements which the user might wish to know about to take further actions,
- Description of jobs of specific personnel judged by health and safety experts to be the key personnel in an adequate management of health and safety, and
- Information about competent exercising professional bodies who can supply further expert advice and information.

(b) the diagnostic session

This session enables the user to interact with the program which, through a series of questions and answers, diagnoses deficiencies and problem areas and then recommends arrangements which should control/eliminate those deficiencies and hence prevent accidents and ill–health. The system supports three modules on which diagnosis and advice can be supplied to the user and each of these modules is described in greater detail in sections below. During HASMAP's diagnostic session, a number of questions are asked in to identify hazards arising from activities and organisational set up, then arrangements are evaluated before conclusion is reached and recommendations made. This diagnostic session is summarised in Figure 8.1.

HASMAP then follows the problem–solving strategies adopted by human experts as described in Chapter 7. Once enough information has been gathered following SHATER, HASMAP applies the ERIM test to identified arrangements which are considered to be problem areas. The strategy SECT is also incorporated in the ERIM test and serves in looking for symptoms which which can be linked to problem areas. Figure 8.2 shows how HASMAP focuses on a problem area (arrangement) and investigates it before handing over to other programs to decide about the conclusion.

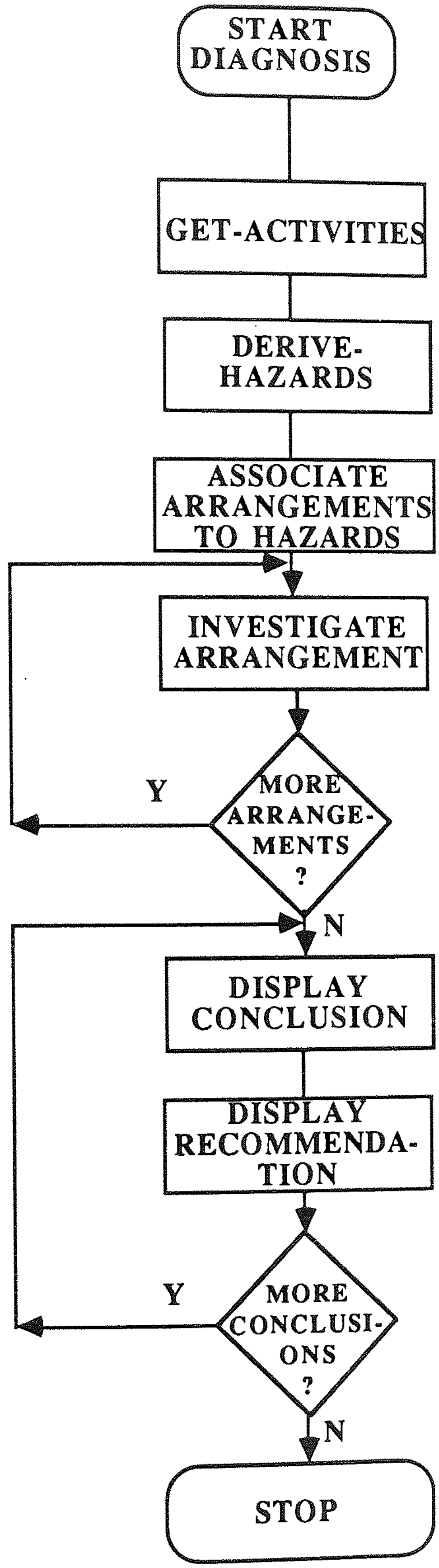


Figure 8.1 Diagnostic steps of HASMAP

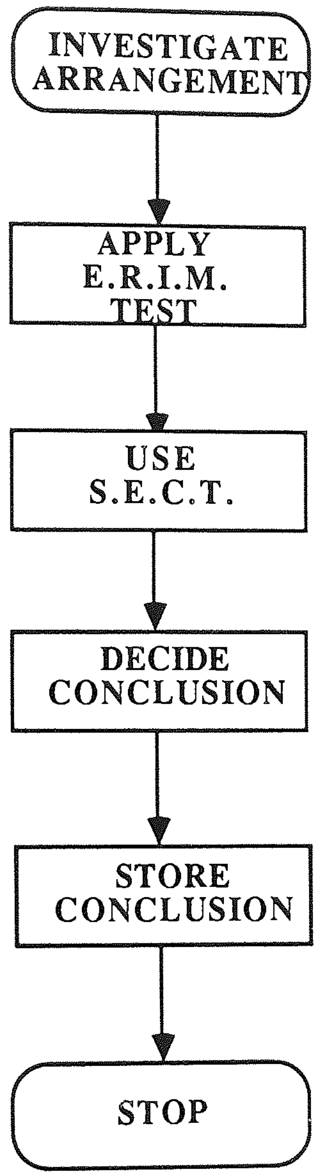


Figure 8.2 Investigation procedure of HASMAP

From Figures 8.1 and 8.2 it can be seen that the arrangements which ought to be in place to control risks are the basic raw materials of HASMAP. The arrangements (or problem areas requiring investigation) are of different sorts as highlighted in the previous chapters and can also be regarded as the causes (if they are absent or deficient) of accidents and ill–health during the investigation of accidents .

8.5 Domain of expertise of HASMAP

HASMAP is designed to simulate the cognitive (not the physical abilities) skills of health and safety experts. And so it either assumes certain things which require physical abilities such as inspecting a guard or relies on the answers of its user about the adequacy of that guard. It concentrates on the cognitive abilities of determining whether the implementation and monitoring of that guard is adequate something which a health and safety expert can advise on from a distance.

HASMAP practices its expertise (basically the test ERIM) on arrangements and in difficult cases it turns certain aspects into arrangements. For example, in the module on maintenance, health and safety problems can be caused in two ways:

- accidents/ill–health due to poor maintenance eg poor guarding can cause accidents, or

- accidents/ill–health can occur during maintenance activities.

HASMAP takes the first situation and having either deduced and found out that the cause of poor guarding is due to poor maintenance then tries to diagnose the causes of poor maintenance before recommending remedies ie problems arising as a result of maintenance not being carried out.

For the second situation - accident during maintenance- HASMAP turns the problem upside down considering maintenance as an activity ie problems arise as a result of maintenance being carried out. In this second case HASMAP relies on its data base to determine how can accidents and ill–health result from maintenance activities. From accident statistics (Tables in previous chapters) it can be seen that there are different types of causes which lead to accidents occuring during maintenance. Each cause would therefore be taken and investigated as to its likelihood of existence in the user's workplace. For example poor permit to work (PTW) system can result in accidents during maintenance of a tank. HASMAP would therefore consider the PTW system as an arrangement and investigate its effect on maintenance as an activity.

8.6 HASMAP's architecture

HASMAP is organised in modules and is designed along the lines of all other production systems used for diagnostic tasks such as Mycin. It adopts different paradigms in the three modules but below is a description of how the main three components of expert systems (eg data base, knowledge base and control structure) have been put together and how they are interrelated.

HASMAP consists of three main parts:

- knowledge base,
- data base, and
- control structure.

HASMAP consists of various programs all called at different stages of a consultation. Figure 8.3 shows how the main three parts of HASMAP are organised and some of the its programs such as:

Help, Explanation, Display–recommendations and Save–session programs.

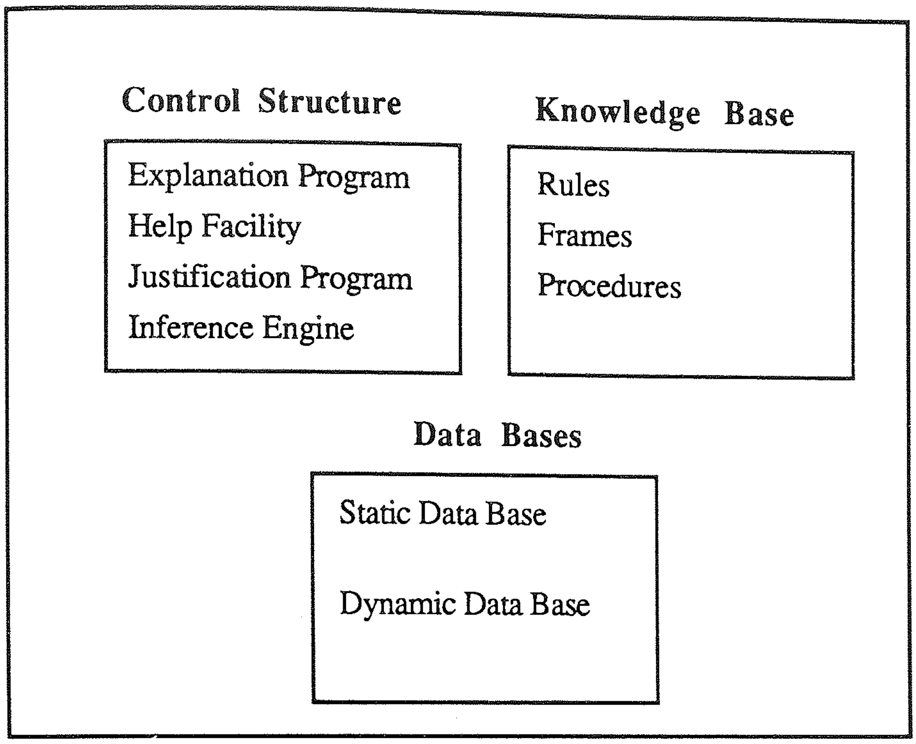


Figure 8.3 Components of HASMAP

8.6.1 The knowledge base

The knowledge base consists mainly of the procedures and functions or rules used to run a session. It contains the expertise HASMAP uses and it is this part that is supplying the control structure and which enables it to run. It is only accessed by the control structure and further improvements and additions to the system should be carried out at this level. Depending on the module, the knowledge base contents are used to elicit information from the user, infer new data from existing data or reach conclusions and display recommendations to the user.

8.6.2 Data base

HASMAP comprises a two–parts data base:

– static data base, and

– dynamic data base.

The static data base holds facts and information about the plastics industry, hazards, health and safety control measures etc. This part of the data base can be accessed by the control structure to pull out information which is used by its inference engine and other interface programs.

The dynamic data base is a session data base which is created while a session is being run by a user. This data base holds data acquired from the user or deduced by HASMAP during a consultation. These data can be saved in a file for future references or consultations if the user wishes to.

The data are facts about the plant, its organisational structure, its activities, personnel etc. which may be used at different stages of a session.

8.6.3 Control structure

This is the 'brain' of the system and consists of sub–systems or programs:

– help interface,

– justification,

– explanation,

– recommendation sub/system.

There have been refinements of HASMAP from the initial version and the way it is designed. The control structure is so designed that more modules can be developed and used if the format adopted in the first three modules is followed.

Future work may involve making the control structure more domain independent and devising an interface to enter data for more modules.

8.7 HASMAP's strategy

In order to diagnose deficiencies in a plastics undertaking, HASMAP applies the ERIM test iteratively to every arrangement which is related to the top–level arrangement it has considered. In accident causation terms, it backtracks from the primary causes to the secondary, tertiary etc. along the causal network shown in Figure 7.5 in Chapter 7 (reproduced below to refresh the memory). Arrangements are control measures before accidents and can be considered as causes after accidents. In the Figure 7.5 below they are represented as causes.

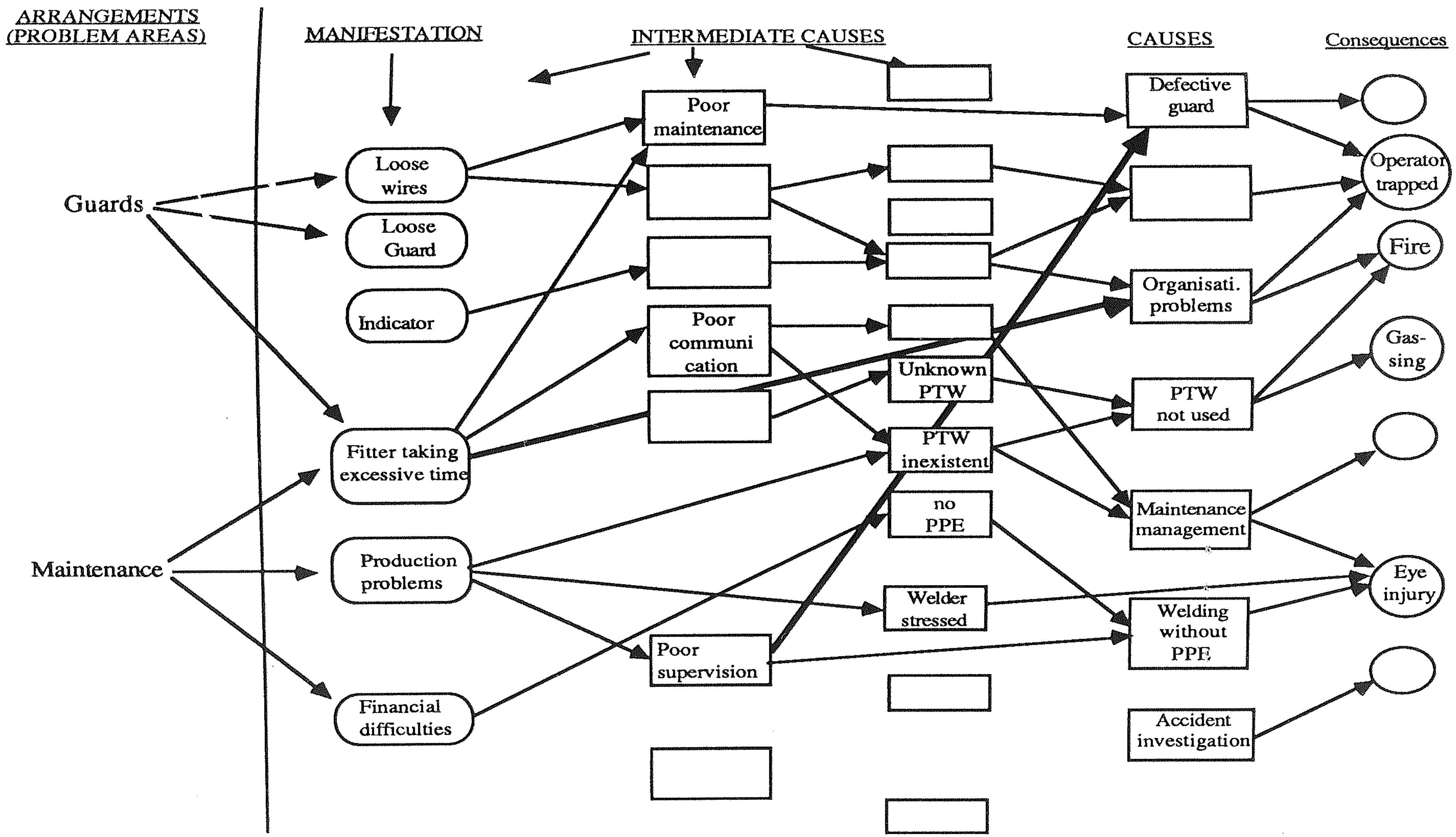


Figure 7.5 Causal network of domain knowledge.

HAMAPS's strategy differs from one module to another and as explained above the system is at its pilot phase and more is needed to build more interrelated modules where the control structure uses the findings in one module in its diagnosis in others.

8.7.1 HASMAP's problem solving

The system can be devised to solve problems in a way similar to that of a domain expert. HASMAP is being built to solve problems along the same strategies adopted by HS experts. It determines the sorts of arrangements required and then applies the ERIM test by assessing the arrangements existence, adequacy, implementation and monitoring. It adopts both backward and forward–chaining strategies to solve problems.

8.7.2 HASMAP's strategies

The system comprises different modules to investigate different arrangements eg maintenance, organisation, and guarding modules.

HASMAP emulates as much as possible HS experts in selecting particular arrangements and investigating them. The control structure comprises various programs amongst which the inference engine. The inference engine adopts both backward and forward–chaining depending on its phase of problem–solving. When an arrangement (or problem area) has been identified, HASMAP invokes a rule whose conclusion clause deals with this arrangement. HASMAP then takes each IF–clause as a new hypothesis and investigates it to determine whether it is true or not.

Once a clause has been selected, HASMAP searches its data base to determine whether there is any information about the assertion otherwise it searches its knowledge base to identify whether there are any rules from which information about the assertion can be inferred. If information can't be inferred then HASMAP asks the user to supply information about the activated hypothesis (ie arrangement).

The forward–chaining strategy is used in HASMAP to infer information from data which exist or which are supplied by the user. Forward–chaining is more difficult to use because of the complexities of the conflict resolution schemes ie deciding which rules to fire when there are several of them. Although this difficulty of using forward–chaining was experienced in early modules of HASMAP (eg the system was taking quite some time before coming to a conclusion). One way of getting round this problem, in one module, was re–arranging the rules so that the search space of the inference engine is effectively structured. Moreover, this should not pose any serious constraints because of the modular nature of HASMAP where only small chunks of rules are worked upon. Figure 8.4 illustrates how HASMAP uses both strategies.

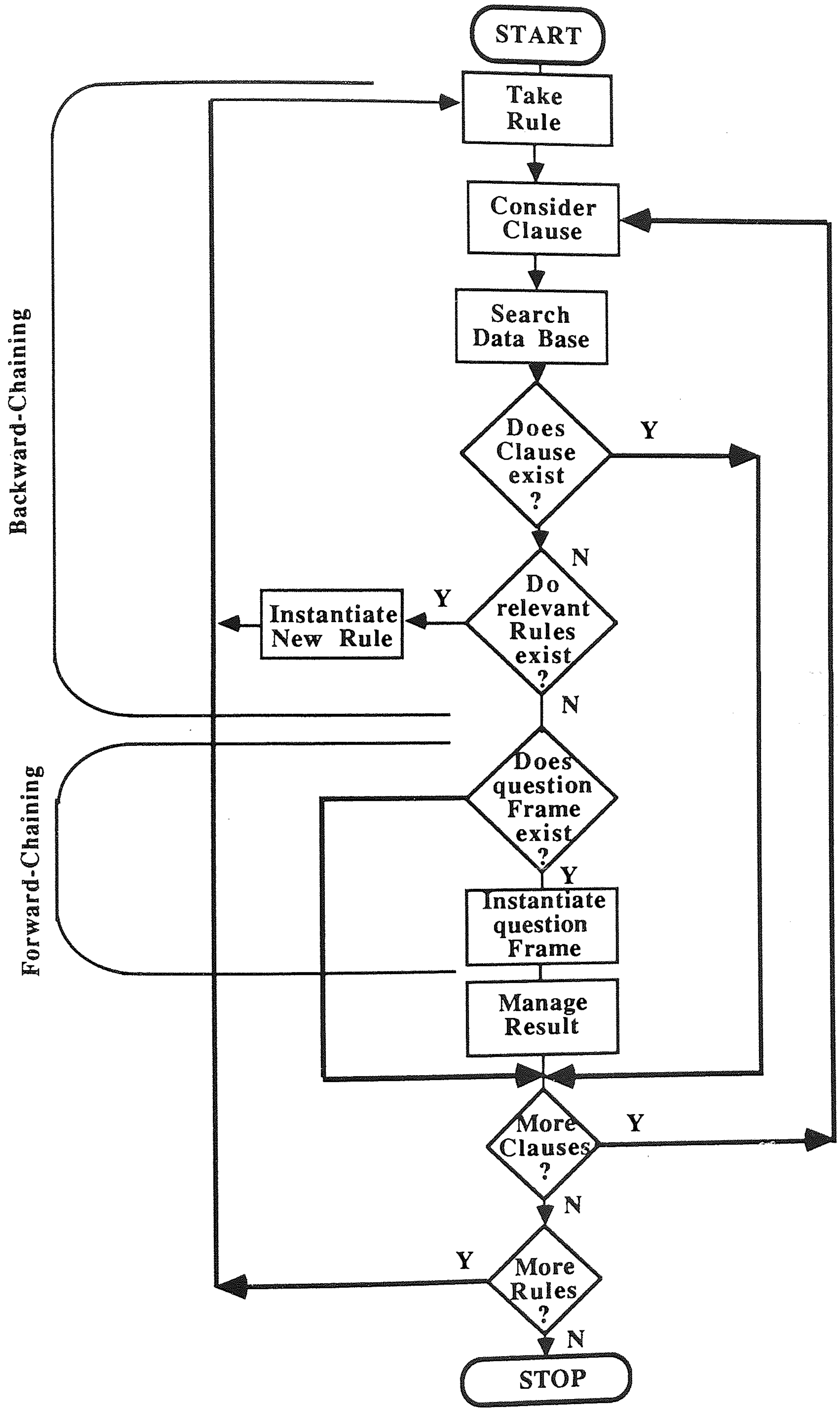


Figure 8.4 How HASMAP works

8.8 HASMAP's Modules

HASMAP consists so far of an introduction module and of another three on guarding, maintenance and organisation as shown in Figure 8.5. A fourth module on fork lift truck is being developed.

The introduction module is merely used to ask basic questions about the activities of the undertaking so that HASMAP decides what sorts of hazards are present and can advise the user on the sorts of arrangements that need to be looked into carefully.

In either of its two modes, (eg diagnostic and consultation mode), HASMAP starts by asking the questions of the introduction module and then lets the user select either one of the diagnostic modules or run a consultation about the arrangements supported and required to be looked at given the activities carried out on the premises.

In the diagnostic mode HASMAP carries out a diagnosis based only on the modules supported. The user is then supplied with a diagnosis and suggestions about the actions necessary to control the identified hazards.

In the consultation mode, HASMAP supplies the user with screens of advice on specific hazards, arrangements, professional organisations, and job specification of key personnel.

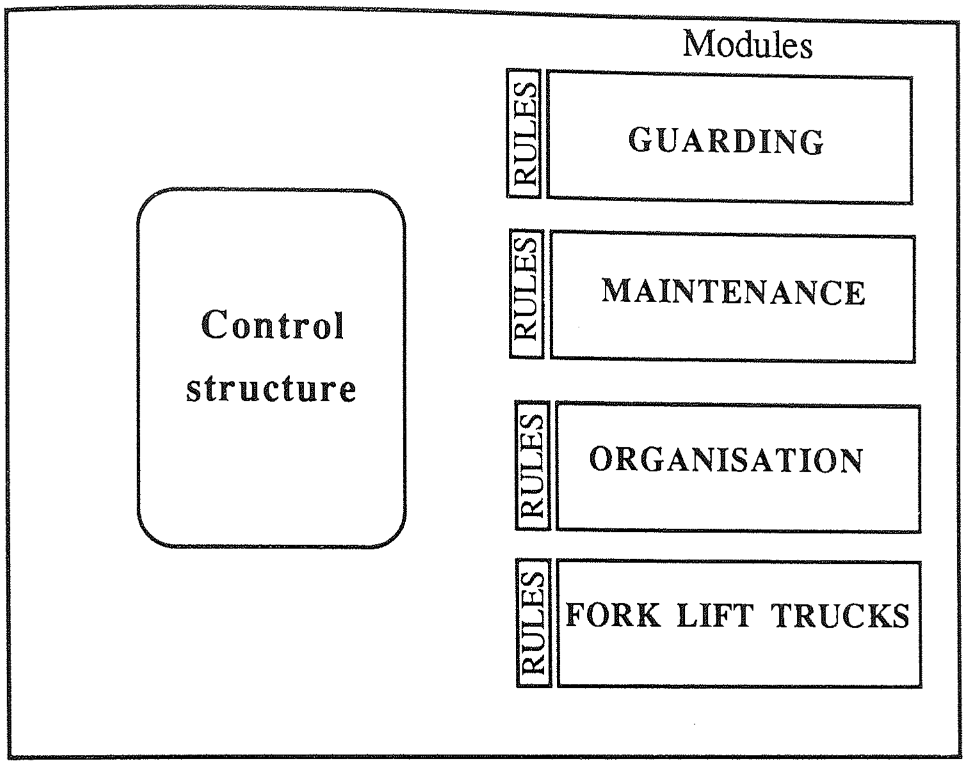


Figure 8.5 HASMAP's modules and their rules organised in packs.

8.9 Guarding

In the module on guarding, HASMAP applies the ERIM test. The three knowledge engineering phases are as follows.

8.9.1 Knowledge acquisition

The main raw material, for this module, is the code of practice on horizontal injection moulding machines published by the British Plastics Federation (BPF 1978) which sets out the criteria for adequacy of such arrangements. Discussions with HS experts helped in formulating questions and deciding on the assumptions to be made and at what level the session (question–answers) starts.

8.9.2 Knowledge structuring

This phase is facilitated by the frameworks developed in Chapter 7, namely SHATER, SECT and the ERIM test , and following the approaches experts have adopted when evaluating machinery safeguards. The general approach health and safety experts have adopted is that of breaking down the task into manageable sub–tasks which frames fit very well. To avoid any confusion with using this term, which is also used for the computer knowledge representation, these sub–tasks will be called boxes instead.

Figure 8.6 illustrates how the ERIM test applies to this identified arrangement where each test is represented by a box. HASMAP then uses the framework SECT to reach conclusion about each test.

HASMAP goes easily through the first and second boxes which are the first two steps in the ERIM. However, in order to deal with the third step of ERIM (eg implementation), HASMAP considers it as a new arrangement and applies iteratively the test ERIM to it eg are guards fixed adequately? This depends very much on who fixed those guards and how competent those people fixing them are.

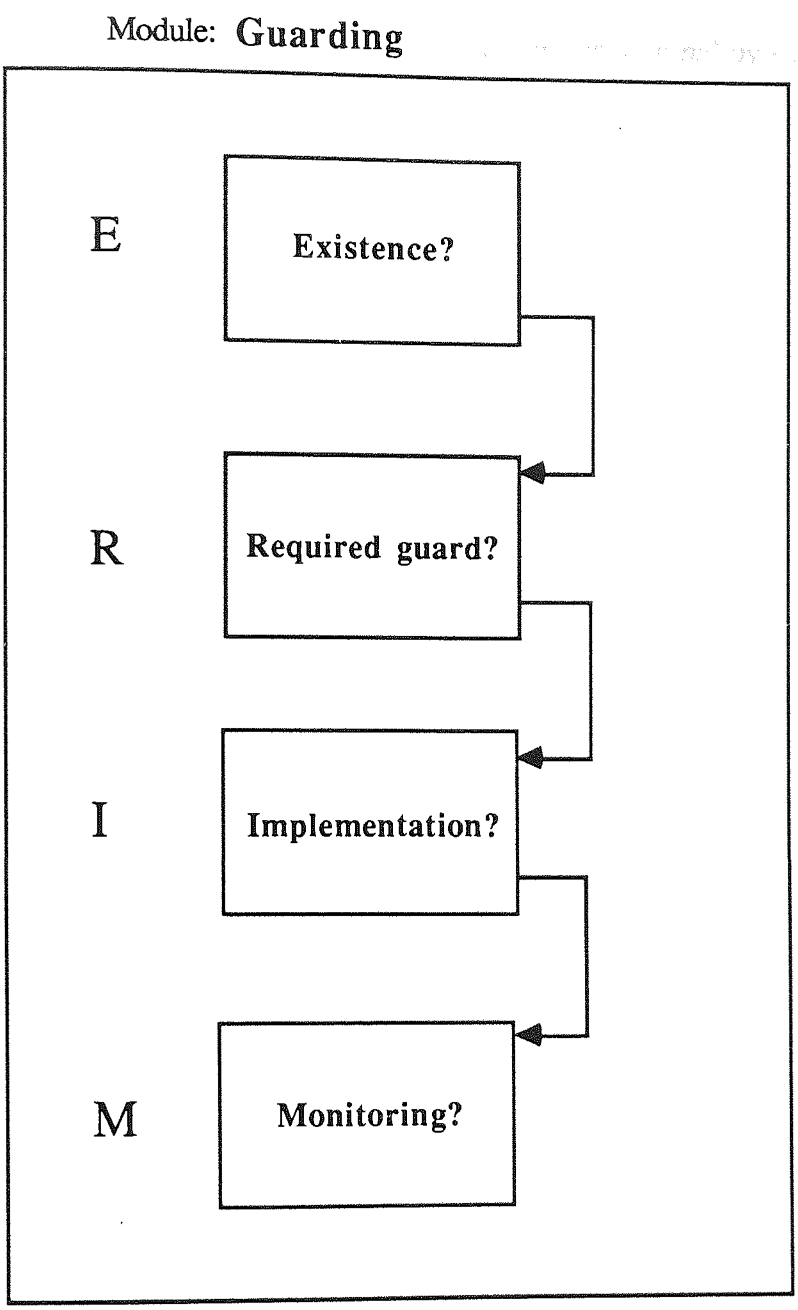


Figure 8.6 Frames (boxes) as contexts as used in the module Guarding applying the ERIM test

In this case there is an assumption, made that the implementation is adequate (this can be taken later by another module when dealing with the training of fitters) and HASMAP moves on to the last test of ERIM about monitoring.

Monitoring of guarding is mainly keeping them in good conditions as required by standards eg BPF code of practice. In order to do so, guards must be maintained. The maintenance of guards can be regarded as a separate module MAINTENANCE. But before their maintenance, guards first need to be inspected for checking their safe operability. Hence inspection, can in turn be considered as an arrangement to be investigated and to which the ERIM test should be applied again eg:

- does inspection exist?
- is it the right type of inspection?
- is it carried out properly?
- is it monitored eg is it acted upon as required (are the actions recommended – following inspections – acted upon in the time prescribed etc.)

8.9.3 Knowledge representation

It was pointed out in the previous section on structuring the knowledge for this module that the knowledge and reasoning is organised in interrelated boxes. This graphical sketch can be ideally represented with frames which are a knowledge representation paradigm (Minsky 1975) and are referred to in Chapter 2.

In this module HASMAP uses frames to evaluate the guarding arrangement making use of the frameworks SHATER and SECT and applying the ERIM test. Each frame contains ten slots with various values and handled by the control structure to ask question, provide the user with help, explanation, justification etc.

This type of representation is very compact and useful to keep the data base and the system as modular as possible. The same paradigm is used to store the information elicited from the user in the dynamic data base.

Table 8.1

An example of a frame used in the module on Guarding

Frame: **Existence**

Question:	The question that is asked
Help – IF–NEEDED:	Displays help screen if user needs help
Test–Answer:	Tests the answer supplied by the user
Acceptable–Values:	Set of values the system expects to get from user
Related–Rule:	The rule in the knowledge base dealing with context
Related–Clause:	The clause from the Related–Rule
Child–Frame:	Name of frame linked to and inheriting from this frame
Parent–Frame:	Name of the frame from which this frame emanates
How – IF–NEEDED:	Displays explanation of how decision was reached
Why – IF–NEEDED:	Displays justification for asking a question
Conclusion:	Manages the conclusion reached.

8.10 Maintenance

Maintenance is a very important and complex area in the prevention of accidents and ill–health. Maintenance can be dealt with under two headings:

– maintenance as an arrangement, and

– maintenance as an activity.

(a) Maintenance as an arrangement

This module of maintenance is linked to the module on guarding because on machines guards are an arrangement and their monitoring is basically keeping them to the standards at which they were originally installed. So maintenance can be regarded as a form of monitoring of guards when considering guards and as an arrangement that needs to be in place for better safety.

Occupational accidents and ill–health can occur as a direct result of either the inexistence or the poor quality of this arrangement. As with guarding, which is an arrangement like ventilation etc., the four tests required for a satisfactory arrangement are:

– does maintenance exist?
– is it the required kind of maintenance?
– is it adequately implemented?
– is it properly monitored?

As an arrangement, maintenance needs to be considered for all types of hardware. There are also other kinds of maintenance for the soft areas (liveware and software) such as maintaining the level of awareness of certain operators against certain hazards by training them, their supervisors, managers etc.

In this module of maintenance, only the maintenance of the hardware will be considered and that includes machinery, plant and equipment, building. Instances of hardwares which require maintenance are numerous and to diagnose any problem due to poor/inadequate maintenance there is a need to take a context as to where the maintenance considered should be applied.

Other examples of maintenance as an arrangement include the maintenance of lifts, cranes, pressure vessels. So maintenance should always be linked to a context otherwise it will be difficult to apply the ERIM test and draw any valid conclusions. Table 8.2 illustrates examples of how maintenance can be considered as an arrangement.

Table 8.2

Applying the ERIM test to Maintenance
(maintenance considered here as an arrangement)

Item requiring maintenance	**Is it done?**	**Is it what is required?**	**Is it done properly?**	**Is it monitored?**
Vessels Guards FLT Cranes				

(b) Maintenance as an activity

Accident statistics show that maintenance workers are a high risk group and reports show that maintenance accidents are about 25% of all fatal accidents (HSE 1985b).

Ill–health can result from health hazards while maintenance activities are carried out by maintenance staff in hazardous conditions or using hazardous substances. As discussed in earlier chapters, chronic diseases are not considered here but a comprehensive organisational set--up which is well–monitored should prevent both acute and chronic ill–health.

Unlike maintenance as an arrangement, maintenance activities cover a wide spectrum and how much of them is carried out depend to a great extent on the type of organisation eg how well are the tasks defined, analysed before they are carried out. In the accident Case 2 study discussed in the workshop in Chapter 7 (Bensiali 1987), the maintenance department was involved in a complex situation which resulted in a fire.

A similar activity would have been carried out without incident in another organisation or even in the same organisation had the conditions been slightly different eg for example had the same person who installed the rubber–lined vessel taken part in its clearance.

Taking the results of the HSE's survey on maintenance accidents, the absence of the arrangements that need to be in place during maintenance activities would be the causes or symptoms of causes of the accidents reported as shown in Table 8.3 which has already been introduced earlier.

Table 8.3

Causes of maintenance accidents
748 attributed causes of maintenance accidents (326 fatal accidents)
three–year 1980–1982 study by HSE–APAU

Attributed causes	Number	Percent
System of work	178	23.8
Unsafe plant/equipment/workplace	157	21.0
Management organisation and/or supervision	100	13.3
Safety equipment or guards	95	12.7
Information,instruction or training	68	9.1
Human error	68	9.1
Unforseeable/not known event	32	4.3
Unauthorised activity	25	3.3
Communication failures	12	1.6
Defective design of plant/equipment	10	1.4
Adverse weather	3	0.4
Total	748	100.0

Source: HSE (1985b)

For a precise analysis of such accidents, each activity needs to be considered separately eg accidents during maintenance of guards, vessels, fork lift trucks (FLT), lorries etc. because of the different health and safety requirements for each activity.

8.10.1 Knowledge acquisition

The knowledge for this module was acquired mainly from two HS experts specialised in machinery and discussions were subsequently needed for structuring the elicited knowledge. This module is based on two interviews with these two experts and discussions with HS practitioners in the plastics processing industry (Bensiali 1987b).

8.10.2 Knowledge structuring

HASMAP selects problem areas eg maintenance, and initially is only responsive to trigger findings. When a plant–specific finding is a trigger of a hypothesis then this is activated ie if the tests applied to a chosen context are true then that context is considered and investigated thoroughly. For example, when maintenance is selected as a problem area, HASMAP triggers one of its rules and considers training as a context to explore. By using its backward–chaining strategy, HASMAP takes training as a hypothesis and first applies a test to decide whether to investigate in detail that hypothesis to determine where the problem lies.

HASMAP uses the SECT framework when applying the ERIM test to identify problem areas which need to be investigated. For example applying one of ERIM tests 'ADEQUACY OF MAINTENANCE' HASMAP uses SECT to find any indicators of inadequacy. It asks a question about the symptom/indicator 'TIME TAKEN BY FITTER' triggering a rule (if fitter takes excessive time then fitter is not competent (likely)).

This symptom about the time taken is linked to one or more of the major problem areas referred to in the last chapter namely knowledge, resources, attitudes, monitoring. If the answer is true the hypothesis that 'FITTER IS NOT COMPETENT' is activated and investigated. Using the statistical model referred to in Section 7.10, the answers to further questions will decide which recommendation the system gives. Figure 8.7 illustrate how this arrangement is linked with the four problem areas.

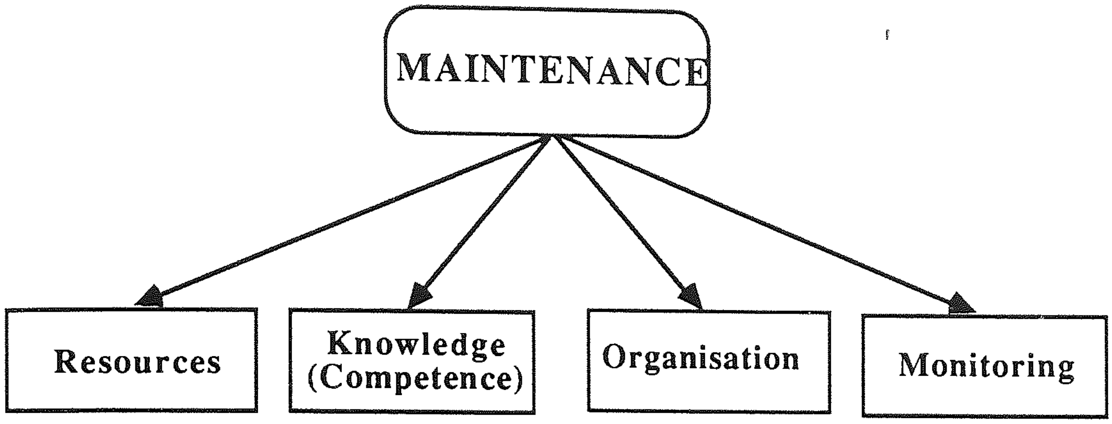


Figure 8.7 Contexts related to Maintenance

In this particular example, HASMAP considers the hypothesis COMPETENCE as being a problem area and investigates it first. It semi–activates related hypotheses branched in its network such as ORGANISATION–OF–TRAINING, RECRUITMENT, NEW–MACHINERY as shown in Figure 8.8.

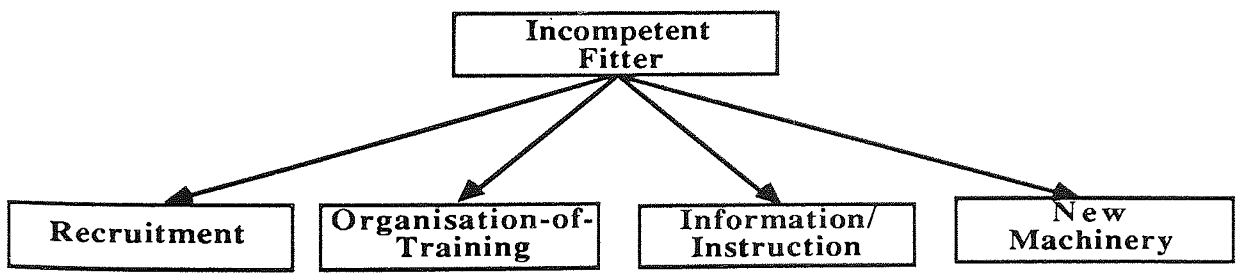


Figure 8.8 Contexts related to the context incompetent fitter

The investigated hypotheses are confirmed or inactivated and the conclusion about them added to the dynamic data base. The rules can be either categorical rules or based on probabilistic estimates that a deficiency (eg a problem area) exists in the organisation under study eg RECRUITMENT is deficient and needs to be investigated if it is shown to be inadequate. Although the probabilistic approach would be preferred using Bayes' theorem (as discussed in Section 7.10 of Chapter 7), HASMAP does not use it due to the time available in this project.

8.10.3 HASMAP's strategy in the maintenance module

The diagnostic strategy adopted by HASMAP is a mixture of backward–chaining (goal–driven) and forward–chaining (data–driven) reasoning processes adopted at specific times of the consultation.

Backward–chaining is used in HASMAP where the topmost assertion that needs to be inferred is the premise of the Goal–Rule, eg 'MAINTENANCE IS INADEQUATE'. The process of control selection, abstracted in terms of the action part of the Goal–Rule, is invoked only if the diagnostic process has inferred the presence of problem areas leading or causing the topmost assertion being true ie 'MAINTENANCE IS INADEQUATE'. Table 8.4 illustrates the Goal–Rule where HASMAP starts the investigation of maintenance.

Table 8.4

Goal–Rule of the Maintenance module	
If	Maintenance is inadequate
Then	Do the following:
	– Select the problem areas causing inadequate maintenance eg rules where the action part is inadequate maintenance
	– Give advice on each problem area.

The LISP rule looks like this:

If **Maintenance is inadequate**

Then **INVESTIGATE maintenance–deficiency–hypotheses**

In order to establish the top level assertion, HASMAP looks for rules whose conclusion is the topmost assertion 'Maintenance is inadequate'. A sub–goal would therefore be instantiated to determine whether the premise (clauses) of the rule (Table 8.5) is true.

Table 8.5

A Rule from Maintenance module

If	**Personnel is incompetent and**
	Resources inadequate and
	Maintenance organisation poor and
	Work procedures unsatisfactory
Then	**Maintenance is inadequate.**

Hence HASMAP follows the strategy illustrated in Figure 8.4 and next looks for rules whose conclusions are the 4 clauses above. The consultation session gradually unfolds by progressively chaining backwards from each triggered antecedent condition (eg clause).

The process of unfolding continues in a depth–first manner until there are no rules along a reasoning path. When there are no rules to be unfolded, the assertion to be established next constitutes a primitive piece of data (eg a terminal node on a reasoning tree such as those given in the module on organisation). HASMAP searches its data base to determine whether that assertion has already been determined. If it has then HASMAP considers the next assertion, if it has not then a forward–chaining process is triggered to try to use the available data (as assertions in the data base) to try to infer the conclusion sought (in the rule recently fired – ie triggered–). If that also fails then the user is asked to supply the data. The process of asking the user is done by triggering a frame whose context is the assertion.

The frame has many slots and one of them is QUESTION which is triggered when data are needed as illustrated in Table 8.1.

8.10.4 Knowledge representation

This module was originally written as a set of procedures dealing with the different nodes (or contexts) the health and safety experts considered and to which a diagnostic program was then applied to infer the adequacy/quality of maintenance in the undertaking. Although the module was working, it was difficult to link it to other modules and it was therefore important to re–design it with sufficient abstraction so that the control sub–system works for this module as well as others. This also is important for the separation of the knowledge base from the reasoning or control sub–system. The rules are organised in the knowledge base in packs (Figure 8.9) separate from the inference engine and other parts of the control structure.

Top Rule

Rule31
Rule32
Rule33
Rule34
Rule35
Rule36
Rule37

Figure 8.9 Rules of Maintenance module

8.10.5 Conclusion on maintenance

It can be seen that the module of maintenance alone can be composed of as many modules as there are items whose maintenance needs to be looked at in order to prevent accidents/ill–

health which might be caused by a poor/inadequate maintenance. Maintenance, like any other module, needs also to have a context eg an application domain around which to build components of such a module.

On maintenance alone, many expert systems can be developed to advise a plant or a company on the health and safety precautions needed for carrying out maintenance works safely and without problems to health.

8.11 Health and Safety Organisation module

This is the third module supported by HASMAP and it covers the management and effectiveness of the health and safety committee which is one important component for an effective organisation of health and safety.

8.11.1 Knowledge acquisition

The knowledge for this module was mainly acquired from an interview of a health and safety expert (Bensiali 1987c). The interview started by asking the expert how he would assess whether the arrangements in an undertaking are adequate and what indicators he would look for to reach a conclusion. The interview was then transcribed and by analysing it, and other literature on the subject of HS organisation and HS committees, a reasoning tree was constructed.

The task consists of identifying the key problem areas which need to be investigated to assess the performance of an undertaking's effort in managing health and safety. According to the expert interviewed, and with whom other experts agreed, there were basically two principal areas that should be considered in the evaluation of the management of health and safety namely the health and safety committee and the organisational arrangements.

– Health and safety committee (HSC)

The expert divided the task of evaluation into further sub–tasks and considered that the evaluation of the safety committee depended primarily on its effectiveness and on its membership as shown in the Figure 8.10

– Organisation effectiveness

Similarly the expert considered the effectiveness of an organisation as an important determinant in the evaluation of the safety management efforts. The interview revealed that, according to the expert interviewed, effectiveness of an organisation depends on four other main areas namely:

- management commitment,
- health and safety resources,
- performance of the health and safety person, and
- assessment of the risk in the workplace.

8.11.2 Knowledge structuring

The knowledge elicited from the expert was structured and organised as a reasoning tree shown in Figure 8.10. On that tree, each node is a context or problem area considered by the expert and has derivations or children nodes (contexts) which the expert used during his problem–solving task to reach a conclusion about the parent node. The tree only reveals the relationship between contexts but it was difficult to establish a cause–effect relation from just that tree and there was a need to return to the expert interviewed to try to understand how he carried out his problem–solving task and how decisions and conclusions were formulated. Other domain experts were also consulted to check the validity of the tree as a representation of the domain and determine how each node is related to its children and parents. This association is both qualitative and quantitative. The tree shows the qualitative associations whereas the tables in the following sections show the quantitative associations.

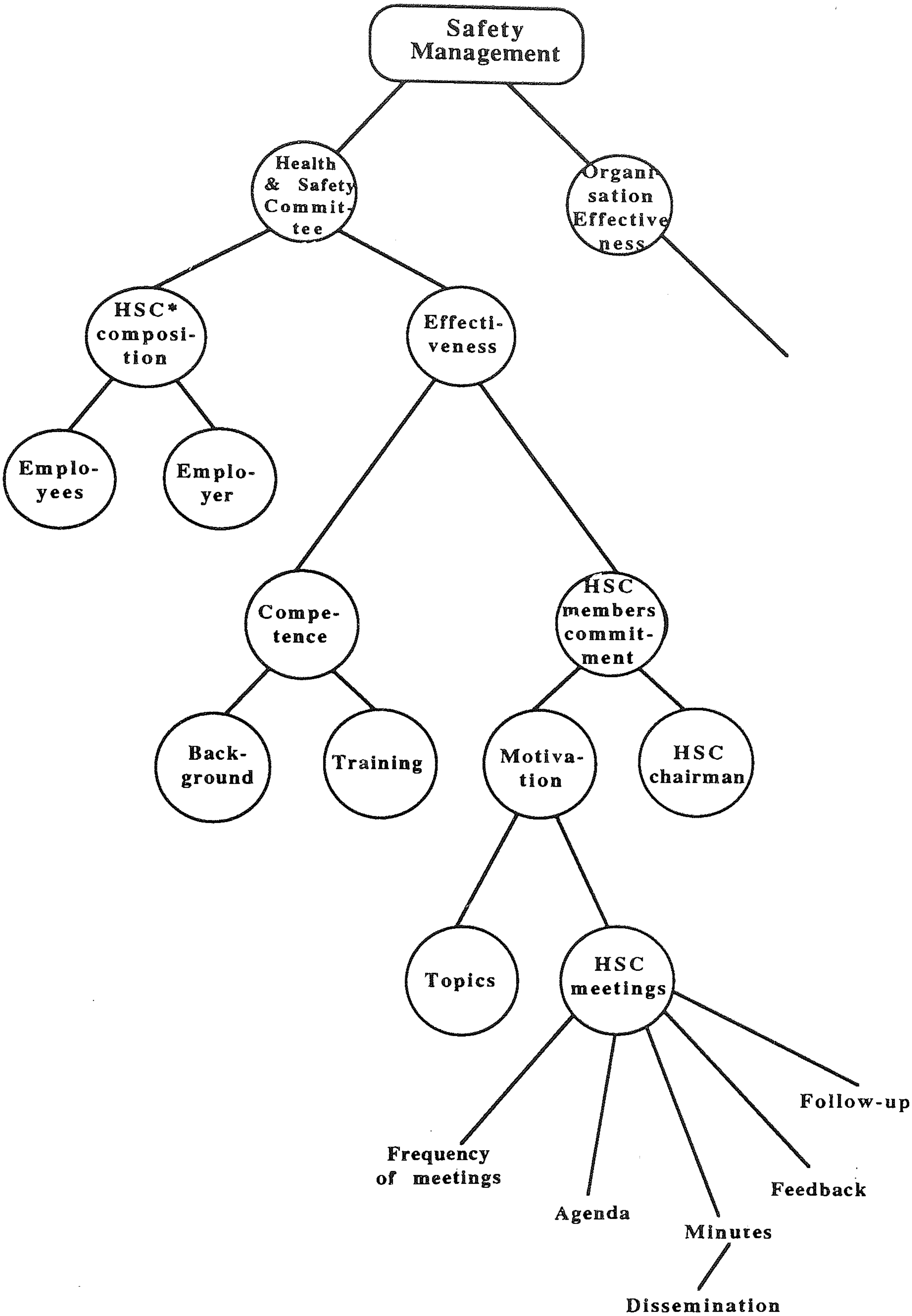


Figure 8.10 Aspects considered in the evaluation of health and safety management

8.11.3 Knowledge representation

After its structuring, the knowledge elicited from the expert had to be represented in LISP so that it could be input to the computer to be used in this module. There was a need to represent not only the knowledge involved (ie facts and concepts) but also the reasoning of the expert (ie the relationships between concepts and facts and the heurisrtics used by the expert to make the decisions regarding the adequacy of the existing set up). This can be called qualitative analysis referred to in Section 8.11.2. Other sessions with the expert proved useful to find out how that knowledge was used. The expert was using a rating system which enabled him to evaluate each context using, as in a fault tree analysis, the results obtained from children nodes. This latter part of the knowledge elicitation is a quantitative analysis.

The rating system (used in the quantification exercise) is arbitrary and was used by the domain expert during his experience of health and safety performance evaluation of companies. It is basically a set of heuristics which are used and about which other experts seemed not to disagree.

The representation paradigm used was a set of arrays where scores are stored for each problem area and from which the overall score is computed. The overall score is then interpreted according to a scale as to the effectiveness of the organisation which is an indicator of the health and safety effort of a company.

Tables 8.6 - 8.31 show how the expert interviewed and other experts agreed to evaluate an organisation and the effectiveness of its health and safety committee.

8.11.4 HASMAP's strategy in the module Organisation

A different approach was adopted in this module whereby the decision making is based on scores as they were attributed by the expert interviewed and others with whom those scores were discussed. Each problem area (or arrangement) is rated according to a set of questions related to children nodes. The tree in Figure 8.10, based on discussions and interviews with HS experts, consists of two main areas which can be used to assess an organisation's performance in health and safety management:

– the health and safety committee, and
– the effectiveness of the organisation.

8.11.5 The health and safety committee (HSC)

Considering the health and safety committee as an important arrangement for identifying, evaluating and controlling hazards, the ERIM test and the SECT framework can be applied to assess this arrangement. However, this module was developed prior to developing these frameworks and so it needs to be re–written. The initial version of this module assessed this arrangement by rating the children nodes of the HSC in Figure 8.10 ie the node HSC score depends on the score of the two children nodes etc. For example the following Tables 8.6 – 8.16 illustrate how the management of the HSC meetings is rated is.

Table 8.6
HSC* composition
How many members are there on the HSC? **Number:**
HSC–employer representatives
How many members on the committee represent the employer? **Number:**
HSC–employee representatives
How many employee representatives are there on the HSC? **Number:**

* HSC is health and safety committee

The competence of the HSC members depends on their background and on their HS training. It is rated according to the Tables 8.7 – 8.9.

Table 8.7

Membership of the health and safety committee

Title	Score
Senior manager (at least department head)	3
First line supervisor (including maintenance)	2
Health and safety adviser (full/part time)	1
Other management (eg personnel, engineer)	1
Employee (Trade Union Reps)	1
Others (eg Occupational health nurse, hygienist, outsider – HSE)	1

Rating:

1 – 3	Very poor
4 – 5	Poor
6 – 7	Good
8 – 9	Very good

Table 8.8

HSC members' training

How can the HS training of the HSC members be described?

0 No training

1 Little training

2 Training more than 2 years ago

3 Training less than 2 years ago

Table 8.9

Competence of the HSC members

Type of training / HSC member	0	1	2	3
Senior manager(s)	0	1	2	3
Manager(s)	0	1	1	2
HS–person	0	0	1	2
First line manager(s)	0	1	2	4
Employee Representative(s)	0	1	1	2
Others	0	1	1	1

Rating: after summing the score for each typical member (ie one person for each group), the score is rated as follows:

0 – 3	Unsatisfactory
4 – 7	Fair
8 – 11	Good
12 – 14	Very good

Table 8.10

Frequency of meetings
(Frequency of health and safety committee meetings and size of plant)

Size (employees)	Frequency		
	less than every 3 months	every 2–3 months	at monthly
5 – 30	2	2	2
31 – 60	1	2	2
61 – 100	0	2	3
> 100	0	2	3

<u>Rating:</u>

0 Very poor
1 Poor
2 Good
3 Very good

Table 8.11

HSC–agenda

How are the items on the agenda dealt with? eg is the time available sufficient to deal with:

1 All of them	3 points
2 Most of them	2 points
3 Some of them	1 point
4 Few of them	0 point

If Minutes are not kept
Then There is no score

If Minutes are kept
Then Questions are asked about who gets those minutes. Depending on to whom they are circulated, the HSC scores are attributed according to Table 8.8.

Table 8.12				
Scores for minutes distribution				
Receiver of minutes/ information	Employees or Reps	Line Management	HSC* Members	Others
Score	2	2	1	1

Rating:

1 – 2	Very poor
3	Poor
4 – 5	Good
6	Very good

Table 8.13			
Feedback to the health and safety committee			
Receivers of Minutes	Type of feedback (FB)		
	No FB	Little FB	Useful FB
Line managers	0	1	2
HSC members	0	0	1
Employees & their Reps	0	1	2
Others who might benefit from information	0	1	2

Ratings:

0 – 1	Very poor
2 – 3	Poor
4 – 5	Good
6 – 7	Very good

Table 8.14

Role of the health and safety committee and its recommendations

Role of HSC / following-up HSC Recommendations	Passive	Fire-fighting	Consultative	Decision-making
Rarely	0	0	0	0
Sometimes	0	0	1	2
Often	0	1	2	3
Always	0	1	3	4

Rating:

0 Unacceptable
1 Very poor
2 Poor
3 Good
4 Very good

Table 8.15

HSC Topics

Which of the following subjects are discussed by the HSC?

a)
1– HS performance
2– Analysis of accidents
3– HS inspection/audits

(Choose one of the following answers below)

	score
0 None	0 point
1 One of these	2 points
2 Two of these	4 points
3 All of these	6 points

Table 8.15 continued ...	
b) 1– Monitoring of HS activities 2– Arousing & maintaining interest in HS 3– Helping to develop safety rules and systems of work (Choose one of the following answers below)	
	score
0 None	0 point
1 One of these	2 points
2 Two of these	4 points
3 All of these	6 points
c) 1– Liaise with HSE or local authorities 2– Study reports from HSE or other bodies & organisations which are of interest 3– Consider relevant information from external resources (Choose one of the following answers below)	
	score
0 None of these	0 point
1 One of these	1 point
2 Two of these	2 points
3 All of these	3 points

Table 8.16

Rating of the Management of the health and safety committee (HSC)

Overall rating:

1 – 5	Very poorly managed
6 – 9	Poorly managed
10 – 13	Fairly managed
14 – 17	Well managed
18 – 23	Very well managed

8.11.6 The effectiveness of the organisation

Considering the problem area ORGANISATION–EFFECTIVENESS, there are 4 sub–problem areas which need to be investigated:

A – Health and safety resources,

B – The HS person's performance,

C – Management commitment,

D – Risk assessment.

The risk assessment problem area is vast and the whole exercise of developing a safety policy is based on the assessment of risks before controlling them. What the expert interviewed meant to find out was whether an organisation assesses the risks at all. That would give a picture about the knowledge, resources and attitudes of the organisation towards health and safety. It is not dealt with it specifically since the whole exercise deals with risk assessment.

A Health and safety resources,

Figure 8.11 shows how the health and safety resources are a function of four other nodes whose scores make up the score for the adequacy of those resources. The children nodes are:

- training,
- budget for health and safety,
- time for HS activities, and
- health and safety committee.

It can be noted that the scores of the HS committee obtained in section 8.12.1 are used here to compute the HS resources score. Tables 8.17 – 8.31 show how each node is rated to compute the parent node overall score.

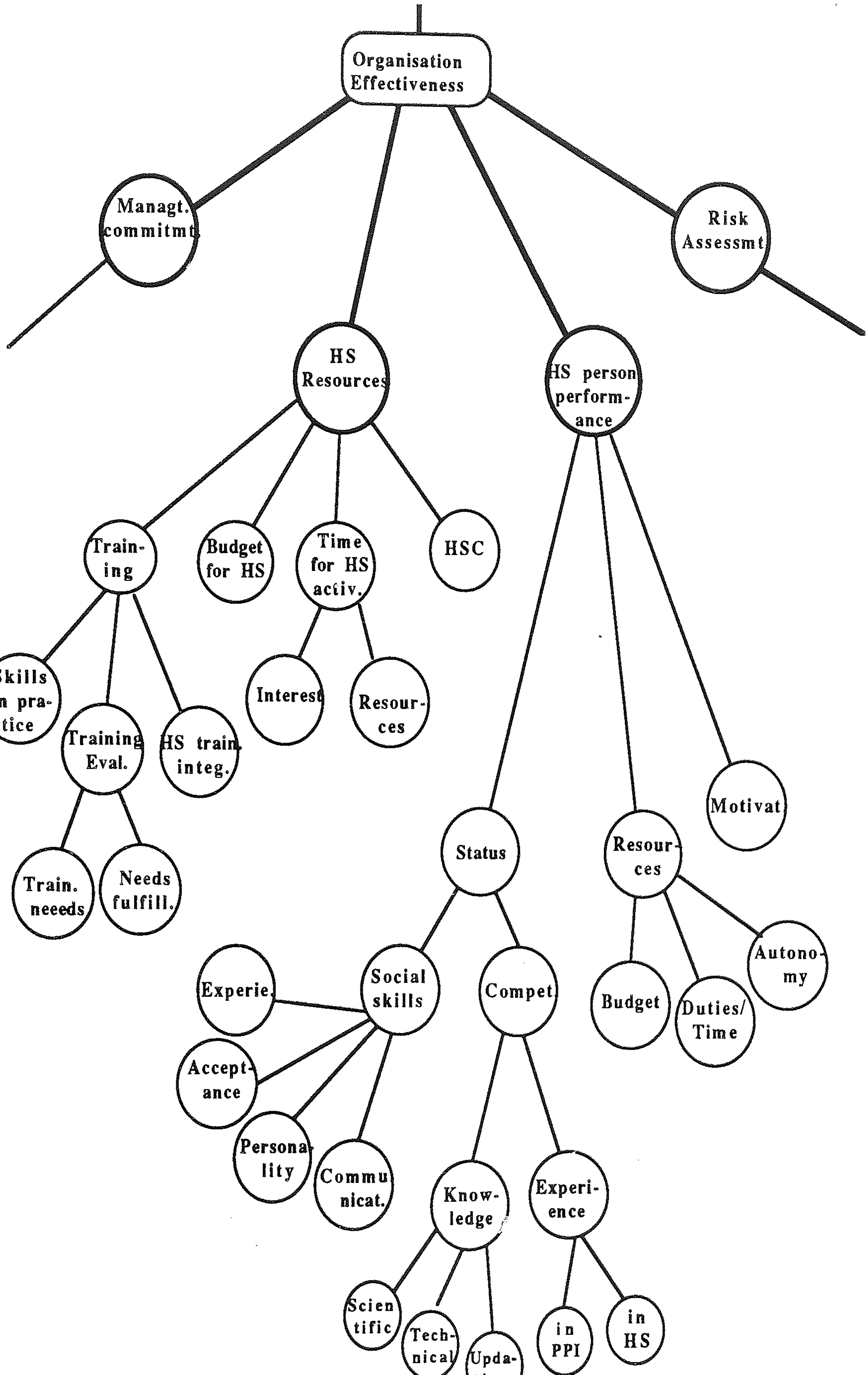


Figure 8.11 Decision tree for the Module ORGANISATION

A1 Training

Table 8.17
A11 Training/acquired skills into practice
Once people have been trained, how far would their training be put into practice? 1 Hardly at all? 2 Sometimes? 3 Always or often?
A12 Training evaluation
1 Training needs
Are training needs analysed: 1 Every year? 2 Every 2 years? 3 Hardly ever analysed?
2 Training fulfillment
Are the organisation training needs fulfilled: 1 Hardly? 2 Sometimes? 3 Always or often?
A13 Training integration
Does the job training of your employees include training on health and safety? How can these two trainings be described: 1 The two are carried out separate? 2 They are sometimes integrated? 3 They are always or often integrated?

Table 8.18
A2 Budget for HS (resources)
Is there a budget for health and safety? (Answer expected Y/N)

Table 8.19
A3 Resources available to employee representatives
A31 Interest in HS
How can the employee representatives' (eg safety reps/shop stewards) interest in health and safety be described: (Answer expected:) 0 Not interested? 1 Reasonably interseted? 2 Very interested?
A32 Activities of employee representatives
How can the HS activities of employee representatives be described: (Answer expected:) 0 None? 1 Poor? 2 Reasonable? 3 Good? This table needs to be used with Table 8.20

Table 8.20

Resources to employee representatives.

Interest in HS **HS Activities**	**0**	**1**	**2**
No	0	0	0
Poor	0	1	0
Reasonable	0	2	1
Good	1	3	3

Rating:

0 Unsatisfactory
1 Poor resources
2 Acceptable resources
3 Good resources

B Performance of the health and safety person

This context consists of considering:

- the status of the health and safety person,
- the resources this person has available, and
- the motivation of this person.

B1 Status

Considering the status, the main indicators HS experts look for to evaluate the status of the health and safety person are:

- competence and
- social skills.

B11 Social skills of HS person

Social skills evaluation depends on skills such as HS person's Experience, his/her Acceptance, Persuasion and Communication.

Table 8.21

B111 HS person's experience in HS

Get the information from the question asked in sub–module on competence of HS person, this is to be used in the computation of the social skills. How can the experienced be described:

0 No experience	0?
1 < one year	1?
2 1 to 3 years	2?
3 > 3 years	3?

B112 Communication skills

How can the ability of the HS person to communicate the health and safety message be described:

0 Bad communicator	0?
1 Reasonable communicator	1?
2 Good communicator	2?
3 Articulate communicator	3?

B113 Persuasion/influence for health and safety

How can the HS person's credibility on health and safety matters be described:

0 No credibillity	0?
1 Hardly credible	1?
2 Reasonably credible	2?
3 Very credible	3?

B114 Acceptance of HS person

How can the HS person's relation with other people be described:

0 Unpopular/troublesome	0?
1 Indifference	1?
2 Natural empathy	2?
3 Excellent	3?

Table 8.22

Social skills score

Social skills score = Communication + Persuasion + Accepance + Experience

<u>Rating:</u>

0 – 3 Very Poor
4 – 6 Poor
7 – 10 Good
11– 12 Very Good

B12 **Competence**

In turn competence can be assessed by considering the knowledge and experience of the health and safety person.

B121 **Knowledge**

To evaluate the adequacy of a HS person's knowledge, experts consider four factors:

- scientific and techical knowledge,
- the HS person's sources of information, and
- how the HS person updates his/her knowledge

Table 8.23

B121 HS person's knowledge	
B1211 HS person scientific/technical knowledge	
How can the scientific and technical knowledge of the person in charge of health and safety be described:	
	score
0 No knowledge and/or no competence	0
1 Limited knowledge and competence	1
2 General knowledge and fair competence	2
3 High degree of knowledge and competence	3
4 Full knowledge and competent	5
B1212 HS person's sources of information	
If the need for information on a health and safety aspect arises, what can the response of the HS person be? Would the HS person know how and where to get that information?	
	score
0 No	0
1 Takes a long time	1
2 HS person usually unsure about that	1
3 HS person has no difficulty if it exists	2
B1213 Up-dating of HS person's training/knowledge	
How is the HS person's knowledge up-dated? This information can be obtained from the answer to a previous question about the training the HSC members have.	
	score
0 No training	0
1 Little training	1
2 Last training was more than 2 years ago	2
3 Last training was less than 2 years ago	3

Table 8.24a
HS person's knowledge score
HS–person knowledge = Scientific/technical knowledge + Sources of information + Updating–knowledge
<u>Rating:</u>
0 – 3 Poor
4 – 5 Fair
6 – 7 Good
8 – 10 Excellent

B122 **HS person experience**

HS person's experience (working in the PPI) can be evaluated by considering his/her experience in:

- the PPI, and
- in health and safety.

Table 8.24b	
B1222 Experience in PPI	
How long has the person in charge of health and safety spent working in the PPI?	
	<u>score</u>
0 Never before	0
1 < one year	1
2 One to 3 years	2
3 > 3 years	3
B1222 **Experience in health and safety**	
How can the experience of the person in charge of health and safety be described?	
	<u>score</u>
0 No experience	0
1 < one year	1
2 One to 3 years	2
3– More than 3 years experience	3

B2 **Resources available to the health and safety person**

The evaluation of a HS person's resources depends on three parameters:

- budget,
- ratio duties/time available for health and safety activities, and
- autonomy in spending the resources available.

Table 8.25

B2 Resources available to HS person

B21 Budget for HS activities

Is there a budget allocated to the HS–person for HS activities?

	score
0 No budget	0
1 Financial situation hardly allows that	1
2 Can be made available if necessary	2
3 Available for use	3

B221 Time of HS person

How can the time the HS person spends on health and safety matters be described?

	score
0 Insufficient	0
1 Barely sufficient	1
2 Fairly sufficient	2
3 Widely sufficient	3

NB There is need here to look at HS person's performance (Accident module will be helpful)

B222 Duties of HS–person

What percentage of time does the HS person spend on health and safety?

(Please enter a number representing that %)

Qualification / % time	HS practitioner	Not HS practitioner
< 25	0	1
25 – 35	1	2
35 – 60	3	3
> 60	5	4

B23 Autonomy of HS–person

How can the HS–person person degree of autonomy to use the available resources to manage health and safety be described?

	score
0 No autonomy	0
1 Little	1
2 Reasonable	2
3 Total	3

B22 **HS person's motivation**

Table 8.26	
B22 HS person's motivation	
How can the motivation of the HS person be described? How can his/her attitude be described?	
	score
0 Indifferent	0
1 Needs incentive	1
2 Reasonably motivated	2
3 Highly motivated	3

C Management's Commitment

Interviews of and discussions with HS experts, revealed that the commitment of management to HS is often considered as depending on the commitment of managers at different levels eg top, middle and first line management. Figure 8.12 illustrates these levels and the indicators usually used when evaluating that commitment.

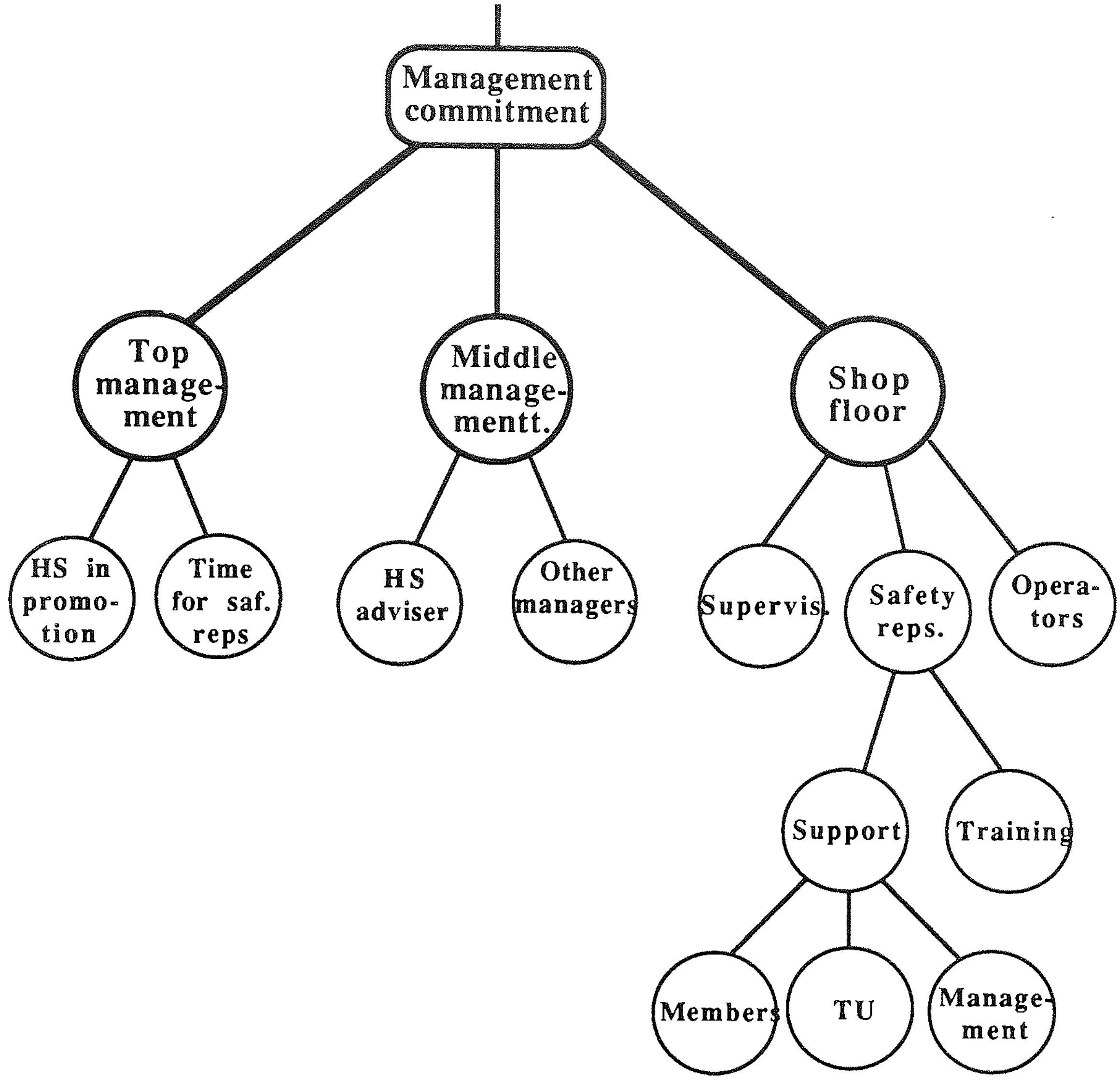


Figure 8.12 Decision tree for the module ORGANISATION - Manangement Commitment

The commitment of management depends therefore on the commitment to HS of the top and middle management and of those on the shop floor. The attitudes of management at one level affect and influence managements at other levels.

C1 **Commitment of top management**

HS experts rely on indicators (eg facts) when assessing top management's commitment to HS. Two of these indicators are whether people's HS performance is considered in promotion and whether there are adequate resources for employee representatives who are dealing with HS. As it has just been poited out, the attitudes of an individual (or group of individuals) affect those of other individuals. And so the resources may be initially available but if the employees' reps are not motivated then the resources may not be provided. Therefore a better assessment of the resources should depend on the assessment of the reps' activities and their motivation.

C1 Top management

Table 8.27	
C11 HS in Promotion	
Is HS performance of individual employees considered in promotion? At what level is it considered?	
	<u>score</u>
0 At no level	0 point
1 At some levels	1 point
2 At lower levels only	1 point
3 At top levels only	2 points
4 At all levels	3 points

C12 Resources for HS

Table 8.28	
C121 HS activities of employees' representatives	
How can the HS activities of the employees' reps be described?	
	<u>score</u>
0 None	0
1 Reasonable	1
2 Satisfactory	3
C121 Motivation of employee reps for HS	
How can the employee reps' interest in HS be described?	
	<u>score</u>
0 None	0
1 Reasonable	1
2 Good	3

Table 8.29

Evaluation of adequacy of HS resources made available by management

HS Activities / HS interest	None	Reasonabe	Satisfactory
None	0	0	0
Reasonable	0	1	3
Good	0	2	4

Rating:

0 – Very poor
1– Poor
2– Fair
3– Good
4– Very good

C2 Commitment of middle management

Discussions with and interviews of HS experts revealed that middle management's commitment seems to depend on the commitment of the HS person and other managers. The score for the HS person's commitment can be taken to be his/her motivation. The score for the other managers' commitment to HS depends on whether:

- managers are motivated for HS,
- attend HSC meetings,
- their contribution in the discussion of HS problems,
- the resources they make available to the safety and other employee representatives.

C3 **Shop floor commitment**

The shop floor's commitment to HS depends on the commitment of:

- first line management,
- health and safety representatives,
- shop floor workers.

C31 **Supervisors' commitment**

Indicators of first line managers' commitment to HS are their production results and their HS performance.

Table 8.30
C311 Supervisors commitment – Production
How can you describe you first line managers' production targets? 0 Hardly met (HM) 1 Met wth difficulty (MD) 2 Often met.
C311 Supervisors commitment – HS performance
How can the HS performance of your first line managers be described? 0 Unsatisfactory 1 Fair 2 Satisfactory 3 Good

Table 8.31 Evaluation of commitment of first line management to HS			
Production target / HS performance	HD	MD	OM
Unsatisfactory	0	0	0
Fair	0	1	1
Satisfactory	1	2	1
Good	2	3	3

C32 **Commitment of safety representatives**

The commitment of the health and safety representatives can be evaluated by considering their motivation which has been dealt with in C122. Indicators of their motivation are the support they get (eg from their members, the trade union (TU) and management) and the training they have. It is a complex situation and a whole expert system can be developed just on this problem area alone.

8.11.6 Conclusion on organisation

Although this approach was working well (despite the subjectivity of the scores attributed), it was difficult to provide explanation and help facilities to the user. To provide those facilities, there was a need to represent the reasoning knowledge using production rules and hence the need to restructure the knowledge. Figure 8.13 shows a graphic description of the architecture of this module in the system's context.

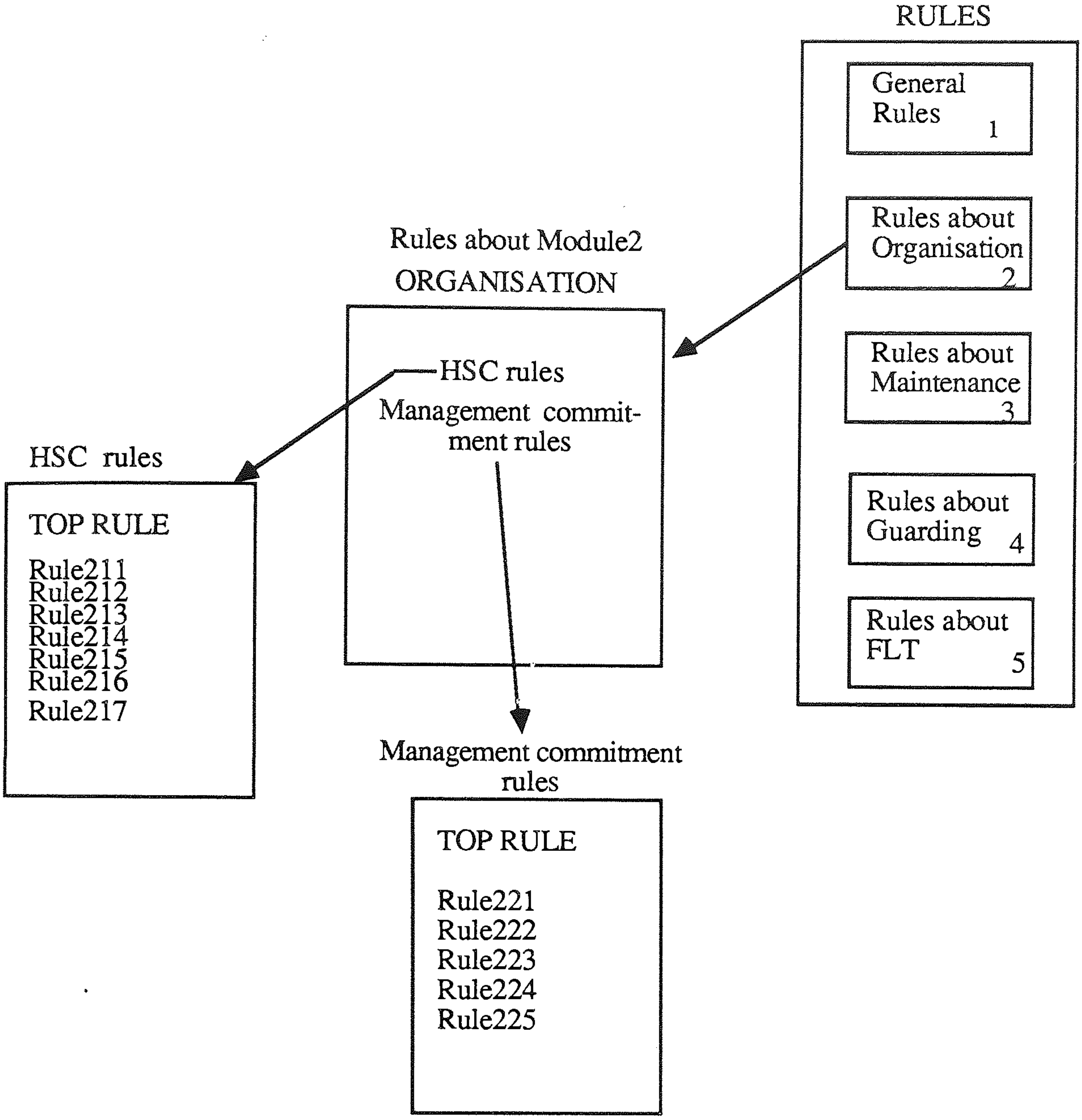


Figure 8.13 HASMAP's organisation module: the rules

8.12 System validation

A new preventive approach is adopted in HASMAP. This approach was described in Section 7.2 of Chapter 7 and consists of the tasks a preventive expert system such as HASMAP should undertake. Those tasks are:

1 collection of all data concerning the situation and problems,

2 examination of those data,

3 isolation of causes of problems,

4 verification that the causes identified are the true causes by setting up validation programmes (ie tests)

5 evaluation of the effectiveness of the programmes.

Using this approach in systems like HASMAP places some constraints on the validation process. Those constraints are due particularly to the last two steps (ie 4 and 5) of this approach because it takes time – especially with the soft arrangements like selection, training, motivation etc – before attributing any improvement in the prevention of accidents and ill health to one particular control measure. For example, HASMAP may recommend that behaviour sampling should be carried out, but there is no guarantee that this recommendation would improve health and safety management. This is difficult because of:

– the multi–causal nature of health and safety probems referred to in Chapter 7,

– it takes time to notice any changes,

– of effects of previous preventive measures and conditions.

The system can, however, include a module which evaluates its prior recommendations or arrangements that are in place and could therefore evaluate the effects of recommendations made as a result of a safety sampling study.

8.12.1 A diagnostic, planning and training tool

HASMAP can be regarded both as a diagnostic and planning tool.

It is a diagnostic tool because it can be used to diagnose existing deficiencies which have not resulted in an accident or ill health. As a planning tool, HASMAP can be used to advise the user on what precautions and arrangements need to be in place to control existing hazards and prevent creating new ones.

When solving a problem, HASMAP is actually trying to identify problem areas in an organisation at a given point of time and in given circumstances and therefore it should be used when conditions have changed. For example, if the company decides to buy a new injection moulding machine, the system should inquire about the relevant facets of this new situation from a health and safety viewpoint and advises the user on the sorts of issues needing attention.

HASMAP can be used as a training tool where the user can learn how decisions are made and problems solved. The consultation part provides a health and safety data base from which the user can get useful information and knowledge.

8.12.2 Criteria of acceptability

The acceptability of an expert system depends on many parameters particularly the speed with which it solves problems, its knowledge, its reasoning process, its user interface (eg explanation and help facilities) and the acceptability of its recommendations. As it is the case with human experts, HASMAP should give its diagnosis at the end of a session and should, immediately after that, recommend appropriate arrangements and how to implement them.

8.12.3 System evaluation

The system's performance can be evaluated by comparing the results from different departments of a company where the system was used. A useful comparison can be made between departments which have used HASMAP and those which have not.

Another criterion for the evaluation of the system is to compare its diagnosis and recommendations with those of human experts.

8.13 Conclusion

A framework of HASMAP has been drawn and modules have been tested. This Chapter has determined the strategies needed for building more health and safety management programs and identified certain pitfalls. The existing HASMAP's modules need to be revised, improved and linked together for effective diagnosis and assessment of health and safety problems. More modules need to be built around the existing ones in order to prepare comprehensive health and safety policies.

HASMAP could be integrated in a more complex system for the management of health and safety as illustrated by the Figure 8.14.

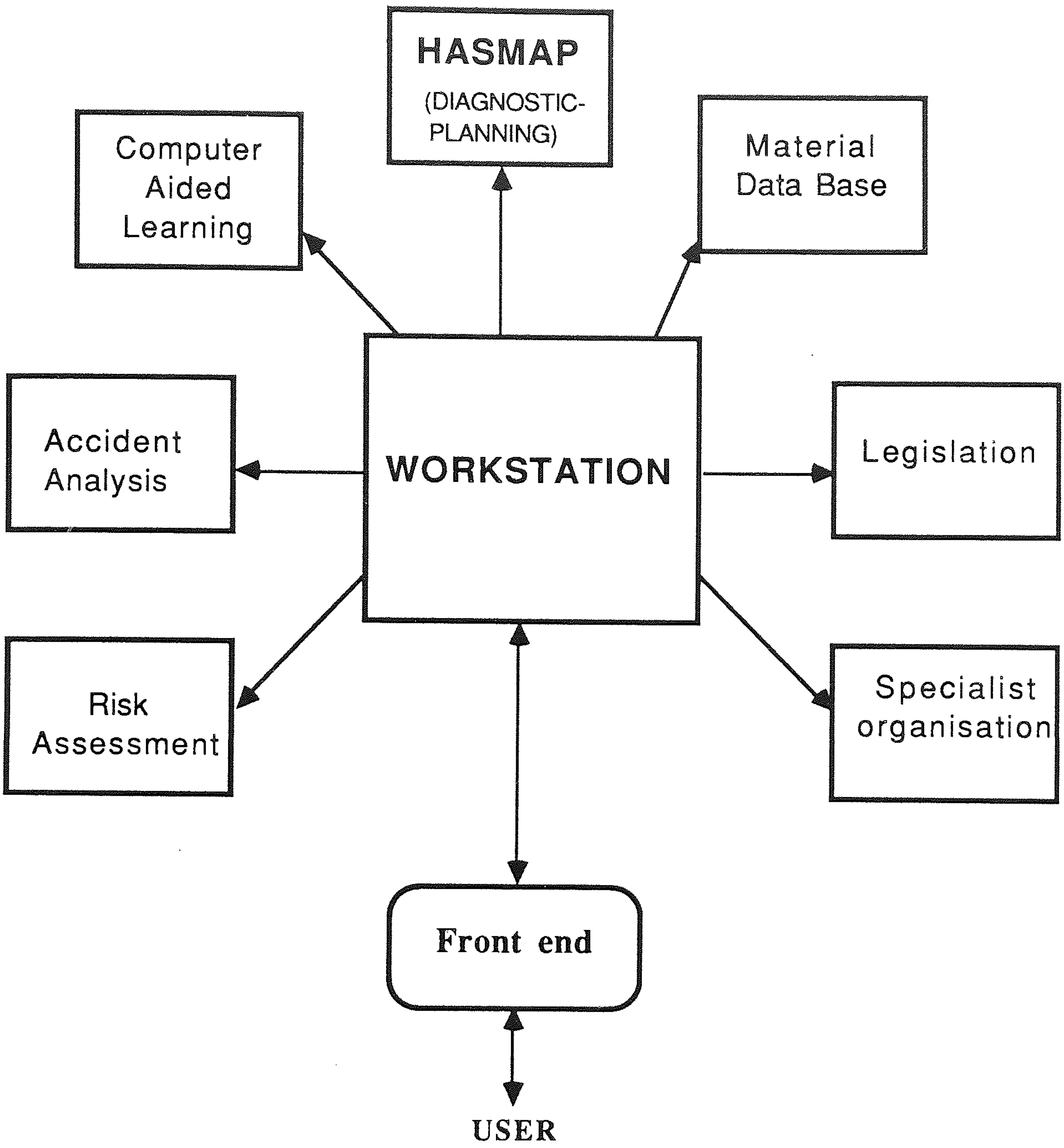


Figure 14 Integration of HASMAP with other HS Management Programs.

CHAPTER NINE

Conclusion

9.1 Conclusion

This project has investigated and analysed the approaches adopted by health and safety experts to solve problems and to make decisions. Frameworks were developed and the different case studies show that experts do follow them when solving health and safety problems. It was also shown that the problem-solving task of HS experts is diagnostic in nature and can be captured by models and frameworks. In the present thesis, models and frameworks were developed. SHATER (Situation knowledge, Hazard identification, Arrangements determination, Testing of arrangements and Recommendations) was developed to model the problem-solving task of health and safety experts. ERIM relating to the testing of arrangements (ie their Existence, Requirement, Implementation and Monitoring) is another model developed to describe the phases of an arrangement testing. The framework SECT was also developed to show how HS experts go about detecting symptoms and analysing findings when testing arrangements. The was also a need to develop statistical models for a better use of HS information in the process of problem-solving and decision making.

As in medicine, it was shown that health and safety expertise can best be conceptualised as consisting of a variety of domains of expertise. Consequently, there can be a multitude of expert systems developed in health and safety. The boundaries of each domain can be determined for an expert system to be developed.

9.2 Health and safety problem–solving

In order to prepare and implement a health and safety policy, health and safety experts have already pointed out the need to know the organisation under study and this is certainly very important at the recommendation and implementation phase. The health and safety expert should recommend feasible and implementable control measures.

HS experts have already started setting criteria for the selection of certain arrangements such as machinery safeguards and similar criteria policy should be extended to all other arrangements.

Clients have shown more credibility in HS recommendations when the protection sought is tangible and clear. The recommended arrangements should be determined according to a cost–benefit analysis and should:

- control the risk,

- be engineering/hardware oriented to avoid placing any extra burden on the human element,

- in the case of the soft issues like training, supervision, information, be dealt with thoroughly. They should be considered as necessary arrangements for adequate implementation and monitoring of the hardware arrangements. They should not be recommended as a first–line arrangement but should always be calle upon only as a back–up,

- more needs to be worked on so that more conceptualisation of the health and safety knowledge is done eg for each activity, ingredients are determined and relevant hazards are related to those activities and ingredients. Control measures should be associated to hazards and more criteria are set as to the evaluation of existing control measures.

Although experts were examined solving more or less similar problems, the preliminary results (as discussed particularly in Section 6.6.8) show that experts have adopted more than one style:

- focusing deeply on each problem area and uncovering the problem causes,

- engaging in a methodical and systematic exploration of a variety of aspects of a situation,

- probing a number of different directions as if the expert were hoping to uncover some important fact almost by chance,

- sequentially looking at a situation eg what activities are carried out, who is doing what, when had the problem started, how had it progressed etc.

9.3 Expert systems

The development of expert systems for the management of health and safety is possible and should be geared towards areas where human health and safety experts exercise their cognitive skills.

Examples of cognitive tasks for which health and safety management systems are suited include evaluating permit–to–work (PTW) systems and monitoring of maintenance. A wide range can be developed but what needs to be done is to clearly define the task of the system eg diagnostic, planning, etc.

Expert systems can also be developed to advise on health and safety legislation requirements, on investigating accidents, etc. and in order to develop such systems, particular emphasis should be on:

- defining the boundaries of the system's expertise,
- developing a framework eg a model to represent the human problem–solving strategies, and
- choosing the right programming tool.

CHAPTER TEN

Future Work

The findings from the present studies of health and safety experts are very promising for the use of Artificial Intelligence techniques for developing more expert systems in health and safety.

The time given for this project does not allow to investigate the many issues related to expert system development to a complex field such as health and safety. Further research is needed to investigate these issues.

There is a large amount of health and safety data which can be used usefully to develop expert systems if it is collected with for this purpose in mind.

HASMAP needs to be tested and improved. Systems such as HASMAP can then be integrated in an organisation's automation network so that they can use the available data for effective monirirng of health and safety.

A knowledge acquisition interface needs to be developed to enable field experts to add more modules to the existing ones.

More systems can be developed in specific areas and there is a need to investigate and determine the symptoms/indicators HS experts use in diagnosing problems and to compile a list of the symptoms-problem areas relationships along the SECT framework. It will also be interesting to investigate whether other tests like those in ERIM are used by HS experts and whether they differ from one domain to another eg agriculture, nuclear industries.

Studies should be carried out to determine how experts describe their problem solving strategies.

REFERENCES

Addis TR (1987) 'The boundaries of knowledge'
in Newsletter of The British Computer Society Specialist Group on Expert Systems
N° 18 August 1987

ACGIH (1987) 'Microcomputer applications in occupational health and safety'
American Conference of Governmental Industrial Hygienists
Lewis Publishers Inc. 1987.

American National Transportation Safety Board (1971) 'Pipeline Accident Report'
in Johnson WJ (1980)

American Society of Safety Engineers (1972) ' Scope and functions of the professional Safety position'
in Johnson WG (1980) 'MORT Safety Assurance Systems'
Marcel Dekker, Inc USA.

Barstow DR, Aiello N, Duda RO, Erman LD, Forgy CL, Gorlin D, Greiner RD, Lenat DB, London PE, McDermott J, Nii HP, Politakis P, Reboh R, Rosenschein S, Scott AC, Van Melle W, and Weiss SM (1983) 'Languages and tools for knowledge engineering'
in Hayes-Roth F et al (1983) 'Building expert systems'

Bennett JS (1984) 'ROGET: Acquiring the conceptual structure of a diagnostic expert system'
in IEEE proceedings workshop on principles of knowledge based systems IEEE computer society December 1984 pp 83-88

Bensiali AK (1986) 'An expert system for the development of health and safety policies/Risk assessment'
in the 17th Annual Chemical Engineering Departmental Symposium.
Friday 4th July and 7-8 July 1986

Bensiali AK (1987a) 'One-day Workshop on Knowledge Elicitation from Accident Investigation Experts'
HASTAM Ltd Aston science park and Health & Safety Unit Aston University Birmingham 28 July 1987.

Bensiali AK (1987b) 'Knowledge elicitation for HASMAP: Interview of two experts on HS in Maintenance'
Health and Safety Unit - Aston University Birmingham 1987.

Bensiali AK (1987c) 'Knowledge elicitation for HASMAP: Interview on Organisation module'
Health and Safety Unit - Aston University Birmingham 1987.

Bensiali AK, Booth RT and Glendon AI (1987) 'Computer-aided safety management'
in the Plastics and Rubber Institute (PRI) International Conference Health and Safety in the Plastics and Rubber Industries
University of York 15-16 September 1987 England.

Bobrow DG and Winograd T (1977) 'An overview of KRL, a knowledge representation language'
in Cognitive science **1** pp3-46.

Booth RT (1976) 'Machinery guarding'
in Engineering December 1976 Technical File N^{O} 36 pp. 1 - 8

Booth RT (1984) 'Cost-effective safety management'
in the Plastics and Rubber Institute (PRI) Conference Health and Safety in the Plastics and Rubber Industries II 16 and 17 April 1984
University of York England

Brachman RJ, Fikes RE and Levesque HJ (1983) 'KRYPTON: a functional approach to knowledge representation'
in IEEE computer September 1983

Brady M Gerhardt LA and Davidson HF (1984) 'Robotics and Artifial Intelligence'
NATO ASI Series. Series F: Computer and System Sciences Vol.11

Bratt, et al v. Western Airlines 155 Federal Reporter 2nd Series 850, 853-854 (10th Cir. 1946)
in Human Factors Feb 1972 pp. 17 - 23

British Plastics Federation (1978) 'Code of practice for the safeguarding of horizontal injection moulding machines'
Publication N^{O} 238/1 June 1978

British Plastics Federation (1982) 'Health at Work' a BPF occupational hygiene publication'
5, Belgrave Square London SW1 1982.

Bonnet A (1985) 'AI Promise and performance'
Prentice-Hall International UK Ltd.

Brachman RJ (1977) 'What's in a concept: Structural foundations for semantic networks'
in Int J Man-Mach Stud **9** pp.127-152

Buchanan BG, Barstow D, Bechtal R, Bennett J, Clancey W, Kulikowski C, Mtichell T, and Waterman DA (1983) 'Constructing an expert system'
in Hayes-Roth et al (1983) 'Building Expert Systems'
Addison-Wesley Publishing Company, Inc 1983.

Buchanan BG and Duda RO (1983) 'Principles of Rule-based expert systems'
in Advances in computers Vol 22 pp. 163-210 1983.

Buchanan BG et Al (1983) 'Constructing an expert system'
in Hayes-Roth et al (1983).

Buchanan BG and Shortliffe EH (1984) 'Other representation frameworks'
in Buchanan BG and Shortliffe EH (1984) 'Rule-based expert systems: the MYCIN experiments of the Stanford Heuristic Programming project'
Addison-Wesley Publishing Company 1984

Buchanan BG and Feigenbaum EA (1978) 'Dendral and meta-Dendral: their applications dimensions'
in Artificial Intelligence 11

Buchanan BG, Shortliffe EH (1984) 'Rule-based expert systems: The **Mycin** experiments of the Stanford Heuristic Programming Project'
Addison-Wesley Publishing Company 1984

Cameron K (1978) 'Measuring organisational effectiveness in institutions of higher education'
in Administrative Science Quarterly 23 December 1978 pp. 604-629

Campbell JP (1977) 'On the nature of organisational effectiveness'
in Goodman PS and Pennings JM (1977) 'New perspectives on organisational effectiveness'
Jossey-Bass, San Francisco 1977, pp.13-55

CCOHS (1987) 'Occupational health and safety information'
in FindIt CCINFO disc A87-1
Canadian Centre for Occupational Health and Safety
250 Main St. East, Hamilton, Ontario L8N 1H6

Cox P (1984) 'How we built Micro Expert'
in Forsyth R (1984) op cite

Crawford RJ (1985) 'Plastics & Rubbers - engineering design & applications
Netherwood Dalton & Co Ltd Huddersfield 1985

Cutler P (1979) Problem Solving in clinical medicine. From data to diagnosis.
Williams and Wilkins, Baltimore 1979

Davis R (1986) of American Association of AI Quoted in Waterman DA (1986) 'A guide to expert systems' p.142
Addison-Wesley Publishing Company 1986

DOE (1975) 'The Flixborough disaster: A report of the Court of Inquiry'
HMSO 1975.

Drake CD & Wright FB (1983) Law of health and safety at work: the new approach
London Sweet & Maxwell

Modern Plastics (1969) 'A modern plastics survey report : Processors face growing safety problems'
in Modern Plastics May 1969 pp.68-70

Editors of Plastics design & processing (1970) 'Safety in the plastics processing plant'
in Plastics design & processing June 1970 pp. 26-30

Editor of PLastics Technology (1979) 'Safety and Health Regulations: Government v. Plastics processors -An assessment. A plastics Technology special report
in PLastics Technology December 1979 pp.43-80

Else D (1980) 'Let's put knowledge into action'
in Occupational Health October 1983 pp. 461-464

Elstein AS, Shulman LA and Sprafka SA (1978) 'Medical Problem Solving: an analysis of clinical reasoning'
Harvard University Press Massachusset 1978.

Erman LD, London PE and Fickas SF (1981) 'The design and an example use of HEARSAY-III'
in Proc.IJCAI-81 pp.409-415

Fagan LM, Kunz KJ, and Feigenbaum EA (1979) 'Representation of dynamic clinical knowledge: measurement interpretation in the intensive care unit'
in Proceedings IJCAI-79 pp. 260-262 1979.

Fain J, Hayes-Roth F, Sowizral H and Waterman DA (1982) 'Programming in ROSIE: an introduction by means of examples'
Technical Report N-1646-ARPA. Rand Corp. Santa Monica, California.

Feinstein AR (1973a) 'The domains and disorders of clinical macrobiology'
in Yale Journal of Biology and Medicine **46** pp 212-232

Feinstein AR (1973b) 'The strategy of intermediate decisions'
in Yale Journal of Biology and Medicine **46** pp 264-283

Feinstein AR (1974) 'The construction of clinical algorithms'
in Yale Journal of Biology and Medicine **1** pp 5-32

Feigenbaum EA (1977) 'The art of Artificial Intelligence: themes and case studies of knowledge engineering'
in the 5th International Joint Conference on Artificial Intelligence IJCAI-77 Vol 2 pp 1014-1029

Feigenbaum EA (1982) 'Knowledge engineering for the 1980s'
Stanford University 1982

Feigenbaum EA and McCorduck P (1984) 'The fifth generation: Artificial intelligence and Japan' computer challenge to the world'
Addison Wesley Publishing Company London 1984 2nd Edition.

Feigenbaum EA (1985) 'Themes and case studies of knowledge engineering'
in Expert systems User September 1985

Forgy C and McDermott J (1977) 'OPS: a domain-independent production system language'
in Proceedings IJCAI-77 pp. 933-939

Forsyth R (1984) 'Expert systems: Principles & case studies'
Chapman & Hall Ltd London 1984

Fox J (1983) 'Intelligent knowledge based systems and man-machine interaction: Final Report. Alvey IKBS Architecture Study.

Gale J and Marsden P (1983) Medical Diagnosis, from Student to Clinician
Oxford University Press 1983

Gilbert GN (1980) 'Being interviewed: a role analysis'
in Social Science Information **19**, 2, 1980 pp.227-236

Greiner R and Lenat DB 1980) 'A representation language.'
in Proceedings AAAI-80 pp. 165-169

Hamilton M (1979) 'No mere scrap 'scarp of paper' '
in Occupational safety and health June 1979 pp.10-15

Harmon P and King D (1985) 'Artificial Intelligence in Business Expert systems'
John Wiley & Sons, Inc 1985.

HASTAM (1987) 'CHASE: Complete Health And Safety Evaluation'
Health and Safety Technology and Management Ltd - Aston Science Park in Birmingham 1987

Health and Safety at Work etc. Act 1974 Chapter 13 London HMSO 1977

Health and Safety Executive (1976) 'Health and safety manufacturing & services industries'
HMSO 1976 p.3

Health and Safety Executive (1978) 'Canvey: An investigation of potential hazards for operations in the Canvey Island/Thurrock area.
HMSO 1978.

Health and Safety Executive (1981) 'Canvey A 2nd Report:
A review of potential hazards from operations in the Canvey/Thurrock area 3 years after publication of the Canvey Report'
HMSO 1981.

Health and Safety Executive (1982) 'Health and safety statistics 1980'
HMSO 1982

Health and Safety Executive (1983 a) 'Plastics, leather and footwear - Health and safety 1976-1982'
HMSO 1983

Health and Safety Executive (1983 b) 'Effective policies for health and safety.'
Second impression HMSO 1983

Health and Safety Executive (1985a) 'Deadly maintenance: A study of fatal accidents at work'
HMSO, first published 1985.

Health and Safety Executive (1985b) 'Monitoring safety: an outline report on occupational safety and health' by the Accident Prevention Advisory Unit of the HSE.
HSE Occasional Paper Series OP9 HMSO 1985.

Health and Safety Executive (1986) 'Our health and safety policy statement'
HMSO 1986.

Heath ED (1985) 'The safety and health policy within the organisation'
<u>in</u> Hazard prevention September/October 1985 pp.30-32

HMSO (1965) 'Report of the investigation of the crane accident at Brent Cross, Hendon, on 20th June 1964'
HMSO 1965.

HSIB (1986) 'Computers in safety'
<u>in</u> Health and Safety Information Bulletin 123, 4 March 1986 PP. 2 - 5.

International Loss Control Institute (1984) International Safety Rating and Physical Conditions Guide for Inspections
ILCI Publishing Highway 78, PO Box 345, Loganville, Georgia 30249 USA.

Johnson WG (1980) 'MORT Safety Assurance Systems'
Marcel Dekker, Inc USA.

Johnston R (1985) 'Shells are not enough for Plessey'
<u>in</u> Expert Systems User September 1985

Jordan and Sons Ltd (1987) 'Britain's Plastics Industry'
Publications of Jordan and Sons Ltd 1987

Kassirer JP and Gorry GA (1985) 'Clinical problem solving: a behavioural analysis'.
<u>in</u> Reggia JA and Tuhrim S (1985) 'Computer-Assisted Medical Decision Making'
Vol 2 Publ. Sringer-Verlag New York Inc. 1985

Kjellen U (1984) 'Occupational Accident Research: Proccedings of the International Seminar on Occupational Accident Research, Saltsjobaden, Sweden 5-9 September 1983'
Elsevier Science Publishers BV 1984.

Kletz T (1985) 'Lost knowledge'
in Health and Safety at Work 1985

Kletz T (1985) 'Layered accident investigation'
in Health and Safety at Work January 1985 p.8

Lancianese FW (1985) 'Safety turnaround at TVA'
in Occupational Hazards February 1985 pp. 74-77

Lenat D (1983) 'EURISKO: A program that learns new heuristics and domain concepts.'
in Artificial Intelligence, **21**

Leopold JW and Beaumont PB (1982) 'Safety policies - how effective are they?'
in Occupational Safety and Health October 1982 pp 24-26

Lippert FG (1947) Accident prevention administration
New York: Mc Graw Hill book company Inc p.96

McCormick CT (1945) Some observations on the opinion rule and expert testimony
in Texas Law Review, 1945, **23** pp. 109- 136

Milby RV (1973) 'Plastics Technology'
1973

Mittal S and Clive LD (1984) 'Knowledge acquisition from multiple experts
in Workshop on proceedings of knowledge based systems
December 3-4 1984 Denver Colorado Sponsored by IEEE Computer Society.

National Computer Centre (1985) 'Expert systems starter pack'
NCC Manchester 1985

NSC (1966) National Safety Council Industrial Data Sheet 585 'Management policies on occupational safety'
Chicago, Illinois: Narional Safety Council, p.1

Parkin A (1980) 'Systems analysis'
Edward Arnold Publishers Ltd 1980

Peirce CS (1878) 'Illustrations of the logic of science, 6th paper- deduction, induction, hypothesis.
in The Popular Science Monthly **1**, pp.470-482.

Petersen D (1978) 'Techniques of safety management'
New York Mc Graw Hill 1978 (2nd Edition).

PRI (1984)
in Plastics and Rubber International Feb 84 Vol 9 no 1 p.8

Pople HE Jr (1982) 'Heuristic methods for imposing structure on ill-structured problems: the structuring of medical diagnosis'
<u>in</u> Szolovits P (1982) Artificial Intelligence in medicine
Westview Press, Boulder, CO 1982.

Power DJ (1985) 'Using symptoms, problems and treatment framework to structure knowledge for management expert systems'
<u>in</u> 'Knowledge Representation for Decision Support Systems'
by Methlie LB and Sprague RH
Elsevier Science Publishers BV (North Holland) IFIP, 1985

PPITB (1985) Report and Statement of accounts for the year ended 31st March 1985.

Price JL (1968) 'Organisational effectiveness: an inventory of propositions'
Richard D Irwin Inc. Homewood IL, 1968.

Reboh R (1983) 'Knowledge engineering techniques and tools for expert systems'
Linkoping studies in science and technology, Dissertation N° 71 Software Systems Research Centre, Linkoping University, S-581 Linkoping, Sweden.

Report of the Robens Committee (1972) Safety and health at work
HMSO 1972, Cmnd 5034

Shortliffe EH (1976) 'Computer based medical Consultations: MYCIN'
New York: American Elsevier 1976.

Shortliffe EH (1983) 'Hypothesis generation in medical consultation systems'
<u>in</u> Artificial Intelligence Approaches, <u>Proc. MEDINFO 83</u>, 1983 pp. 480-483

Slatter PE (1985) 'Cognitive emulation in expert system design'
<u>in</u> Knowledge Engineering Review **1** (2) pp. 28 -40

Society of the Plastics Industry (1973) 'Plastics industry safety handbook'
Cahners Publishing Company, Inc USA 1973.

Steers RM (1975) 'Problems in the management of organisational effectiveness'
Administrative Science Quarterly **20** (1975) pp. 548-58

Steers RM (1977) 'Organisational effectiveness: A behavioral view'
Goodyear Pblishing Co, Inc Santa Monica, CA, 1977

Stevenson AW (1980) 'A guide to action - planned safety management'
Printed by Cradeley Printing Co Ltd, Cradeley Heath, Warley West Midlands.

Szolovits P, Hawkinson LB and Martin WA (1977) 'An overview of OWL, a language for knowledge representation.'
MIT/LCS/TM-86, Laboratory of Computer Science, Massachusetts Institute of Technology

Warren D & L Orchard (1982) 'An evaluation of written safety policies in use in polymer processing companies'
The Rubber & Plastics Processing Industry Training Board Decembre 1982

RPPITB (1976) 'Guidelines for formulating a safety policy'
RPPITB The Rubber & Plastics Processing Industry Training Board Brentford March 1976

van Melle W (1979) 'A domain-independent production-rule system for consultation programs'
in Proc. IJCAI-79 pp. 923-925

Waterman DA (1986) 'A guide to expert systems'
Addison-Wesley Publishing Company 1986

Weiss SM and Kulikowski CA (1979) 'EXPERT: a system for developing consultation models'
in Proc. IJCAI-79 pp. 942- 947

Weiss SM and Kulikowski CA (1984) 'A Practical guide to designing expert systems'
Publishers: Chapman and Hall London 1984.

Edwards v. National Coal Board [1949] 1 K.B. 704 at page 712

Marshall v. Gotham [1954] A.C. 360 at page 373

GLOSSARY

1 Computer terminology

Algorithm	A formal precedure guaranteed to produce correct or optimal solutions
Artificial intelligence	The part of computer science concerned with developing intelligent computer programs.
Backward chaining	An inference method where an expert system starts with the conclusion it wants to prove and establishes the facts it needs to prove that conclusion.
Certainty factor	A number that measures the certainty or confidence one has that a fact or rule is valid.
Clause	A hypothesis in the IF part (antecedent) of a rule in a rule-base system
Consequent	A conclusion (action) in the THEN part of a rule.
Context	A domain entity considered as a hypothesis and investigated by a domain expert. May also mean an object (variable) forming part of the context tree.
Data base	The set of facts, assertions, and conclusions used to match against the rules in a rule-based system. In computing this has a broader meaning.
Data structure	The organised form in which grouped data items ae held in the computer (eg lists, trees, tables, strings).
Domain expert	A person who through years of training and experience has become proficient at problem solving in a particular domain.
Domain knowledge	Knowledge about the problem domain; eg knowledge about medicine in MYCIN an expert system for diagnosing blood infectious diseases and meningitis.
Expert system or Knowledge-based system	A program in which th edomain knowledge is explicit and separate from the program's other knowledge.
Forward chaining	An inference method where rules are matched against facts to establish new facts (see backward chaining).

Frame	A knowledge representation method that associates features with nodes representing concepts or objects. The features are described in terms of attributes (called slots) and their values.
Heuristic	A rule of thumb or simplification that limits the search for solutiopns in domains that are difficult and poorly understood.
Inference engine	That part of an expert system that contains the general problem solving knowledge.
Interpreter	The part of the inference engine that decides how to apply the domain knowledge.
Knowledge	The information a computer program must have to behave intelligently
Knowledge base	The portion of an expert system that contains the domain knowledge
Knowledge engineer	A person who designs and builds an expert system
Knowledge representation	The process of structuring knowledge about a problem in a way that makes the problem easier to solve.
Metaknowledge	Knowledge about the use and control of domain knowledge in an expert system.
Rule	A formal way of specifying a recommendation, directive, or a srategy, expressed as IF *premise* THEN *conclusion* or IF *condition* THEN *action*.
Scheduler	The part of the inference engine that decides when and in what order to apply different pieces of domain knowledge.
Search	The process of skillfully looking through the set of possible solutions to a problem so as to efficiently find an acceptable solution.
User interface	The components of an expert system that allows bidirectional communication between the expert system and the user.

2 Health and safety terminology

Job safety analysis	Review of adequacy of operations, equipment and building safety.
Manifestation/indicator	Symptom indicating an abnormal situation in a person, organisation, ...
Permit to work system	A document used to control the conduct of activities by specifying the work to be done, defining the responsibilities of individuals, by eliminating/controlling the hazards and ensuring proper monitoring after the work has been done.
Plant safety review	Review of adequacy of operations, equipment and building safety.
Safety audit	A management tool used to examine and assess in detail the standards of all facets of a particular activity. Consists of 5 elements: identification, assessment, selection of measures, implementation and monitoring.
Safety inspection	A scheduled inspection of a unit.
Safety sampling	A specific application of safety inspection designed to measure accident potential. A systematic sampling of particular dangerous activities, processes or/and areas.
Safety policy	A document which all employers of 5 or more people are legally required to prepare, implement and monitor (HSWA 1974, Section 2(3)).

3 Abbreviations

BPF	British Plastics Federation
CBI	Confederation of British Industries
FA 1961	Factories Act 1961
GMBATU	General, Municipal, Boilermakers and Allied Trade
HS	Health and safety
HSE	Health and Safety Executive
HSC	Health and Safety Commission
HSWA	Health and Safety at Work Act etc, 1974 Chapter 34
IOSH	Institution of Occupational Safety and Health
MORT	The Management Oversight and Risk Tree
NSC	National Safety Council
PPITB	Plastics Processing Industry Training Board
PTW system	Permit to work system
RPPITB	Rubber & Plastics Processing Industry Training Board
SOP	Safe Operating Procedures
TLV	Threshold Limit Value(s)

APPENDICES

APPENDIX 1

BPF Data Sheet

Subjects typically covered by data sheets for substances used in the plastics industry (BPF 1982)

1. Introduction

2. Potential Hazards
   - 2.1 Toxicity
   - 2.2 Inhalation
     - 2.2.1 Fume Evolution
     - 2.2.2 Power grades
   - 2.3 Ingestion
   - 2.4 Physical contact
   - 2.5 Fire
     - 2.5.1 Ignition
     - 2.5.2 Products of combustion
   - 2.6 Dust

3. Recommended Precautions for Transportation, Handling and Storage
   - 3.1 Health and hygiene considerations
     - 3.1.1 Granules
     - 3.1.2 Powders
     - 3.1.3 Working and storage areas
     - 3.1.4 Materials handling
     - 3.15 Ventilation
     - 3.1.6 Skin contact
     - 3.1.7 Smoking, eating, drinking
     - 3.1.8 Cautionary notices and safety equipment
   - 3.2 Fire
   - 3.3 Explosion
   - 3.4 Storage
     - 3.4.1 Bag storage
     - 3.4.2 Bulk storage

4. Recommended Additional Precautions for Compounding, Processing and Fabrication
   - 4.1 Effect of heat
   - 4.2 Ventilation
   - 4.3 Protective clothing
   - 4.4 Fire
   - 4.5 Melt processing
   - 4.6 Other precautions
     - 4.6.1 Room temperature processing and handling
     - 4.6.2 Cutting and granulating

5. Recommended first aid treatment
   - 5.1 Eye injuries
   - 5.2 Inhalation of fumes
   - 5.3 Burns
   - 5.4 Medical attention

6. Waste disposal

7. References and sources of information
   - 7.1 References
   - 7.2 Sources of information

APPENDIX 2
Project Questionnaire

PLANT, PROCESSES AND MATERIALS

1 Plant or Company NAME: ....

2 a) On how many sites is the plant distributed? ....

b) Please specify the type of activities carried out on each site:

....

....

....

3 Who is the person with the major responsibilities for practical day to day management of Health and Safety (Please tick one box)

☐ Health and safety practitioner (please specify title) ....

☐ Works Manager

☐ Personnel Manager

☐ Other (please specify) ....

☐ No-one

4 Does he/she have other responsibilities?

☐ Yes What are they: ....

....

....

☐ No

5 Please list the final products by total sales, volume:
(eg polythene sheets, telephone sets, pipes, etc)

a) ....

b) ....

c) ....

d) ....

....

....

6 What are the main raw materials used?

Product	Main Material Used	Form
(eg telephone sets)	(ABS, PVC)	(Granules)

a) ....

b) ....

c) ....

d) ....

e) ....

7 What are the company's main activities?
(eg Extrusion, moulding - injection/blow/compression, vacuum forming, printing, assembling, storage)

a) ....

b) ....

c) ....

d) ....

e) ....

8 What ingredients are used and which can be a hazard?
(Toxic, fire, corrosion, environmental hazards)
(eg stabilisers, plasticisers, fillers, lubricants, impact modifiers, processing aids ...)

[Please list them in order of importance of hazard (from most to least serious hazard)]

Ingredient	Hazard

1 ....

2 ....

3 ....

4 ....

....

9 Have you got a plan of the plant?

☐ Yes (Please enclose it)

☐ No (Please sketch it on the sheet provided)

EMPLOYEES

10 How many employees does the company employ altogether?

Male ....

Female ....

Total ....

11 Does the firm employ YTS trainees at present?

☐ Yes

☐ No Have you ever employed any YTS or YOP trainees?

☐ Yes

☐ No

12 Does your firm employ any apprentices on the premises?

☐ Yes (Please give more detail when possible, regarding their number specialisation, ...)

....

....

☐ No

13 Please indicate approximate number of:

Operatives ....

Supervisors ....

Others (managers, technicians, clerical, ...) ....

14 What is the system of work?

Normal working day (eg 8-hour) (Please tick one box)

Two-shift system (eg 12 hour each)

Three-shift system (eg 3 x 8 hour)

Other (please specify)

TRADE UNIONS

15 Are all workers members of a trade union?

☐ Yes all Which one(s)? ....

☐ Yes some Which one(s)? ....

☐ No

16 What written agreements are there between management and Unions within the company?

....

....

17 How would you describe Management-Union relationship at this plant?

....

....

18 How many shop stewards are there are at the company as a whole?

Total number ....

How are they distributed throughout the plant (eg some in the extrusion department, some in the assembly section ...)

....

....

....

HEALTH AND SAFETY

19 How much time is spent on health and safety matters? By whom (eg line managers, 1st line supervisors, specialist, etc)

By Whom	Approximate time spent				
	<10%	<25%	50%	75%	>80%

20 How would you desribe the safety literature available on site? (See page 328)

1 Excellent

2 Good

3 Reasonable

4 Poor

5 Non existent

☐ On legislation (Please fill in box with one of the five above and add any comments when possible.)

....

☐ Works related

....

☐ General safety

....

21 Who generally uses this safety literature? (Please tick all which apply)

☐ Safety Manager

☐ Supervisor

☐ Works Manager

☐ Other (specify)

....

SAFETY REPRESENTATIVES

22 Do you have safety representatives?

☐ Yes How many? ....

How are they distributed on various shifts and places?

....

....

☐ No (Please go to next section)

23 Please describe their role within this workplace.

....

....

....

24 Are they also shop-stewards(S S)? (please tick one box)

☐ All Safety Reps (S R)

☐ Some S Rs are S S

☐ No S Rs are S S

SAFETY INSPECTIONS

25 Are formal safety inspections carried out?

☐ Yes

Who carries them out? ....

How often are they carried out? ....

....

When are they carried out? ....

Is there a followed procedure? ....

Are inspections carried out

over the whole premises

parts of factory (please state which areas)

....

....

☐ No

Why not? ....

....

SAFETY COMMITTEE

26 Is there at least one safety committee for the premises?

☐ Yes

(please answer the following questions for each committee if there is more than one)

When was it established? ....

How often does it meet? ....

Who chairs it? ....

Who sits on it? ....

....

....

....

What does it discuss?...

....

....

☐ No Why not? ....

....

....

27 How can the role of the health and safety committee(s) best be described in your premises? (Please tick all which apply).

☐ Has overall responsibility for safety

☐ Consultative role

☐ Overseas safety policy operation

☐ Promotes health and safety

☐ Secondary role

☐ Other (please specify) ....

TRAINING

28 Who in the company is responsible for all training (please specify job title not person's name).

....

29 Is training his/her only reponsibility?

☐ Yes

☐ No What are his/her other responsibilities? ....

....

30 Is he/she also in charge of health and safety training?

☐ Yes

☐ No Who then is in charge of health and safety training? ....

....

31 How is the Health/Safety training carried out? (please tick all which apply)

☐ In plant By whom ....

☐ At company training centre

☐ Consultant training company

☐ Other (please specify) ....

32 What categories of employees have taken safety training? (Please tick all which apply)

- [ ] Senior management
- [ ] Supervisors
- [ ] Training manager
- [ ] (All) workers
- [ ] Safety reps
- [ ] Other (specify) ....

HAZARDS AT WORK

34 Please rank the following accident types by numbering the boxes provided in a descending order (eg 1 for the most frequent type then 2,3,4, etc) according to their prevalence in this company.

A - Accident types (please add any comments when possible concerning these types and whether steps have been taken to prevent them).

- [ ] Handling ....
- [ ] Driving types (Fork L T) ....
- [ ] Lifting ....
- [ ] Falling ....
- [ ] Slippery floors ....
- [ ] Misusing Equipment ....
- [ ] Unsafe system ....
- [ ] Other ....

....

....

35 How would you rate the hazards on this factory premises? Please use the following scale and enter a number between 1 and 5 in the appropriate box to mark how serious a hazard is:

Extremely serious (1)	Very serious (2)	Fairly serious (3)	Not serious (4)	Not applicable (5)

(eg if fumes are an extremely serious problem then put (1) in the box for fumes)

A - Specific hazard

☐ Electricity ....

☐ Temperature ....

☐ Noise ....

☐ Lighting ....

☐ Radiation ....

☐ Fumes ....

☐ Dusts ....

☐ Fibres ....

☐ Biological ....

☐ Solvents ....
(liquid
vapour, mists) ....

☐ Fire ....

☐ Dangerous
parts of
machinery ....

☐ Falling objects ....

☐ Confined spaces ....

☐ Dangerous
place of
work ....

(If there are any other hazards, please specify them)

....

....

....

B - General Hazards (Please fill in in the same way as for (A))

☐ Housekeeping ....

☐ Walkways ....

☐ Means of access ....

☐ Other hazards ....

ARRANGEMENTS

36 Do the workers exposed to hazards kown about the dangers and hazards they are exposed to? (Please tick box and comment when possible)

a They know about

☐ All the hazards ....

☐ Most of the hazards ....

☐ Some of the hazards ....

☐ Few hazards ....

☐ No hazard ....

b How did they know about the hazards?(please tick box and comment when possible)

☐ Through experience ....

☐ Told by supervisor/foreman ....

☐ Told by Safety Rep ....

☐ During an organised training ....

☐ Other (Please specify) ....

....

....

....

37a Who in your organisation usually deals with health and safety problems?

....

b Have you every sought advice form outside health and safety expert consultants?

☐ Yes On what safety problems ....

....

☐ No

38 Is adequate monitoring done? (eg identified, assessed, controlled)
(Please tick one box)

☐ For all hazards

☐ For most hazards

☐ For few hazards only

☐ No monitoring

39 Who carries out this monitoring?

....

40 Who is informed of the results of this monitoring?

....

....

....

FIRE/EXPLOSION PREVENTION

41a Who is nominated to coordinate fire prevention activities?

....

b What arrangements are there for fire fighting? (Please tick all which apply)

☐ Sprinkler

☐ Portable extinguishers

☐ Mobile (Vehicles, hose reels ...)

☐ Other (specify) ....

c Do you have a fire drill book?

☐ Yes When was the last entry? ....

☐ No (Why) is there another alternative? ....

....

d How frequent are fire drills (tick appropriate box)

☐ Once a year

☐ Twice a year

☐ Four times a year

☐ Other (please specify) ....

42 Did your company experience a fire at all?

☐ Yes When ....

Cause ....

Seriousness Major Manageable Small

☐ No

43 Does your company have a proper evacuation procedure that is implemented during drills? (Please tick one box)

☐ Yes

☐ No

44 Have the areas of major fire hazard been identified?

☐ Yes What are they? ....

....

☐ No

MEDICAL FACILITIES AND WELFARE

45a Is there an occupational health service at this plant? (Please tick one box)

☐ Yes Who is in charge of it? ....

☐ No What arrangements do you have for first aid and medical supervision (eg are you a member of a local occupational health service .....)

....

....

b Keeping of medical records:

Who keeps them? ....

Who uses them? ....

What are they used for? ....

46 Have there been any cases of Occupational Diseases in this company? (Please tick one box)

☐ Yes Please give details ....

☐ No

47 What sorts of injuries are sustained in this factory? (Please insert number in the appropriage box to show their frequency of occurence eg (1) for most frequent, then (2), (3) etc)

☐ Burns

☐ Cuts

☐ Sprains

☐ Gassing

☐ Bruises

☐ Fractures

☐ Skin problems (rashes, irritation)

☐ Head injuries

☐ Eye injuries

48a Where is the accident book kept?

....

b Where are all statistics displayed?

....

c Are the accident statistics used?

☐ Yes By whom? ....

Why? ....

☐ No

INVESTIGATIONS

49a Are major accidents investigated?

☐ Yes By whom? ....

How long after the accident? ....

....

How are the results used?..

....

☐ No Why ....

....

b Are near misses (eg minor accidents that resulted in no loss of life, limb or asset) investigated?

☐ Yes By whom? ....

How long after the accident? ....

....

How are the results used?..

....

☐ No Why ....

....

50a Is safety performance (number of accidents, injuries, safety training, preventive measures) given the same attention as production? (Please tick the appropriate box)

- [ ] Always
- [ ] Often
- [ ] Sometimes
- [ ] Occasionally
- [ ] Hardly ever
- [ ] Never

b Is safety performance discussed

- [ ] Yes   Who discuss it? ....

  When is it discussed (eg during safety committee meetings, ...) ....

  ....

- [ ] No   Why ....

c Are the standards of health and safety performance set out in the company health and safety policy? (please tick one box)

- [ ] Yes
- [ ] No

FIRST AID

51a How many first aiders are there in this company?

Total .... Male .... Female ....

One each shift ....

b What type of certificate do they hold? (please list types of certificates held eg St John Ambulance, ...)

1) ....

2) ....

3) ....

APPENDIX 3

HSE's checklist on HS policies

APPENDIX 4

List of health and safety hazards in the PPI

Hazards in the plastics processing industry (PPI)

Hazards in extrusion, PVC covering	
HAZARDS	**Action**
Machinery	Guards must be on extruder drives before operation Trained operators, PPE
Housekeeping	Spillages of granules kept clear Operator should leave area tidy Marked gangways never blocked
Lifting	Assistance should be sought when lifting heavy loads, supervision, training
Genklene tank	Operated only by trained operators PPE (avoid breathing genklene fumes)

Hazards in Desprue Department	
HAZARDS	**Action**
Drilling	Guards required. Make sure machine switched off before guard opened to change jigs/cutters
Slicing machines	Guards required (sharp revolving blades)
Trimming	Care necessary when trimming moulds by hand (knife, sprue on floor) usingsharp knife Floor kept clear and tidy
Stapling machine	Instruction, supervision.
Pallets	Should be correcty located, never blocking gangways and exits or impede access
Spillages	Good housekeeping

Hazards in Auto Electronic	
HAZARDS	**Action**
Drilling	Guards correctly fitted No long hair, ties, loose sleeves
Hand operated press tools	Supervision, avoid misuse, instruct
Soldering (heated irons)	Can be dangerous, handle correctly Instruction, supervision, replace iron in holder after use
Trimming (flying clippings	Safety goggles Must be confined to one area
Solvents (Toluene used to assemble components)	Care required, ventilation monitoring
Radioactive components	Proper storage facilities bearing trefoil sign, permit to work
Housekeeping	Area tidy, clean, clear gangways

Hazards in Administrative Block	
HAZARDS	**Action**
Filing cabinets	Should never have more than one drawer open
Cables (electric/telephone)	No trailing cables Excess cables to be coiled and neatly taped out of the way
Doors and walkways	All doorways should be approached with caution Should be clear and not obstructed
High shelves and cupboards	Use correctly kick-stools for above normal heights
Electrical equipment	Never tamper with it No drinks near electrical appliances
Housekeeping	Area tidy, clean, clear gangways Have waste removed daily

Hazards in Assembly Department	
HAZARDS	**Action**
Blocking machine	Guards securely fixed and checked by setter before work starts
Shrink wrap machine	Only setter allowed to remove for clearing the tunnel of work
Spray booths (Solvents spillage)	Never leave solvents around Water to be changed weekly, ventillation
Belts	To be kept clear of pallets Belts speeds altered only by supervisor
Pressor machine	Safety guards, instruction for operator
Eyelet machine	Dual control safety system, instruction
Trolleys and cages	Cages must be secured with wooden chocks Trolleys must be pulled and not pushed to be able to control them
Stapling machine	Instruction, supervision, loose staples to be kept in box
Pallets	Should be correctly located Never blocking gangways and exits or impede access Broken pallets should be discharged or repaired
SpillagesGood housekeeping	
WalkwaysTo be kept clear	

These are the hazards spotted during a three-hour visit to packaging plant Company D	
HAZARDS	**Action to take**
Metallic objects falling in material waste that is going to be processed	Should be kept clean, make sure nothing falls in containers
Materials supplied in bags, containers	Plastics should be stored in clearly marked air-tight
Dust	Avoid making dust when handling colour or regrind
Traps in hopper	Never put arms or fingers into hopper or feed ports
Fumes during extrusion and conversion	PPE, extract ventilation

Continued ... Hazards in Company D

High pressure (air plastic material, hot molten plastic leaks through joints)	Die and extruder must be very strong Fitting joints secured and checked Never stand in front of die Wear safety spectacles Wear heat resistant gloves near die or when dismantling Make sure there is no pressure (residual pressure in die)
Trapps on Haul-off	Haul-off to be well guarded Access door to be interlocked
Fire hazards caused by hot plastics in waste bins	Metallic bins with no flammable material retain heat for a long time
Electrical hazards (on extruder barrel on heater bands)	Be alert, keep well clear, Report any control boxes and panels with open or faulty doors
Compressed air on extruder	Never misuse. Handle with care
Nips on in-running rollers on reeling and winding machines	Guards must be in position
Eye hazards from sharp pieces thrown back up the throat of waste grinders	Eye protection
Noise from grinders and other machines	Engineering measures, exposure duration, Hearing protection
Ejection of material caught in grinder	Disconnect power before cleaning grinders Wait for blades to stop Install time delay switch Provide safe system of work
Falls: Oil, granules, parts on floor	Good housekeeping
Strains from manual handling Back injuries	Correct manual handling
Mechanical handling	Instruction, training, care
Flammable vapours: solvents, inks	Ventilation, ppe, safe procedures, safe place of work

Hazards in Injection Moulding areas	
HAZARDS	**Action**
Machinery	Guards must be on extruder drives before operation, PPE, do not adjust Moving parts, trained operators, purge guards in position when purging the cylinder
Housekeeping (granules, oils, water on floor)	Spillages of granules kept clear Operator should leave area tidy Be careful when walking, never run Marked gangways never blocked
Lifting	Assistance should be sought when lifting heavy loads, supervision, training Trained operators drive stacker trucks Signs, mirrors, only approved and tested equipment,
Gas pipes	Defective gas pipes should be handed in to supervisor
Desprue drills	Cutting tool must be properly guarded Never leave running whilst unattended
Desprue guillotines	Corectly adjusted and fully guarded
Desprue rotary cutters	Correctly adjusted and guarded Never leave unattended
Granulating machines	Never place hands in hopper Machine isolated when cleaning it

Hazards in Pre-packing, drilling of PVC	
HAZARDS	**Action**
Machinery	Guards must be on before operating machinery (drills, stamping/cutting press) Trained operators, PPE
Housekeeping	Marked gangways to be kept clear Operator should leave area tidy

Hazards in Derivative Laminates	
HAZARDS	**Action**
Harmful liquids gasses, substances (caustic soda, acids, steam)	Equipment must be depressurised, drained, discounnected liquids, motive power. Valves locked in closed position and tagged
Enclosed space work	Permit to work (PTW)
Removing hazardous materials	PTW system
Electrical Exposure	Isolation equipment connected to electrical supply. Training, supervision, padlock isolator and tag it, PTW system
Driven equipment (mechanical work on electrically driven equipment)	Electrical isolation Tagged, permit. For contractors supervisor uses safety lock, supervision. If isolation difficult then remove fuses
Machine setting and cleaning	Same as above + setting tag, work procedure

Hazards in Print Department	
HAZARDS	**Action**
Machines (offset 4 colour and 2 colour machines	Guards must be on at all times Report failure of guards, training Instruction, safe system of work Changing of knife only when machine is off
Housekeeping	Marked gangways to be kept clear, sign No debri, oil, water
Dark room	Safe working practices required (emulsions degreasers) Monitoring, avoid contact with eyes and skin acidic photo-stencil emulsions
Handling	Handling and data sheets should be obtained
Screen printing (screen-wash flammable)	Dashpots used Ventilation

Hazards in Maintenance shop	
HAZARDS	**Action**
Drilling	Chuck-guard required Work to be held in vice or clamp
Welding	Permit to work Welding curtains, PPE
Oxy-burning	Permit to work, qualified user No combustible floor PPE
Turning (lathe)	No loose garments, rings, watches Use chuck-guard
Sawing	PPE (eye protection) Check work secure in vice
Grinding	Experience operator, instruction. PPE (eyes)
Housekeeping	Walkways clear, clean floors No oily rags, no waste, no grease
Lifting tackle	Faultless tackles necesssary Register for inspection (6 month) Current certificate tackle only Do not exceed safe working load
Storage	Keep racks neat and tidy

Hazards in Stores	
HAZARDS	**Action**
Transport (fork lift trucks, pallet trucks	Authorised drivers, instruction, training Signs, mirrors, safe driving, only manageable weights. Use proper equipment
Housekeeping	Marked gangways to be kept clear, sign. Remove all polythene bags on floor. Remove all rubbish and empty pallets
Stacking	Boxes and items stacked to safe height (6 boxes high or 10 feet high) Boxes not to be stacked on the top of racks eg blocking sprinklers

Hazards in Stores continued...

Lifting	Instruction, training, supervision, assistance should be sought when lifting heavy weights (manual, mechanical) Use proper equipment
Fire	Signs, smoking prohibited (in some areas 1/2 hour before end of shift)
Stapling machine	Should be properly used, instruction
Dock leveller	Leveller extension should be carefully re-housed after use to avoid personnel collapsing while standing on it
Loading bay	Supervision, instruction when reversing into loading area
Horseplay	Dangerous particularly near stairs, windows loading bays, machinery etc.
Fire	No smoking in the warehouse

Hazards in Tool rooms

HAZARDS	Action
Machinery	Trained personnel, supervison, instruction, permit. Do not clean moving machinery PPE and eye protection
Housekeeping	Swarf and oil removed Marked gangways kept clear Heavy pieces of metal to be left in stable position
Lifting	Lifting equipment to be used for lifting moulding tools
Substances	Mineral oils and paraffins
Benches	When mould tools are built and serviced on benches, the stacking of steel plates is a necessity. These must be stacked flat for safety.
Grease, oil and anti-freeze make benches hazardous	Housekeeping
Bench drills	Care to avoid being trapped by belt driving drill when changing speeds Care due when operating spring loaded lever

Hazards in Tool rooms continued ...

Surface and bench grinders	Care necessary, training , supervision Operators must know 1970 Abrasive Wheels Regs.
Stock racks	When removing replacing streel or brass sections handle with care Use correct equipment when lifting
Lifting tackle (and hoist trolleys)	Should be faultless and inspected every 6 months and used for specified load. Register all inspections, issue certificate
Engraving Dept.	Ventilation to extract paraffin fumes generated by spark erosion

Hazards during Vacuum Forming

HAZARDS	Action
Machinery	Guards have to be removed to change moulds and frames during this operation - care required
Guillotines	Guards must be fitted Safety devices funcitoning
Routing machines	Set by qualified setter, Operated by experienced & authorised operator, Safeguards
Vertical/Horizontal Bandsaws	Guards must be lowered to minimum height required, Should never be left running unattended, Saw sticks must be available
Circular saw	Training, experienced operator
Presses machines	Operated by qualified operator Guards
Cut and creases machines	Guards must be in correct positon Safety stop bar must be checked
Roller-cut machines	Care is required when feeding matrix in this machine

Hazards during Vacuum Forming continued ...

Drilling	Guards must be used, never leave unattended No long hair, loose sleeves, ties, scarves
Clicking presses	Supervision, training, instruction No other person allowed in immediate vicinity of machine, both hands required to operate it
Toxic and flammable liquids	Data sheets should be referred to Spill and fleash-proof containers required

APPENDIX 5

Expert Observation

Health and Safety Management Program (HASMAP)
Knowledge Elicitation

EXPERT OBSERVATION

A.K. BENSIALI
Health & Safety Unit
Dept. Mechanical & Production Engineering
Aston University in
Birmingham

MANCHESTER 19/6/87

Contents

Health and safety problem solving

Expert observation

Introduction

Problem solving is a critical function performed by health and safety experts, yet the process that underlie this intellectual activity is poorly understood. In order to attempt to explicate the components of the diagnostic process, there is a need to look into such experts' problem solving processes. Previous experiments revealed little as it was difficult to assess how experts solve problems and why they ask the questions they ask. It was difficult for them to articulate what they have been practicing for years, and to explain how the information gathered is to be used particularly when the task has not been well defined or when the exercise is a mock-exercise (i.e. not a true life-problem). Another limitation of those experiments was the difficulty to motivate an expert to just think of all possible abstract facets when solving a fictitious problem. That difficulty arises when he/she has to make an unlimited number of assumptions and link all triggered hypotheses about the problem areas he/she might decide to solve. There was consequently a need for seeing a HS expert solving problems 'live' and this is the purpose of this exercise.

Aim

Is to observe a health and safety expert during his task of analysing health and safety problems and recommending arrangements for their control. Observing a health and safety expert to elicit his expertise is a fundamental phase in the development of expert systems.

Objective

There are more than one objective which can be summarised under the following. It is:

- identify the problem solving strategies adopted by HS experts,
- see the sorts of questions are asked,
- see how experts manipulate the data and information they elicit,
- what problem areas are dealt with.

Methodology

A health and safety expert e.g. LB is followed for a whole day carrying out a health and safety survey for his client a food company. The expert's activities were tape-recorded and transcribed below. The expert was called in by the client (JC) to undertake an office health and safety survey on the 19/6/87.

The survey consisted of two sessions:

- a discussion or interview, and
- a physical survey e.g. inspection of the office complex.

The interview was carried out in an office whereas the second part of the survey involved the expert and other members of the company (those concerned by the management of health and safety) going round different parts of the office complex. LB was using a check list called 'Audit checklist', compiled by AMI in January 1987 (see Table 5.6 in main text), and was asking questions about each heading as it will come out in the interview transcript.

Because expert systems are only good in simulating the cognitive tasks of a human expert and because of confidentiality , only the interview part is available.

The interview

LB

In that policy does it actually spell out who is responsible for the HS management within the offices here. It is obviously down to yourself.

JC

Yes

LB

OK. And your title?

JC

Office manager

LB

And then obviously if you need assistance or advice then you will go to Vick or Alan.

JC

Yes absolutly. We **involve them** **all the time.** As I said although we do not have a lot of documentation, we have an awful lot of **contact**. We contact whenever is necessary, if there are alterations, if we have structural alterations we get them across, we involve the fire dept. if every thing is OK, emergency situation ....

LB

Just for KB's benefit, Vick and Alan are the safety manager and asssistant safety manager who look after fire safety, security, ...

JC

I suppose really, I do not know how it is like in other organisations, but we seem to be ....(20) But for the number of people we have got here, I suppose for this building we might appear we are a bit lenient. But it works.

LB

You are responsible for what parts of the premises? You are responsible for this particular block , basement, one ground floor, ... all that is your domain. So that we know exactly what is going on.

So from the organisation's point of view there is yourself,
do you have a number two who gets involved?

JC

I do not. We do have safety reps on each floor of the building..

LB

And these are ASTMS?

JC

No. No union.

LB

So they are just elected then or appointed.

JC

Whoever will do it rather.

LB

How many safety reps then?

JC

We have got one on each floor.

LB

Is that three?

JC

Yes. I do not know whether that comes under different section. We have them under groups as fire wardens.

LB

OK. I have got a section on fire.

So you have 3 safety reps. What sort of training do they have? Have they been on any sort of formal training course?

JC

Well we have had fire fighting certainly....

LB

Have not there been like the basics of health and safety.

JC

No .... Let us put it this way LB. Not since I have been involved. This was underway when I took over so they may be out of date anyway ...

LB

So no recent training. It is really hazard spotting. So it is really those bits we have done at Keele.

So that is the organisation.

Now do they, together with you, have an office safety committee?

JC

Yes these do form the office safety committee. The office safety committee does extent a little bit further than this building although my responsibility is this building. For example we would include a representative from the laboratories ....

LB

Do you chair that yourself?

JC

No. ...

LB

Do you sit on it?

JC

Yes

LB

Who chairs it then?

JC

A person called Alan Walker.

LB

So he is one of the reps?

So there is a chairman every time?

JC

No, he is the chairman all the time. There is another rep from MIS. He works in MIS.

LB

What is MIS?

JC

That is Management Information Service. So he is chairman of the safety committee.

LB

So what is his job title?

JC

He is a computer operator.

JC

We include the labs, we have got a lad from the labs, we have a reprepresenting engineering. We have one from factory personnel & training.

LB

What do you call it?

JC

Factory personnel.

LB

So there are the 3 office safety reps + yourself.

And how often does that meet Jack?

JC

A question!!! We should actually meet every two months but ... we do not.

LB

Meet too infrequently. So I will put a recommendation so that gets formalised.

JC

As I said we tend to react and do things right away.

LB

I think it is good without formality though.

JC

A two monthly meeting, of course, is merely just to exchange ideas. We do get things, and get side tracked ....

We find we do spend far too much time talking about the health and safety problems of VDUs, because someone has read something in the press ... it has been on ..... otherwise we do get on with the business and try to prevent it.

LB

Do the safety committee undertake any formal hazard spotting audit at all or do they just wait as you say for things to happen?

JC

They .... We do not do it formally. We tend to .. They either spot it themselves or people will go and tell them that so an so is not quite right.

LB

I think there is space for a formal audit as long as you let the informality occur at the site. When somebody does report a hazard, ... what happens?

JC

I investigate it. It is not very much as a rule.

LB

No, is there any sort of documentation, any recording of that such as a hazard log book?

JC

No

LB

That is something which we would advocate. (I will jot it down).

JC

It is all done verbally. We are very light on documentation. We tend to react to situations ....

LB

That is the best way. What we are moving in to is the idea of having a formal hazard log where if they come to you, you will have an A4 exercise book, date of hazard, location, nature, action taken to prevent recurrence, who's responsibility it is, date completed, and then when you get any problems it is there. And then the thing can be revealed at the safety committee or if they undertake a formal hazard spot they can then turn round and say :'well it has been done, that is when it was spotted let us get on with it.'

JC

You see, what I do .... I walk around the office several times a day to all floors.

;;;;;;;;;;;;;;;;; Now Dr SD enters and says:

SD

Forgive me I... we have got a training day on today and I thought I may get my stats sorted out today.

(LB explains to SD what he has been through). **(107)**

JC

It is really a matter of making myself available. I was few times today. I was just saying that we do not have any doccumentation we should have on safety, we tend to sort of have a problem, react to to it, sort it out and then that is it.

Probably some form of log as LB said SD that is what we are short of.

LB

The whole point is do not want to cut across the informal system. Because if that works and people are reporting hazards then that is good.

LB

So we have got the overall responsibility for health and safety management is down to yourself with obviously help from Alan & Vick when there is a sort of technical advice, and SD when there is medical problems.

So let us skip through to the section on **SAFETY ADVISER** ...

Provision of safety advice

JC

yes that will be down to Alan & Vick ....OK (125)

LB

On to **safety Training** side, you mentioned **first aid**? So we can zoom in on that at the moment.

JC

Did Colin P are the two names who are first aid trainees.

SD

We have the site medical department is just across the way. We have appointed a first aider on the top floor Andy Malcolm and in principle it has been agreed that we will have first aiders appointed on the other two floors,

LB

That is a good ideaa. On day light people with minor complaints are going to walk across the road ...

JC

We have Ham Lee who works on the first floor. She works in office services which I think is ideal for someone like her. On the second floor there is Karen Booth who works in finance.

LB

They are going to be trained obviously in accordance with the regs. When an injury is reported to them they will just give the basic first aid treatment and then if it is any thing more, important, more serious ...that is where they will .....

JC

This is what steve is going to do

SD

We will brief them on this. They are provided with a small 1st aid pack which has got the simple first aid provisions you would expect ....

LB

Rather like the travelling 1st aid kit.

SD

That is right. And plus accident forms. But basically any thing other than a trivial thing like a cut finger or a minor headache they will be referred.

LB

What reporting do they do then? Have they got their own BI 510 accident book or do they record every thing on an accident form or what ...?

SD

She keeps record form in fact. We do it actually on a quarterly basis. Mandy has just reported for the first quarter. She had 24.

LB

Is this for every thing, illnesses, accidents and the rates are differenciated when you get the (148) report?

SD

Oh yes. As I said we have a coding system across the way. Other than giving a standard treatment record form + a couple of the company accident forms for safety investigation & so on ... they need very few. They do not need a huge number of sheets. A small aid pack, a couple of treatment record sheets and an accident form or two.

LB

Say for example one of the things we are going to look at later are accident statistics. If I said what reports have you had from the office block in terms of injuries, complaints, illnesses, eye strains .. could that be broken down for this block? Because that information will be very useful for the second stage of this survey obviously.

SD

I would like to give you a nice clear definitive answer: we have accident statistics categorised by department on site. There is a category for staff but that will blurr the difference between staff in the factory and staff over here in the administration block. The other area is really on the coding side for the nursing team they are actually coding medical and accident problems by the ICB coding.

LB

This will leads you to computerisation.

SD

Yes. As I said the report you 'll get from Mandy are very simply broken down. But the numbers are so few that I guess ... (149)

LB

Because it will be handy we are going to be as a result of today's survey probably pointing Mark Walker in certain directions from an environmental physical measurements point of view. It will be a pity of we went .... say for example we have got the photocopier area: Is there any one who has complained about headaches, dizziness because ther might be a high level of ozone ... I do not know what the situation looks like in there.

It will just be nice to see the records and if it is possible to have a copy.

LB

So are at the stage SD where we are not quite there with getting the stats broken down in that way.

SD

Even not as much as the ability to record that little detail. Actually, (this is outside the audit) in a professional sense take a (point 160) .... of the degree of detail that you record, do you, if in 20 years time X becomes an industrial disease, somebody will have to say you have had this computer for the last 20 years Doc let us have a look at what it says. So it was so trivial we never bothered to record them. But you know it is all this type of fitting work group that people had. So it is so difficult. Do you record everything, something or nothing?

We have taken the middle path and just categorising things by dept. by general type: muscular skeletal problems, skin problems, infectious problems, just by dept. and it is half way (168) analysis it gives us a handle. We can on occasions we do have complaints that we had more headaches in certain depts in the factory on occasions, use those general numbers to give us a feel for whether a dept has shown an increase or not and there is a need to go back to the details in our records manually.

LB

So Mandy's records then will have all illnesses, treatments, headaches, cuts .. the lot.

SD

Just in the same way as we had over there (in the factory). What we had to do was to code it retrospectively.

LB

OK. How far back could you go because I would like to have a look at those.

JC & SD

Just ask Mandy to show you her record sheets.

LB

Because, again, to take some copies away to have a look at them and do an analysis from my own point of view will be useful.

SD

She may have well passed last quarter to our Sister in charge but I am not too sure we would like you to take away the actual thing.

LB

OK. May be if you can provide that analysis then I could built that into the report. There might not be any pointers in there. But I think it will be very remiss of us not to look at them.

SD

Yes. I would add that all this is quite recent actually. Mandy is the first aider. She was trained only last October.

That is quite recent. We were concerned that from our medical point of view about a number of times the secretaries were coming across and asking for a big bottle of paracetamol.

There was a secretary in Les........... some years ago who committed suicide because she took an overdose of paracetamol. You only need 20 or 30 tablets to kill yourself and one of our nurses who works here had first knowledge of the case and ....the company are liable.

They have a row with their boy-friend before coming to work and the boss shouts at them and then they go to coffee break and they feel depressed and they come back to their desk and swallow the tablets.

LB

OK. So that is on the **first Aid** side, no other obviously specialist training for the offices on health and safety.

SD

Are you thinking of fire?

LB

Yes, I am sort of thinking about the sort of basic safety, specific safety things like on the factory you talk about: (and mentions the list of things the expert would have looked at and considered had he been on a factory premises such as:)

abrasive wheels, power presses, woodworking, fork truck, breathing apparatus. **(204)**

There is nothing like that obviously here.

How about **general safety training**, induction for new starters, how is that undertaken? Have you got some new YTS people or ....new starters in the office?

JC

No.

SD

I guess for the staff you are right JC we do not have any thing like that. I think YTS had an induction programme that involves general safety awareness and they have other days appreciation training and taken around the factory and so on .... and are shown the different services and they have specific safety awareness. But for the general staff, ... there is nothing here. **(213)**

LB

But you mentioned you have got this the safety film in, **It is not Thursday.** Was that for a particular group of people?

JC

Oh yes we had that. Everybody saw that at the time. Where we had a couple of safety films, but this was just a one-off thing.

LB

So that is just sort of sitting the people in front of the film.

JC

Yes this is going back now for 3 or 4 years or may be more. I believe that film is still talked about because it caused quite a laugh here when we showed it because the sort of leading lady in that film was making all the mistakes, a lady called Dorothy Stringer. An we got a lady called Dorothy Stringer (a big laughter ....)
It took us some while to convince her that we did not know anything about that until we saw the film. But it was very useful.

LB

So there was no training for managers or supervisors at all?

SD & JC

No. No systemised training.

LB

So really nothing other than your 2-days at Keele.

JC

Yes that is right.

SD

Oh people like JC of course have become knowledgeable and experts through sort of job development and off-the-job training and I think they can learn in a number of ways because JC has

been involved in a some of our other safety meetings.
Formalised training is fine but sometimes you learn as much through work experience.

JC

That is true. I was saying to LB before you came SD, we have got some quite keen peole like Else on the 2nd floor, Alan Walker ... These people who are sort of ....

LB

Well if you have got key people, the idea will be to have a one-day session on certain things for them to hold them up.

SD

JC you are the chairman of the office health and safety committee?

JC

No, just secretary. Alan Walker is chairman. I was also saying before you(SD) arrived that for a variety of reasons we do not meet perhaps as we should. And we have got to get back on to that as two-monthly sort of schedule. (247)

LB

Ok. So training then a bit on the specialist side, probably room for improvement on one or two of the general areas and also we have actually said that the members of the safety committee probably could benefit by a sort of an improved awareness on hazard spotting and that sort of ....

JC

As I said they are pretty good already but they could be improved. It is quite a good barometer really: if I could walk passed Elsie and nothing happens then if there is nothing that she says safety-wise then things are OK

LB

Going on to sort of the recording of training, we have said that there is not all that much at the moment, but I know from the experience we had SD with the engineers, to computerise a printout, would that apply to the staff as well?

SD

Yes, the computer printout we had looked at by engineers are staff training records and all company staff will be on. So that we said pull off the engineers, pull off JC or myself ....

LB

So with a bit of luck the Keele course will be logged on the computer?

SD

It has been. I supplied the details from our course and in fact I must say actually I specifically asked for the engineers' records to be up-dated. I just check whether whether the Keele one was actually understood rather than actually instructed. I must follow that one.

LB

That is OK for formal training but say for example that now you had people sitting down in front of that safety film, would that have got on the record?

JC

No probably that would not have gone at that time.

LB

No, but if you did it again it would? Because it is important to record any training whether it is formal, informal, on-the-job, off-the-job, what have you ...... and I think that is again if you have a nice computer system use it and put these things in there.

If say for example you have taken somebody out of a secretarial environment and put them to work on a VDU, then obviously we have got this subjective assessment but would there be a degree of training given on how to use it and the sort of ergonomic aspects and things like that or would you just plank them in front of it? **(282)**

SD

In terms of VDUs I have been battling for the last couple of years. Firstly with Paul Cox and so on, but trying to get some initiative on this but in fact with the appointment of a new manager in MIS dept. and the setting up of **user-groups** and a more structured way of monitoring the introduction and assessing the appropriateness of the future equipment coming into the company, MIS dept have issued guidance to members of the user groups on the appropriate ergonomics of computers (lay out ...). Having said that I am not aware that if my secretary had a word processor on her desk, any body comes along and spends an hour with her and said this is the contrast, this is ... , this is the sit position,... nobody goes through a formal programme.

This company is lean and mean therefore one does not have too many spare people floating around and can provide this kind of ....

LB

Really this is down to the office supervisors to have the knowledge to be able to pass it onward and they got new people coming on to that ......

SD

I am hoping that one of the aspects of this survey will be such that you will give us some **objective opinions and guidance** so that people like JC who has got the very important role of monitoring what is going on in this building and equally if we ever have the opportunity in te future to build new offices, we will actually influence the environments and the ergonomics obviously of that so that we can make advantage of what we got that works well but also correcting the mistakes ....

LB

Yes I think the combination of me coming and doing the sort of physical safety aspects survey today and then Mike coming to do the **environmental**, I think the two together, the two reports together.

JC

I think what might be worth making comments on at this time may be of course is that we may sometimes know the ideal position for the person to sit, where that person actually sits.

LB

It is down to personal preference ....

JC

No No No. It is down to the space available. We are very congested in this building and people often have to sit where we could fit them in rather than where the ideal where they should be.

LB

OK. So **Training records** (this is on the audit check list)

Safety reps we have mentioned them

Safety committee We have mentioned that

Safety inspection and audit other than your own sort of physical walk round and certainly the safety reps obviously do an informal inspection otherwise they would not come up with things. We have agreed that there is nothing, there is no formal group of people walking round doing an audit?

JC

No. I walk around for several reasons you know. At least twice a month I walk round everybody.... (332)
I look at the desk, housekeeping, and all that kind of thing. But if you spot anything obviously ..... and safety you make note of that as well.

LB

Again what other things, you mentioned documentation is one of the disciplines to get into would be, to have a safety committee every two months, probably an afternoon, once every two months in the morning you can have the formal physical walkround as we are going to do later today opening all the doors, leaving no stone unturned and then entering the things into the hazard log to get the action taken. I know you are doing that informally anyhow but I think it shows that not just inside, it shows the outside world that you are doing things that are logical and practical. OK so that is OK. (346)

LB

When we have got, looking at the **accident reporting procedures**
We are just making use of the Kellogs internal system?

JC

Yes.

LB

Just to refresh my memory, how does that work, JC?

JC

Accident reporting system: perhaps SD could, it is all done by SD dept. (i.e. medical dept).

SD

In the event of the first aider, or a member of the medical staff sees someone who ....

LB

An injured person reports either to a first aider or the medical centre?

SD

Yes, that is right. See someone who has had an alleged industrial accident will complete an accident industrial form which is one of these carbon which are accessible, he fills in the white sheet and there is a series of coloured sheets. The Sister or the first aider will complete the first part for the patient, occupation, date & time, and the location and the sort of brief details of what alleged has happened with a brief account of the medical injuries and so on .....
There is a second section then for a statement on the individual (by the injured person) as to what, in their view, the accident circumstances contributed to the accident.

LB

Do you get good conformity to that? No refusal?

SD

In the past years we had the occasional person in the factory ....particularly where there has (375) been some sort of dispute about why things happen. There has been a union problem on one or two situations where they have wanted to compromise themself by saying what has happened. But

I have to say that these last 18 months or so there has been very few of those. We have had fewer and fewer accidents of course. Our minor injury rates last year was 176 whereas 2 years before that was 305. So that is a remarkable injury rate.

LB

And that is the real test.

SD

And filing that statement we will also ask for the name of any witnesses. The procedure is that the top copy (the white copy and the pink copy) go back to the dept with the individual and we have got agreement from supervisors.

I am really describing the factory system and we get so few accidents in the office block here, but perhaps in a whole year, including staff in the factory as well as the office block here, all things are a bump or a twist or a slip .... and it is mainly, the number of accidents over here, I have to go back, they are possibly 2 or 3.

So I think the reinforcement and the awareness of managers over here is to what they can do..... they may get an accident in their dept. once a lifetime ...... so I guess they have to be guided by the medicals.

The copies that come back, and the agreements that we have as a company is that we involve the safety reps, as well as obviously the supervisor who has to do an immediate investigation. By that I mean within the next half hour to one-hour. In that time he goes to have a look at the accident scene and make sure that remedial action is taken.

And the safety reps, the factory senior manager have agreed that safety reps will be involved in that process. Right across the company, safety reps like the first aiders must be in jobs where they can be released without all the hustle that has got to be involved with or complement any investigation. Having made that report, it goes through to the head of dept, the manager concerned and eventually wins its way back into the safety dept for Alan and to myself to correlate the statistics ....

LB

In that report I have not obviously seen one but I will presume that, from what you have said, that all the important question is what they have done to stop it happening again, ...

SD

Oh yes there is a report and comments from the management concerned

(426)

LB

So the investigation is undertaken here JC primarily by yourself and the final investigation. Do you act actually as the over lord of the ... the office supervisor basically as they will report through to you?

You are exactly the head of dept.?

JC

No, not exactly.

SD

Taking that accident which has happened to the secretary a year ago which tripped over a carpet tab is not she, and that will go to the manager in charge e.g. the head of marketing or the head of sales ....

LB

And you get to know about it?

LB

So you get to know about the accident?

JC

Obviously, because I will have to fix the carpet.

LB

OK that is what I was trying to ascertain. That is good.

So that it looks at the accident situation,
now in terms of **accident statistics** we know that a breakdown is available and I would appreciate SD if it is possible to see generalities obviously I understand to think about the medical. But if we can break that down into injuries and any sort of health related complaints. As far back as it is possibly easy, say the begining of 1985.
Just the ones related to the office block.
I would like to have a look at those before I instruct Mike Walker (hygienist).

LB

Do we encourage reporting near miss situations and damage, they may be very very few I would have thought.

JC

Yes we do get them but they are just .....

LB

And people in an office environment will be conditioned to report injuries rather than near-miss and damage I would suggest?

JC

No No. We get quite a lot of near-miss, because things do happen. We are a compact unit here. As I said I walk around a lot and make myself available. People may not come to your office door and knock on the door and say by-the way so and so has happened. But if you are walking by and you make yourself available then they will tell you.

LB

Yes, so this is really managing by walking around we are talking about.
If the supervisor has time and walks around employees are likely to inform him/her about near-misses

SD

We have a very security conscious company and of course JC has already mentioned that these security activities and clean desk policy are very important and our chairman and directors are very hot on housekeeping. If they see a bundle of old files at the back door which might be a fire hazard or whatever from our point of view they are looking at the same situation from their point of view.

I used to get complaints about before we moved the offices about the amount of stock in cardboard material and serial products like that **Mr Hamilton** (delete on thesis) the director ... restoring.
WE see a lot of complaints about the fire hazards being stacked against the wall, but it was **(500)** part of this kind of review of housekeeping and tidiness.
You go away at 5 o'clock and you clear your desk, ...

JC

One of the first things you will notice when you go round the building is the tremendous contrast between the 3rd floor and the other two floors because the 3rd floor has been refurbished and the other two have not. So you will see a tremendous amount of difference.
We are using system's furniture on the 3rd floor whereas we use the conventional ,the old stuff on the others.

LB

Is it planned to do the other two floors?

JC

Well it was.

LB

You need to have written **safe systems of work and safe operating procedures.**
Are there any one of those that apply within the office?

JC

No.

LB

There is no formal system for the fire detection and equipment in the computer room or anything like that? Systems for making sure it is on manual when there are people in there?

JC

Oh possibly yes. There would be for that.

LB

Any areas of the offices where when you got people coming in to do maintenance there is a need for permit-to-work system. e.g. entry into confined spaces if you are looking at the ventilation or ... will all maintenance work come through yourself.

JC

Indirectly it does.

LB

Are there any areas where, if you just think about it now, that you think there should be a permit-to-work system? for electrical isolation, or entry in confined spaces?

JC

(pause.........) I can't think of anything really. One of the things we do have to watch of course is any body who is working in anything like confined spaces, we make sure that is isolated .....

LB

But there is no sort of formal PTW.

There are very rigid PTW systems over there (in the factory) and I just wondered whether you should adopt it.

JC

We operate exactly to the same work standards, electrical work ....

LB

OK, I will put that as just something to consider.

(While JC and SD were out, KB took this opportunity to ask LB about the number of employees)

LB

Numbers employed: office block has got something like 470 employees on the 3 floors.

We have got 3 floor-office block (I would say that we probably talk about 300 people, but I will check with JC).

LB

What is about the portacabin, are they a sort of temporary permanents are they?

SD

They are really because we are recruiting more staff. One of the objective of refurbishing the 3rd floor is to fit more people into the same area by actually acting on the furniture.

LB

Well as long as we do not exceed the 14 sq-ft we are alright. (613)

SD

Well it will be interseting to look at that. I think in one or two areas it is a little bit congested because of the need to include ancillary equipment such as photocopiers, filing cabinets,...

There are what some people call work station. Some find that somewhat psychologically restrictive and do not adapt very well.

Within my own medical dept which is in the basement of the factory there are no windows, no natural light, and I think similar psychological problems can arise when you have got people into a modular office system: away from a window, within a corner, they can feel a bit like being in a pigeon hole. But again it is horses for courses. Some people self select and adapt.

LB

I must admit I was thinking about it subjectively. If I was in an office without a window ....

(JC has just come back in and LB asks him about the number of people in the building)

LB

I was chating with SD who reckons that there are about 500 employees.

JC

Oh no less than that.

The majority of the staff works over the road (in the factory).

I think in this building we probably have got less than 300.

LB

That is what I thought.

JC

Probably 280 - 290.

Side B of 1st Tape

LB

How would **contractors** liaise with you. Would they liaise with yourself or with the guy who has actually asked them to come on site?

JC

Normally myself because I normally handle all the contracts. Now services and maintenance, regular routine stuff I do not see those people.

There is a chap who does not actually work for me, he actually reports to the plant engineering dept, but in essence he works for me because he is based in this building all the time.

LB

So he is an engineer?

JC

Yes. He will take care of them and instructs them.

LB

So he reports to who?

JC

To the plant engineer but he is based in this office. His title is office technician.

He does the work maintenance himself. He is responsible for the air condition, the boiler, and any thing that crops up. He has got lots of safety jobs for me.

He does routine maintenance, ...

LB

Do any of the contractors have to go through the company contractors vetting procedures?

JC

Oh yes. They all do. They are all meant to sign the agreement.

LB

Do you ever have interest to have a look at spot check on their contractor safety policy? I do not know whether Alan Vick will do that at all?

JC

No we do not. We check on the insurance. We make sure they are adequately insured for any damage that they might do. Barry is our technician who watches them.
Alan spot checks them. He does just a simple thing.
We were watching this ourselves (pointing to some works outside the window, where portacabin is being connected to the main building via a foot path) and it was very visible (26)
When these guys (e.g. the contractors construction workers) are on the scaffolding for example they were not wearing their hard hats Alan was .... 28 .
It is that sort of things. That is something that is very visible. You can see that just by walking outside. ...

LB

Would there be any need for ... we said hot work there will be systems, have they had in the contract this formalised PTW system do you think? or is that done by the liaison? There is not one of course there is one over the road (i.e. in the factory).

JC

I am saying there is none over here, I have not heard of one. May be Vick ....

LB

OK, I put it down as a suggestion, because obviously when this report comes through there is going to be lots of things that probably you need to have a look at so it will be a memory jogger for yourself.

JC

We always take those precautions that we do not let him (contractor) go into a confined space without a PTW, or welding without a fire extinguisher near-by ... and these sorts of things. This sort of common sense type of things. Well you say they are common sense but yet do not follow it.

LB

Yes, the documentation then because the aid memoire to make sure that people actually do things.

Visitors

The system with visitors ..... (the expert looks in an inspecting way. ..... and said)
Have you got your badge KB?

KB

No.

LB

Has it dropped off?

KB

No. I was not given one.

LB

So you walked in. (addressing JC the administration officer) you see. So you only get a visitor's badge when you come by car!?

JC

No, you get one when you walk in.

LB

You should do. Should not you?

JC

Yes ummm...........

LB
OK,

KB
I came through this side gates which are over there. (I arrived at 8.30 am and there was a side gate that I first saw. People were coming through it. I asked some of them about the reception and they showed it to me. So I thought this may be the pedestrians gate. It did not look the plausible way to go through but everybody was going through there. I was a bit surprised that there are no security guards at the gate but I tried to convince myself that this can be used by pedestrians but certainly proper security is for car users. So I walked passed the security cabin and tried to make myself noticeable invinting their attention. Nothing happened and I presumed I should report to the reception which I did).

JC
So you slipped through the net ....

LB
That is right. You should not be able to do that .....(laughter)

JC
Mind security is another thing. There are lots of things our security manager would like to do which would really tighten things up a lot but he is not allowed to because of Union wants certain gates open.

(SD has just come back in and LB is informing him of this last point)

LB
We have just established that KB has slipped into the factory without passing through the security checking and get a visitor's badge. I will make a point. Because he walked in.

SD
(addressing KB and seemed to be concerned as how did this happen)
Which way did you come in?

KB

I came through this side gate.

SD

One could get in through the back door here without being challenged.

LB

We also came through the reception here and the reception lady did not notice either.

KB

I passed near the security people who were watching me but I thought that was for the cars.

SD

I am sure Mr B will be concerned.

LB

That is right.

SD

Having said that, we have now got certainly for out of hours, outside day hours and outside sort of normal week days we have a card key system and each of the floors is guarded so that you can only get entrance only if your card key is valid and in fact there is a computer log for which card keys are going in and out outside normal hours because as JC has already described even if there are no people around, we are all on the ball watching for things. If you saw somebody suspicious and wondering in and out ....

If you came in this morning and managed to by-pass the system then once you are in the purchasing dept, you would not be there very long before somebody tells you who are you, what are you doing ....

Out of hours you get a card key to get into the building through the main door and you need another key to get through the actual floor. It gets you through the stairwell, but to get into any one floor, or any one dept .... **(81)**

JC

That works even for employees. A person working on the 2nd floor, they would only get a key for that floor.

LB

But generally once visitors are here they are the responsibility of the person who is obviously receiving them.

JC

Yes, absolutely.

LB

As SD has said there is this system of challenge and people are not afraid to come forward and say what the hell are you doing?

JC

That is right.

LB

Good. Normally if we are doing a sort of full survey we start thinking about
Hazardous operations: Handling of corrosives, flammables, radiation

SD

That is still applicable.

LB

There will be some areas where hazardous chemicals are used.

SD

That is right. I gave you a checklist and I am sitting here now, I mean.. I am thinking now that I omitted to tell you about the art studio and the photographic lab (SD omitted to mention that in his letter to LB)
They have in the past asked me about fumes and so on .... Someone who was on the YTS scheme was asthmatic so I think that is one area to look at today.

LB

Let me try to make a list now of the sorts of areas where we have where we have got hazardous operations within this block.

SD

Chemicals will be handled within the art studio and photographic lab.

LB

Is there an ozone risk in the photocopier room?

SD

We have moved a number of copiers, have not we JC into a more general working areas and put them near windows and put them inside offices which are not absolutely general working areas. Just sticking with chemicals for a while, I do not know whether there are any cleaning chemicals stored in the building JC e.g. contract cleaners.

JC

The contract cleaners they keep their stuff in the services tunnel between the toilets.
Barry (the office engineer) has an office downstairs and has stuff also in there.

SD

I guess on the 2nd floor, I do not know whether there are any fluids kept there e.g. solvents, by the computer people for cleaning disks, disk heads or computer equipments. There are chemical for wiping screens ... that is a question to ask.

LB

There is obviously the fire extinguishing system. What is it? Is that PCF halon?

JC

Yes.

LB

There are gas cynlinders there?

You mentioned the laboratory with the labs not in this block, they are over there. OK

SD

I do not think there will be any chemicals on the top floor here.

LB

Is your photocopying system all electronic or do you use these sort of toners and solvents ...

JC

They are all Xerox (123)

SD

Having said that there is one in the office service area which reproduces microfiche. I think that is a solvent based.

LB

You have not got these drawing copies using ammonia and things like that ...

SD

Office services, I think they may have something as I said with some solvents ...

They might have some solvents. It just happened that the actual copier maintenance rep was in and ...

LB

With all these things you come to the inevitable question about hazard data sheet.

SD

We do not have any system for that.

LB

So obviously this is going to be one of the recommendations.
Because obviously it is an idea for you to have what a hazard data sheet for everything that is used in the office, that the safety reps can have access to.
In other operations that go on here that you would say are risky or hazardous that we probably need to look at while we are here?
It is unlikely but you never know ....?

SD

Can we include physical agents like noise? Because the computer suite is a noisy area.

LB

Yes. We will have also to take few measurements.

SD

I have done some noise measurements about 18 months or so ago in the computer suite.

LB

And what level were you getting?

SD

Oh, in excess of 90, particularly the printer hoods are left up and the tape doors are left open. In fact some of the newer disk drive units have got quite noisy fans at the back. So noise levels are in excess of 90.

LB

We have got S coming in to do some on the plant and we will ask him to spend a couple of hours in the computer room.

SD

I would just add as well that I did circulate to all the managers in the building because the building is on 3 levels and there is a user director or manager such as DM, BM, DH ..... I circulated letters that you were coming today and most of them have been extremely pleased.
Patterson for example is very keen to have any measurements taken, very keen to improve the environment...

LB

Great. .

The situation is that the company has been investing very heavily in new plants and facilities and we were very concerned with our people. One of the ways in which we are able to spend money is if we could show a clear environmental improvement to benefit people and help them work more productively.

Alan is very interested in our survey and noise is an area in the computer suite which we will be looking at.

LB

What I propose to do after we have done the basic survey will be to sort of have gone round today I will identify areas where I feel beneficial to take noise measurements and similarly on the environmental side.

I will make sure that Mike looks at that .....

SD

I have obviously missed the art studio ....

LB

Oh yes you need setters like this (discussion) to spark ideas .....

JC

As far as manual handling is concerned we do have a stationary store here, and there is a YTS lad.

LB

Has he been considered say for kinetic, handling course?

JC

Not as far as I know.

It is a new job. It is not for a long time.

LB

It does not hurt. Do you run your own course on that?

JC & SD
Yes.

LB
Put him on that then. So he is YTS.

JC
The lad has done it for about six years. He has started straight from school, he has moved on ...

LB
I will make that as a specific recommendation that you bang him on a kinetic handling course if he has got a lot of problems.

So anything else you would think of that you would say we might even need to think about a written system or ....

We are coming on to **Fire drills, fire safety,....**

JC
VDUs of course ....
Every body is getting a screen now and people reading about the health and safety hazards ...

LB
My own view is that, there has been a lot of scareman about the VDUs. There are some basic problems .... and not the new technology. Mainly in the ergonomics, the layout, ...

SD
A secretary has genuinely come to see me who has worn in the past contact lenses and whose optician has advised her that really she is working more and more should really wear spectacles ....

LB

Yes the anti-glare ones.

SD

That is right as you know with VDU operators they blink less often because it is a sort of staring job and if they are close to the screen they get a heating effect and so they can get drying of the skin and their eyes can dry and the combination of these may in certain people perhaps who are more sensitive with their eyes and contact lense-wearers can be quite prone to these sensations. (203)

She quite properly had advice and she will be more comfortable not doing herself any permanent harm but it is uncomfortable ... she will be better with spectacles and the question then is which came to the staff personnel, or medical dept, or safety or somebody paying for her spectacles.

The answer is no. If you provide spectacles for someone in that respect, and won a lot of sympathy, it will be nice if you could with confidence look after a few people when ......
It is a system that is open to abuse because you have to rely on people's good nature and confidence and trust and that they won't claim symptoms that they have not got which you can't disprove, and suddenly you file all these people.

My vision is almost normal but it is not quite ... I am sort of part 6/6 which is normal but when you are reading a lot you need probably a perspex ....

Where do you draw the line.

LB

I think you draw the line when people start possibly becoming absent because of problems, and getting really niggly, I think then you have really got to look at that.
But today from what you have said there have been very very little complaints on the VDU.

JC

There is also the sort of general conditioning, legionnaire disease ...these have been discussed several times. We use twice the normal doses in our equipments on the air conditioning treatments.

LB

Is this with the biocide?

JC

Yes, we are absolutely certain that we are in no danger at all. People just need reassuring. Again you get scares in the press, do not you things like VDUs etc...

LB

So this is for what? For water treatment? Do you know what you are using? Because there is another chemical isn't there?

JC

Yes. I could not tell you.

LB

I better put that down .....Water treatment, chemicals.....
You are not chlorinating it?

JC

I do not think so.

LB

Barry might be the guy who can show us round if he could. He might be useful.
I will come back to air conditioning if I may.
Now **Fire Safety**
You mentioned that each floor has got its own warden ....

JC

Yes each floor has got a warden who reacts when the alarm bell goes off.

LB

OK, Fire warden.
How often do you have fire drills?

JC

Once a year.

LB

And that is a full evacuation.

JC

Yes, which we are managing just over 2-minutes I think normally.
We have assembly points on here. Each warden will have a checklist of people and they sweep the building, toilets,....everything.
The first thing they do is to stop the lifts, to prevent people jumping into that.

LB

And that is everybody. I mean everybody from the boss, managers and all....

JC

Oh yes from the telephone and down. We treat it as a real emergency situation.

LB

Have you ever tried the obstructed exist drill that I mentioned at Keele where you say to people ....
Ideally it would be a good idea to do one every six months.
One properly full evacuation, no problems, but
one every now and again, you might say there is a fire where that sliding door as you can not go that way folks. This gets them to know the secondary means of escape. So I put that down as .....

JC

I think tha's what we agreed at Keele .

LB

So we go for two a year. You see you are talking about a lot of people.

How about disabled personnel when you can't use the lift, have you got any disabled personnel on this, 2nd or 3rd floor?

JC

No there is no problem with the disabled. We have installed alarms....

LB

When you are actually testing the fire alarm system?

JC

That is every week.

LB

So on a weekly basis, is that by your engineer? & does he go round the different alarm points on a regular basis or what......?

JC

Yes, he does the main check.

LB

How often will each alarm point is checked roughly?

JC

I would imagine probably quarterly.

LB

OK.

JC

Have you seen the panel?

LB

No but I would like to see it.

JC

This is where they go to when they test the alarm.

LB

When do you test the alarm?

JC

Usually, round about early morning.

LB

So we have missed it today. It is a good idea to check it before 9 o'clock because what happens if there is a fire? Is there a system for a different sound for ....?

JC

No no it is exactly the same.

LB

So if it went off at 8.45 am?

JC

We are not always here, it may have been tested before we arrive.

LB

I was just thinking if it was a real life situation.

LB

When it is normally sounded for your testing, like a drill, is it a sort of a one off drill, will it be a continuous noise that is on all the time ....?

JC

There are two signals. the bell and then the sirene.
The bell means that people sit at the desk until they are told to evacuate.
The sirene means GET OUT

LB

So he is just checking the bell not the sirene?

JC

Yes

LB

Good, so who checks the sirene? (smile)

JC

Well they probably do.

LB

Alan explained to me because you have got the delay because of the fire brigade because of the minor fires you have been having ....

JC

And false alarms .....

We had one in this building, not in my experience.

Sirene means evacuation

LB

So we mentioned that new starters might be shown the fire drill apart from the induction or are you happy that they are? (346)

JC

I am not entirely happy that they are but really they should be.

LB

What I am going to suggest is that there should be like an induction checklist which includes safety and fire features.

JC

What we tend to do with staff people is they get some form of induction in their own dept., but they tend to wait until they get about half a dozen or so to give them this sort of main induction.

LB

But what happens if something happens the first day in ......?

JC

Yes.

LB

On the **Fire evacuation, fire procedures** is there an immediate evacuation drill written up anywhere?

JC

Yes, each area warden is made responsible for will have a checklist of names.

We do not want a real life situation before we had a drill.

With the fire drill of course when you know it is coming up, at least the fire warden knows the others do not.

Then they go through their home work in advance and find out who is in who is not.

Of course in a real life situation, it is really more difficult to fly round the last minute to see who is in and who is not.

LB

Fire prevention obviously, the main advice comes from Alan and Vick.

JC

Oh yes absolutely.

LB

Have ERM as part of their own insurance survey looked at the office block?

JC

No

LB

or have you had any fire prevention advice from your fire prevention officer?

JC

Oh yes.

LB

(Just for KB's benefit ERM are the European Risk Management who provide a fire and consequential loss advisory service for K)

So ERM no survey, FPO has been in. (e.g. Fire Prevention Officer)

JC

I have got a very good relationship with him.

LB

What methods of fire detection are used generally and obviously we will zoom in on the computer section? (394)

JC

We have got smoke detectors. That is the main one.

LB

And there is no sprinkler system?

JC

No.

LB

And smoke detectors throughout the building?

JC

Absolutely.

LB

And what is about the computer? Is that then halon is linked to smoke detection?

JC

Yes.

LB

And you have got what, roof and floor void detection?

JC

Yes.

LB

OK detection in roof and floor voids.
No other forms of detection, infra-red, or thermal energies ....?
And then the smoke detectionwill be linked through.

So extinguishing mediums will be portable fire extinguishers plus halon system in computers.
What about boiler room?

JC

We have our own boiler room in the basement here.

LB

What sort of extinguishing medium is used there?

JC

I will to check on that. I don't know.

LB

Is it oil fired or gas?

JC

Oil.

LB

So it will have a fusible link?

JC

Yes. we have just spent a lot of money on that actually. Putting new control panels in, different things. We really had a little bit of a scare round Christmas time where a minor fire in there... made us think.

Because we had a nasty experience at our Spanish plant, where a boiler actually moved 15 feet fortunately nobody was standing in the way. So we did .... job after this, we probably spent far more money than we needed to but we never know.

LB

I actually had a look in there at the, when we were doing the engineers training and that escape route out of the conference room.

I will have a look at that today.

JC

That was the only way out.

LB

That is a tricky hazard and the potential of having it locked.

JC

Oh yes, we have overcome that.

LB

OK. I will not go into specifics.
With extinguishers, what is the policy on training?
This is something that Peter .... on to Keele, did not he?

JC

Yes, here again there is a certain apathy. People just seem reluctant to go ....

LB

Is the message GET OUT first, or .....

JC

Oh yes. Peter is very good with his communication. He goes out to all managers etc...

LB

No I mean the general evacuation procedure is not to get everybody out rather than to fight the fire.

(453)

JC

Oh yes indeed , ...

LB

Or is it down to the wardens to fight the fire?

JC

That is right. All the fire wardens have been trained at some time but I feel refresher training should be carried out. People just ....
It is a problem of time.
A person due to go on a fire fighting course, for half a day 9 'oclock in the morning .... what takes priority is the job....

LB

What about extinguishers, you have what, water, powder, CO_2, you have the whole range ....?

JC

It is a voluntary thing, being a fire warden. If he would have too much hustle of their boss , then they will say . ...

LB

So they do not get a penny for that?

JC

No.

LB

I know .... having talked to Peter, the message we got at Keele, the message we got at the fire, at the engineers meeting, the need for upgrading every fire extinguisher trainee. Some of them are going to be a key recomendation of this report, to get it formalised and to get it done....
What about the Safety reps, have they been trained?

JC

Some of them yes.

LB

So I will put that " and safety reps?".
You have got a guy who is good at doing it, I think you get him to do it.

JC

I went on it (fire fighting training) in Scotland.
But I mean that is why we need a refresher because we have forgotten really what I have learnt.

LB

And of course if we asked the computer who has been trained, it would probably come with a big blank.

Talking about the actual 'escape route' 'protected exits' and these sorts of things, who checks those? making sure they are clear, unobstructed, clearly signed etc....

JC

I do that. We have got the fire hoses all over the place of course. We want to make sure they are never blocked or fire exits are never blocked. (500)

LB

So you check that. OK.

JC

This is something as I have said, we keep very close contact with ....

LB

Who checks those hose reels and extinguishers, is that contracted down?

JC

Yes that is it.

LB

Six monthly or yearly? Perhaps yearly.

Does any body do spot checks on odd extinguishers and odd hose reels to see if they have been done?

JC

I rely on Alan.

Health problems

LB

Over the years, have there been any known health problems in the offices here that come to mind? .... OK I will get some data from SD but ...... no allergies, dermatitis ,..... obviously we got noise as a possible problem but it is not actually caused anything yet.

JC

No.

LB

You said you get water system that is treated. That has not been a problem but they are treated?

JC

No.

LB

VDUs again discussed but no problem.

JC

Again what I said before, may be there are areas where people who may be sitting the other way round or whatever, there may be time for space and of course......

LB

Has anybody been in and undertaken and environmental survey in the office as we are planning to do?

JC

No.

(point 549 of Tape I side B)

LB
Any jobs or operations where protective equipment is used at all that you are aware of. I should not think so.
But again glare screens on VDUs....
Do they use any other protective equipment.

JC
I do not know, they might have it but that again is a restricted area the computer room.
I have not actually seen anybody wearing any protection. Because that is not an area that we wander into.

LB
It might be an idea to get Sidel to put a couple of dose meters on people who work in there to see what noise level we are going to get. I make a note of that just to ask him.

OK.

Now **Medicals**

Probably I will ask SD about this.
Are there any pre-employment medicals?

JC
Oh yes, everybody has to go through pre-employment. There are medical checks available to staff. They are not compulsory, in the factory they check everybody every year. Factory people have a re-check but staff people are not on that kind of schedule. but they can walk in and ask for a check.

LB
Good.
Product liability there is no real problem there other than to say 'get the product safety data sheets in for ....' may be the thing you do is to get yourn engineer to keep you a full list of every chemical used in the block and then as we discussed at Keele, get the hazard data sheets. There won't be that many.
And I think you are in line for COSHH then there might be one or two chemicals that fall within COSHH and so we make sure what they are.

At the engineering sessions we did we said, contractors we want control. And now every project engineer is going to be asked to get a list of all chemicals the contractors want to bring on site before they bring them so we can approve them. That system, hopefully is going to be set up. We suggested it should be.

LB

OK. Just few basic things to do with the offices themselves now:
Computers, VDUs, Noise we have talked about.............
oh yes the heating and ventilation systems, are they inspected at all from a statutory point of view?
Has any one come and have a look at them or do your own people undertake the............ Is that down to Barry?

JC
We will check that with Barry.

LB
And things like temperature control. Is that also down to Barry? and humidity

JC
Yes.

LB
And then checks on air balance?

JC
Yes especially when you have got a lot of girls working. Men do not bother ......

LB
The thing with photocopiers, you moved them all to one particular area?

JC
No.

LB
But there is one main photocopying area?

JC
Yes that is the service area the main photocopying area and then there is a photocopier at least one on each floor, a small one meant to do few copies. **(657)**

LB
Some general points; is there anybody who does general lighting checks in the offices?

JC
Oh yes it is Barry.

LB
Do you know what he actually does?

JC
I say Barry does it but of course it is also part of the factory system to go round cleaning lights, cleaning the covers .....

LB
I mean doing intensity checks. Barry would not do the cleaning..?

JC
No he would not do that.

LB
Is it worth getting Barry in for a bit to have a chat about some of these before we go and walk about ..?

We talk about
Heat, ventilation, lighting and the last one is what the policy says on smoking.

Shall we do smoking first and then see Barry later to talk about lighting and heating?

JC
The policy on smoking is that people can smoke if they want but . . ...

TapeII
19/6/87

LB
Let me just recap:
Current policy is that people can smoke if they want.
Has been discussed more on smoke than smokers.
No major complaints?

JC
Two people in particular were very upset for a long time mainly because I think it is a matter of occasion basically they were two non smokers in the area where everybody else smoke.
But we sort of have rearranged not for that but because people have moved jobs .... and that problem disappeared. People used to find it annoying but now with reorganising .... We get back to something because of what the newspapers report again.

LB
Yes this sort of passive smoking, air conditioning, sick building syndrome and all what they read about ...
But there is no real formal complaints and illnesses resulting from it. It is all conjecture and supposition.

JC
No. But we had actually people complaining.
You can't win with people. There are always complaints you have got to learn with.

LB
Do you have any policy which says do not smoke for the last half hour, the old fire precaution type policy.

JC
No.

LB

It is difficult to enforce.

JC

Before, we used to have that about 30 odd years, we used to have the restricted smoking policy in those old days.

LB

Probably it is difficult to decide which is the last half hour......

If it is possible to have a quicck word with Barry before we go round.

KB

You seem to have asked 2 or 3 questions about the computer and how it is used?

Do you have a health and safety auditing system on the computer?

LB

No. What they are working towards is accident statistics on the computer. It will not on the main computer here. It will be on the mini computer that they got over in the medical centre.

The main reasons for asking the computer questions is (40)

a) about the fire prevention and detection mechanisms and

b) because if you have got people in there when you have got an automatic detection system, there is a risk, although being small of people being stuck in the computer area when the halon gas is injected into there and then it is toxic.

So you have got that risk so I wanted to make sure that they are aware of the possible evacuation problems.

What happens with computers is that lots of people build them in and they do not think about the safety implications.

Resume or diagnostic of the expert:

LB

A brief summary of thoughts so far is that there is not all that much that is wrong.

I think we need to think about getting them to do a formal hazard log system regular reporting and things but generally we are OK.

(JC has just come back into room)

KB

Who is Barry?

JC

Barry Secam is the office technician. He is an engineer. The office based engineer. He reports to the engineering dept across the way . He is quite useful to us really. (66)

LB

Were you involved in any of the engineering safety courses we did on the basement.

BS

No

LB

Did not they tell you?

All it is Barry as you know AMI is involved with K on various things, environmental monitoring, and training aspects etc.. we are doing the office health and safety and there is a couple of areas where obviously we need your expertise:

1- one of them is on heating and ventilation and the systems in the building and

2- on lighting.

With the heating and ventilation system we have established from JC that we do water treatment ... do you know what chemical you are using on that to treat the water?
JC said you double dose it.

BS

We have got an automatic chemical dosing equipment. This is called DEARBORN 921 and 947.

LB

What sort of chemicals are involved?

What we need is to make sure you have got the product safety literature for those. DEARBORN are pretty good at sending those out.

BS

Dearborn check the dosing and also take samples away every week.

LB

So dosage is checked by Dearborn every week , this is to make sure the system is working and giving the right dose? So that is Monthly?
And you take samples weekly?

BS

The lab people do that. They take samples weekly and analyse them (in-house analysis)

LB

So that is the actual water treatment.
Do you do any inspection of the ventilation system yourself and any maintenance routine inspections?

BS

Yes we do maintenance routine. We have people once a month to open the boxes up and inspect them and correcting the necessary.

LB

And what will they be physically be looking for? Blockages in filters, and things like that?

BS

Yes blockages, correct operation of the actual mixer boxes, ...

LB

And this is by the people who installed it or is it just by engineering.

BS

By engineering. Fitters are changed 4 times a year,

LB

When you say the mixer boxes, what do you actually mean? Is it where they take in the fresh air and mixing it?

BS

No we have a cold duct and a hot duct...

LB

Ah so it is the temperature control.

Do they find much muck on the filters?

BS

It has been quite bad the last 18 months. Normally it is not too bad.

LB

I have heard you are actually improving the air on traffic parking!? (laughter)
What sort of checks do you do yourself on temperature and humidity, do you do any spot measurements yourself, in the offices?

BS

Well when required. Just when people complain then I make tests and correct that.

LB

Are there any thermometers dotted around. Do you ever go and do spot checks on what temperatures are achieved in other than the ones where there is a complaint?

BS

Not really.

LB

So you are not really sure what the ambiant temperature is or the ambiant humidity?

BS

Oh yes, it is 72.

LB

What temperature or humidity?

BS

Temperature approximately 72 throughout the building.

I have senses throughout the building and they all feed down into my office. I have got full range of temperatures for every floor.

LB

So you have a remote sensing temperature checks.

BS

And I have also temperature checks of the ducts hot duct and cold duct. And also fan failures which are automatically detected.

LB

For the humidity you would have to do wet bulb and dry bulb?

BS

I have also got humidity readings.............. I am the only one without a descent office.

JC

Yes that is true. We are working on that.

LB

When the heating and ventilation engineers come in, do they do the air balance checks? or do you do them?

BS

We do them together. And that is done monthly.

LB

What are finding. Is it reasonably OK?

BS

Yes not bad. Some of the equipments are old and need replacing. It is an expensive system we have got. It is about 25 years old now.

LB

Do they have a 'fire fighting' service i.e. if you can't cope with that, they are pretty quick?

BS

Yes

LB

Moving on to the **lighting** side, again we have heard that there is planned maintenance to get things cleaned.... Do you do any measurements of lighting levels in any of the offices parts?

BS

No. What we had was a survey last year, a full survey on lighting and had the tubes are changed frequently. We do not wait for the tubes to go. We have a replacement theory.

LB

Who has the report just in case I need to get hold of it? (159)

BS

Bill Howson (he is the plant engineer) should have the report.

LB

OK, are there any areas other than heating,lighting and ventilation you are concerned that could be relevant?...........such as the boiler room?

So what system have you got there. It is oil fired, fusible system? ....

Any smoke detectors, heat detectors?

What about extinguishing medium?

BS

Just hand held. No automatic

LB

If there was a problem there that would alarm again in the main security situation...?

BS

Yes.

LB

Right, that is it unless you have got anything else you can think of?

BS

We have got the sanitary. We have got contractors for the sanitary, cleaning things,.....

LB

You do not have any problem with rats pest or .....?

JC

Nc no .

LB

When you say Rentokil that what people tend to think of.

So these people do the loo's and towels ......

JC

They have got so many divisions .....

LB

We are here most of the day, when is it possible to come and have a look at your areas?

BS

2 o'clock.

LB

OK. Really what we want to do is to look round all this building, leave no stone unturned undertaking full survey then what we might probably be advising later is that we will get somebody else to come in to do like an environmental survey.

So if tere is any areas that you feel you would like checked by our independant guy, then let JC know and when he comes in he will liaise with JC.

A guy called Mike Walker who will be doing environmental monitoring. **(210)**

It will be in August that he will come in.

BS

We had emergency lighting on our stairways, just the basement.

LB

Have you got a battery room?

Is that maintained externally as well or you get involved with that? Are they dry batteries?

BS

Yes.

LB

So there is no acid mixing or anything like that?

BS

No they are acid batteries.

LB

Are you involved with topping them up?

BS

Well I get all the contracts in.

LB

I would like to have a look at one of the acid rooms.

JC

As I said before most of these things are done on contract.

BS

You have got to get the specialist in anyway.

LB

Is there a stand-by generator involved with the computer at all?

BS

No. If power goes down it is down. We are on a double feed are not we. from the electricity board.

LB commenting on the checklist said:

There is no way you can remember all that lot and make sure you are going to cover it and it is the same if you are doing a physical audit. (306)

I have not got a checklist for the physical auditing but I tend to just look round and then if I see any thing I put it down on the magic tape, get the tape notes back and then draft my report from there.

The other thing it does because you are putting your notes down on the tape, you do not miss much and when you come to write it up you got the chronological order of where you saw things.

The way I do my report is that I will write a general section, general comments will be on the overall system & procedures, that will be developed from the notes we have taken, from the interviews with SD, JC, BS. That will comprise the first section of the report again recommendations will come out of that.

The second section of the report will involve the specific survey that we are going to do of the office complex, taking hazardous noted from the tape and then adding recommendations to them for example if I am going around and I see particular something it triggers off in my mind that I need to refer to a particular health and safety executive guidance note well I put that on the tape.

When I am writing the report, I will have the guidance note in front of me and I will be able to make recommendations based on the guidance.

What we also do to ensure that people have not got to wade through a very thick report is that to have:

an action check list at the begining of the report, which is a rather punchy summary which tells people on the genearl system & procedure side things we want them to do and

on the specifics recommendations that we make and for example here we are going to be recommending

the use of hazard log systems,

getting the product safety data sheets,

possible training for safety reps,

obstructed exit fire drill increase the frequency on the fire drills, and

probably some environmental checks like use of noise, dosimetry in the computer room if we think that the noise is high; we have indications that it is.

And so then they will have a punchy action list and hopefully be able to implement it.

That is how the report will come out. (344)

KB

What relevant documentation you said you will be looking at?

LB

The relevant documentation, they have not got any thing that is specific to this office environment. They use the general K group health and safety policy and manual which we know about and is OK.

The accident reporting documentation is not currently available. SD the medical officer has said he is going to let me have some information on that but the indications where that they were few and far between in terms of accident numbers and health risks which is a good thing.

Other basic documentation they are not using the accident book **BI510** that is the one first aider that we have found is using some form of sheets.

Again I will get that back from the medical centre.

They do not appear to have any reportable injuries. Normally if you have a look at the **F2508** for example in a factory situation you can get an indication of what is going wrong. (365)

But I tend to look at the accident book because you get all reported injuries or first treatments in there and I think that is much more useful.

But in an office environment they are not going to get all that many. So I am not going to push them for documentation because as JC started off by saying they have not got much.

KB

You had here in your checklist, **company health and safety policy**, have you had already had a look at that?

LB

I have got a copy of the group policy and it is pretty good and it delegates responsibility. As long as I have established that JC is responsible for this office block I then know the way it fits further up the tree.

KB

I was wondering why you did not ask for that.

LB

Obviously if it was somewhere where we did not have been before then

we get a copy of the policy,
take it away,
look at it,
compare it with HSE requirements for a three part policy and then
make recommendations accordingly.

So there is no need for this particular situation.

KB

The other thing which you probably know already because you have been before here is that how does this block with JC & SD fit within the organisation. You are going to make recommendations, so how sure are you about them being implemented if you do not well the organisation?

LB

As far as most of the recommendations are concerned they are not going to cost all that much, and then therefore it would be down to JC to set up an administrative system because he is the administrative manager to make sure that the things happens.

Generally as this is the administration block of the company and the chairman and chief and chief executives and the senior people of the company work in this block, it is likely that the action will be taken.

This is the head office.

KB

Do you have a picture of how you are going to start the physical survey?

LB

Yes, we will now literally walk round every office, probably not going in every little office, and do a physical, leaving no stone unturned type walkround. Looking in cupboards, getting locked doors open, hopefully going through the whole thing.

KB

Do you rely on one of the people taking us around?

LB

You have got to do that.

You have got to be firm but polite and say can we have a look in there please otherwise we might miss things.

KB

OK, are they particular places you want to go to?

LB

Definitely. There are the heating and ventilation areas, the boiler room, the computer room, where the contract cleaners store stuff and ..... So we will have a good look around.

With offices a lot of them are similar in the sort of layout.

You need to see a representation.

Expert observation programme

This is a one-day spent with a health and safety expert in a food-plant e.g. from 9 am to 4pm. The programme of the day was as follows:

9.00 - 9.30	Introduction
9.30 - 11.30	Office interview,
11.30 - 13.00	Physical inspection of offices
13.00 - 14.00	Lunch
14.00 - 15.30	Physical inspection of utilitiy services
15.00 - 16.00	Feedback and conclusion.

APPENDIX 6

Accident Form F2508

Health and Safety Executive
Health and Safety at Work etc Act 1974
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1985

Spaces below are for office use only

Aston University

Content has been removed due to copyright restrictions

APPENDIX 7

A sample of typical questions asked by HS experts

Appendix 7

A sample of typical questions asked by HS experts
(Bensiali 1987b)

Do you manufacture dies or is it just repair and maintenance?

Are your machines used for batch or continuous production?

Are the machines British or are they imported from somewhere else?

Are there monitoring mechanisms on machines e.g. lights on valves, ...

How often do you require people to go inside the mould area?

Do they lock off the machine when they go between the platens?

You have a carburator on the machine as well and that is dumped?

Are the guards on your machines fitted locally or do they come with machines?

How frequent are the inspections carried out on the injection moulding machines (IMM)?

What sort of access hazards do you have on these IM Machines?

How did you decide that the housekeeping on machines is not good and how important is that?

What records do you keep on each machine in terms of maintenance?

When you send people doing jobs, on what basis do you allocate tasks to engineers and on what basis do you put priorities?

What sort of spare parts do you keep in the stores, do you have a stock or when a machine .... you order say pumps and solenoid valves?

You know that there are some solenoid valves have got limited life and need to be replaced once every often, especially the ones which cause the platen to close and open. Did you have much failures with this type of solenoid valves, master control valves?

What do you check when you check guards? You have got some limit switches,....

Do you still operate the machine while the guard is being repaired or you take it out?

How many factories do you have on site?

Who is the person in charge of the maintenance?

How many supervisors are working under the leadership of the maintenance manager?

Are these supervisors specialised as mechanical and electrical supervisors?

Who is in charge of the general maintenance?

Do you have job descriptions and are the duties of supervisors clearly stated?

Are the responsibilities well understood and abode with?

Are there instances when the demarcation of responsibilities was not clear?

Do you think given the way things are done, it can happen?

Who decides what type the work to be carried out is ie whether it is electrical or mechanical?

Who makes decisions about this point (eg electrical or mechanical job)?

Are mechanics and electrical issued with work dockets before they are sent to do a job?

Who reports breakdowns on a machine?

Who is it that breakdowns are reported to?

Who carries out the repair?

How are emergency breakdowns reported? eg by phone, in writing.

Are breakdown repairs recorded?

Do the people designated to undertake a maintenance job sign in before and after the job is carried out?

Is time spent on the job recorded and maintenance costs assessed?

Are details of the repair/maintenance jobs done, recorded?

Are deteriorations noticed on machines while doing a maintenance job, recorded?

Is monitoring of the recording system carried out regularly?

Who carries out this monitoring?

How are these deteriorations dealt with?

Who takes the decision about priorities of maintenance work?

How far is safety taken into consideration when decision is taken regarding the prioritisation?

How long has the maintenance manager been working in this plant?

Does this manager sit on the safety committee?

How would you describe the safety training this manager had?

How long has this manager been working in the PPI machinery maintenance?