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Grounded Theory for Knowledge Acquisition

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Grounded Theory for Knowledge Acquisition
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ABSTRACT

Knowledge acquisition is the process of acquiring knowledge required for the development of a knowledge-based system. The process of knowledge acquisition involves eliciting knowledge from an expert, interpreting the expert's decision making processes and creating a model of this knowledge that can be used to develop a computerised system to automate the task. However knowledge acquisition is still considered the bottleneck in the development of such systems. Knowledge acquisition is a time consuming process. This research has tested an original approach to knowledge acquisition based on Grounded Theory.

In order to test the grounded theory approach to knowledge acquisition, a case study has been carried out in the domain of dial-a-ride scheduling. Dial-a-ride services provide transport in wheelchair accessible vehicles for people with mobility difficulties who are unable to use conventional public transport. This domain is one in which expertise is not gained through study and training, but through experience and colleagues. The knowledge applied involves a strong component of common-sense reasoning and also needs temporal and spatial reasoning. However, it is a job that experienced despatchers perform considerably better than lay people. It is primarily a planning task rather than a diagnostic one.

Grounded theory is a qualitative method used in the social sciences in order to acquire theory from data, where the data is typically textual information, notes of observation, and transcripts of interviews. The focus of this research has been to develop a knowledge acquisition method based on grounded theory. The first stage has been to determine which knowledge elicitation techniques work with grounded theory. The selected techniques have been applied, and a grounded theory process has been carried out. The knowledge produced by this process has been evaluated in terms of whether it provided a good model of the dial-a-ride scheduling process and in terms of how well it could be translated into a prototype knowledge-based system to support the scheduling process.

This research identifies a number of knowledge elicitation techniques that are suitable for use with grounded theory. It shows how grounded theory can be used as the basis of a knowledge acquisition method to produce a conceptually rich model of the knowledge used in the domain under study. The research produces a model that can be used as the basis of a computerised knowledge-based system. In this research a prototype knowledge-based system for decision support has been developed using the output from the knowledge acquisition process. The grounded theory approach has assisted in identifying task that can be usefully automated, and those tasks which can be supported.
# TABLE OF CONTENTS

1. INTRODUCTION ................................................................................................................................. 10
   1.1 THE RESEARCH ISSUES ................................................................................................................... 10
   1.2 KNOWLEDGE ACQUISITION .............................................................................................................. 12
      1.2.1 The Aims of Knowledge Elicitation .......................................................................................... 13
      1.2.2 Knowledge elicitation and its problems .................................................................................. 14
   1.3 THE DOMAIN APPLICATION ........................................................................................................... 17
   1.4 THESIS STRUCTURE ....................................................................................................................... 17
   1.5 THE RESEARCH QUESTIONS RE-STATED ......................................................................................... 19

2. KNOWLEDGE ELICITATION TECHNIQUES ......................................................................................... 21
   2.1 INTRODUCTION ............................................................................................................................... 21
   2.2 INTERVIEW ....................................................................................................................................... 23
      2.2.1 Structured Interviewing ........................................................................................................... 23
      2.2.2 Unstructured Interview ............................................................................................................ 24
      2.2.3 Advantages and Disadvantages of Interviews ....................................................................... 25
   2.3 PROTOCOL ANALYSIS ...................................................................................................................... 26
      2.3.1 Advantages and Disadvantages of Protocol Analysis ............................................................... 27
   2.4 TEACHBACK ...................................................................................................................................... 29
      2.4.1 Advantages and Disadvantages of Teachback ....................................................................... 30
   2.5 WALKTHROUGHS ............................................................................................................................ 31
      2.5.1 Advantages and Disadvantages of Walkthroughs .................................................................. 31
   2.6 OBSERVATION .................................................................................................................................. 32
      2.6.1 Visible Observation .................................................................................................................. 33
      2.6.2 Participant Observation ............................................................................................................ 33
      2.6.3 Advantages and Disadvantages of Observation .................................................................... 34
   2.7 REPERTORY GRID ............................................................................................................................. 35
      2.7.1 Advantages and Disadvantages of Repertory Grid ................................................................. 37
   2.8 CARD SORTING ................................................................................................................................ 39
      2.8.1 Group Separation ...................................................................................................................... 39
      2.8.2 Group Creation .......................................................................................................................... 39
      2.8.3 Triadic Comparisons ................................................................................................................. 40
      2.8.4 Advantages and Disadvantages of Card Sorting ................................................................... 40
   2.9 INDUCTION ....................................................................................................................................... 40
      2.9.1 Advantages and Disadvantages of Induction ......................................................................... 41
   2.10 MULTIPLE EXPERTS ....................................................................................................................... 42
LIST OF FIGURES

FIGURE 1.1 STAGES OF KNOWLEDGE ACQUISITION (JACKSON, 1990) ............................................................ 13
FIGURE 2.1 ELICITED GRID FOR EVALUATION OF PROGRAMMING TECHNIQUES (HART, 1985) ............ 37
FIGURE 2.2 A POSSIBLE HIERARCHY ................................................................. 39
FIGURE 3.1 PROCESS (STRAUSS AND CORBIN, 1990) ................................................................. 55
FIGURE 3.2 GROUNDED THEORY PROCEDURES ............................................................................... 56
FIGURE 3.3 EXAMPLE CATEGORY CARD ............................................................................................. 57
FIGURE 3.4 PARADIGM MODEL (STRAUSS AND CORBIN (1990) .................................................... 57
FIGURE 3.5 EXAMPLE AXIAL CODING ............................................................................................... 58
FIGURE 3.6 CODING AND DATA LINKS ............................................................................................... 58
FIGURE 5.1 INTERNAL PILOT DATAFLOW DIAGRAM ......................................................................... 73
FIGURE 6.1 AXIAL CODING - ROUTE ................................................................................................. 93
FIGURE 6.2 THE STORY LINE .............................................................................................................. 95
FIGURE 6.3 SELECTIVE CODING ......................................................................................................... 96
FIGURE 7.1 GROUNDED THEORY DIAGRAM ...................................................................................... 112
FIGURE 8.1 SYSTEM DEVELOPMENT LIFE CYCLE ............................................................................. 115
FIGURE 8.2 TOP LEVEL DFD .............................................................................................................. 117
FIGURE 8.3 LEVELLED DIAGRAM ..................................................................................................... 117
FIGURE 8.4 LOGICAL DATA STRUCTURE ......................................................................................... 119
FIGURE 8.5 FRAME TRIP BOOKING .................................................................................................. 124
FIGURE 8.6 RULE 13 ........................................................................................................................... 125
FIGURE 8.7 BOOKING CONTROL WINDOW ....................................................................................... 126
FIGURE 8.8 TAKE BOOKING WINDOW ............................................................................................. 127
FIGURE 8.9 EXAMPLE SHIFT WINDOW ............................................................................................... 128
FIGURE 8.10 GET POST CODE ........................................................................................................ 129
FIGURE 8.11 DISPLAY POPULAR ADDRESS WINDOW ....................................................................... 130
FIGURE 8.12 SCHEDULING ASSISTANT ............................................................................................ 131
FIGURE 9.1 SUMMARY OF EVALUATION STRATEGY ....................................................................... 133
LIST OF TABLES

TABLE 4.1 ELICITATION TECHNIQUES FOR GROUNDED THEORY .......................................................... 68
TABLE 5.1 KNOWLEDGE ELICITATION SESSIONS ................................................................................. 82
TABLE 6.1 OPEN CODING CONCEPT CARDS .......................................................................................... 90
TABLE 6.2 AXIAL CODING INDEX ............................................................................................................ 92
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1. INTRODUCTION

1.1 The Research Issues

Knowledge acquisition is the process of acquiring knowledge needed for the development of a knowledge-based system. The goal of knowledge acquisition is to understand how a person carries out some activity so that the activity can be automated or supported (Scott et al., 1991). This research has tested a novel approach to knowledge acquisition based on Grounded Theory. Grounded theory is a qualitative method used in the social sciences (Glaser and Strauss, 1967) in order to derive theory from data, where the data is typically textual information, notes of observations, and transcripts of interviews. In order to use grounded theory in the knowledge acquisition process, it was necessary to determine which knowledge elicitation techniques (used to elicit knowledge from human experts) were most appropriate to and consistent with the grounded theory approach.

In order to test the grounded theory approach to knowledge acquisition, a case study has been carried out in the domain of dial-a-ride scheduling. Dial-a-ride services provide transport in wheelchair accessible vehicles for people with mobility difficulties who are unable to use conventional public transport. Four UK dial-a-ride operators collaborated in the research and each provided access to a despatcher, an expert in the scheduling process from whom knowledge was elicited. These dial-a-ride operators also participated in the evaluation of the products of the grounded theory knowledge acquisition process. This domain is one in which expertise is not acquired through extensive study and training (such as in medicine), but through experience and from colleagues. The knowledge applied involves a strong element of common-sense reasoning and also requires temporal and spatial reasoning. Nonetheless, it is a task in which experienced (expert) despatchers perform considerably better than lay people. It is primarily a planning task rather than a diagnostic one.

The process of knowledge acquisition entails eliciting knowledge from an expert, interpreting the expert’s reasoning processes and creating a model of this expert knowledge (Scott et al., 1991). However, while the representation and implementation stages of knowledge-based systems development have advanced with time, knowledge elicitation is still considered the bottleneck in the development of such systems (Nicholson, 1992). Knowledge acquisition is a time-consuming process. It has been argued by Cooke (1989) that this is because knowledge engineering techniques impose a structure on the process of knowledge acquisition, and by Davies and Hakiel (1988) that this structure does not allow for the nature of human expertise. Given the nature of the domain of
study and these concerns about the time-consuming nature of knowledge acquisition, grounded
theory is proposed as a method, which, because it is recognised as a sociological research method
that allows for the systematic generation of conceptual models from qualitative data, may be able to
address the problem of the knowledge acquisition bottleneck.

Although knowledge acquisition is now carried out for a number of reasons, for example, to prepare
training materials, to capture and document organisational knowledge, or to build ontologies, it has
its roots in the development of knowledge-based systems (or expert systems), in the need to document
the knowledge of the human expert, to structure it and to represent it in a form that can be used
directly or indirectly to develop a computerised system to automate the task formerly carried out by
the human expert or to support that expert in his or her task. In this research a prototype knowledge-
based system for decision support has been developed using the output from the knowledge
acquisition process.

The focus of the research has been whether it is possible to develop a knowledge acquisition
methodology based on grounded theory. To do this it was firstly necessary to determine which
knowledge elicitation techniques would work with grounded theory. The selected techniques have
been applied, and a grounded theory process has been carried out. The represented knowledge which
has been produced by this process has been evaluated firstly in terms of whether it provided a good
model of the dial-a-ride scheduling process, and secondly in terms of how well it could be translated
into a prototype knowledge-based system to support the scheduling process. As such, the main
research questions can be summarised as follows.

- Which knowledge elicitation techniques are suitable for use with grounded theory?
- Can grounded theory be used as the basis of a knowledge acquisition method to produce a
  conceptually rich model of the knowledge used in the domain under study?
- Can the model produced be used as the basis of a computerised knowledge-based system?

This research has covered three years of which the first six months consisted of a literature review of
knowledge elicitation techniques, the problems associated with knowledge elicitation, the use of these
techniques in a number of domains and grounded theory analysis. The next year was spent eliciting
data from dial-a-ride experts at three Community Transport sites. Grounded theory analysis was then
carried out on this data and a grounded theory produced. The following year was spent performing
systems analysis and design on the grounded theory and developing a prototype knowledge-based
system. The final six months were used to evaluate the knowledge-based system. The writing up of this research was carried out during the final 12 months of this research.

In the rest of this chapter, knowledge acquisition is discussed in more detail, and the domain of application is described. A breakdown of the contents of each subsequent chapter is provided, and finally the research questions addressed in this work are stated.

1.2 Knowledge Acquisition

Knowledge acquisition is the stage in the development of a knowledge-based system that entails acquiring knowledge from the expert, interpreting the reasoning process and creating a model of expert knowledge. The stage of acquiring knowledge from the expert is defined as the knowledge elicitation stage, involving processes by which facts, rules, patterns, heuristics and operations used by humans to solve problems in the particular domain are elicited (Garg-Janardan and Salvendy, 1988).

The process of knowledge acquisition requires the structuring of problems and the gathering of deep knowledge or intuition (Massey and Wallace, 1991). Jackson (1990) suggests an analysis of knowledge acquisition with a process model of how to construct a knowledge-based system, see Figure 1.1.

The stages can be summarised as follows:

- **Identification** - Identify the problems, data and criteria the system will work with;
- **Conceptualisation** - Uncover the key concepts and relationships between them. This should allow for different kinds of data, the flow of information and the underlying structure of the domain;
- **Formalisation** - Understand the nature of the underlying search space and the character of the search that will have to be conducted;
- **Implementation** - Turn the formalisation of knowledge into a runnable program which includes the specification of controls and the details of information flow;
- **Testing** - Evaluate the knowledge-based system on a large and representative sample of test cases.
Conceptualisation of the domain is one of the most important and difficult knowledge acquisition tasks according to McGraw and Harbison-Briggs (1989). They point out that eliciting, analysing and depicting concepts is not easy and that many interactions between the domain expert and the knowledge engineer are needed. The research described in this thesis is concerned primarily with the stages of identification, conceptualisation and formalisation. The stages of implementation and testing are addressed in so far as a prototype knowledge-based system was developed and evaluated. This is however only as a means to validate the outcome of the knowledge acquisition process.

1.2.1 The Aims of Knowledge Elicitation

There are two main reasons why the subject of knowledge has become increasingly important to cognitive psychologists and knowledge engineers:

- The developing significance of domain knowledge in the solving of problems.
- The wish to create intelligence in machines.

Both cognitive psychologists and knowledge engineers share the same interest in human experts. Evans (1988) characterises this shared interest using two features:

- The parts that perception, memory, language and thinking play in the subject under study.
- The theoretical perspective in which human beings are viewed as information processing systems.

The quantity of knowledge kept in the human brain is enormous and its organisation extremely complex (Evans, 1988). This knowledge is distinguished as declarative and procedural knowledge,
corresponding respectively to “facts” and “rules”. Declarative knowledge is static knowledge consisting of what we know about things such as objects, events, relationships between concepts and sequences of events (Gordon, 1989). Procedural knowledge is the knowledge of how to do things, for example rules, heuristics and algorithms. It is procedural knowledge that is hard to extract as it is often so automated in the brain that it is very difficult to describe this knowledge either orally or in writing. However, this knowledge must be clearly expressed before it can be of use to a knowledge-based system. Choosing the appropriate elicitation techniques and a suitable analysis methodology is of great importance if the knowledge acquisition bottleneck is to be reduced and if the knowledge is to be elicited accurately.

Wolfgram et al (1987) further describe knowledge (in the context of knowledge acquisition) as consisting of preliminary and detailed knowledge. They list the objectives of knowledge elicitation for preliminary and detailed knowledge. Preliminary knowledge is the fundamental understanding an expert has of a subject. It is high level knowledge. Detailed knowledge is the ‘private’ knowledge that an expert has acquired by years of experience and training. Such knowledge is low level knowledge.

1.2.2 Knowledge elicitation and its problems

Knowledge elicitation is generally regarded as the chief constraint in the development of a knowledge-based system. Cooke (1994) believes the major problem involves the abstracting of appropriate models of expert knowledge from data gathered during elicitation. These limitations arise for a number of reasons. Davies and Hakiel (1988) suggest that the problem arises from the nature of human expertise and its foundation on increasing levels of intrinsic physical and mental processes. The example of trying to explain to a non-driver how one would drive to work is used to illustrate their argument. Most people drive to work on ‘autopilot’ and are commonly unable to describe anything seen along the way. The first section of knowledge required by the non-driver is relatively simple to obtain. By describing approximate distances, which turnings to make and landmarks along the way that distinguish the route, the expert can easily communicate their expertise of the route to the non-driver. As Davies and Hakiel (1988) point out, the problem arises when the expert is required to tell the non-driver how to handle the car. Many features of driving are so automatic that they are impossible to explain, for example, how does one explain the “biting point” of the clutch and how would one describe such a feature? The expert may regard certain knowledge as being so obvious they do not describe it and therefore fail to communicate this knowledge to the knowledge engineer.
Further problems with eliciting knowledge are caused by human biases on the part of the expert and the knowledge engineer that can greatly affect the knowledge gathered. Bias is the alteration of an expert’s thought processes or the reporting of this (Davies and Hakiel, 1988). Bias can enter into knowledge elicitation from two quarters, the expert and the knowledge engineer. Experts can be susceptible to what they think the knowledge engineer wants to hear. This susceptibility can be caused both by the human need to be accepted and because people are generally unaware of how they solve problems and make decisions. Bias can also come from the knowledge engineer’s interpretation of what the expert has told them. The knowledge engineer can interpret the expert’s knowledge in their own way, not realising that this structure is different from that of the expert.

Forsythe and Buchanan (1989) suggest that problems with knowledge elicitation are not necessarily due to the elicitation methods used, but are due to lack of communication skills in the knowledge engineer. Davies and Hakiel (1988) agree:

"In the construction of an Expert System, the burden of providing such an explanation rests on the chosen domain expert; the task of obtaining it, making it as comprehensive and comprehensible as possible, and checking its utility, belongs to the knowledge engineer."

Such views suggest that knowledge elicitation and the analysis of it should take a more empirical form by paying more attention to the heuristics being used. Forsythe and Buchanan (1989) argue that artificial intelligence has ignored the overlap it shares with qualitative sociology in the areas of problem definition and methodology. Grounded theory is a qualitative research method developed originally for sociological use. Both artificial intelligence and qualitative sociology are concerned with how humans understand, organise and process information. Both disciplines also share some of the same basic knowledge elicitation techniques, interviewing, observation and documentation. By using an ethnographic method, Forsythe and Buchanan (1989) argue that a deeper understanding of what an expert says and does can be obtained. Ethnographic methods of data collection have been developed to ease data gathering in informal and unstructured settings. The knowledge engineer not only elicits knowledge in the environment where it is used, but also helps the collection of "common sense" knowledge as well as knowledge that is "formally" ordered.

Berry (1987) argues that effective knowledge elicitation can be carried out if the existence of different forms of knowledge is recognised. Different kinds of knowledge require different knowledge elicitation techniques. The problem lies with matching up the correct technique for eliciting a type of knowledge. The issue of knowledge types and appropriate elicitation techniques is discussed further in Chapter 2 as each technique is reviewed.
The knowledge acquisition bottleneck is discussed further in Cullen and Bryman (1988). The contention is that the knowledge acquisition bottleneck is not a result of inadequate elicitation techniques or failure by the knowledge engineer. They argue that problems within the subject itself and with the implementation of a knowledge-based system are the cause of the bottleneck. They suggest that by using elicitation techniques that are compatible with the knowledge structures of the domain, it is possible to reduce the bottleneck problem considerably. Neale (1988) also states that knowledge elicitation techniques should be chosen to suit the domain, the task, the expert and the knowledge engineer. The selection of techniques suitable for the domain in this research is discussed in Chapter 5.

Knowledge elicitation commonly involves some form of verbal report by the expert. Verbal reports are criticised as being incomplete and inaccurate (Nisbett and Wilson, 1977). A further problem that can be met in an expert’s report is that he or she may simplify or distort their view when explaining it to a non-expert (Cooke, 1994).

The complication that underlies all knowledge elicitation discussions is how the knowledge engineer can elicit the most complete knowledge required by the system. The difficulty lies with finding a solution to such a seemingly simple task. The problems associated with knowledge elicitation discussed in this section suggest that communicating the knowledge is the biggest obstacle in developing knowledge-based systems. Qualitative methods of data collection are designed to deal with human communication and could possibly provide a solution to the difficulties encountered by knowledge engineers. The communication skills of the knowledge engineer can be improved by becoming well versed in the problem domain before performing knowledge elicitation with the expert. In the case of this research however this would not be appropriate. The knowledge engineer should have as few preconceptions of the domain as possible in order conduct grounded theory.

The problem concerning bias is perhaps the hardest issue to work through. The literature would suggest that using knowledge elicitation techniques that are not biasing could help to overcome the problem of bias. The methods suggested as not being biasing are qualitative methods that would imply that qualitative knowledge elicitation techniques will cope better with research that has high human involvement.
1.3 The Domain Application

The domain chosen to test the research hypothesis, outlined in section 1.1, is Dial-A-Ride. The domain was already being used for an EPSRC research project and the resources required for this research were readily available. This section introduces the domain and explains why it was chosen.

Knowledge-based systems range from advisory programs that assist non-expert users to job aids for experts themselves. (Scott et al, 1991). It was felt that the nature of the domain in this research, dial-a-ride services, required the type of system that allowed high human involvement in decision making.

Dial-a-rides are door to door transport services for passengers who are mobility handicapped and unable to use conventional public transport because of a disability. The services are typically provided in minibuses adapted to carry wheelchairs and fitted with wheelchair lifts. Bookings are taken in advance and allocated to vehicle shifts with each vehicle shift containing many trips.

The computer systems available for scheduling bookings are based on mathematical techniques, such as linear programming. It has been found that dial-a-ride despatchers do not recognise the heuristics used in this scheduling software (Bennett et al, 1995). Human experts do not only use algorithms to solve problems (Hart, 1985). Expertise is gained over a number of years and is comprised of more than just facts and rules. An expert will try different ways of problem solving and develop rules of thumb in order to produce an adequate answer rather than a mathematically correct answer (Hart, 1985). Discussions with despatchers and their managers suggest that there should be a middle way that exploits the benefits of computerisation, by handling the administrative functions of database management, and enhances the skills of the despatchers. In other words the despatchers are freed up to give greater attention to making allocative judgements.

1.4 Thesis Structure

Chapter 1 has explained the background to this research and introduced the research questions. These issues are: which knowledge elicitation techniques are suitable for use with grounded theory; can grounded theory be used as the basis of knowledge acquisition method to create a conceptually rich model of the knowledge elicited; can the model produced be used as the basis of a computerised knowledge-based system; and does grounded theory reduce the time issue in the knowledge
acquisition bottleneck? This thesis is structured to show how the research was executed to ascertain the extent to which the research questions were answered.

Chapter 2 discusses the wide variety of elicitation techniques that are available to the knowledge engineer. The advantages and disadvantages associated with each technique are discussed and the most suitable areas for using each technique are also considered. The aim of Chapter 2 is to critically analyse a selection of knowledge elicitation techniques so that an informed decision can be reached when choosing techniques for use in this research.

A critical review of grounded theory is provided in Chapter 3. There is a discussion of two different approaches to grounded theory known as the Straussian and the Glaserian approaches and of why this research followed a Straussian approach. The aspects and stages of grounded theory are described in detail and some evaluation techniques for evaluating grounded theory are considered. Finally Chapter 3 looks at some of the problems associated with grounded theory. Chapter 3 aims to introduce the main concepts of grounded theory and provide the reasoning for the selection of knowledge elicitation techniques.

In Chapter 4 the suitability of knowledge elicitation techniques for grounded theory is evaluated. A set of criteria by which each technique is judged is established. Each technique is assessed to ascertain which of the criteria it meets and then judged on how well grounded theory analysis will work with the technique. Chapter 4 aims to provide the rationale for the data collection and analysis in this research.

Chapter 5 restates the aim of the research in regards to Chapters 2 to 4, that is does grounded theory analysis provide rich and complete knowledge that facilitates building computer systems? An overview of the methods used in the research is given, showing the problems faced and overcome in pilot studies and the knowledge elicitation exercise. A number of alternative research methods are also considered. The objective of Chapter 5 is to present the data collection methods employed in this research.

Chapter 6 describes how the knowledge acquisition data is analysed using grounded theory coding. The results of the coding procedures are discussed using examples taken from the research. A brief appraisal of some of the software available for grounded theory coding is also given. Chapter 6 offers an example of a grounded theory analysis in the domain of dial-a-ride scheduling.
The grounded theory product is detailed in Chapter 7. The processes of designing and writing the grounded theory are reported. A discussion of the grounded theory produced in this research follows. The evaluation criteria and results of the grounded theory are also included in the chapter. The chapter concludes with an attempt to represent the grounded theory graphically. The objective of Chapter 7 is to discuss the grounded theory product of this research.

Chapter 8 describes the development of the prototype that is intended to show how grounded theory coding can be embodied in a form suitable for systems analysis and design. The chapter discusses the systems analysis carried out based on the grounded theory coding developed during the research. The design processes based on structured analysis and frames are described using examples from the research. The type of prototype knowledge-based system developed is also explained. Chapter 8 aims to show how the grounded theory coding can be represented in a form suitable for use in systems analysis and design.

The evaluation requirements for the prototype knowledge-based system are described in Chapter 9. The techniques used to carry out the evaluations are discussed. A full review of the evaluations in relation to the research question, data reliability and the analysis methodology is also provided. Chapter 9 aims to show how grounded theory can be used in the development of a knowledge-based system and the extent to which the grounded theory methods used in this research are of use in the knowledge-based system.

Chapter 10 presents a summary and discussion of the research findings. The discussion attends to the research issues and investigates the extent to which they have been met. A summary of the research processes are also provided. The limitations of the research are identified as are the implications of the research. Chapter 10 also identifies possible future work from the research.

1.5 The Research Questions Re-Stated

The research questions addressed in this work were stated earlier. They are restated here with subsidiary questions which will be addressed in this thesis.

- Which knowledge elicitation techniques are suitable for use with grounded theory?
Has the application of these knowledge acquisition techniques in conjunction with
grounded theory overcome any of the problems associated with the knowledge acquisition
bottleneck?

- Can grounded theory be used as the basis of a knowledge acquisition method to produce a
  conceptually rich model of the knowledge used in the domain under study?

- Has the use of grounded theory made it possible to develop a model of knowledge which
  is human-focused and allows for the nature of human expertise rather than structured by
  the nature of the environment in which it will be used?

- Is grounded theory a suitable analysis method for a domain where the experts are non-
technical and where expertise is acquired largely through experience rather than formal
  education or training?

- Has the iterative nature of grounded theory made it a suitable method of analysis for the
development of a knowledge based system?

- Can the model produced be used as the basis of a computerised knowledge-based system?

- Has the grounded theory approach produced a model which can be translated into
  appropriate representations for use in a knowledge-based system?

- Has the grounded theory approach assisted in identifying those tasks which can be
  usefully automated, and those tasks which can be supported?
2. KNOWLEDGE ELICITATION TECHNIQUES

2.1 Introduction

This chapter discusses knowledge elicitation techniques. Knowledge elicitation is the process of collecting facts, rules, patterns, heuristics and operations that are used by humans to solve problems in a particular domain (Garg-Janardan and Salvendy, 1988). Although solutions to the problems associated with knowledge elicitation continue to be of interest, the techniques used in elicitation are well established.

Knowledge can also be found in written documentation, although the common approach to knowledge elicitation is to ask an expert in a particular domain what they know (Cullen and Bryman, 1988). Even though the answers to the questions put to the experts are essential to the construction of a knowledge-based system they can be inadequate in a number of ways (McCloskey et al, 1991):

- They are incomplete;
- They are insufficient;
- Experts can find it difficult to articulate their expertise in the form required by the knowledge engineer;
- The knowledge engineer may have chosen an elicitation technique that is not suited to the knowledge-based system under development or the domain under study.

Knowledge based methodologies are available for knowledge acquisition, for example KADS (Knowledge Acquisition and Documentation Structuring). A knowledge based system in KADS is a model of some problem solving exercise. However, it is not the intention of this research to investigate previously tried knowledge based methodologies.

In order to ease articulation of expertise, it is important to identify the purpose of the knowledge-based system being developed, and the nature of the knowledge required and then try to match the nature of the knowledge required with the nature of knowledge being elicited (McCloskey et al, 1991). Each elicitation technique described in this chapter is generally discussed in relation to the requirements of this research.
Each technique is also examined for the type of knowledge it elicits. Researchers are interested in eliciting both procedural and declarative knowledge, however not all techniques can elicit both of these. This chapter comments broadly on the type of knowledge these techniques elicit, a detailed discussion of these is in Chapter 4.

Knowledge can also be elicited using machine learning algorithms to induce knowledge. Some authors believe that the rules used by the human expert can be better determined using a machine-learning data-driven method (Kattan et al, 1993). The aim of this thesis is to investigate a human focused approach to knowledge elicitation and therefore machine learning techniques are not discussed in detail. Boose (1989) provides a summary of computer-based knowledge elicitation tools.

Elicitation exercises are usually carried out with a single domain expert (Mittal and Dym, 1985). However, there are times when using multiple experts may be more efficient (Moore and Miles, 1991). A number of elicitation techniques are available for multiple experts and these are discussed in section 2.10.

It is not the purpose of this research to conduct an exhaustive review of knowledge elicitation techniques. The techniques described here are described and discussed only in enough detail to determine their suitability for use with grounded theory.

The techniques discussed here are grouped under non-scaling techniques, scaling techniques, machine techniques and techniques for multiple experts. Section 2.2 investigates two types of interview techniques: structured interviews and unstructured interviews. Section 2.3 looks at the verbal protocol technique. The teachback technique is discussed in section 2.4 and walkthroughs are examined in section 2.5. Section 2.6 explores two types of observation: visible observation and participant observation. The scaling techniques of repertory grid and card sorting are examined in sections 2.7 and 2.8. Section 2.9 describes the induction technique. Techniques that are suitable for multiple experts are discussed in section 2.10. Each technique has strengths and weaknesses that affect their suitability for this research. Therefore the advantages and disadvantages of each technique in the context of this research are discussed at the end of each section. The chapter finishes with a review of any issues arising in relation to these techniques and this research.
2.2 Interview

Interviews are used mainly during the elicitation of preliminary knowledge to make a first conjecture of the problem structure, rules and control strategy. The interview approach is considered one of the most common methods for eliciting an expert's knowledge (Cordingley, 1989; Forsythe and Buchanan, 1989). This research requires the elicitation of both procedural and declarative knowledge. One of the knowledge types elicited by interviews has been found to be declarative (Gordon, 1989). Interviews are used to elicit knowledge across a number of disciplines including the social sciences. Given that this research will use a social science methodology to analyse the data collected the interview was considered an appropriate elicitation method to examine.

The method is simple and provides immediate response to help clarify issues (Holsapple and Raj, 1994). There are a number of conditions required for a good interview session:

- The knowledge engineer should have the “trust” of the expert.
- The knowledge engineer should have some background understanding of the domain concepts and vocabulary.
- The knowledge engineer should be sufficiently trained in interviewing techniques, style, and poise to hold the interest of the expert during the interview sessions.
- The knowledge engineer must be skilled at facilitating conversation (Scott et al, 1991).
- Interruptions of any form should be kept to a minimum.
- Privacy should be maintained.

There are a variety of interview techniques that can be used in sessions with the expert (Jones et al, 1996). This chapter reviews two of the most common types of interview, the structured interview and the unstructured interview.

2.2.1 Structured Interviewing

In structured interviewing the knowledge engineer uses subject headings to control the order of the interview. The format and line of questioning are planned in advance. Holsapple and Raj (1994) list three conditions that must be met when using structured interviewing:

- The knowledge engineer must be well acquainted with the domain terminology.
- The knowledge engineer must have good interviewing skills.
- The expert must be prepared to answer some potentially annoying questions.

There are two main approaches to structured interviewing, Twenty Questions and Laddered Grid (Neale, 1988). In Twenty Questions the interviewer has a set of examples of solved problems and the expert asks the questions, to which the interviewer may only answer "Yes" or "No". This method allows the knowledge engineer to discover quickly what information the expert needs to solve the problem and to get some idea of the structure of the problem solving. The success of Twenty Questions is dependent on the choice of solved problems and therefore can be biased. In Laddered Grid the interviewer starts the expert with a seed item from the domain. The aim is to build a "map" of the domain on paper by asking for examples of the seed item and for what the seed item is an example.

Structured interviewing is aimed at capturing precise codable data (Fontana and Frey, 1994). Given that the suitability of grounded theory for knowledge acquisition will be evaluated by building a prototype decision support system, the codability of the data collected is an important issue to consider.

2.2.2 Unstructured Interview

Cooke (1994) is one of the most recent and up to date references for knowledge elicitation techniques that summarises older papers. Unstructured interviews are interviews where the format and line of the questioning are not planned in advance (Holsapple and Raj, 1994). The expert is permitted to introduce concepts, vocabulary and ideas and set the overall direction of the interview. The knowledge engineer records the expert's statements and encourages clarification of important points. Fontana and Frey (1994) argue that unstructured interviews have a qualitative nature and provide a greater breadth of knowledge.

A requirement of grounded theory analysis is that the researcher should have no, or as few as possible, preconceptions of the domain under study. Unstructured interviews attempt to understand behaviour without imposing any prior categorisation that may limit the field of inquiry (Fontana and Frey, 1994). Therefore this form of interviewing appears in this sense to be appropriate for this research.
2.2.3 Advantages and Disadvantages of Interviews

Unstructured interviews are useful in obtaining a sense of the domain and the range of issues that need to be addressed. They do not require detailed domain knowledge by the knowledge engineer (Cooke, 1994). Unstructured interviews are therefore appropriate for use with an analysis method such as grounded theory.

The main disadvantage with unstructured interview methods is that they can produce copious and unwieldy data. One of the causes of the knowledge acquisition bottleneck is that the process is very time consuming. It is therefore important for this research to consider the possibility that the unstructured interview may increase the problems associated with time rather than reducing it. Cooke (1994) recommends that for larger, more complex projects unstructured interviews should only be employed as a knowledge "discovery" tool, rather than for an exhaustive recording of knowledge. This is a potential use for unstructured interviews in this research.

The main advantage of structured interviews is that they are more systematic and therefore gaps in knowledge are easier to identify (Cooke, 1994). Experts also prefer structure because the information they are required to give is more explicitly defined. The grounded theory in this research developed from the knowledge elicitation is going to be used as the basis for a prototype knowledge based system. Therefore a technique that lends itself more to structured coding may be more apposite to producing rules for such a system.

The main disadvantage with structured interviewing is that the data produced can be inexact. Neale (1988) warns that although this form of interview can show the detailed structure of a concept, there is a risk that the knowledge elicited is an artefact created under the pressure of questioning. Also the method relies on the assumption that an expert can reliably express his or her knowledge (Welbank, 1990). Inaccurate knowledge could lead to the failure of the grounded theory analysis to represent the true concepts used in dial-a-ride scheduling. Therefore it will be impossible to evaluate the extent grounded theory can reduce the knowledge acquisition bottleneck. Avoiding misreported knowledge is therefore a serious consideration when selecting appropriate knowledge elicitation techniques.

A further disadvantage is that structured interviews require more preparation time and domain knowledge from the knowledge engineer (Cooke, 1994). This would suggest structured interviews could augment the knowledge acquisition bottleneck problem of time and increase the likelihood of the knowledge engineer having preconceptions of the domain.
### 2.3 Protocol Analysis

Protocols are the verbal reports that an expert generates which show how decisions are made and information is processed (McGraw and Harbison-Briggs, 1989). The technique of protocol analysis involves asking the expert to "think aloud" all the time while solving a problem. This is then tape-recorded, transcribed (with notes of action) into a protocol and then examined for meaningful connections (Neale, 1988).

Verbal protocol analysis is commonly used to elicit *detailed knowledge* from the expert on the sequencing and structure of subtasks (Greenwell, 1988). Neale (1988) believes the verbalisations of the expert can show the heuristics that are used in problem solving. The outcome of the analysis provides the researcher with a map of the sequencing of thoughts involved in making a decision as it occurs (Ericsson and Simon, 1980). Researchers are interested in eliciting both procedural and declarative knowledge. Berry (1987) argues that protocol analysis is a suitable method for eliciting implicit knowledge therefore this technique may suitable for this research.

Collopy and Armstrong (1989) find protocol analysis particularly useful where the expert's awareness of the problem-solving process is low. The experts in this research can be described as novices in that they have not taken part in a knowledge elicitation exercise before. It is likely the experts will not be aware of their problem-solving processes and therefore protocol analysis would appear to be an elicitation technique that should be discussed in this research.

As with the interview technique, there are a number of conditions that must be met if the analysis is to prove successful:

- The knowledge engineer needs to be well acquainted with the domain.
- The problem selection should be a representative and sufficient sample of the expert's knowledge.
- The knowledge engineer should be experienced in analytical skills to reconstruct the solution from verbal protocols.
- The knowledge engineer needs to structure verbal protocol sessions to minimise interference.
- The knowledge engineer should give preliminary instructions in protocol analysis to motivate the domain expert to verbalise at all times. It is important for the knowledge engineer to inform the expert that they are concerned with the way the expert performs the task (Greenwell, 1988).
The knowledge engineer should be aware that verbal protocol analysis proves more valuable in some domains than in others, for example some situations may lead to little or no verbal expression (Evans, 1988).

It is recommended that protocol analysis is not used alone but in conjunction with other techniques such as interviews (Burton et al, 1987).

Green (1995) details some different conditions under which verbal protocols can be collected:

- **Concurrent** - the protocol is generated simultaneously with the expert performing the task.
- **Retrospective** - the protocol is generated after the expert has finished the task. The retrieval process is more accurate the earlier the protocol is collected.
- **Individual** - an individual works alone on a task to produce the protocol.
- **Group** - more than one individual works simultaneously on the same task to produce the protocol.
- **Unaided Verbalisation** - the expert thinks aloud and is prompted only when he or she pauses for a time.
- **Aided Verbalisation** - the expert is asked questions about the task.

Ericsson and Simon (1980) recommend the use of concurrent protocol analysis as a delay between completing the task and producing the verbal report can introduce inaccurate knowledge because information can be lost from memory.

**2.3.1 Advantages and Disadvantages of Protocol Analysis**

There are a number of advantages to using the technique. Hart (1985) claims that experts find it much easier to talk about specific examples of problems than to talk in abstract terms. By concentrating on the task at hand the expert is less likely to digress and their comments will be more coherent and structured. Hart also argues that the transcripts of the protocols describe the comments of the expert at work and recount exactly the expert's decision making as they go through it. Researchers are particularly interested in decision-making processes therefore, on this basis, protocol analysis should be considered as an appropriate technique.

Ericsson and Simon (1980) argue that verbal protocols are usually accurate and representative measures of cognitive processes. The situation in verbal protocol analysis is more realistic than a
false interview situation. Accuracy of knowledge is essential to the development of a knowledge-based system.

There are several disadvantages associated with verbal protocol analysis. The method tends only to be accepted if no other method will work (Welbank, 1990). Verbal protocols are designed to elicit information from the expert while they are in the midst of solving problems and making decisions. Schweiger (1983) argues that verbal protocol analysis has the potential for being obtrusive in the processes of problem solving and decision making, Ericsson and Simon (1980) however dispute this claim and discuss how verbalisation operates and how concurrent verbal protocols affect problem solving and decision making processes. They conclude that concurrent verbal protocols do not change the structure of problem solving and decision-making processes. Schweiger (1983) points out that evidence supporting this conclusion is limited and goes on to quote another study which found that in an experiment where problem solving was done both silently and aloud that processing was done more rapidly during the aloud stage. Nisbett and Wilson (1977) also argue that experts cannot always report reliably on relevant information that appears to have influenced particular decisions.

However, Green (1995) points out that there are two problems with Nisbett and Wilson’s arguments. Firstly, that the verbal report procedures described were inadequate due to time lags during which knowledge could have been lost. Secondly, the subjects in the study had been asked to describe their cognitive processes, which according to Green is not possible. Therefore it is not surprising the subjects speculated about why they behaved as they did. Schweiger (1993) goes on to argue that any negative effects caused by obtrusion could be compensated by the positive effects of verbalisation on memory. This shows that although the expert may slow down the task they are performing during verbalisation, it should be noted that usually only the speed of the task is affected and not the task process or structure. A badly structured verbal protocol session could allow too much interference. If the expert is asked to report information or do something not usually associated with the performance of the task, the reporting could change the expert’s normal performance. However, as grounded theory requires that the knowledge engineer should have as few as possible preconceptions of the domain, the knowledge engineer will be particularly aware of not interrupting the expert.

Fox et al (1985) note that verbal protocols are limited because they are unable to elicit some types of knowledge. Examples of such types are task structure and strategies for exceptions where an event may not occur during the protocol. The human focused approach to this research suggests that exceptions will occur during the decision making process. This could therefore be a potential problem with using protocol analysis.
Problems with verbal protocols can also arise if the task is complex, as only a partial trace of the process is recorded, leading to some details of the expert's behaviour being missed. However, this problem can be overcome in a number of ways:

- By combining several verbal protocols.
- Using probes and questions requesting more detail.
- By breaking the task into manageable portions by finding natural breaks in the task.
- Using other knowledge elicitation techniques alongside the verbal protocol.

Given that this research intends to use more than one elicitation technique, the problem of missing knowledge should be overcome.

Greenwell (1988) recommends that the expert be trained in protocol analysis, as it is unlikely they will have experience in talking while doing their job. Information can be omitted if the expert falls silent whilst performing a complicated task or a task so routine it is completed automatically. Some basic training in protocol analysis may make the expert aware of such problems and in turn encourage them to overcome any silences. As a final resort, as it could be classed as interference, the knowledge engineer can encourage the expert to "keep talking". This would suggest that, for the purposes of this research, if the knowledge engineer and expert were fully aware of these potential problems, protocol analysis would be a suitable technique.

2.4 Teachback

Teachback is the process of the expert describing a procedure to the knowledge engineer, who then explains it back in the expert's terms and to the expert's satisfaction (Neale, 1988). When the expert and knowledge engineer agree they are sharing the same concept. In other words, the knowledge engineer has understood the expert. Greenwell (1988) suggests there are three prerequisites that must be satisfied if the teachback is to be successful:

- Both the knowledge engineer and the expert should believe the knowledge engineer has a good understanding of the task.
- The task should be a realistic situation but not too complex.
- The expert should be on hand to guide the knowledge engineer.
Johnson and Johnson (1987) argue that teachback is a method of eliciting qualitative data. Researchers are particularly interested in elicitation methods for qualitative data. Teachback is an elicitation method that captures the expert’s conceptual structure and not just their procedural skills. The grounded theory method of analysis is based on the coding of concepts elicited from the domain. Teachback has been used to elicit knowledge using school children as experts. It is likely that school children can be classified as novice experts. Therefore teachback seems to warrant discussion for this research.

2.4.1 Advantages and Disadvantages of Teachback

There are a number of advantages that can be gained from using the teachback technique. Performing the task can uncover any ambiguities and misunderstandings of which the knowledge engineer may not have been aware. It ensures the knowledge engineer performs the right action for the right reason (Greenwell, 1988).

Neale (1988) suggests the further advantage that there is no doubt about the expert authenticity of the data. This suggests that if the teachback technique is conducted with an experienced knowledge engineer, the knowledge elicited would be accurate and the knowledge-based system would therefore reflect the concepts precisely.

An additional advantage to the teachback technique is that it produces a fund of data authenticated by the expert (Johnson and Johnson, 1987). Therefore if the knowledge-based system failed to show the concepts used in dial-a-ride scheduling there would be a strong possibility this was not due to inaccurate data collection. The worry with using teachback in this research however is that there will be so much knowledge to be taught, the process will prove too time consuming. A fundamental disadvantage with the teachback technique is that it is very time-consuming (Neale, 1988). This would suggest that teachback could add to the knowledge acquisition bottleneck problem of time, an important consideration in this research. The teachback technique is not a strongly structured technique and so requires general interview training (Johnson and Johnson, 1987). This again could lead to more time consuming problems.

A further drawback to using the teachback technique is that it can be tiring for the knowledge engineer (Neale, 1988). One can probably assume that the technique would also be tiring for the expert. This could lead to inattention by both the knowledge engineer and the expert that would
possibly result in the elicitation of inaccurate knowledge and therefore the failure of the knowledge-based system to reflect the concepts being investigated in this research.

2.5 Walkthroughs

A walkthrough is the process of asking the domain expert to walk the knowledge engineer through the task. Walkthroughs are particularly useful in giving first indications of how experts use shortcuts and rules of thumb. They are also useful for eliciting procedural knowledge. This technique differs from protocol analysis in that it is not the thought process that is being considered but the steps that the expert follows to do their job. It is the priority and subordination of certain rules that are of interest. The knowledge engineer can also interrupt the expert and probe why or how they are doing the job. There are two types of walkthrough:

- The domain expert pretends to be accomplishing a task and verbalises the various steps needed to accomplish the task.
- The domain expert acts as an instructor and describes the skills and strategies needed to perform the task.

Given the amount of the knowledge the knowledge engineer would require in order to follow the expert’s instructions, the first type of walkthrough would appear to be more appropriate for this research.

2.5.1 Advantages and Disadvantages of Walkthroughs

The main advantage to walkthroughs is that the technique is similar to verbal protocol analysis. The technique will therefore capture procedural knowledge. It is recommended that, as with verbal protocols, walkthroughs are used in conjunction with other knowledge elicitation techniques. The intention of this research is to use more than one knowledge elicitation technique therefore techniques that work well with other techniques are of interest.

The main disadvantage associated with walkthroughs is that they are not “real time”. As the task performed is a simulated task, knowledge about how one task interacts with other tasks may not be obtained. The knowledge engineer may not be getting the details of normal problem solving. This
Knowledge Elicitation Techniques

A.C. Chimall

1998

raises the problem of being unable to elicit knowledge that is used for exceptions because exceptions may not be used in the walkthrough examples.

A successful walkthrough needs the knowledge engineer carefully to define the task to be examined. Due to the nature of walkthroughs the knowledge engineer will need to interrupt the expert. This can cause the expert to digress and be diverted. However careful design of the session should allow the knowledge engineer to prevent the expert going off at tangents and prevent the problem of incomplete knowledge.

2.6 Observation

"Observation is one of the earliest and most basic forms of research... As members of society, we make observations of the everyday world. These guide us in forging paths of action and interpreting the actions and reactions of others" (Adler and Adler, 1994).

Observing an expert in action is a good source of complex experiential knowledge (Neale, 1988). Asking an expert to perform his or her task rather than describe it produces a more true-to-life record of expertise, especially as it is generally more comfortable for the expert. Observation can be particularly useful to show subtleties that will not come across when the expert is interviewed and to verify an expert’s description of what he or she does (Cooke, 1994).

This research requires the elicitation of both procedural and declarative knowledge. Procedural knowledge is difficult to describe and knowledge that is elicited through verbalisation is more often than not declarative in nature (Gordon, 1989). Procedural knowledge can however be inferred from observing the expert’s actions. Observation could therefore be an appropriate method for eliciting procedural knowledge for this research.

This research is investigating knowledge elicitation techniques that are suitable for grounded theory analysis. Grounded theory analysis considers the affect of the environment on a subject to be important (Strauss and Corbin, 1990). As observation normally takes place in the expert’s domain, the effect of his or her environment can be recorded by the knowledge engineer (Meyer, 1992). Therefore observation would appear to be a knowledge elicitation technique that should be considered for this research. The two types of observation that are reviewed in this research are visible observation and participant observation.
2.6.1 Visible Observation

In visible observation the knowledge engineer has no control over the expert's behaviour under study and plays a passive and non-intrusive role in the research situation (Cooke, 1994). By watching in the background the knowledge engineer is able to observe the expert's actions without influencing the expert. This allows the knowledge engineer to capture information about what the expert actually does rather than what the expert thinks he or she does.

This research is taking a human centred approach to knowledge acquisition. Therefore a knowledge elicitation technique that is commonly used to elicit knowledge concerning human interactions is of specific interest. Visible observation can be used for task analysis which in turn is typically performed to integrate human factors into a system interface (Hoffman, 1989).

2.6.2 Participant Observation

In participant observation the knowledge engineer is not a detached observer but a participant in the activities of the expert (Meyer, 1992). There are five reasons why participant observation is particularly suitable for eliciting knowledge for a knowledge-based system:

- To familiarise the knowledge engineer with the domain under study.
- To obtain knowledge from an expert that cannot easily be acquired through other elicitation methods especially interviewing.
- To put the knowledge engineer in a position to hear the expert's views of themselves and colleagues.
- To investigate the social processes by which the expert's knowledge is developed and supported.
- To help the knowledge engineer construct models of the events and objects in the domain under study.

Researchers are interested in using a social science method of data analysis that is based on the generation of theory. Therefore elicitation methods that have a reputation for encouraging theory generation are of particular importance. Participant observation is considered an anthropological technique traditionally used to improve rapport with those being studied. Anthropologists have also found that participant observation has augmented the generation of hypotheses which could then be investigated further using more structured elicitation methods such as interviewing (Meyer, 1992).
2.6.3 Advantages and Disadvantages of Observation

There are a number of advantages and disadvantages associated with both visible and participant observation. As observation does not involve giving instructions, the knowledge engineer can access knowledge without altering the expert’s behaviour by asking the expert to follow different paths. Meyer (1992) argues that observation also allows the knowledge engineer to fill information gaps and correct inaccurate information that can result from verbal descriptions. There are a number of reasons why this can happen. Experts are unable to describe their problem solving processes because they are unconscious of their behaviour or because the processes are informal. Another reason is that experts cannot describe their processes if they are asked out of the context in which they normally perform. Experts can also tend to give overestimated accounts of their actions either because this is what they think the knowledge engineer wants to hear or because they are more aware of rules than their actual actions.

Knowledge engineers can also be prone to record inexact information because they misinterpret an expert’s actions. It is also possible that, having learnt something about the domain under study, the knowledge engineer can think they know more than they do and make their own and probably inaccurate assessment of an action. Observation can provide a check on the knowledge engineer misunderstanding the expert (Meyer, 1992).

The chief disadvantage associated with observation is that while it is naturalistic, interpretation is difficult for an inexperienced knowledge engineer (Welbank, 1990). Some verbal accounting may also be required from the expert.

A further problem could occur with observation in that although the technique is unobtrusive, any outside presence could affect the expert’s behaviour. This could particularly be the case with participant observation.

The next three sections of this chapter will discuss a series of elicitation techniques known as scaling techniques. Scaling techniques were originally developed by psychologists to investigate cognitive structures (Jones et al, 1996). Scaling methods are based on the idea of concepts mentioned by the expert that are pertinent to the domain. These concepts are represented as some form of matrix in order to show the ways in which they are related. The scaling techniques considered in this research are repertory grid and card sorting.
2.7 Repertory Grid

Repertory grid is a technique that can be used to elicit the factors that an expert considers in making decisions (Nicholson, 1992). The technique developed out of Kelly's Personal Construct Theory, a method of eliciting an individual's way of thinking described with the mental constructs they use (Kelly, 1955). The theory of personal constructs is used in psychotherapy where a patient's personal-social behaviour is influenced by their internal representation of their feelings towards other individuals who play an important role in their life (Crowther et al, 1998). Perceptions are represented by what Kelly called constructs. Constructs are used to show discriminations between events, that is how similarity or lack of similarity can be represented. These similarities and differences are called elements and be objects, situations and individuals. The results of this technique are organised and analysed within a framework called a repertory grid.

Crowther et al (1998) described how personal construct theory is relevant to knowledge elicitation. For use in knowledge based systems, experts are required to identify discrete classifications that become the column headings of the grid. Groups of three of these are then taken and the expert is asked to identify what differentiates one from the other two elements. These differentiates are known as constructs. All elements are then rated against the construct as either totally belonging or not belonging to groups on a scale of 1 to 5. This construct then becomes the label for a row of the grid. Patterns and associations of the elements and constructs are identified and rules generated. Rules can be generated by concentrating on extremes of rating in grids. These can then be refined by finding the concepts which are best at differentiating between the elements. Elements that are very dissimilar are easy to distinguish whereas elements that are very similar are more difficult.

Hart (1985) uses a grid that shows an evaluation of programming techniques as an example, see figure 2.1. The knowledge engineer should define a particular problem for the expert to think about, along with producing elements and constructs that are considered relevant to the problem by the expert.
### Investigation of Computer Programs

<table>
<thead>
<tr>
<th>Construct (C)</th>
<th>Element (E)</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>E5</th>
<th>E6</th>
<th>E7</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 Poor variables</td>
<td>E1</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>Meaningful</td>
</tr>
<tr>
<td>C2 No comments</td>
<td>E2</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>Comments</td>
</tr>
<tr>
<td>C3 Poor structure</td>
<td>E3</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>Good Structure</td>
</tr>
<tr>
<td>C4 Bad layout</td>
<td>E4</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>Good layout</td>
</tr>
<tr>
<td>C5 No gotos</td>
<td>E5</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>Gotos</td>
</tr>
<tr>
<td>C6 Not readable</td>
<td>E6</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>Readable</td>
</tr>
<tr>
<td>C7 No procedures</td>
<td>E7</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>Modular</td>
</tr>
</tbody>
</table>

Anne (bad)
Tim (bad)
Fred (OK)
Dave (very good)
Sally (good)
Bill (poor)
Neil (poor)

(Key: C = Construct, E = Element)

**Figure 2.1 Elicited Grid For Evaluation Of Programming Techniques (Hart, 1985)**

### 2.7.1 Advantages and Disadvantages of Repertory Grid

As with all knowledge elicitation techniques, there are a number of advantages and disadvantages associated with the repertory grid. The main advantage of the repertory grid technique is automation. McGeorge and Rugg (1992) argue that because of the formalised nature of repertory grid, data elicitation is easy without the need for manual transcription. However, given that this research is taking a human focused approach to knowledge elicitation, this advantage is not relevant in this context.

Hart (1985) describes a range of advantages to using the repertory grid technique. She too agrees that the method is useful in coding knowledge and points out that the method can identify correlation...
between constructs and concepts that are grouped or similar. Grounded theory coding requires that concepts are grouped together. Therefore repertory grid could be appropriate to use in this research.

It is also possible to reveal implicit structures in the expert's construction of the domain (Shadbolt, 1988). Nicholson (1992) believes that even though repertory grid technique is indirect it can gather a partial domain model and a sufficiency of cases in a single procedure. The gathering of implicit knowledge is a requirement in this research. However, repertory grid is not guaranteed to elicit such knowledge.

McGeorge and Rugg (1992) argue that if the knowledge engineer has some knowledge of the domain before using repertory grid then adequate results can be secured. Nicholson (1992) agrees, "It is clear that the list of elements is crucial and the questions asked to elicit them should be designed carefully to obtain both elements that are typical and atypical."

It would appear that if the knowledge engineer and expert were trained in the use of repertory grid, the technique could be used in this research.

A disadvantage to repertory grid is it is unlikely the expert will know about the technique. It is possible that this will reduce the expert's participation and cause some unwanted defect (Greenwell, 1988). There have also been reports that the technique is disliked by experts because they consider it inefficient (Burton et al., 1987). Training the expert in the use of repertory grid may overcome the problem of limited participation. However, there is little point in alienating the expert by making them use a technique they do not like.

Furthermore there is some debate over the usefulness of data from the repertory grid technique. Repertory Grid only seems relevant to classification or diagnosis problems. The procedure becomes unmanageable with more than about ten elements. Nicholson (1992), on the other hand, argues that if the number of elements is too small then triads cannot be found. Shaw and Gaines (1988) suggest the optimum number to be between six and twelve elements. Repertory grid needs a balanced selection of items if a satisfactory coverage of the domain is to be obtained. Given the lack of repertory grid experience on the part of the knowledge engineer in this research, the learning of the technique to be able to judge the optimum number of elements may prove too time consuming.

Evans (1988) argues that a further problem associated with repertory grid is that the results are very subjective. It only appears to be useful for diagnostic type expert systems. Repertory grid is classificatory and little information concerning the expert's procedural knowledge is provided. This
research requires that both procedural and declarative knowledge is elicited. Therefore techniques that provided both types of knowledge are of more interest.

2.8 Card Sorting

Card sorting techniques are used to elicit an expert’s specialised theoretical knowledge (Rabbits and Wright, 1987). Domain elements are stored as names on cards that are repeatedly sorted into piles by an expert. This results in a qualitative multi-dimensional map of the domain (Shadbolt, 1988). The purpose of card sorting is to give the knowledge engineer access to relationships between objects, experiences or rules and improve the understanding of the structure of the knowledge underlying the expert’s jargon. Rabbits and Wright (1987) describe some card sorting tasks: group separation, group creation and triadic comparisons. The three tasks are described in the next three sections.

2.8.1 Group Separation

The whole set of cards is sorted into two groups that are named. The cards are shuffled and then sorted into three named groups. Following this the cards are reshuffled and sorted into four named groups. The four groups can be represented as a hierarchy against which the expert’s view can be checked. The example used by Rabbits and Wright is sorting cars, see figure 2.2.

```
FOREIGN
  /  
CARS  ESTATES  SPORTS  FAMILY
     /       
EXPENSIVE LESS EXPENSIVE EXPENSIVE LESS EXPENSIVE
```

Figure 2.2 A Possible Hierarchy

2.8.2 Group Creation

The expert is asked to find a pair of cards in the set that are more similar to each other than any other possible pairing. The groups and links are named and the relationships between the cards can be explored as the cards are sorted.
2.8.3 Triadic Comparisons

Three cards are taken at random from the set of cards. The expert is asked to put the cards into two groups so the two cards in one group are more similar to each other than the third. The expert then explains how the groups differ.

2.8.4 Advantages and Disadvantages of Card Sorting

Gammack and Young (1985) conclude card sorting is useful when there is a large set of concepts in the domain that need structure to be practicable and that sorting is a task people find natural and easy. This would suggest that card sorting would be a useful technique for this research given that the elicitation of concepts is of primary importance.

Burton et al (1987) warn of problems arising if the expert does not like the technique. There have been reports that experts are unenthusiastic about the task and find it irritating. Given that the experts in this research are not experienced in knowledge elicitation this may be not be a suitable technique to use.

2.9 Induction

The principal aim of this research is to investigate alternatives to computer-based knowledge acquisition methods. Therefore the focus of this chapter is on human to human elicitation techniques. However, it is important to examine why machine elicitation techniques are unsuitable. The section discusses induction, a form of human to machine elicitation technique.

Induction is a form of machine learning whereby general rules are generated from a set of examples. Instead of trying to describe their rules, the expert supplies a set of domain examples of different types of decisions called a training set. Also supplied are the attributes that describe the examples and values that are assigned to the examples (Neale, 1988). The training set forms the input to a computer program that uses a rule induction algorithm to work out a set of rules (Evans, 1988). The rules are often constructed as a decision tree. Hart (1986) lists several requirements for successful rule induction:

- The algorithm must be good.
The training set must contain suitable information, in an appropriate form, about the problem.

To use the algorithm it must be possible to indicate and use all the necessary concepts in the input and output.

The training set must be rich enough to contain enough examples with sufficient descriptors to be able to induce these concepts.

2.9.1 Advantages and Disadvantages of Induction

Hart (1986) and Neale (1988) both refer to work by Michalski and Chilausky (1980) in which knowledge taken directly from the expert was compared with a method based on inductive learning from examples. The comparison was done in the context of developing rules for soybean disease diagnosis. This particular example found the induced rules were more efficient than the expert when presented with new examples. Hart (1986) advocates induction as objective, repeatable, indefatigable, consistent and easy to understand,

"Computers are objective, without preconceived ideas...experts cannot always see a simple pattern or principle, and suggest overly complex rules, when they describe what they think they ought to do, rather than what they actually do...a computer program can induce neater and simpler rules than people can."

Kattan (1994) believes induction should be used for the following reasons:

- Experts have difficulty explaining their decision processes.
- Experts are more confident demonstrating their decision making processes than defining them.
- Data-driven approaches are less time consuming.
- Experts can be reluctant to reveal their rules directly.

It would therefore appear that induction is more reliable than human experts. Researchers are interested in the way in which humans make decisions. The prototype knowledge-based system will therefore need to reflect the way humans work and should not be structured so that the expert fails to recognise their behaviour.

The main problem with rule induction is that the knowledge engineer does not know in advance whether the training set and algorithm will be good enough. This is due to the expert being unable to account for all they know (Neale, 1988). Evans (1988) argues that induction takes no account of analysis or understanding of cognitive processes. Given the human focused approach of this
research, the cognitive processes of the experts are of paramount importance. On this basis, induction does not appear to be a suitable technique in this context.

The method is liable to include errors and biases in the rules induced. Induction is only suitable for rule-based systems. Further problems identified by Hart (1985) include the fact that most implementations of rule induction do not cater for exceptions. She also points out that the more attributes there are, the larger the training set must be and the harder it is to assess the training set. The part that exceptions play in the decision making process make it a priority of this research to use techniques that will elicit such knowledge. Induction is not an appropriate technique for this research as the technique cannot elicit exceptions.

Rule induction does not appear to be appropriate for planning tasks because the volume of data that must be used changes with each additional case. For the first booking there would be no existing bookings, but as each successive booking is made, the outcomes of the previous decisions become input to the new decision. It is difficult to see how rule induction can work with continuously varying amounts of input data and how it could generalise the rules.

2.10 Multiple Experts

Human experts can work alone and/or in groups (Medsker et al, 1995). Therefore, there are cases where using multiple experts is a more appropriate method. Although it is the intention of this research to use multiple experts, the experts will not be gathered as one group. This was because this research aims to gather data about different groups and the different methods used by each group. The techniques described here are to gather consensus data from multiple experts and not different data. However for the purposes of completeness, aspects of knowledge elicitation techniques for groups of experts required investigation when discussing knowledge elicitation issues. There are several issues that need to be addressed when the possibility of using multiple experts arises (Medsker et al, 1995):

- There are three configurations of multiple experts that should be examined; using experts individually and combining their knowledge later; using primary and secondary experts; and using experts in small groups. This is where the experts use the same method of working.
- The appropriate experts must be recruited to compose a workable group.
- The required knowledge needs to be divided into suitable portions with designated experts.
• The group size will need to be chosen. The specific problem will determine the number of experts used.
• The group structure will need consideration. The configuration of experts will influence how the group is organised.
• The knowledge elicitation techniques need to be chosen based on the specific problem, on the resources available and possibly on experience.
• The co-ordination of meeting times will need considerable thought due to experts’ schedules and work demands. The geographic distribution of experts may be an additional issue.
• The experts may require an assurance of privacy on certain topics.

McGraw and Seale (1988) recommend that by using elicitation techniques adapted for groups of experts the problems associated with multiple experts can be reduced. Elicitation techniques for multiple experts are, on the whole, borrowed from decision-making studies rather than designed specifically for knowledge engineering. Some examples of where techniques are used for groups of experts are discussed below.

2.10.1 Brainstorming

Brainstorming can help stop immediate criticism and reduce discussion-inhibiting comments (McGraw and Seale, 1988). Brainstorming is designed to promote thinking and generate ideas that may not be conventional. McGraw and Seale (1988) approach brainstorming by suggesting the following rules:

• Explain brainstorming rules.
• Give the experts a problem or topic to consider.
• Generate ideas by either getting the experts to call out ideas whenever they can or by participating in turn.
• The knowledge engineer records all ideas.
• Continue brainstorming until there are no more ideas being generated.
• Discuss as a group the ideas generated.

Greenwell (1988) however believes that brainstorming with multiple experts is no more important than with a single expert.
2.10.2 Consensus Decision Making

Consensus decision making is used to find the best possible solution. Experts assess the advantages and disadvantages of each answer (McGraw and Seale, 1988). The following guidelines are recommended:

- Explain the purpose and process of consensus decision making.
- Outline the problem and the possible solutions.
- Give each expert three votes and place the limitation on them that they cannot place more than one vote by any one option. After voting is completed any options that have less than a previously agreed number of votes are deleted.
- Continue the rounds using only two votes per expert until two options remain or there is a clear winner.
- Discuss the options left.

Consensus decision making is an appropriate technique for domains where system functionality is not specific. Greenwell (1988) accuses McGraw and Seale (1988) of not actually carrying out consensus but of simply holding a ballot. Greenwell does point out that balloting is a much quicker way of reaching a solution and therefore a better method than consensus.

2.10.3 Nominal Group Technique

Nominal group technique is a problem solving procedure that helps reduce conflicts and increase participation (Greenwell, 1988). The group members are located together but are allowed to work independently or anonymously. McGraw and Seale (1988) advise the following guidelines:

- Explain the nominal group technique.
- Ask the experts to list, without discussion, any advantages and disadvantages they can see in the problem.
- The knowledge engineer collates the advantages and disadvantages.
- The experts anonymously rank the items on the list.
- The knowledge engineer leads a discussion on the advantages and disadvantages, focusing on the priorities the experts used to decide the ranking.
- The experts list, without further discussion, possible solutions to the problem.
- The knowledge engineer collates all the solutions to the problem.
- The group discusses the solutions to the problem, aiming to find the best solution.

The main disadvantage associated with group problem solving is that it may not reach the optimum solution but end up with a compromise which falls short of the "best" solution (Greenwell, 1988).

2.10.4 Debriefing

Debriefing is a method of bringing the elicitation session to a close. It addresses the tasks of summarising and recording the problems, solutions, and ideas discussed during the session (McGraw and Seale, 1988). The knowledge engineer can debrief the group and each individual.

2.10.5 Advantages and Disadvantages of Multiple Experts

There is some debate over the complexity of using multiple experts. As Hayes-Roth et al (1983) say, if knowledge acquisition for an expert system with a single expert can be described as a bottleneck, acquisition from multiple experts has the potential to become a "log jam". There are those who argue that using multiple experts can offer many advantages over the single expert. Moore and Miles (1991) show how the use of more than one expert can improve the efficiency of the elicitation approach and the quality of the knowledge acquired.

They list nine advantages to using multiple experts:

- Reduced inaccessibility - If one expert was unavailable, another expert would be accessible.
- Alternative source of explanations - If one expert finds it difficult to articulate a problem, another expert can explain.
- Two approaches to the problem available - Different experts may have different decision making patterns. This enables a more complete picture of the overall domain structure to be built.
- Less chance of missing vital information - Using multiple experts provides more opportunities to elicit more expertise.
- Elicitation of "exceptions to the rule" - Using more than one source of knowledge means that there is more than one opportunity to elicit unusual cases and the probability of acquiring exceptions is increased.
• **Two sources of explanation** - Having alternative sources of explanation available means the expert does not have to repeatedly explain the same concept to the knowledge engineer. Repeated explanations can lead to the expert oversimplifying his or her interpretation that can result in the misrepresentation of knowledge and loss of important information.

• **Preferences due to familiarity counterbalanced** - If an expert is more familiar with a specific domain concept, it can cause decisions to be biased towards that area. Using other knowledge sources can help to prevent this biased perception of the domain.

• **Reduction in duration of project time** - Although elicitation time is increased when using multiple experts, the quality of the knowledge acquired is much richer. This means productivity is increased and the project time is reduced.

• **Immediate verification procedure** - With multiple experts immediate verification for any information obtained is available. This also provides more sources of criticism before the knowledge base is implemented which helps to justify the chosen technique.

Mittal and Dym (1985) found in their study that talking to a variety of experts early in a project helped to get a better understanding of the different kinds of expertise common in the domain. They also discovered that having different people working on the same problem helped to fill in many holes in their specification. The argument that a single expert may have expertise in only a small subset of tasks in the domain (McGraw and Seale, 1988) is the strongest for using multiple experts.

There are, however, several arguments against using multiple experts. Medsker et al (1995) list eight disadvantages to using multiple experts:

• **Different mental models** - Groups of experts may not agree with each other.

• **Reduced accessibility** - The experts may be geographically dispersed thereby reducing their availability.

• **Too many sources of explanation** - Group reasoning can be difficult to see.

• **Increase in the duration of project time** - There may be lower productivity if the process is flawed and the knowledge engineer may have to repeat knowledge elicitation exercises.

• **Negative view of committee work** - Some of the experts may resent working in groups.

• **Socialising and working in groups** - There could be some loss of efficiency due to socialising and status seeking.

• **Personality and professional conflicts** - Experts may display disrespect for other experts because they use different methodologies or because their track record is superior.
- Domination by one or a few - Processes can be influenced too strongly by individuals. There may also be limited idea generation due to fear of expressing opinions.

Greenwell (1988) suggests the biggest problem with using multiple experts is that of complexity. Greenwell mentions how getting three experts in the same room at the same time, sharing the same information can be surprisingly difficult.

The problem of contrasting information has been seen as the major difficulty with using multiple experts (Greenwell, 1988). Moore and Miles (1991) did not experience this problem although they agree contrasting information can produce a completed system that is unreliable or inadequate. All authors suggest using one expert as the final judge. Another difficulty when using multiple experts is the extra skills required by the knowledge engineer. McGraw and Seale (1988) stress that besides being proficient in task analysis, interviewing, protocol analysis and general communication skills, the knowledge engineer must be experienced in group dynamics.

Greenwell (1988) draws attention to the difficulties associated with using multiple experts and advises against projects that involve them. There are times however when the knowledge engineer will be forced to use multiple experts. In the case of this research, although multiple experts are used, they are used separately and not in a group. Therefore the techniques associated with multiple experts are not required.

2.11 Discussion

Chapter 2 has described a number of elicitation techniques and discussed the advantages and disadvantages associated with each in relation to requirements of this research. It is the intention of this research to use more than one technique. Therefore techniques that work well with other techniques merit consideration. The research requires both procedural and declarative knowledge to be elicited, therefore techniques which provide both types of knowledge are of interest. Many of the techniques are criticised for being time consuming, however some are criticised more than others. Therefore techniques which are especially time consuming will not be considered. Given that the experts in this research are novices to knowledge acquisition, techniques that are complicated and likely to required learning on the part of the expert are probably best avoided to prevent resentment and possible alienation of the expert. Although machine induction and techniques for multiple experts have been discussed in this chapter, they will not be used as elicitation techniques for this research.
Interviews are suitable for this research because they can provide both basic introductory information about the domain under study and also more detailed knowledge. However, the technique is very time consuming and is prone to eliciting inexact knowledge. There is some criticism of the interview technique that it actually exasperates the knowledge acquisition bottleneck. However, the interview is a simple technique to use and is popular with both knowledge engineers and experts so is a contender for use in this research.

Verbal protocol analysis appears suitable for this research because, if done concurrently, the technique provides real-time decision making processes, however there is some question over the accuracy of the knowledge elicited and the types of knowledge elicited. There do seem though to be ways of overcoming these problems and protocol analysis would appear appropriate for use in this research.

The teachback technique is commonly used to elicit qualitative data, which is the type of data required for this research. The technique also elicits conceptual and procedural knowledge. However, the learning process on the part of the knowledge engineer would seem to be very time consuming in the context of this research. For this reason, it is unlikely teachback will be a suitable elicitation technique.

Walkthroughs hold the same advantage as protocol analysis in that procedural knowledge is elicited. However walkthroughs are not real-time and therefore run the risk of failing to produce exact knowledge.

There are two types of observations described in the chapter, visible and participant. The main problem with participant observation in relation to this research is that the knowledge engineer may interfere with the expert’s decision making. Given that multiple techniques will be used in this research, the fact that verbal backup is usually required with visible observation is not an issue. Therefore observation would appear an apt technique for consideration.

Repertory grid and card sorting elicit knowledge in a more structured way which could be useful when coding the prototype knowledge-based system. However, the techniques have a reputation for irritating the expert. Given that this research is taking a human focused approach to knowledge elicitation, it would therefore seem more acceptable to consider the needs of the expert rather than the knowledge-based system. It is unlikely that the scaling techniques will be used in this research.
Some elicitation techniques employ machine learning, for example induction. It was felt however that using elicitation techniques for machine learning would not have the necessary focus for a human centred approach therefore only one such technique is described. A full discussion of a number of tools for machine learning can be found in Boose (1989).

There are techniques available for eliciting knowledge from groups of experts. There is some argument over using multiple experts and it is generally better to use just a single expert. However there are cases where multiple experts have to be used and therefore there are elicitation techniques designed for this purpose.

The knowledge elicitation stage of building a knowledge-based system is a complex and difficult area. This chapter has examined a number of elicitation techniques and considered the advantages and disadvantages associated with each in the context of this research. A few tentative suggestions as to which would be the most suitable, have been made. However, the main aim of this research is to find elicitation techniques that are suitable for grounded theory. Therefore while some of the techniques seem inappropriate for the research generally, they may be suitable for use with grounded theory. The suitability of each technique for used with grounded theory is discussed in Chapter 4 of this thesis.
3. GROUNDED THEORY

3.1 Introduction

This thesis has introduced knowledge elicitation and discussed some of the problems associated with this area. In this chapter the grounded theory method is introduced and the aims of using grounded theory are explored. The areas where grounded theory is commonly applied are described using examples of some of the research carried out in these fields. Finally this chapter examines the procedures that should be followed when employing the grounded theory method using samples from this research.

As discussed by Forsythe and Buchanan, knowledge elicitation shares a number of commonalities with qualitative sociology. Grounded theory is a sociological research method. Grounded theory is an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic while simultaneously grounding the theory in empirical observations or data (Glaser and Strauss, 1967). The term researcher used in this context is analogous to that of knowledge engineer. Whereas knowledge engineer is used in expert systems, the term researcher is commonly used in sociology.

The grounded theory method was developed in the 1960s by Anslem Strauss and Barney Glaser during a study of dying. The results of this research were published in the book Awareness of Dying (1965). In 1968 The Discovery of Grounded Theory was published. This described the grounded theory method. A third book Theoretical Sensitivity was published by Glaser in 1978. Following these publications Glaser and Strauss have since gone separate ways and this has resulted in different interpretations of grounded theory. The approaches will be referred to as the Straussian and Glaserian methods after Strauss and Glaser. Stem (1994) suggests that Basics of Qualitative Research (Strauss and Corbin, 1990) is a reply to criticisms levelled at grounded theory’s looseness, its lack of verification and the convoluted description of it in The Discovery of Grounded Theory. Basics of Qualitative Research is a modification of the original concept of grounded theory as emergence to a codified structured operation (Stem, 1994). Glaser on the other hand does not believe such modification necessary. Basics of Grounded Theory Analysis the response to Basics of Qualitative Research, was published in 1992. In Basics of Grounded Theory Analysis (1992) Glaser points out what the differences are and claims that the Straussian methods make no scholarly sense. Glaser identifies two main differences between the two methods of grounded theory: Basics of
Grounded Theory does not ask what the chief problem in the area under study is and what accounts for the majority of the variation in processing the problem; and what category does the problem show. Glaser goes on to demand the two methods should have different names: grounded theory for the Glaserian method and conceptual description for the Straussian method. The approach taken in this research is the Straussian method. The Straussian method provides a more structured approach to grounded theory analysis. Also Basics of Qualitative Research appears to be the only book that provides a tutorial on how to actually do grounded theory analysis. While Glaser in Basics of Grounded Theory Analysis (1992) considers Strauss to be deforming the original method of allowing theory to emerge, it is hard to see beyond Glaser's tendency for tirade against The Basics of Qualitative Research (Strauss and Corbin, 1990). Basics of Grounded Theory Analysis (Glaser, 1992) discusses the "emergence of data and categories". It does not however explain how this emergence occurs or what to do with such an emergence.

3.2 The Aims of Grounded Theory

Charmaz (1983) lists five principles that the grounded theorist endorses:

- Discovering and analysing social and social psychological processes.
- Data collection and analysis phases of research proceed simultaneously.
- Analytic processes prompt discovery and theory development rather than verification of pre-existing theories.
- Theoretical sampling refines, elaborates and exhausts conceptual categories.
- Systematic application of grounded theory analytic methods progressively leads to more abstract analytic levels.

The intent of grounded theory is to construct theory and not to test it (Pierce, 1991). Grounded theory aims to generate theoretical constructs that explain the actions in the context under study (Stern, 1980). There a number of ways in which grounded theory differs from similar methodologies (Baker et al, 1992):

- Grounded theory seeks to explain social process rather than describe psychological structures.
- The conceptual framework is generated from the data rather than from previous studies.
- Everything is data to the grounded theorist. That is any observations, listening or reading can show data in the area under study. Data is also usually collected through a combination of methods.
- Sampling continues until each concept is saturated and a conceptual framework is developed and verified. Grounded theory uses iteration. In other words, the selection of data is a function of emerging hypotheses.
- Data collection and analysis occur concurrently and are based on constant comparative methods. That is each piece of data is compared with every other piece of data rather than comparing the total number of components.

A grounded theory must meet four main criteria: fit, understanding, generality and modifiability (Glaser and Strauss, 1967 and Glaser 1978). The theory should explain what has happened, predict what will happen and interpret what is happening. That is, it should fit the reality of the area under study. As the theory represents reality it should be understandable to the people who were studied. The theory should be general enough to make it applicable to all contexts related to that concept. The theory should achieve modifiability so that emerging categories can be modified to refit them to the data as the research continues.

3.3 Grounded Theory Applications

Grounded theory as a social science methodology is commonly used in sociology, nursing research (Aamodt, 1983 and Brandriet, 1994), increasingly for research in psychology (Polkinghorne, 1994, Rennie, 1994 and Henwood and Pidgeon, 1995) and to some extent in education (Spector and Gibson, 1991 and Weingand, 1993). This section will discuss some examples of research carried out in these areas.

Grounded theory can be used to develop theories about social worlds in the domain of reproductive science. The issue of social worlds theory as promoting comparative analysis is also considered. Grounded theory also stresses the importance of the environment and employs comparative analysis. Grounded theory has also been used in sociological research in the domain of cancer research. The grounded theory concepts of theoretical conceptualisation, constant comparisons and sampling are present in the account.
It is interesting to note that the examples of grounded theory in sociological research have a domain with a medical base. Grounded theory has its roots in sociological research in the world of medicine (Glaser and Strauss, 1965). One of the key areas where grounded theory research is employed is nursing. Although Aamodt (1983) does not specifically mention grounded theory as a research method, his/her review of qualitative methods in nursing research implies that grounded theory would be an appropriate analysis approach. In particular the importance of discovery as being a fundamental force for grounding qualitative research is emphasised (Aamodt, 1983). Grounded theory also stresses the significance of discovering concepts that can be directly grounded in data. Brandriet (1994) investigates the suitability of both ethnography and grounded theory for research in gerontological nursing. Grounded theory is considered appropriate for exploring a number of research questions in gerontological nursing including moral, ethical, legal, social and human components of care. The reason for grounded theory's suitability is due to its ability to question or challenge nursing dogma and discover basic social processes.

Polkinghorne (1994) claims that qualitative research methods, grounded theory in particular, are increasingly making a contribution to the discipline of psychology. He found that using grounded theory methods produced theories that were methodologically sound. Rennie (1994) uses grounded theory to analyse data collected using interviewing and storytelling. Although no criticism of the grounded theory method is provided in Rennie (1994), the results of the research were found that using grounded theory research could have positive implications in this area of psychology. This would suggest that the grounded theory method was a successful analysis method for the investigation. Henwood and Pidgeon (1995) look at the suitability of grounded theory for psychological research. Changes to the grounded theory method are suggested, for example being able to use grounded theory but not having to build a ‘total’ theory, however the method is complimented as allowing researchers to keep on an analytic path.

Spector and Gibson (1991) used the grounded theory method to investigate students’ perceptions of what eased their learning of science. The grounded theory generated a model for teaching science in certain types of schools that had great promise for enhancing teacher education. Weingrand (1993) built a grounded theory that identifies library anxiety among students and its underlying causes. She concludes that the grounded theory developed a better understanding by the librarians of the problems facing students. The investigation concludes that grounded theory should hold a high place in research methods.
All the above research examples claim that grounded theory has provided a good insight into the problems under study. Therefore grounded theory could be a successful research method for knowledge elicitation due to its qualitative nature and human input.

3.4 Aspects of Grounded Theory

In the description of grounded theory that follows the author has drawn mainly on the account of the application of grounded theory by Strauss and Corbin (1990). Where the work of other authors enhances or contradicts the approach of Strauss and Corbin, specific reference will be made to their published works. Grounded theory is based on the method of comparative analysis. The data is broken down into units, or codes. The codes are grouped together according to their 'commonalities' or categories. The categories are then searched to find similarities between the categories. The similarities among categories are conceptualised by the grounded theorist as higher order categories. This conceptualisation creates a hierarchical structure in which, eventually, a supreme higher order category called a core category is grounded in the categories it subsumes. The categories beneath it are grounded in the categories beneath them and so on until the lowest categories are reached, which are grounded in the codes. The codes are grounded in the data (Rennie, 1994). The theorist records any analyses related to the formulation of theory in memos. Memos contain the products of actual coding, theoretically sensitising and summarising notes and provide directions for sampling. The memos form the basis for writing a thesis on the research.

3.4.1 Theoretical Sensitivity

Theoretical sensitivity refers to the ability of the researcher to indicate an awareness of the subtleties of meaning of data. That is, to recognise what is important in data and to give it meaning. A researcher should be sufficiently theoretically sensitised so he or she can conceptualise and formulate a theory as it emerges from the data (Glaser and Strauss, 1967). It is theoretical sensitivity that helps to formulate theory that is faithful to the reality of the area under study (Glaser, 1978). There are two sources of theoretical sensitivity, technical literature and professional experience, both of which can be brought into the research situation. Strauss and Corbin (1990) point out that theoretical sensitivity is also acquired through the research process through continual interactions with the data.
3.4.2 Process

Process is the analyst's method of accounting for or explaining change, (see Figure 3.1). Strauss and Corbin, (1990) list the ways that this can be achieved by noting:

- The change in conditions influencing any actions or interaction over time.
- The responses to the changes in conditions.
- The consequences that result from those changes.
- How the consequences become part of the conditions influencing the next sequence of actions and interactions.

![Figure 3.1 Process (Strauss and Corbin, 1990)]

There are two ways of conceptualising process:

- To view process as stages and phases of a passage, along with an explanation of what makes the stages move.
- To view process as an action that is flexible, in flux, responsive and changeable in response to changing conditions.

3.4.3 Theoretical Sampling

Theoretical sampling is the process of data collection for generating theory. The analyst jointly collects codes and analyses the data and decides what data to collect next and where to find it as the theory emerges (Glaser and Strauss, 1967). Sampling is done on the basis of concepts that have proven theoretical relevance to the emerging theory (Strauss and Corbin, 1990). That is, the researcher chooses the concepts that will generate as many properties of the categories as possible and that will help relate categories to each other (Glaser and Strauss, 1967). Theoretical sampling continues until theoretical saturation of the categories is reached.
3.5 The Stages of Grounded Theory

The basis of grounded theory is comparative analysis of data. The data is broken down into units or codes (Strauss and Corbin, 1990). Commonalities in the codes are identified in order to group them into categories, and these are then searched for similarities between them. This process is known as open coding. These similarities are conceptualised by the researcher as higher order categories, known as axial coding. The process is repeated to produce a hierarchical structure, which eventually produces a core category, the process of selective coding. The categories in this hierarchy are grounded in those beneath them (that is, categories which have lesser explanatory power), until the lowest level categories are grounded in the codes, which are grounded in the data (Rennie, 1994). Figure 3.2 illustrates the procedures in grounded theory.

![Grounded Theory Procedures Diagram](image)

**Figure 3.2** Grounded Theory Procedures

#### 3.5.1 Open Coding

Open coding breaks down, examines, compares, conceptualises and categorises the data (Strauss and Corbin, 1990). Sample open coding concept cards can be found in Appendix B. The first task is to label the phenomena that the knowledge engineer considers important. The knowledge engineer studies the data for categories and concepts that describe the phenomena in the data. Turner (1981) suggests using category cards as a method of recording the developing labels (see Figure 3.3). The example used in Figure 3.3 is taken from the data collected in this research. The theme of popular destinations is used throughout the examples in this thesis to show how grounded theory can be traced from the original transcripts through to the grounded monologue and, in the case of this research, the computer system. The results of the research are discussed in detail in Chapter 6. The
labels are noted on index cards as a method of recording the data. As the data is analysed more concept cards are generated as different phenomena emerge. The data should also produce further instances of previously discovered phenomena.

<table>
<thead>
<tr>
<th>Location in data</th>
<th>Card Number</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card 7 (j)</td>
<td>Scheduling Considerations</td>
<td></td>
</tr>
<tr>
<td>para 45: look for popular destinations because chances are someone else has probably booked there.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>para 515 try to make trips follow on</td>
<td></td>
<td></td>
</tr>
<tr>
<td>para 434 make sure information such as multiple pickups is clear to the driver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>para 491 thing about other trips booked to the same destination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>para 508 consider the trip type when trying to tie trips together</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cross-references: Note of incident

**Figure 3.3 Example Category Card**

### 3.5.2 Axial Coding

Axial coding is the process of relating subcategories to a category (Strauss and Corbin, 1990). That is, connections are made between the categories developed in open coding. This is achieved by using a coding model, known as the paradigm model (Figure 3.4).

![Figure 3.4 Paradigm Model (Strauss and Corbin (1990))](image)

The paradigm model indicates a central phenomenon. The phenomenon is developed in terms of the events that lead to the occurrence of the phenomenon, the circumstances under which the phenomenon occurs, the broader background environment, the actions and interactions that are executed on the phenomenon and the consequences that result from such actions. Figure 3.5 illustrates how the connections are made between axial coding and the categories developed in open coding. The entries under each heading in Figure 3.5 are taken from concept cards developed in this
research. This example of axial coding does not show the full axial coding for Route for reason of space. The full axial coding can be found in Appendix C The results of this research are discussed in detail in Chapter 6.

<table>
<thead>
<tr>
<th>Causal Conditions</th>
<th>Phenomenon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building a schedule</td>
<td>Route</td>
</tr>
</tbody>
</table>

Properties of Building a schedule


Specific dimensions of Route

| Intervening Conditions |

| Local Knowledge (7.L p.313, 9.L p.18, 256) |


Action Interactional Strategy

| Look for trips that cross over (7.L p.169, 257) |

Consequences

| Create most efficient route (9.L p.43, 415) |

Figure 3.5 Example Axial Coding

3.5.3 Selective Coding

Selective coding is the process of choosing a core, or central, category to which all other categories are related. The first step in selective coding is to explicate the story line. That is, to conceptualise the story line which is the core category (Strauss and Corbin, 1990). Using the paradigm model, subsidiary categories are linked to the core category. These links are then validated against the data that also provides the opportunity for any further development of categories that may be necessary. Figure 3.6 demonstrates the linking of data to selective coding.

Figure 3.6 Coding and Data Links

SC = selective coding, AC = axial coding, OC = open coding
It is this type of rigid approach to grounded theory that Glaser is opposed to. The Glaserian method would argue that the idea of such a clear hierarchy imposes structure on the data that prevents theory from emerging. However, Figure 3.6 plainly shows how the coding procedures used in the Straussian method are grounded in the data. It is possible to follow a path from the selective coding through to the data collected.

3.6 Evaluating Grounded Theory

A grounded theory is built on the results of selectively coding the data. The purpose of a grounded theory is to set out the conditions that produce the actions that are applied to an idea and the outcomes that follow. Glaser and Strauss (1967) define criteria for a quality grounded theory as:

- Codes that fit the data and the area from where it was taken.
- An explanation of the major action and interactional strategies and what will happen under certain conditions.
- Possessing relevance to the core category and an ability to explain the ongoing processes.
- Being modifiable and flexible to the setting.
- Having density and integration to ensure there is a tight theoretical framework.

Strauss and Corbin (1990) suggest seven questions that can be asked of a grounded theory that serve as criteria to judge the theory:

- Are concepts generated and if so, are the concepts grounded in the data?
- Are the concepts systematically related by links that are grounded in the data?
- Is the theory linked in terms of categories and subcategories and are the categories theoretically dense?
- Is much variation built into the theory and how specific are the variations shown in relation to the data?
- Are the broader conditions that affect the phenomenon under study built into its explanation?
- Have any changes in the form of process been identified and specified and linked to the conditions that cause the change?
- Do the theoretical findings seem significant and to what extent?
3.7 Problems with Grounded Theory

There are a number of problems associated with grounded theory. Pidgeon et al (1991) discuss the practical problem that grounded theory is highly labour intensive. Bryman and Burgess (1994) question if it is even possible to accomplish a grounded theory given that most time scales do not allow for it. It is suggested by Pidgeon et al (1991) that the researcher ensures that grounded theory is actually appropriate for the proposed application. The details they recommend that should be considered are that the data is suitable and likely to be available, the features of the problem domain and the final system requirements. By doing these simple checks the researcher will be sure that the area is worth the labour. In the case of this research a number of dial-a-ride groups had offered to provide data for analysis. A questionnaire completed by the dial-a-ride groups interested in participating in this research supplied information regarding the suitability of the data and the features of the domain. It was also made clear to all the dial-a-ride groups that the final system would be a prototype based on the procedures currently employed and not a full scheduling package. Turner (1981) warns that when the area of research is new, a large number of categories will be developed initially. However, as the research continues a set of basic categories or concepts will be developed initially. However, as the research continues a set of basic categories or concepts start to express much of what is important to the area and so the need to add to the set lessens.

The original grounded theory account is criticised for advocating the emergence of theory. Theory cannot merely ‘emerge’ from data because all observation is pre-interpreted in terms set by existing concepts and theory (Henwood and Pidgeon, 1995). The problem is resolved by viewing any ‘emergent’ theoretical accounts as the result of a constant interplay between data and conceptualisation. Bryman (1988) also questions whether grounded theory actually produces theory. He points out that much of the approach is focused more on the generation of categories rather than theory. Turner (1981) also quotes Bulmer's (1979) doubts that

"The researcher is genuinely capable of suspending his or her awareness of relevant theories and concepts until a relatively late stage in the process"

as a further possible problem with grounded theory. On the whole, it appears to be the researcher him or herself who is responsible for the success or failure of a grounded theory. In other words, is the researcher capable of following a method that denies what might have been advocated to the researcher previously? A further problem with grounded theory associated with the researcher is that different researchers may develop different categories and accordingly a different theory from the same set of data (Rennie, 1994). Glaser and Strauss (1967) and Glaser (1978) argue this is acceptable as long as each analysis is grounded in the data.
3.8 Discussion

The aim of the research is investigate the suitability of grounded theory as a means to analyse data gathered from a knowledge elicitation exercise. This chapter introduced the grounded theory research method. There is a choice in grounded theory regarding exactly which method to follow, Glaserian or Straussian. The Glaserian method claims to be a more scholarly approach, remaining faithful to the original concepts of grounded theory. However, there is very little instruction on how to actually carry out grounded theory. The Straussian method provides a more ordered style of procedure. Although Glaser (1992) condemns this use of structure when using grounded theory, it was felt that in this research a more ordered approach would be more appropriate. The grounded theory is going to be used as the basis for a prototype knowledge-based system. The framework of the Straussian coding procedures was deemed more apposite to producing rules.

The aspects that constitute grounded theory are discussed coupled with examples developed in this research. The three types of coding used in Straussian grounded theory are open, axial and selective coding. The process of developing each type of coding is explained along with a description of how each coding case links to the other coding cases.

Any analysis method needs to be evaluated to ascertain the validity of the research. This does not necessarily mean that the results of the research are what were expected at the outset of the research. The evaluation of an analysis method should ensure the correct procedures were followed and the results are represented faithfully in the final analysis. This section also gives a summary of how an evaluation of a grounded theory can be carried out. The evaluation of the grounded theory produced in this research is discussed in detail in Chapter 7.

There are a number of problems associated with grounded theory. The process can be very labour intensive to the extent that most time scales do not allow for full coding and theory to develop. However by ensuring that sufficient data is available, the time required will be worth the labour. In the case of this research the sources of data were known to be available. The details that needed to be confirmed were what would be the most appropriate knowledge elicitation techniques for use with grounded theory. Chapter 4 discusses this issue based on the information provided in Chapter 2 and Chapter 3.
4. ELICITATION TECHNIQUES FOR GROUNDED THEORY

4.1 Introduction

To enable a knowledge engineer to employ grounded theory when developing an expert system, consideration has to be given to the question of which knowledge elicitation technique or techniques might be the most appropriate. Clearly, the domain that is being tackled, the types of knowledge being elicited, and the environment in which the expert works are amongst many factors that influence the selection of knowledge elicitation techniques. However, the purpose of this part of the research is to find the most suitable techniques that will provide knowledge and data in an appropriate form for analysis by grounded theory. In this chapter each of the knowledge elicitation techniques described in Chapter 2 is evaluated against a set of criteria that reflect grounded theory requirements.

In order to evaluate the appropriateness of different knowledge elicitation techniques to use with grounded theory, it is necessary first to identify some of the requirements of grounded theory (Strauss and Corbin, 1990).

- The technique should support an iterative approach, that is it should allow for the process of progressive category clarification and definition (Tesch, 1991). Grounded theory requires the knowledge engineer to refine and abstract categories, and therefore to return to the subjects for clarification. Knowledge elicitation techniques that produce a 'one-off' result are therefore inappropriate.
- The technique should produce textual material that is capable of further analysis. This material should allow for the evolving nature of change and process, that is it should be transparent.
- The technique should not prejudge the structure of the knowledge that is being gathered, either by structuring the knowledge elicitation in a way which presupposes particular outcomes or by imposing on it a structure which implies a future knowledge representation.
- The technique should reveal and capture both procedural and declarative knowledge and not be biased towards one or the other. Declarative knowledge is static knowledge consisting of what is known about objects, events, relationships between concepts and sequences of events (Gordon, 1989). Procedural knowledge is dynamic knowledge about how to do various activities. The techniques should therefore elicit not only what the expert says that he or she does, but also what his or her actual actions are.
There has been little adequate analysis of knowledge elicitation for grounded theory. Pidgeon et al (1991) investigate the use of grounded theory for analysing data but only look at the interview technique. Miles and Huberman (1994) suggest that interviewing and observation are techniques that provide data suitable for grounded theory analysis but only in the sense that these techniques are apposite for qualitative data analysis generally. Strauss (1987) advocates the use of observations, interviews and documents for generating data for grounded theory analysis. These techniques are productive because they produce rich data immediately and can reflect the results of coding and categorisation in later iterations. Although the use of documentation has been suggested as an appropriate source of data, the domain under investigation does not keep statements of rules and procedures that are suitable for analysis.

The lack of research in this area (grounded theory and knowledge elicitation) has meant that much of the analysis in this chapter regarding the suitability of knowledge elicitation techniques for grounded theory is based on an analysis of how each technique matches the criteria listed above. The analysis is based on how each technique is executed, how effective each technique has proved in other areas and in which other areas the techniques have been used. Each technique has been reviewed in Chapter 2 of this thesis.

4.2 Interview

Grounded theory is recognised as a qualitative research method, that is, research that produces results not arrived at by quantification methods such as statistical analysis (Strauss and Corbin, 1990). To use the grounded theory method effectively, rich and detailed data is required (Charmaz, 1990). One of the main components in qualitative research is descriptive data. Data in qualitative research is most commonly collected using interviewing techniques. Interviews are also routinely used to augment and clarify issues that have been observed.

Forsythe and Buchanan (1989) argue that artificial intelligence ignores the overlap it shares with qualitative sociology. Polkinghorne (1994) also criticises researchers in general for not making use of the interview techniques as:

"The technique that often produces the most authentic and deepest descriptions. Skilfully conducted interviews can establish a climate of trust and openness between researchers and their subjects."
Pidgeon et al (1991) discuss the relationship between knowledge elicitation and grounded theory and describe the use of grounded theory as an analysis method for the interview technique.

Interviewing can help the knowledge engineer to appreciate the problem under study through the eyes of the expert (Hutchinson, 1993). It also allows the knowledge engineer to 'direct' the conversation to suit the expert's status (Charmaz, 1990). It is also suggested that the interview technique is suitable for grounded theory because interviewing can provide the variety of accounts of main issues and processes required for grounded theory analysis. Hutchinson (1994) also points out that interviews can move from general subjects to more particular questions. This allows the knowledge engineer to elicit information such as dimensions, strategies, consequences and contexts that are fundamental to grounded theory analysis.

The interview technique is an iterative approach. Interviewing can be easily repeated with a different emphasis each time and allows the knowledge engineer to build on previous sessions. This recognises the nature of experience as continually evolving and places emphasis on change and process. The interview technique is also flexible and comprehensive, allowing the knowledge engineer to clarify meaning (O'Reilly, 1995). Provided care is taken, employing the various interview methods does not bias towards procedural or declarative knowledge. If the interview is based on familiar problems the expert will use procedural knowledge, whereas if the interview poses new situations the expert will fall back on his or her declarative knowledge (Gordon, 1989).

4.3 Protocol Analysis

Grounded theory is concerned with the representation of reality. The theory should be understandable and make sense to both the knowledge engineer and the expert. The most appropriate technique for this criterion appears to be protocol analysis. This technique relies on the expert performing real-time tasks and the knowledge engineer recording the tasks as they occur and the expert's explanation of what he or she is doing. This shows awareness of the active role of people in shaping the world in which they live. It also shows recognition of the interrelationships between conditions, meaning and action.

Furthermore, protocol analysis can be used iteratively. The expert can repeat protocol analysis to enable the knowledge engineer to confirm when a process is used regularly and to identify new features or elements. As with interviewing, protocol analysis can be repeated with a different
emphasis each time. Ericsson and Simon (1980) describe the exploratory nature of verbal protocols and how the main aim of protocols is to produce concepts rather than to investigate questions of validity and generality.

Protocol analysis elicits knowledge in a real-time situation from the expert. This prevents the knowledge engineer from prejudging what the expert will do or say because even if certain events may be expected, there is no guarantee that they will happen or that something different will occur.

The nature of protocol analysis involves the expert being asked to perform some task and to talk his or her way through the task. Gordon (1989) believes that this use of these two behaviours causes the expert to use a mixture of declarative and procedural knowledge.

4.4 Observation

Rennie (1994) claims that the task set by grounded theorists is to understand and represent the meaning of information about human experience and behaviour. The argument goes on to say that any human experience about which information is available may be the subject of research. The information is usually textual, produced by the participants in the research or produced by the subject under study. In order to obtain such information, the knowledge engineer needs to observe the expert as he or she works, or to do the work themselves. The knowledge engineer needs to go out into the field of research in order to understand what is happening. Observation allows the knowledge engineer to record the tasks as they occur.

One of the aims of grounded theory analysis is to observe behaviour in a 'naturalistic' manner and to gain 'ecological validity'. This allows the knowledge engineer to remain open to all the features that he or she wants to understand (Turner, 1983). Observation is a common technique for such data gathering and has been used in anthropology and sociology for many years (Turner, 1983). Observation also has the advantage of allowing the knowledge engineer to record and analyse non-verbal responses (O'Reilly, 1985).

Observation is a technique that can be repeated, thereby providing the iterative approach required for the grounded theory. Brown (1973) and Turner (1981) both agree that observation is particularly useful for gathering data for grounded theory analysis because it captures behaviour that has a repetitive character.
Observation is especially useful for generating data that can be subject to further analysis. Observation will often show the expert doing something that he or she may not be aware of. The knowledge engineer can use this data in interviews or protocol analyses when a certain emphasis is required. It is also possible to infer procedural knowledge from an expert by observing the situation characteristics and actions of the expert (Gordon, 1989).

4.5 Walkthroughs

Walkthroughs are used to elicit procedural knowledge. However, using a technique such as walkthrough, which is process based, with grounded theory provides a means of eliciting both the processes and the concepts used by the expert.

The case-based nature of walkthroughs makes knowledge elicited using this method close to reality. Although the technique provides artificial cases for the expert to work through, the actual decisions made during the walkthrough are real time in that the expert is able to respond immediately to the data. Walkthroughs can be repeated and therefore support the iterative character of grounded theory.

However, walkthroughs do prejudge to a certain extent the structure of the knowledge being gathered. As walkthroughs are designed in advance of the elicitation session, it is possible to impose structures that can lead to only certain outcomes arising and leave no room for new issues to emerge.

4.6 Teachback

The teachback method of elicitation supports grounded theory analysis in that it supports an iterative approach. The knowledge engineer will probably need more than one session before he or she will be capable of teaching back all the knowledge acquired to the expert.

Some elicitation techniques are process based, eliciting procedural rather than declarative knowledge from the expert. Teachback is one such method. A further drawback to the teachback method is that this technique is not based on tasks as they occur and in this respect could be considered slightly less suitable for grounded theory analysis. It is likely that the knowledge engineer will impose his or her structure on the knowledge in order to organise it and teach it back. Teachback is not a suitable method for areas where large amounts of knowledge or a very high level of knowledge are required to complete even simple tasks.
4.7 Repertory Grid

Although repertory grid supports an iterative approach to knowledge elicitation, the implication is that the grid produced represents the expert’s knowledge of the categories concerned. Therefore to go back to the expert and ask him or her to reconsider the grid would imply that the expert had got it wrong. The use of techniques that produce ‘one-off’ results are not deemed suitable for grounded theory analysis. There are also limitations on the size of the problem that can be tackled by repertory grid.

Repertory grid appears to be good at capturing declarative knowledge, but poor at capturing procedural knowledge (McGeorge and Rugg, 1992 and Boose, 1985). Furthermore the nature of repertory grid suggests that some of the structure will be prejudged as the knowledge engineer must choose the elements that will be used in advance.

4.8 Card Sorting

Card sorting supports an iterative approach due to the method of repeatedly sorting cards into piles. Card sorting also supports many of the processes involved in grounded theory analysis. It allows the knowledge engineer access to the actions and interactions between objects and is particularly effective for structuring large sets of concepts (Gammack and Young, 1985).

Due to the fact the naming of cards is done in advance with some thought given to the concepts that will emerge it can be that, as with repertory grid, a prejudged structure is unavoidable. Repertory grid and card sorting are elicitation techniques that can be grouped under the heading multidimensional techniques. That is both techniques aim to elicit structural criteria (Neale, 1988). This similarity would suggest that card sorting, like repertory grid, is more suited to eliciting declarative rather than procedural knowledge.

4.9 Rule Induction

Rule induction imposes a structure on the data that presupposes a knowledge representation based on production rules. It is in a way the antithesis of grounded theory, allocating to a machine the task of extracting theory from data. Rule induction also focuses on procedural rather than declarative knowledge. The output produced is not necessarily transparent.
### Table 4.1 Elicitation Techniques for Grounded Theory

<table>
<thead>
<tr>
<th>Technique</th>
<th>Supports Iteration</th>
<th>Transparency</th>
<th>Does Not Prejudge</th>
<th>Procedural and Declarative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Protocol Analysis</td>
<td>+</td>
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<tr>
<td>Observation</td>
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<tr>
<td>Walkthroughs</td>
<td>+</td>
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<td>Teachback</td>
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<tr>
<td>Repertory Grid</td>
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<tr>
<td>Card Sorting</td>
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<tr>
<td>Induction</td>
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</table>

(Key: + means that the technique supports the grounded theory requirement.)

The ways in which each technique meets the grounded theory requirements is summarised in Table 4.1. Based on the extent to which each technique is suitable for grounded theory, it can be seen that interviews, protocol analysis and observation are the most appropriate for grounded theory analysis. The case-based techniques of walkthroughs and teachback appear to be suitable in at least two aspects, that is, they support iteration and have good analysis capabilities. The multidimensional techniques of repertory grid and card sorting fare less well and induction can be seen to be completely inappropriate for grounded theory.

Evaluating knowledge elicitation techniques for suitability of use with grounded theory is a new area of research and very little has been written concerning this. Many of the evaluations made on these techniques are based on an analysis of how each technique appears to meet grounded theory requirements on paper. The exceptions to this are interviewing and observation. Both these techniques are commonly used in qualitative analysis and therefore there are many references to them in the literature for this area. The common use of interviewing and observation both in social science and knowledge elicitation makes it more likely that they will be suitable for use with grounded theory. The lack of practical research in this area does, therefore, make it possible that the conclusions reached in this chapter may prove less practical than their theoretical assessment.
suggests. Chapter 5 discusses how the theoretical assessments of the most suitable techniques fared when evaluated in a practical setting.
5. RESEARCH METHODS

5.1 Introduction

As discussed in Chapter 1, knowledge acquisition is generally perceived to be a bottleneck in expert systems development (Feigenbaum and McCorduck, 1983). One of the reasons for this is that human experts are inadequate knowledge sources because they find it difficult to explain how they make decisions (Nicholson, 1992). Although machine learning processes can overcome some of the problems associated with the use of human experts, some problem domains are not appropriate for this type of knowledge acquisition (Nicholson, 1992). The principal aim of this research is to investigate alternatives to computer based knowledge acquisition methods that are human focused and based on grounded theory. The aim is to explore whether analysis of data using grounded theory provides rich and complete knowledge that facilitates the building of expert systems and overcomes some of the problems associated with human experts.

There are a number of qualitative research methods available for the analysis of data. Researchers are interested in the grounded theory method. This chapter examines the use of pilot studies and case studies as ways to collect data. There is limited literature on case study research (Yin, 1993). Yin (1993) and Yin (1994) are the two main texts about this research method and have provided the justification for using case studies in this research. Sample knowledge elicitation transcripts can be found in Appendix A.

5.2 Pilot Studies

Pilot studies are used to refine data collection plans regarding both the contents of the data and the procedures that will be used (Yin, 1994). The criteria for selecting the pilot site vary from project to project. Convenience, access, geographical proximity and the complicity of the site are the main criteria. Pilot studies can provide insight into the basic issues being studied and information about relevant field questions and the logistics of the inquiry. The pilot study can allow the researcher to focus on particular areas and to test certain questions (Janesick, 1994).

The aim of pilot studies is to provide information on the lessons learned for both research design and procedures (Yin, 1994). In the following section the use of an internal pilot study is discussed.
5.3 The Internal Pilot

In this section the use of an internal pilot study is described which allowed the knowledge engineer to practise the knowledge elicitation. Although the knowledge engineer did not want to become biased in her study of the domain, a basic requirement for the successful execution of observation and protocol analysis is some procedural knowledge of the tasks and decisions being made by the expert (Holsapple and Raj, 1994). The interview technique is considered to be the most effective method of eliciting procedural knowledge (Aouad et al, 1994). However, there are a number of pitfalls associated with interviewing including (Pidgeon et al, 1991):

- The failure to establish ‘rapport’ with the expert.
- Inadvertently dominating interview sessions.
- Asking ‘leading’ questions.

To gather data is are rich and complete and to avoid ‘thin’ data that does not reflect substantive issues, interviews should be recorded and complemented with field notes (Pidgeon et al, 1991).

5.3.1 Internal Pilot Methods

It was felt that the interview technique should be piloted internally to ensure that any obvious problems were overcome. The internal pilot study had three aims:

- To evaluate the interpersonal and documentary skills of the knowledge engineer.
- To provide data that gave information that allowed observations and protocols to be understood.
- To provide data that could be analysed using grounded theory.

The knowledge engineer had already gained some familiarity with the domain by reading literature related to the domain under study and by conducting some informal interviews and observations. A ‘substitute’ expert with some knowledge of the domain under study was interviewed by the knowledge engineer using some general headings based on a list of despatch duties from a community transport group. The use of general headings in this manner has three main aims:
• To provide guidelines for an over-enthusiastic expert.
• To encourage an expert to start talking.
• To allow some structure to be placed on the interview without too much rigidity.

The pilot session was observed by a third party to provide critical feedback on the knowledge engineer's performance.

5.3.2 Internal Pilot Results

Interviewing is a task that requires good interpersonal skills combined with the ability to document well (Pidgeon et al, 1991). According to the third party who observed the pilot interview the knowledge engineer made good contact with the expert and, by using physical movements such as nodding the head and saying yes or no at intervals, succeeded in keeping the interview flowing. The knowledge engineer also built up a good rapport with the expert.

Criticisms of the knowledge engineer suggested that even though the interview was recorded, note taking during the interview was also required. The interview could have been further improved by the knowledge engineer briefing the expert on what the interview would cover, the main topics of discussion and how long the interview was going to take.

The second objective of the internal pilot study was to provide data that gave information that allowed observations and protocols to be understood. By building a data flow diagram using Yourdon methodology the knowledge engineer showed what and how the expert was using processes, see Figure 5.1. The diagram shows three data stores, booking forms, passenger cards and a whiteboard, with data flowing between them via four processes: confirm/refuse booking, take a booking, fill-in a worksheet and checking a whiteboard. Data also flows from the processes to entities outside the system, the passenger, the driver and the vehicle. The interview transcripts provided data on the types of problems solved and the functions performed by the expert.

The third aim of the internal pilot study was to test if the data produced from the interview was suitable for grounded theory analysis. The first stage of grounded theory analysis is to conceptualise the data. By using the system recommended in Turner et al (1981), the knowledge engineer was able to produce a number of cards with titles that described the concepts in the data and start to group similar concepts to form categories. Although the interview data did produce categories, the categories were very process orientated and failed to show declarative knowledge. The grounded
theory analysis did however prove highly successful in identifying 'gaps' in the data. The knowledge engineer was able to draw up a list of questions that would provide the required data in the next stage of the knowledge elicitation when the suitability of observation and protocol analysis techniques for grounded theory were to be evaluated.

![Diagram](image)

**Figure 5.1 Internal Pilot Dataflow Diagram**

### 5.4 The External Pilot

The purpose of the external pilot was to test a number of elicitation techniques in the domain under study and to evaluate their suitability for analysis using grounded theory. The external pilot was therefore designed with the following objectives:

- To test the knowledge elicitation techniques of interviewing, observation and verbal protocol analysis.
- To assess the effectiveness of each technique in eliciting data in the domain.
- To test alternative knowledge elicitation techniques if any of the above techniques are not appropriate.
To assess the effectiveness of the alternative knowledge elicitation techniques.
To provide the knowledge engineer with experience in knowledge elicitation.
To provide the knowledge engineer with experience in documenting data collected in the knowledge elicitation.
To provide the knowledge engineer with experience in open coding.
To assess the appropriateness of the data for open coding analysis.

At the time of the internal pilot there were three community transport sites available to use as an evaluation site. Site one was based in an urban city area and ran a number of services such as group hire, dial-a-ride, a hospital service, a community car scheme and a 'shoppa' service. There were three despatchers working on the dial-a-ride, hospital and shoppa services. Site two operated over 160 square miles of mainly rural and some urban areas and used four despatchers to operate dial-a-ride, dial-a-bus and group hire services. One despatcher was used for each service. The environment covered by site three was mainly urban with some rural areas. Passengers were registered with the service and could make three types of booking: two weeks in advance to request a trip for a special occasion, such as a wedding; one week in advance to request a trip for an appointment; and two days in advance of the required trip where an immediate yes or no answer was given. Site three used only one despatcher and provided the most straightforward scheduling system. One of the main objectives of the pilot was to allow the knowledge engineer to gain experience in using the knowledge elicitation techniques. It was anticipated that using a simpler scheduling service would allow more concentration on the techniques under investigation. Using an uncomplicated scheduling system was also more likely to produce relatively simple data. If the open coding stage of grounded theory could not be applied to such data, this would show the techniques were unsuitable for analysis.

5.4.1 External Pilot Methods

The initial aims of the external pilot were to examine the effectiveness of certain elicitation techniques in the domain. Subsequent aims of the pilot were to evaluate the suitability of data gathered using these techniques for analysis using grounded theory.
The unstructured interview technique was piloted first. Following the results of the internal pilot, the knowledge engineer employed the following procedures:

- To introduce the interview.
- To explain how long the interview would take.
- To ensure that only essential equipment was visible.
- To provide non-verbal feedback to the interviewee, for example, to use plenty of eye contact, to nod the head and to look interested.

Using experience gained from the internal pilot and earlier introductory talks to community transport groups, the knowledge engineer decided to draw up a list of topics that should be covered in the interview. This ensured the interview would prove useful and informative. The areas to be covered in the interview included general duties such as taking bookings, incidental duties like dealing with emergencies and daily duties such as handing out schedule sheets.

The interview lasted approximately forty-five minutes and was taped. The expert answered all the questions fully and needed very little prompting from the knowledge engineer.

The second knowledge elicitation technique to be piloted was observation. The knowledge engineer observed the expert for a full session while the expert carried out her duties. Talking to the expert should be avoided during observation. Although the expert did not describe what she was doing, she did talk to the knowledge engineer during the session. Given however that conversation between the expert and her colleagues was commonplace in the office, the knowledge engineer concluded that the data collected was valid and the observation technique appropriate for the domain.

Verbal protocol analysis was the third technique tested. Grounded theory should be understandable and make sense to both the knowledge engineer and the expert. That is, it should realistically represent the expert's domain. The most appropriate technique for this criterion appeared to be protocol analysis. Protocol analysis relies on the expert performing real-time tasks while thinking aloud and on the knowledge engineer recording the thoughts as they are verbalising. However, when protocol analysis was tested in the domain, it proved to be totally unsuitable. This was due to the context in which the expert was making decisions. Much of the expert's decision making took place while she was on the phone taking the booking. The expert was unable to 'think aloud' during a
conversation with a passenger which prevented the protocol from being collected concurrently with the event.

A number of other elicitation techniques were considered to replace protocol analysis. It was decided that the walkthrough technique was the next most appropriate technique and therefore should be evaluated in the domain. A walkthrough is the process of asking the expert to walk the knowledge engineer through the task under observation. Walkthroughs are particularly useful in giving first indications of how experts use shortcuts and rules of thumb. This technique differs from protocol analysis in that it is not the thought process that is being considered but the steps that the expert follows in her job. There are two types of walkthrough:

- The domain expert pretends to be accomplishing a task and verbalises the various steps needed to accomplish the task.
- The domain expert acts as an instructor and describes the skills and strategies needed to perform the task.

The first type of walkthrough was used because it was felt the second type would be too time consuming due to the type of skills used by the expert in this domain. Due to the nature of grounded theory analysis, that theory should be developed from the data and not from hypotheses, it was decided that the second type of walkthrough might prevent an unbiased assessment of the data and documentation used in the domain. The knowledge engineer designed a number of bookings based on real cases and recorded the expert as she built a fictitious schedule from these bookings. The walkthrough technique proved successful in the domain because it provided knowledge of the procedures used in scheduling and the knowledge engineer could interrupt the expert as she explained how she was scheduling to clarify any decisions made. No further techniques were piloted. Interviews, observations and walkthroughs were considered suitable knowledge elicitation techniques for the domain.

5.4.2 External Pilot Results

The objective of the informal interview was to provide basic background information on the procedures involved in scheduling which could be analysed using grounded theory. The interview was transcribed and examined for possible categories that would describe the fundamental procedures used in taking and then scheduling a booking. The transcript provided information
regarding when bookings were taken, the order in which a schedule is built, dealing with staff sickness, the method of storing data and dealing with cancellations. The knowledge engineer also collected samples of paperwork used by the expert when scheduling.

The interview provided the necessary background for the knowledge engineer to pilot the observation technique. This allowed the knowledge engineer to observe the actions of the expert in detail, noting exactly what the expert was doing. The knowledge engineer was also able to draw up a plan of the expert’s environment. This again alleviated the need for unnecessary questions. The observation stage of the pilot revealed some of the detail required to support data from the interview. It also set forth a clearer picture of the expert at work. More importantly, following the development of some additional categories from the observation data, the knowledge engineer was able to identify ‘gaps’ in the decision making of the expert.

The knowledge engineer progressed onto piloting verbal protocol analysis. Using the ‘gaps’ identified from the observation, the knowledge engineer was prepared to ensure the expert clarified her actions as she performed them. However, the knowledge engineer experienced unforeseen difficulties with the verbal protocol analysis technique. As a passenger was given an immediate answer to their booking request, much of the decision making process was made while the expert was communicating with the passenger. The expert was unable to describe her thought processes and decision making concurrently with her actions. The data produced from the verbal protocol analysis is therefore very poor. No new categories were produced from the transcription of the verbal protocol analysis and none of the ‘gaps’ were clarified.

Following the assessment of more elicitation techniques, the knowledge engineer decided the most appropriate alternative to verbal protocol analysis was the walkthrough. The walkthrough permitted the expert to ‘think aloud’ as she built the schedule and also allowed the knowledge engineer to interrupt and clarify any points.

The interview transcript and observation field notes were analysed using the first stage of grounded theory, open coding. Open coding breaks down, examines, compares, conceptualises and categorises the data (Strauss and Corbin, 1990). The walkthroughs, as the final stage of the knowledge elicitation, are designed to validate the concepts and categories that have emerged during the grounded theory analysis. The process of validation in grounded theory is known as theoretical sampling and occurs during each stage of grounded theory. Theoretical sampling is based on concepts that have proved theoretically relevant to the evolving theory (Strauss and Corbin, 1990).
The knowledge engineer should repeat the process of interview, observation and walkthrough until no new concepts and categories develop from the data, that is theoretical saturation of each category is reached (Glaser and Strauss, 1967). Strauss and Corbin (1990) define theoretical saturation in open coding as when no new or relevant concepts emerge from the data. The walkthrough data produced no new categories when analysed using grounded theory open coding but did confirm the existing knowledge that had already been gathered.

The main categories developed illustrated the following key concepts:

- The methods used to plan a route while scheduling.
- The reliance of the system on passenger flexibility with his or her times of travel.
- The consideration of the disability, the amount of assistance required and the type of mobility aid a passenger may use.
- Certain types of trips take priority on the schedule and therefore dictate what the schedule is built around.

The knowledge engineer moved onto developing some axial coding. Axial coding is a set of procedures where the data is organised in new ways after open coding. Strauss and Corbin (1990) describe an axial coding paradigm (see Figure 3.4).

The causal conditions are the events that lead to the occurrence of a phenomenon, that is the central idea, event or happening. Context is a set of conditions that influence action/interaction. Intervening conditions are general conditions such as time, culture and economic status that bear on action/interaction strategies. Action/interaction strategies are the managing, handling, carrying out responses to a phenomenon. Consequences are the outcomes of action and interaction taken in response to a phenomenon.

The knowledge engineer organised the categories using axial coding. However it proved too early in the grounded theory analysis to do this. It proved difficult to differentiate between properties and specific dimensions with the same terms sometimes appearing under both headings. Details would often be repeated under different headings on the same paradigm card. When there was more than one causal condition it was problematic working out properties and specific dimensions. Intervening conditions did not always exist and categories that represented processes did not seem to fit into axial
coding. It appeared that there was not enough data to generate axial coding and this caused a few occasions where the paradigm model could be completed.

5.4.3 External Pilot Conclusions

The pilot study sought to evaluate the suitability of various knowledge elicitation techniques in the community transport domain. The site with the simplest scheduling method was chosen, and interview, observation and verbal protocol analysis were the techniques selected to test initially. Verbal protocol analysis proved inappropriate and was replaced successfully with the walkthrough technique.

The numbers of categories that have emerged suggest that these techniques are suitable for the open coding stage of grounded theory analysis. Full axial coding was not successful but this is believed to be due to the quantity rather than the quality of the data. It was anticipated that the application of these techniques at other sites would allow a full grounded theory to be developed.

5.5 Case Studies

The case study approach collects information about a limited number of cases in order to understand how and why they have developed in a certain circumstance. The case study approach is used in social science research in a variety of circumstances:

- When 'how' or 'why' questions are being posed.
- When the researcher has little control over events.
- When the focus of the research is within a real-life context (Yin, 1994).

Bryman (1989) argues that most qualitative research is actually a form of case study, although the terms should not be used synonymously because quantitative research methods are also used in case study research. Also most developments in expert systems have been based initially on small case studies rather than attempts to apply techniques to a wide range of different types of systems and problems. There are a number of reasons why case studies are an appropriate research method to use in conjunction with grounded theory analysis in the research considered here:
Case studies use a range of data collection methods and commonly use a number of techniques during one investigation (Bryman, 1989). The intention of this research is to investigate the use of a number of knowledge elicitation techniques.

The research is using the decision-making procedures of Dial-A-Ride despatchers to test the usefulness of grounded theory in reducing the knowledge acquisition bottleneck. The aim is to capture decision-making based on how and why bookings are scheduled in the way they are.

The nature of grounded theory disallows any form of prejudged structure leaving the knowledge engineer with no control over what will happen during an elicitation session. Case studies are often useful for providing an understanding of areas that are not well documented (Bryman, 1989).

Grounded theory also aims to collect data that is grounded in reality, in other words to collect data from a real-life context. There is a strong emphasis on context in case study research. This form of research allows the researcher to know what it is like to be in the organisation that is being studied (Bryman, 1989).

Grounded theory, like case study research, emulates the scientific method (Yin, 1993). Strauss and Corbin (1990) express the opinion that if procedures are followed properly, grounded theory satisfies the principles for doing competent science.

It is common for case studies to focus on two or more sites to enhance the generalisability of the research and allows special features of cases to be identified and compared (Bryman, 1989). It was therefore decided that three sites should be used to gather data for grounded theory analysis. Case study sites need to be chosen with some sort of rationale, and with access and entry being two of the most important considerations (Janesick, 1994). The knowledge engineer must also establish a rapport with the expert in order to better capture the expert's knowledge (Janesick, 1994). Following the pilot study, which by using one of the original sites had eliminated that site from further investigation, another of the community transport groups had to withdraw from the research and it was necessary to choose two other sites as case studies. Using a questionnaire designed to elicit information on the dial-a-ride services offered by community transport groups, a further two sites were chosen to act as case studies. The three groups are described below in sections 5.5.1, 5.5.2, and 5.5.3.
5.5.1 Barnsley Dial-A-Ride and Community Transport

Barnsley Community Transport operates three services: dial-a-ride, dial-a-bus and a social car scheme. The dial-a-ride was the most important service to the group’s operation. The group operates ten wheelchair accessible minibuses and six cars and has an office staff of ten, eleven professional drivers and sixteen volunteer drivers.

Barnsley Community Transport covers both urban and rural areas with the dial-a-ride. Two despatchers are used exclusively for the dial-a-ride. Bookings for the service taken over the phone can be made by passengers a minimum of two days in advance and a maximum of seven days in advance. Schedules are built two days in advance when most of the booking requests are available and passengers are called back with confirmations or rejections of their trips. Although this method of scheduling would appear appropriate for verbal protocol analysis, it was decided for the purposes of consistency not to use that technique.

5.5.2 Sheffield Community Transport

Sheffield Community Transport operates several services: dial-a-ride; dial-a-bus; group hire; social car scheme; and day/half-day excursions. The area covered by the services was urban. The group has seventeen wheelchair accessible minibuses, three non-accessible minibuses and one car. Group hire is the main service provided by the group. The staff consists of fourteen office staff, five professional driving staff, four hundred and fifty volunteer driving staff and one mechanic.

Three despatchers are used exclusively for dial-a-ride services and bookings are taken seven days in advance. As with Barnsley, passengers are called back once the schedule had been built with confirmation or rejection of their trip request. The main difference lay in the method of taking booking requests which was done via answer machines.

5.5.3 Central London Dial-A-Ride Ltd.

Central London Dial-A-Ride is part of London Transport Unit for Disabled Passengers. London Dial-A-Ride services run only dial-a-rides and have two hundred and twenty wheelchair accessible minibuses. The total number of office staff employed is one hundred and twenty one and the number of drivers is three hundred and twenty two. Volunteer staff are not used. These statistics apply to the
whole of London; Central London staff consists of six despatchers who work in shifts, approximately 20 drivers and 30 vehicles.

Although all the areas covered can be described as urban, Central London Dial-A-Ride covers areas that are particularly congested and built up in terms of buildings, people and traffic. Normal bookings are taken two days in advance although there are criteria for accepting advance bookings. Booking requests are taken over the phone at set times during the day or by letter, and all bookings receive an immediate yes or no answer. Schedules are examined after booking hours and searched for space that may not have been immediately obvious at the time of booking. If space is available passengers whose bookings were rejected are called back with the offer of a trip.

5.6 Knowledge Elicitation

A number of knowledge elicitation techniques were discussed in Chapter 2. A selection of techniques had been piloted before full knowledge elicitation began. At each group just one despatcher was chosen in order to avoid the difficulties associated with multiple experts. The knowledge engineer visited each group sequentially carrying out a number of interviews, observations and walkthroughs at each. This allowed similarities in data to build up and be verified and showed clearly any differences that arose. The number of elicitation sessions at each group is shown in Table 5.1.

<table>
<thead>
<tr>
<th></th>
<th>Interview</th>
<th>Observation</th>
<th>Walkthrough</th>
</tr>
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<tr>
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<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Sheffield</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>London</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 5.1 Knowledge Elicitation Sessions

5.6.1 Barnsley Dial-A-Ride and Community Transport

Knowledge elicitation started at Barnsley with an informal interview that lasted approximately forty-five minutes. This was followed up with four observation sessions that covered different parts of the day. The observations built on the general description of events from the interview and allowed the knowledge engineer to understand the operations in use during the scheduling process. The nature of observation means that the knowledge engineer should not interrupt the expert during the session. Although the observations had provided a clear understanding of the basic scheduling processes, a number of questions arose which, when answered, would clarify why procedures were followed.
A series of four interviews allowed the knowledge engineer to investigate the outstanding questions and to gain more detail on all aspects of scheduling. The most important outcomes of the interviews were the explanations of why the expert was performing certain actions. The knowledge engineer was now able to develop walkthroughs.

The walkthroughs were designed to cover all aspects of the processes and decision making that had been observed and discussed in earlier sessions. The knowledge engineer listed a number of bookings that had been made previously and read these out to the expert. The expert then scheduled the bookings while explaining how and why to the knowledge engineer. The list of bookings consisted of a variety of types:

- Very simple bookings.
- Bookings that clashed with other bookings.
- Bookings with different trip purposes.
- Bookings where passengers were in a wheelchair.
- Bookings where passengers wanted to take an escort.
- Passengers who were flexible and would alter travel times slightly.
- Passengers who were not flexible.

The aim of the walkthroughs was to cover as many different types of decision making, ranging from straightforward scheduling to moving bookings around and refusing others. As the walkthroughs had been based on past schedules, the expert tended to repeat the booking patterns and the results of the walkthrough schedule were very similar to the original schedules.

The problem of the expert simply repeating previous schedules needed to be resolved before further walkthroughs could be attempted. It was necessary however to continue using old schedules as the basis for the walkthroughs in order to preserve some realism. It was decided that combining more schedules and making bigger alterations to booking details would overcome the problem. New walkthroughs were therefore designed using these methods.

However, before the new walkthrough could be attempted, the difficulty of accounting for human nature in experts arose. Two appointments were made to see the expert and conduct the walkthrough. In both cases the expert had experienced problems in scheduling that day's actual bookings and was 'not in the mood to do any more scheduling'. The use of more than one elicitation technique however
meant that the knowledge engineer could still elicit knowledge from the expert but not have to force the expert to complete a walkthrough unenthusiastically. An informal interview was conducted instead. It is possible that any data collected from an unwilling source would not be accurate and would not exemplify true decision making. The use of other elicitation techniques did not cause the knowledge engineer to lose or waste time. The walkthrough was completed successfully at a later date. The schedule produced by the walkthrough covered a number of decisions and clarified any outstanding questions or matters.

5.6.2 Sheffield Community Transport

The second site for knowledge elicitation was Sheffield Community Transport. The method of scheduling for Sheffield is similar to Barnsley in that the schedule is built when all the bookings have been collected and passengers are called back with a booking confirmation or rejection. The similarity in operational procedure meant the knowledge engineer only needed two interviews and four observations before embarking upon walkthroughs.

A slightly different approach to the walkthroughs was taken at Sheffield. Rather than designing a number of bookings in advance, the despatcher used actual bookings to illustrate the decision making involved in building the schedule. The knowledge engineer was still able to interrupt the expert to clarify any decisions that the expert did not explain clearly. Sheffield Community Transport only operates five buses for dial-a-ride and only runs the buses between 09.00 hours and 17.00 hours. The simplicity of the Sheffield operation made eliciting the decision making processes a relatively straightforward task and once the walkthroughs were complete, no further interviews or observations were required to clarify the data.

5.6.3 Central London Dial-A-Ride

The final case study for the knowledge elicitation was Central London Dial-A-Ride. This site is the largest of the three cases and operates the greatest number of vehicles and the longest opening hours both for making bookings and taking trips. The method of taking bookings is different at the London site. Passengers are given an immediate yes or no answer to their booking request because the despatcher schedules the booking while they are on the phone. An initial interview followed by three observations raised a number of questions that concentrated on the differences in procedures between using a first come, first served booking system and building the schedule with all the bookings present. Having noted all the differences in the two types of operation, further interviews and
observations provided the knowledge engineer with information on the similarities between the two systems. Due to the size and complexity of the London operation, three walkthroughs were required to cover all aspects of the scheduling process. The knowledge engineer returned to the old walkthrough method of building a list of bookings from some old schedules. Alterations were made to the times of the bookings, the number of passengers per booking and the destinations of some of the bookings. This method still allowed the despatcher to recognise some regular bookings but also provided the opportunity to show how decisions are made at the time of booking. In Central London Dial-A-Ride once a booking period is complete all the schedules will be examined together to try and find spaces or alterations that can be made in order to improve the efficiency of the schedule. If possible, more bookings will then be accepted onto the schedule. Unfortunately the walkthrough technique does not allow for this process and the knowledge engineer had to utilise the observations and interviews that had covered this stage of scheduling.

5.7 Alternative Methods

There are a number of alternative research methods that were examined before case study research was chosen. Some of the methods such as survey or experimental research were considered unsuitable due to the type of data that needed to be collected. Survey research is not appropriate for this research because not enough organisations have been involved and insufficient detail would be provided. Experiments could not performed therefore an experimental approach is not suitable. Action research was investigated in more detail.

5.7.1 Action Research

Action research is the process of systematically evaluating the consequences of decisions and adjusting practice to maximise effectiveness (McLean, 1995). The method is commonly used in teaching but is also used to some extent by social scientists (McLean, 1995).

The main drawback to action research is the conceptualisation process that occurs before the research begins. This involves the consideration of the inputs under study and what outcomes can be expected. The necessity of such background work for action research goes against the grounded theory requirement that the structure of data should not be prejudged and that particular outcomes should not be presupposed. Action research also implies changing practice that was not the intention
of this research. It was therefore felt that action research was not suitable for use with grounded theory.

5.8 Case Study Suitability for Grounded Theory Analysis

In this section the appropriateness of case study research for grounded theory analysis is discussed. Case study research is used in social science research to investigate areas where the research question takes the form of 'how' and 'why' (Yin, 1994). Case study research lends itself to evolving the research and the understanding of a problem. The scope of case study research explores phenomena that are within their real-life context (Yin, 1994). These two explanations of case study research suggest immediately that this method of research is suitable for collecting data for grounded theory analysis. Grounded theory is concerned with capturing both procedural and declarative knowledge. Declarative knowledge is about what is known about relationships and sequences of events, in other words the 'why' of a process or decision (Gordon, 1989). Procedural knowledge involves knowledge about the actions taken to do various activities, that is, 'how' a process is done.

Further evidence can be found for the suitability of case study research in general by looking at the features and aims of ethnography. Ethnography is used to work mainly with unstructured data, in particular data that uses verbal descriptions and explanations (Atkinson and Hammersley, 1994). Case study research is often focused on areas which include decisions, individuals, organisations, processes and events (Yin, 1994). Social science research into such topics will often provide unstructured data. Case study research also uses data collection methods that incorporate interviews and observations. A further feature of ethnography is that it commonly investigates a small number of cases in detail (Atkinson and Hammersley, 1994). Case studies normally focus on two or more sites to allow the identification of special features and details (Bryman, 1989).

Using case study research also allows some of the aims of grounded theory to be achieved. One of the key strengths of case study research is that it is not only a data gathering activity but it allows theory to be generated because tasks are not approached with precisely defined hypotheses to be tested (Babbie, 1989). In grounded theory, data collection and the analysis phases of the research progress concurrently (Charmaz, 1983). It is possible with case study research to collect data from one case, start to analyse it and also start to collect data from another case. A further objective of grounded theory is to explore and examine social processes (Charmaz, 1983). Case study research is concerned with questions that focus on how things are done (Yin, 1994).
There is some question over the aspect of case study research in its use of a limited number of 'cases'. This can raise questions about the generalisability of the findings. However, case study research is a common research method both in qualitative research and knowledge-based systems research. For the purposes of building a prototype for this research, the issue of generalisability is not a problem and could be an issue for further research.

5.9 Discussion

Chapter 5 has discussed the research methods used for this research. Following the evaluation of a number of knowledge elicitation techniques for use with grounded theory analysis, two pilot studies were executed to test technique suitability in the research domain. The first pilot provided evidence that interviewing was an appropriate technique to use in the domain of dial-a-ride and also gave the knowledge engineer some experience in the technique. The second pilot study examined the techniques of interviewing, observation, verbal protocol analysis and walkthroughs at an evaluation site. The evaluation site was selected because the level of complexity of its operation would provide enough data to assess the techniques but would not take too long to understand and therefore detract from the assessment of the suitability of the techniques. The interview and observation techniques were tested first and both produced data of an acceptable standard for grounded theory analysis. Verbal protocol analysis was the next technique to be evaluated. The technique proved to be completely unsuitable for the domain. The despatcher was unable to verbalise her decision-making processes because the decisions were being made while the despatcher was on the phone to a passenger. The data produced from the verbal protocol analysis was unsatisfactory for grounded theory analysis. Following further evaluation of the remaining knowledge elicitation techniques, walkthroughs seemed to be the next best fitting technique for grounded theory analysis. This view proved to be correct when the technique yielded satisfactory results. It was therefore decided that interviews, observations and walkthroughs would be the best techniques to gather data suitable for grounded theory analysis.

The knowledge elicitation exercise was performed at three sites of different sizes that used different methods of scheduling bookings. Although the sites were different from each other, the grounded theory analysis of the data collected showed many similar decision making processes. The actual results of the grounded theory analysis will be discussed in more detail in Chapter 6, Grounded Theory Analysis.
6. THE GROUNDED THEORY PROCESS APPLIED

6.1 Introduction

As described in Chapter 3, grounded theory is a methodology for developing theory that is grounded in data systematically gathered and analysed (Strauss and Corbin, 1994). It is basically a 'bottom-up' approach to the conceptual analysis of unstructured qualitative data (Pidgeon et al, 1991). Grounded theory is employed in areas where theories do not exist and need to be generated from data rather than with the testing or verification of existing theories (Martin and Turner, 1986). Grounded theory analysis is best used when dealing with qualitative data gathered from observation sessions, from unstructured interviews and from case-study material (Turner, 1981). A more detailed evaluation of knowledge elicitation techniques suitable for grounded theory analysis was provided in Chapter 4.

Once data has been collected it is necessary to develop concepts and categories that not only describe the data but also provide analytic and interpretative procedures (Strauss and Corbin, 1990). This is done through a coding paradigm which operates as a model to code data for relevance to whatever phenomena are referenced by a category (Strauss, 1987). The three types of coding, open, axial and selective, were described in Chapter 3.

This chapter is concerned with the data and coding produced from the knowledge elicitation exercises carried out at the three dial-a-ride sites. The coding procedures used to analyse the data are described followed by a brief discussion of the software available for grounded theory coding.

6.2 Coding Procedures

There are three types of coding that need to be completed before a full grounded theory can be written: open coding; axial coding; and selective coding. Full descriptions of each coding method are described in Chapter 3.

6.2.1 Open Coding

This is the first type of coding done in grounded theory analysis which aims to produce concepts that appear to fit the data (Strauss, 1987). It is assumed that some data will have been collected, using
unstructured interviews for example, and that this data will have been transcribed. A problem arises at this stage in that there are very few guidelines on how to handle this data using grounded theory (Turner, 1981). However, Turner does provide some instructions which are useful for starting grounded theory analysis and which were used in this research in conjunction with Strauss and Corbin's (1990) coding procedures.

Open coding refers to the strategic stages of moving from data to concepts (Martin and Turner, 1986). Turner (1981) observes the following stages. The first step in open coding is to label the events that the knowledge engineer judges to be significant to the research. This is done by numbering each paragraph in the transcripts and then starting with the first paragraph of the transcript, examining the data for concepts that describe or account for the events discussed in that paragraph. When a concept has been identified it must be noted down on an index card together with the paragraph number and then filed. Further cards may be needed which refer to other potentially important events in the paragraph. When cards for all the concepts referred to in the paragraph have been generated the knowledge engineer can move onto the next paragraph. It may become possible at later stages to combine concepts cards if they deal with the same events.

It is important at this early stage that the concept cards describe exactly the events in the data in order to maintain fit. This is to ensure the theory explains what has happened, predicts what will happen and interprets what is happening. Open coding concludes when no new concepts are being generated.

The data collected in this research study produced 79 concept cards from three case studies. A list of the concept cards that were generated can be seen in Table 6.1. A sample of the concepts cards developed in this research can be found in Appendix B. The concepts that developed tended to be based on the scheduling process of taking bookings, scheduling the bookings and dealing with refusals. The process of scheduling the bookings accounts for a number of sub-categories that included all the details that had to be considered when building a schedule. It is possible to see many similarities in the concept names and areas for each dial-a-ride group despite different operating procedures. Such similarities become even more apparent when examining the incidents that represent each concept. Obviously not all the concepts were relevant to the scheduling process and even though such concepts were not used in the axial coding, the concepts were still recorded by the knowledge engineer in the event that the generality of the grounded theory was questioned.
<table>
<thead>
<tr>
<th><strong>Barnsley Concept Cards</strong></th>
<th><strong>Barnsley Concept Cards</strong></th>
<th><strong>Sheffield Concept Cards</strong></th>
<th><strong>Central London Concept Cards</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Taking bookings</td>
<td>Staff positions</td>
<td>Booking system</td>
<td>Booking types</td>
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<td>Shift record details</td>
<td>Passenger flexibility</td>
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<td>Sickness and Holiday</td>
<td>Operation details</td>
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<td>Priorities</td>
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<td>Flexibility</td>
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<td>'Playing' the service</td>
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<td>Reasons for refusals</td>
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<td>Representation</td>
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<td>Service aims</td>
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<td>Usability criteria</td>
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</tbody>
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Table 6.1 Open Coding Concept Cards
6.2.2 Axial Coding

Open coding splits the data and allows the identification of concepts (Strauss and Corbin, 1990). In axial coding, the data is put back together in new ways by making connections between a category and its sub-categories (Strauss and Corbin, 1990). Axial coding involves carrying out analysis around one category at a time using the paradigm model (see Figure 3.4) hence the name axial coding because the analysis revolves around the 'axis' of one category at a time (Strauss, 1987). The paradigm model shows links and relationships between the categories developed in open coding. Although the paradigm model is discussed in depth in Chapter 3, for the sake of clarity the terms used in the paradigm model are defined again for this chapter:

- **Causal Conditions**: events that lead to the occurrence of a phenomenon.
- **Phenomenon**: the central idea which a set of actions/interactions is directed at handling.
- **Context**: the particular set of conditions within which the action/interactional strategies are taken.
- **Intervening Conditions**: the structural conditions that affect the action/interactional strategies that are relevant to the phenomenon.
- **Action/Interaction**: strategies devised to handle and respond to a phenomenon under a specific set of perceived conditions.
- **Consequences**: Outcomes of action and interaction.

Twenty-six categories were produced from the axial coding (see Table 6.2). The axial coding was developed using frameworks that show the ways in which the subcategories interact with each other, and the category to which they are related (Strauss and Corbin, 1990). An example of an axial coding framework can be seen in Figure 3.5. The corresponding paragraph references were also listed so each occurrence of the paradigm model could be traced directly to the data. It is possible to see from the axial coding phenomena listed in Table 6.2 that different causal conditions can cause different action/interactional strategies and consequences for the same phenomenon.

Figure 6.1 shows an example of the axial coding results. This example is discussed in detail to show how each process in axial coding is developed using actual results. The central idea or phenomenon identified for this example is route. The event that has led to the occurrence of this phenomenon is the need to build a schedule. It is possible to have more than one causal condition although in the case of this example there is only one. Once the phenomenon and the causal conditions have been
identified, the properties and dimensions need to be determined. Causal conditions can be found in the data by looking for phrases such as 'when', 'while', 'since', 'because', 'due to' or by looking back through the data for events that seem to precede the phenomenon.

The particular context within which the action/interaction strategies are taken to manage the phenomenon is in this case possible multiple pickups, making the schedule flexible, using ideas that have worked previously and trying to keep passengers on the same shift. In other words, these strategies form the context in which routing is handled. For example in the case of routing it is possible to say that routing is important when the possibility of multiple pickups arises.

<table>
<thead>
<tr>
<th>Axial Coding Categories</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Checking details</td>
<td>Passenger type</td>
</tr>
<tr>
<td>Despatcher visualisation</td>
<td>Target pressure</td>
</tr>
<tr>
<td>Route</td>
<td>Trip type</td>
</tr>
<tr>
<td>Last minute bookings</td>
<td>Service aims</td>
</tr>
<tr>
<td>Normal booking</td>
<td>Trends</td>
</tr>
<tr>
<td>Advance bookings - with details</td>
<td>Driver sheet</td>
</tr>
<tr>
<td>Advance bookings - without details</td>
<td>Temporary membership</td>
</tr>
<tr>
<td>Cancellation - by passenger</td>
<td>Automatic knowledge</td>
</tr>
<tr>
<td>Cancellation - by CT service</td>
<td>User criteria</td>
</tr>
<tr>
<td>Cancellation - passenger forgets booking</td>
<td>Problem areas</td>
</tr>
<tr>
<td>Refuse advance booking</td>
<td>Refusal</td>
</tr>
<tr>
<td>Transfer booking</td>
<td>Priorities</td>
</tr>
<tr>
<td>Resource allocation - availability of resources</td>
<td>Resource allocation- environmental factors</td>
</tr>
</tbody>
</table>

Table 6.2 Axial Coding Index

There is a second set of conditions that relate to the phenomenon under study, the intervening conditions. Intervening conditions are the broader structural contexts that have a bearing on the phenomenon (Strauss and Corbin, 1990). Such conditions can include time, space, culture, economics, technology, history and individuals. In the case of this example these conditions can be seen to be trip target, popular destinations and passenger targets. These are classified as intervening
conditions because they are targets that must be met for economic reasons but will affect the way a route is scheduled.

Grounded theory is an action/interactional orientated method of theory building (Strauss and Corbin, 1990). In other words, whatever is being studied there will be some kind of managing or handling in response to the phenomenon. Action/interaction must have certain properties (Strauss and Corbin,
1990). It should have process, purpose and be goal orientated. There are particular cues in the data that should point to strategies, for example phrases that show a response to something happening to the phenomenon. The current example shows where trips can be moved in response to two routes synchronising.

Any strategies that are taken in response to or manage a phenomenon will have outcomes or consequences (Strauss and Corbin, 1990). In the case of this research, looking for routes that synchronise with other routes or follow on may result in the best schedule possible being built.

Axial coding can be carried out in parallel with open coding although it is not likely to be useful early on in the data analysis due to the lack of depth developed in the concepts (Strauss, 1987). The depth required for axial coding comes as new aspects of the phenomena are discovered. Full grounded theory analysis continues with selective coding after axial coding. However there may be projects that can be stopped after axial coding if the researcher is only interested in theme analysis or concept development (Strauss and Corbin, 1990).

Selective Coding

Selective coding is the process of selecting the core category, systematically relating it to other categories, verifying those relationships, and filling in categories that need further elaboration and development (Strauss and Corbin, 1990). Selective coding allows the theory to become more focused and integrated (Strauss, 1987):

"The other codes become subservient to the key code under focus. To code selectively, then, means that the analyst delimits coding to only those codes that relate to the core codes in sufficiently significant ways as to be used in parsimonious theory"

The final integration of the categories in selective coding is not markedly different from axial coding, however it is carried out at a higher more abstract level of analysis (Strauss and Corbin, 1990). The first step in selective coding is to explicate the story line. This is the formulation of a story line that conceptualises a descriptive account of the central phenomenon of the study (Strauss and Corbin, 1990). Figure 6.2 shows the story line that was explicated for the research described in this thesis. The explication of the story line is basically a summary of the selective coding developed in this research which can be found in Appendix D. All the dial-a-ride groups aim to build schedules that get as many people as possible on the buses. The schedulers are all aware of certain conditions that affect the way they schedule.
The main story is about how schedulers in Dial-A-Ride build their schedule. They have criteria regarding advance and priority bookings and once they’ve scheduled those they start to put the other bookings on. The schedulers are aware of peak travel times and adverse weather conditions. The schedulers know in advance resource allocation. All the schedulers rely on passenger flexibility. If passengers will accept alternative trip times, often the schedule can be improved and the main aim of getting as many people put as possible is achieved.

Figure 6.2 The Story Line

Following the explication of the story line, the next step is to relate subsidiary categories to the core category using the model paradigm. The selective coding can be validated against the data to complete its grounding. The selective coding for the dial-a-ride problem is displayed in Figure 6.3. It is possible to see where the data identified as phenomena in the axial coding shows in the framework for selective coding.

The core category developed was scheduling. The scheduling process is triggered by passengers calling to make bookings. The type of booking being made is dependent on the trip type. If the trip purpose is going to a wedding for example, then the booking type is advance and may be made in advance of normal bookings. There are however limitations with all booking types on whether they are accepted. The bookings are recorded and the passenger is given an answer. Different types of trip can affect how a booking is taken, for example if could be possible for a low priority trip to run slightly late. The nature of trips may lead to certain trips being prioritised. An example of this would be where a passenger has an appointment time to keep. Trends in bookings and trips are monitored for report details such as peak booking times and the number of passengers using the service. Routes are built around some of these trends but also take into account resources and areas. The route taken is affected by resource allocation and target pressures set by outside concerns that have to be met by the dial-a-ride groups. The despatchers will discuss possible routes and modify them to create the most efficient route.

There are a number of contexts in which categories occur. For example, the driver sheet records scheduling details in a form suitable for the dial-a-ride bus drivers. It is also common for despatchers to use compiled knowledge to schedule certain bookings, that is knowledge they use without being
aware of it. An example of this use of knowledge can be found in the concept card *Checking Details*. The despatcher may not realise he or she has known a passenger name automatically from looking at the passenger number. In this case, scheduling in the context of automatic knowledge allows the despatcher to take bookings faster and schedule more rapidly because the despatcher does not need to ask for all the passenger details, many of the required details are automatically known by the despatcher. Scheduling is also based in the context of the resources available that vary from day to day. The resources available are affected by environmental factors and the extent that the scheduler knows about the resources. For example, a traffic jam is an environmental factor that can affect a resource by holding up a bus. When the bus is free again the scheduler needs to be informed...
otherwise they will not be aware that that particular resource is available. In the case of booking in advance, the scheduler may have started to use alternative resources and will need to be informed so they can use the original resource again. User needs are another area where scheduling is affected by its context. Different passengers have different requirements and the schedule must be built in accordance with these. The type of trip and whether it is considered to be flexible or not, can affect scheduling as some trips must run on time whereas other trips can be slightly modified in time.

The general strategies that influence the action/interactional strategies in this research tend to be policies that affect passenger numbers. Temporary membership, for example, can impact on scheduling because it causes passenger numbers to go up and down. The biggest intervening condition on scheduling is outside pressure to meet targets. The pressures are caused by policies that can force schedules to be built in a certain way in order to reach the targets.

In axial coding, strategies are composed to manage and respond to a phenomenon under certain conditions (Strauss and Corbin, 1990). For example, in this research there needs to be an action that transfers advance bookings to the regular schedule in response to the normal booking process starting. Cancellations of bookings are actions in response to a number of causes such as driver sickness or passenger error. Further actions are taken in reaction to cancellations, the despatcher will try to fill any spaces created on the schedule by a cancellation. The refusal of bookings is an action that reacts to both resources available and the operating methods of the dial-a-ride. For example, a passenger may have used up their trip limit for using dial-a-ride but can still use an alternative service. An action in response to a refusal will be to record the refusal reason for statistical purposes. Often despatchers will know areas well and will visualise the most likely route a bus will take while they are building a schedule. If an area is not well known the despatcher can act on their lack of knowledge by checking details with other despatchers. The primary action in scheduling that arose from this research is that of routing. During routing despatchers accounted for pickup addresses, destination addresses, the booking time, the day required for the trip, adverse traffic conditions and the resources available. The most basic consequences of these actions are that bookings are either accepted or refused. Other consequences lead to the service aims being met. These are basically to achieve multiple occupancy, meet target pressures and building the most efficient schedule possible.
6.3 Coding Using Software

Software packages are available to manage qualitative data although none of them are specifically for grounded theory. QSR NUD*IST software was recommended as the most suitable for grounded theory analysis. It is a system designed for non-numerical unstructured data indexing, searching and theorising. It is from these purposes the designers got its name. NUD*IST was designed by Tom and Lyn Richards at La Trobe University, Australia to overcome the problems associated with qualitative research and grounded theory analysis. The aims of NUD*IST are described in *Qualitative Data Analysis: Can Computers Do It?* (Richards and Richards, 1987):

- To capture the combination of coding and categorisation on one hand, and the emergence and exploration of data reduction and theory construction on the other.
- To remove the manual constraints on the volume of data, complexity and detail of classification associated with grounded theory.
- To add new abilities to the traditional methods, such as, detailed exploration of the multiple meanings given to data, automatic recording of the history of analytical processes and instant modification of indexing structures.

It is not the purpose of this research to evaluate any software packages available for qualitative research. However it was thought appropriate that the suitability of at least one of these software packages was investigated for possible future use in further research issues. Following a recommendation Q.S.R. NUD*IST was deemed to be the most appropriate for this type of project.

NUD*IST stands for Non-numerical Unstructured Data Indexing Searching and Theorising. It is a software package designed to help users in handling non-numeric and unstructured data in qualitative analysis. The software replicates methods of analysis particular to qualitative methods, whilst using the memory, speed and power of the computer to overcome the constraints on those methods (Richards and Richards, 1987). Grounded theory constraints are discussed in Chapter 3.

NUD*IST stores information in tree-structured indexes. The program allows the process of coding to be integrated with the processes of discovery and exploration while still managing the current state of theorising and meaning making (Burroughs-Lange and Lange, 1993).
The designers of NUD*IST (Richards and Richards, 1987) consider it an appropriate tool for use with qualitative research for a number of reasons. The number of index categories is unrestricted. NUD*IST supports a high level of categorising and cross-filing. It imposes no limit on the number or variety of index entries for a record. NUD*IST also supports complex indexing and is also designed to combine text indexing with analyses using data about text files. The system aims to encourage the emergence of themes by processes of 'grounded theory'. Although there is no critical review of these claims, Burroughs-Lange and Lange (1993) also argue that NUD*IST makes moving from open coding, fracturing the data for axial coding and regrouping the data for selective coding a simple procedure.

A small subset of the grounded theory developed in this research was taken and re-coded using NUD*IST. Data was indexed using tree-structures, which makes it very easy to trace down from high level selective coding to the basic open coding concepts. However, even when using only a small amount of data, NUD*IST was very slow to index even this quantity.

Given the lack of software package speciality for grounded theory it was decided that for the purposes of this research, a manual card approach to grounded theory coding would be more appropriate. This would prevent the research process from being dictated by a piece of software and stop any restrictions that can be imposed by such tools.

It was decided that using a software package to carry out the grounded theory coding would not be appropriate for this project. The researcher wanted to ensure the data and findings were not restricted by such a package. An initial evaluation of one package, NUD*IST, showed that while the data was stored in a way that allowed the researcher to trace through from open to selective coding, the indexing of the data was slow. If the project was bigger and more data needed to be handled it may be coding by hand would be so slow it would make the NUD*IST speed acceptable. However, the amount of data for this research can be handled manually. The evaluation of software packages suitable for grounded theory research would make an interesting issue for further research.

6.4 Discussion

Chapter 6 has discussed the grounded theory coding processes and described the main results from this coding. The open coding produced a sufficient number of categories for axial coding to be developed. Although there are no guidelines as to what a good number of categories are, the
knowledge engineer knew from the pilot study that there could be too few categories for axial coding. In the axial coding three phenomena emerged as being particularly rich in concepts: priorities, service aims and routing. These frameworks are shown in section 6.2.2. A core category was developed in the selective coding, the category of *scheduling*. It was also possible in the selective coding to use and link the phenomena chosen in the axial coding.

The depth of all the coding suggests that the data collected from the expert was productive enough for grounded theory analysis. The resulting grounded theory will be investigated and evaluated in Chapter 7.
7. THE GROUNDED THEORY EVALUATED

7.1 Introduction

The coding processes used in the grounded theory method are described in detail in Chapter 3 and Chapter 6. However grounded theory is not just a way of analysing data, grounded theory is also the term given to the product. The product of grounded theory can be described as a sociological monograph, a written piece that deals with only one domain (Glaser, 1978). An explanation of the reasons why the grounded theory is similar to a monograph is given in section 7.2.

This chapter shows how a grounded theory, as a product, is developed following the coding processes described in Chapter 6. Section 7.2 explains the various techniques that should be employed when writing a grounded theory. In section 7.3 the actual grounded theory product is discussed. The evaluation criteria to examine the validity of the grounded theory are considered in section 7.4. The methods used to evaluate the grounded theory are described in section 7.5. The chapter finishes with an analysis of the results following the evaluation of the grounded theory in section 7.6 and an overall discussion of the chapter in section 7.7. The full grounded theory is located in Appendix E.

7.2 Writing a Grounded Theory

The chief objective of this research is to examine other options to computer based knowledge acquisition methods that are human focused and based on grounded theory. Grounded theory is both a process and a product. It is possible to carry out grounded theory processes and not produce the grounded theory monograph. In order to follow grounded theory through to its conclusion it was decided that a grounded theory monograph should be generated from the coding results and evaluated by the experts using a set of criteria produced by the knowledge engineer. In this section the methods available for writing a good grounded theory are considered. Feedback is the best evaluation of the analysis carried out in any grounded theory research (Glaser, 1978).

Glaser (1978) classifies grounded theory as a sociological monograph because it is constructed on the basis of a 'little logic' and a standard shape. A 'little logic' is defined as a sentence or two that states an interest, a general idea, a logical derivation, a hypothesis, a finding to be investigated or an explanation. In the case of a grounded theory this will be the core category. A grounded theory...
follows the standard shaping of sociological monographs in that it is made up of an introduction, sections and general conclusions. The introduction should describe the general problem, in other words the core category, the methodology and provide a general outline of the monograph. The sections report the analyses, and the general conclusions should suggest where else the core category would be useful.

Section 3.2, gave details of the history of grounded theory and the current disagreements between Strauss and Glaser regarding further development of grounded theory. In the case of writing a grounded theory Glaser (1992) argues that selective coding will have already delimited the categories and their properties to those that are relevant, fit and work. Glaser (1992) goes onto say that by trying to squeeze the grounded theory into a paradigm, the data is forced into a conceptually preconceived model. This logical sorting by Strauss and Corbin (1990) is, in Glaser's opinion, the exact reverse to sorting in Glaser (1978). However, for the purposes of this research the advice from Strauss and Corbin (1990) on how to write a grounded theory was considered more appropriate for this project because of the fact it produced more structured writing, and software design requires a lot of structure. According to Strauss and Corbin (1990), writing a grounded theory requires the following:

- A clear analytical story.
- Writing on a conceptual level, with description kept secondary.
- Clear specification of relationships among categories and clear levels of conceptualisation.
- The specifications of variations and their relevant conditions and consequences.

Some of these requirements are not that far from those Glaser (1978) recommends. The importance of writing conceptually rather than just making descriptions is emphasised. The researcher is also advised to stress that all the concepts are well grounded but the extent of this grounding cannot be shown in a monograph due to the size it would become.

Glaser (1992) objects mainly to the amount of structuring of data that Strauss and Corbin (1990) advocate, although in the case of writing procedures it is possible once again to see similarities between the two methods. One of the issues addressed in this research is the ability of grounded theory to produce a conceptually rich model of the knowledge used in dial-a-ride scheduling. The relevance of this approach is investigated in a prototype decision support system. In order to design such a system it was decided that a structure style would be a more suitable way of writing a
grounded theory as software design needs to be structured in order to work well. Strauss and Corbin (1990) recommend three procedures for writing a grounded theory:

- Sketch an overall logic outline. That is think about the 'little logic' that informs the story.
- Construct outlines that provisionally list and order chapters. This links sections together and places them in order.
- Imagine visually the 'architecture' of the main outline. It is possible with a grounded theory to move away from the traditional structure of writing (introduction, literature review, findings, summary) and organise the data by visualising a kind of 'spatial metaphor'.

Strauss and Corbin (1990) recognise that some grounded theories will have to be written using a certain structure in order to meet requirements. However, by using the first two procedures a good grounded theory can be produced.

7.3 The Grounded Theory - Scheduling Dial-A-Ride - A Discussion

This section will examine the ways in which the grounded theory produced from this research meets the aims and requirements discussed by Glaser (1978) and Strauss and Corbin (1990). In other words, how well the grounded theory meets the standards of a sociological monograph. For the purposes of this research, the grounded theory monograph should also produce a clear explanation of the scheduling processes that can be easily recognised by the experts. The results of the evaluations of this grounded theory are considered in section 7.5.

The grounded theory produced for this research starts with some background information about the domain under study. Although this information is descriptive rather than conceptual it was considered important to the understanding of the work. The knowledge elicitation techniques employed and the methods used to collect the data are explained to show the reader how the research was carried out. This provides background to the research processes. The problem that established a need for the research is also explained.

The 'little logic' statement is the first sentence of the first section following the introduction, Causal Conditions: 'The core category in dial-a-ride services is the process of scheduling.' This statement indicates to the reader that this grounded theory is about how a schedule is built and why a schedule is built in such a way.
The sections in the grounded theory report the findings of the analyses carried out during the grounded theory coding. The results of the open, axial and selective coding were examined in Chapter 6. The sections in the grounded theory discuss the concepts that affect the scheduling process, the impact concepts have on the process and other concepts, and the importance of the concepts within the process and for other concepts.

This grounded theory is structured around the paradigm model which directs the way axial and selective coding are developed. The paradigm model was described in Chapter 3 and examples of its use can be found in Chapter 6. It was decided, that since the theory was concerned with a process, a step by step structure would be the most appropriate. The paradigm model used takes the scheduling process from what causes a booking to be required to the consequences that result from a booking being scheduled.

A grounded theory should finish with a conclusion that suggests where else the core category would be useful (Strauss and Corbin, 1990). This grounded theory however does not do this. The purpose of writing this grounded theory was to test the ability of grounded theory analysis to produce data in a form that was fit to constitute a knowledge base for a decision support system for scheduling dial-a-ride. It was decided that considering other uses for the core category at this stage in the research would detract from the rest of the investigation and that further research issues would be more appropriately discussed at a later stage. There may be abstract higher level models that would be relevant to other domains, for example, timetabling.

7.4 Evaluation Criteria for a Qualitative Study

Qualitative studies have been rejected as subjective, open to doubt and unsubstantiated (Kvale, 1996). One of the reasons for this is the lack of explicitly stated, well-defined and generally approved criteria for evaluating qualitative studies (Athens, 1984; Burns, 1989). There has been a renewed interest in establishing a set of criteria, as the use of qualitative research methods has become increasingly more popular (Altheide and Johnson, 1994; Muecke, 1994). However, while this interest has led to some degree of agreement about the requirements for an established set of criteria, it has proved very difficult to find a specific list of standards against which a qualitative study can be measured, except that developed by Strauss and Corbin (1990). In this section the broad themes that follow through qualitative evaluation in general will be considered in addition to the more explicit guidelines provided by Strauss and Corbin (1990).
7.4.1 Criteria for Judging a Qualitative Study

The best evaluation of a theory is that which comes from feedback (Glaser, 1978). The importance of user evaluation is discussed by a number of authors. For example, the approach used by Patton (1990) has its focus on intended use by intended users. The aim of qualitative research is to look for practical validation of results based on the applicability to and use by the intended user (Patton, 1990). Similarly, Murray (1993) stresses that users must be involved in both the design and evaluation stages of research.

There are, however, some potential problems with user evaluation. When assessing the validity of a theory, it is possible that more than one user will review the findings. The researcher should bear in mind that validity would be different for different users (Altheide and Johnson, 1994). Kvale (1996) draws attention to the fact that while the user is the ultimate measure for deciding the validity of a theory, he or she may not have the methodical or theoretical expertise to evaluate the theory fully.

Qualitative studies often take the form of case studies and therefore stress context (Green, 1994). The importance of context should consequently be implicit in the evaluation and the evaluator should be context aware (Burns, 1988). If an expert who contributed to the data collection is used this ensures the evaluator is context aware.

7.4.2 Criteria for Judging a Grounded Theory

Strauss and Corbin (1990) provide a comprehensive set of criteria for judging both the research processes of a grounded theory and the actual grounded theory product. The criteria for evaluating both is due to the necessity to check that the processes of developing a grounded theory are accurate in order to assess the grounded theory product. Glaser (1992) argues that the criteria provided in Glaser and Strauss (1967) and Glaser (1978) are completely ignored in Strauss and Corbin (1990). The grounds for this argument come again from the idea of trying to structure the data too much and not allowing for the fluidity of theory development. The result of trying to structure in this way leads the researcher to 'wrestle' with principles that are used for judging quantitative research and which are not appropriate for evaluating grounded theory. However, as stated earlier in this section, it is now agreed that an established set of criteria for judging qualitative research is required. The Straussian method of grounded theory analysis has been used throughout this research. Therefore the structured criteria suggested by Strauss and Corbin (1990) were thought to be appropriate for evaluating this research and this grounded theory. The need to use the concepts developed in the
grounded theory as the basis for a decision support system prototype again made using a more structured approach a more appropriate conclusion.

7.4.2.1 Evaluating The Detail of The Grounded Theory

Strauss and Corbin (1990) identify three areas that should be evaluated in a grounded theory: the validity, reliability and credibility of the data; the acceptability of the research process; and the empirical grounding of the findings. The relevancy of the data in this research has already been judged during the pilot study and coding processes. It would not have been possible to start the coding if the data collected was inadequate. Therefore this section will concentrate on criteria for judging the areas of research process acceptability and grounding of the findings.

Judging the components of the research process is difficult to judge because only the researcher is present during the analytic sessions. Strauss and Corbin (1990) suggest asking the following questions of the monograph and using the answers to indicate how they could serve as evaluative criteria:

- On what grounds was the original sample selected?
- Did major categories emerge?
- Were there any events that pointed to these major categories?
- How did theoretical sampling proceed?
- How were some of the hypotheses relating to conceptual relations made?
- Were there instances where the hypotheses did not hold up against what was actually happening?
- How and why was the core category selected?

If the questions can be answered satisfactorily, an evaluator can use the criteria to assess how well the research process was completed. That is, check to see that the answers to the questions can be found in the grounded theory data.

7.4.2.2 Evaluating The Output of The Grounded Theory

Strauss and Corbin (1990) also provide a series of questions that are the equivalent to a set of criteria for the empirical grounding of the research:
• Are concepts generated? As the basics of a grounded theory are the concepts grounded in the data, the first question that should be asked of any grounded theory is does it produce concepts through coding?

• Are the concepts systematically linked and grounded in the data? It is important that not only are concepts generated, but that concept linkages exist and that these linkages are grounded in the data.

• Are there many conceptual linkages and are the categories well developed? Conceptual linkages are developed through the paradigm features (described in Chapter 3 and Chapter 6) and provide the theory with density and explanatory power. The theory will not be satisfactory without these.

• Is the theory varied in its phenomena and conditions? A grounded theory should not be limited to one phenomenon and just a few conditions under which it appears.

• Are the broader conditions that affect the phenomena under study built into its explanation? The analysis should show conditions that originate from macroscopic sources and how these sources are directly linked to phenomena.

• Has process been taken into account? It is important to identify and specify change in a theory to show fluidity and response to changes in conditions.

• Do the findings seem significant? It is possible to develop a theory that shows very little but can still be grounded. A significant theory should mean something to evaluators.

Strauss and Corbin (1990) point out that the above criteria are only guidelines but argue that by sticking closely to them it will make it easier to judge the overall adequacy of the theory. Demonstrating some of the research procedures can also help in judging the theory. The extent to which this grounded theory meets these criteria is discussed in section 7.6.

7.5 Evaluation Methods

It was decided that the evaluation of the grounded theory as a knowledge elicitation technique should take place in two stages:

• Evaluation with dial-a-ride managers and review of grounded theory based on any criticisms the managers might have.

• Evaluation with dial-a-ride managers and experts with initial criticisms incorporated and further review of grounded theory if required.
The evaluation of the prototype knowledge based system developed from the grounded theory is discussed in Chapter 9. The first of the two evaluations are based on questions that will show if grounded theory can be used for knowledge elicitation. The two evaluations can be found in Appendices F and G. The evaluation of a prototype knowledge based system developed from the grounded theory is discussed in detail in Chapters 8 and 9.

Following completion of the grounded theory, a copy was sent to each of the dial-a-ride managers together with instructions how to evaluate the theory and a brief explanation of the coding process. The managers had previously attended a seminar where the grounded theory coding results had been presented. It was hoped that following this, a brief reminder of the coding process would be sufficient to overcome the problem of lack of evaluator expertise. The problem of differing users and differing views of what should be in the grounded theory was tackled by explaining that the analysis would produce a model that reflected decision making processes that were at a more abstract level than normally thought of. The researcher interviewed each manager using a list of criteria that reflected what the theory was intended to produce. The results of the evaluations are discussed in section 7.6.

Stage two of the evaluation consisted of sending a copy of the reviewed grounded theory and questionnaire to the dial-a-ride managers and also the experts. The questionnaire was based on the criteria used by the researcher in the first stage of the evaluation. The aim of the second evaluation was to get more detailed comments on the theory without having to ‘iron’ out any minor inconsistencies. When the questionnaires had been completed the researcher interviewed the managers and the experts to discuss the results of the evaluations.

7.6 Evaluation Results

Evaluation of the grounded theory monograph was carried out in two parts. The first evaluation provided the knowledge engineer with a general overview of what the experts thought of the grounded theory results. This ensured that no obvious errors were present in the grounded theory. The second evaluation was in more depth and more detailed. A questionnaire was developed to check the grounded theory met certain criteria.
7.6.1 Evaluation Stage 1

The first evaluation took place at the site used to pilot the knowledge elicitation techniques (Nottingham). Although none of the data from the pilot exercise was used in the grounded theory analysis, it was felt that evaluation by this dial-a-ride would show if the theory was generic. The evaluator understood the grounded theory processes and that the theory contained information from other groups. The evaluator commented that the theory provided a good explanation of how a booking was scheduled from a telephone call to being completed. On the whole the evaluator found the theory to be accurate and acceptable although it did not account for any ‘surprises’ that might happen during the day.

The second evaluation was for Barnsley. Unfortunately the evaluator here was understaffed and had been very busy. The grounded theory had been read but the evaluator had been unable to give it much thought and could only give an evaluation based on first impressions. The manager could recognise concepts that related to his dial-a-ride and that much of what had been captured would not have shown through using conventional interviewing methods only. The issues of target pressures and priorities were of particular interest because they were new concepts and represented how the service was changing.

The third evaluation was carried out at Sheffield. The response at Sheffield was very similar to that at Nottingham. The theory was accurate and demonstrated many of the decisions made while scheduling in Sheffield. Again, the issue of different practices in the other groups was raised but the explanation that these practices did not describe the Sheffield group was accepted. Sheffield dial-a-ride did not require any changes to be made.

The fourth evaluation took place in London. The manager had decided to include the expert in the evaluation so both evaluators were present for the interview. There was some criticism of the phases or wording used in the theory. Alternatives were discussed and agreed upon. The content of the theory was considered to be satisfactory, comprehensive and accurate. All the required changes were made to the grounded theory.

7.6.2 Evaluation Stage 2

The questionnaire designed for Stage 2 of the evaluation consists of five sections. Parts A to D collect information about the group in general, for example, the size of the group and the importance
of dial-a-ride within the organisation. Part E of the questionnaire is concerned with the grounded theory and the extent to which it shows the scheduling processes used. If the experts think the grounded theory represents their scheduling processes, it will be possible to show that grounded theory can be used for knowledge elicitation in this domain.

It was decided that the data collected from the external pilot site, Nottingham, would not be relevant because it would not be used in any further research. Therefore this group was not required to fill in the questionnaire. It was not possible to perform Stage 2 of the evaluation at Central London Dial-A-Ride. However, the group had provided detailed feedback after the first evaluation that could be used in the final evaluation.

The questionnaire was completed by the manager and the scheduler at Sheffield. The Sheffield group had very similar answers for the comprehensibility section of the grounded theory. The grounded theory was found to be understandable and issues relevant to Sheffield were clearly recognisable. The grounded theory was found to be complete in that it portrayed the activities that were going on in the scheduling process. Comments were made that limitations and the need for more knowledge were difficult to judge because there were always going to be new situations that would require a decision at the time and may never occur again. The grounded theory was judged as being consistent in what it says although the problem of new situations arising that required one off decisions could also apply here. The grounded theory is accurate as far as Sheffield is concerned. The level of detail in the grounded theory was also found to be deep enough to show how scheduling issues affected Sheffield.

The questionnaire was also filled in by the manager and despatcher at Barnsley Dial-a-Ride. Again, the answers given were very similar. The grounded theory was clear and easily understandable. The grounded theory contained ideas that represented the scheduling process in Barnsley. Although the group found limitations in the grounded theory, they did not feel much knowledge could be added because the knowledge required would only be found in one off situations. The grounded theory was judged to be consistent in its content and provided an accurate description of the scheduling processes in Barnsley. The level of detail in the grounded theory represented the policies that affected the scheduling process.
7.7 A Diagrammatic Representation of the Grounded Theory

The common product of grounded theory analysis is a sociological monograph. It was decided that a graphical representation of this monograph would be of benefit to the evaluation process because diagrams are easier to understand and explain to an expert. It is also common practice in the computer industry to show experts diagrams because they are easier to understand and simpler to explain. Graphical representations are generally more readable and can be used to communicate ideas. Such representations do not need to show completeness or accuracy. One of the aims of this research is to investigate the suitability of grounded theory coding for developing a prototype DSS. It was therefore decided that if the grounded theory could be represented diagrammatically this could make the translation of the theory easier to computer form. A diagram was produced that showed how all the concepts in the grounded theory linked together.

As there is no standard form of graphical representation for grounded theory, the knowledge engineer developed a series of boxes and links intended to show the grounded theory product pictorially. The diagram developed from the grounded theory, *Scheduling A Dial-A-Ride*, is shown in Figure 8.1. The diagram was centred on the core category, scheduling. Causes, properties, dimensions, conditions, strategies and context are shown linking to the core category. Intervening conditions and consequences are placed outside the main diagram to show their outside effect.

The grounded theory diagram represents conceptual relationships that are a fundamental basis of knowledge based systems. These concepts can then be used to instruct frames to develop knowledge based systems. However, the diagram is static and does not show procedural knowledge. An issue for further research could be to design a diagram that does show procedural knowledge.
Figure 7.1 Grounded Theory Diagram
7.8 Discussion

In this chapter the issues surrounding the writing and evaluating of a grounded theory have been explored. Writing a grounded theory is the same as writing a sociological monograph that includes a 'little logic', an introduction, sections and a summary. The chapter outlines a number of requirements that help to structure the grounded theory appropriately. The arguments put forward by Glaser (1978) against structuring the data like this are considered although it was decided that the structured approach was more appropriate for this research. A discussion of how the grounded theory developed for this research was written shows that using the structured approach as the writing style, was a more suitable writing method for this research.

This chapter moved onto investigating the evaluation criteria for qualitative studies in general and the criteria deemed specifically pertinent to grounded theory. The criteria for judging a grounded theory can be divided into two lists, those that judge the coding process and those that evaluate the empirical grounding of the theory. The methods used to implement the evaluations are described in section 7.5 of this chapter. The reasons for this implementation are also discussed.

Stage 2 of the evaluation showed that the both groups that took part in the exercise found the grounded theory to be accurate and complete. The only problem with the theory was that it did not cover every possible exception that could arise in the scheduling process. The grounded theory did not catch the nature of each exception but did capture the fact that these do exist. However, the research aims to find knowledge that can be usefully computerised, leaving the despatchers free to make more complicated decisions. The data draws the boundaries between what is automated, what is supported and what is left to the despatcher.

So it can be seen that the grounded theory demonstrates successfully the concepts at work in the scheduling process. It is possible to say that the knowledge elicitation techniques used to extract the data for the grounded theory were successful and are appropriate for grounded theory analysis. The next stage in the research is to identify the tasks that can be usefully computerised and evaluate to what extent the grounded theory concepts can be used in a prototype decision support system.
8. THE PROTOTYPE

8.1 Introduction

This research aims, in part, to evaluate the suitability of grounded theory to produce a conceptually rich model of the knowledge used in the domain under study. This can be investigated by building a prototype decision support system to show the richness of the concepts collected in this research. This chapter investigates how the grounded theory can be taken and represented as knowledge in a computer prototype decision support system which will be evaluated to see the extent to which this aim is met. In order to build a prototype decision support system some systems analysis and knowledge representation need to be carried out. This evaluation is discussed in Chapter 9. Investigating systems analysis and design and knowledge representation are not part of this PhD, these techniques are used purely to build the prototype. The systems analysis carried out based on the grounded theory is discussed in section 8.2. Section 8.3 considers why frames were chosen as the knowledge representation and section 8.3 describes the design carried out for the prototype decision support system using the grounded theory. The discussion at the end of the chapter assesses the extent to which grounded theory can be developed into a computer form and a prototype. A sample of the systems analysis and design can be found in Appendix H.

8.2 Systems Analysis

The development of software systems is broken down into a number of stages known collectively as the Systems Development Life Cycle (SDLC). In order to determine the extent to which grounded theory can be developed into a prototype it is necessary to know where it features in the SDLC. Figure 8.1 shows the different stages of the SDLC and where the data from knowledge elicitation and grounded theory coding fits into the SDLC. The knowledge elicitation data is included because at times it did become necessary to return to the knowledge elicitation transcripts. This issue will be examined further in section 8.5. Systems analysis and design is the process of designing computer software to serve the needs of users (Fertuck, 1995). The analysis stage of the SDLC is to translate the two main inputs, user requirements and project charter, into a structured specification (Yourdon, 1989). In the case of this research the inputs and user requirements came from the grounded theory coding that had been produced using data elicited from the experts.
The analysis stage comprises sorting the data into a number of structures that represent how the data is used in the system (Yourdon, 1989). There are a number of technical and documentation standards that can be used for systems development, for example Yourdon or SSADM (Structured Systems Analysis and Design Method). CASE (Computer Aided Software Engineering) tools are available for these methods. CASE tools automate the drawing of diagrams and error-checking tasks. As Select Professional, a CASE tool to implement SSADM, was already accessible to the knowledge engineer and SSADM is a recognised systems analysis method, it was decided that some aspects of SSADM diagrams should be used for the systems analysis.

The system being implemented in this research is only intended to be a prototype decision support system (DSS) and not a fully developed software package. For this reason the knowledge engineer did not use all the data modelling techniques available in SSADM. It was decided that using data flow diagrams (DFDs), entity relationship diagrams (LDS) and a data dictionary would be sufficient to produce enough systems analysis for a prototype DSS. The first task with the systems analysis was to decide which type of grounded theory coding would be the most appropriate to use as the basis for DFDs. The grounded theory and the selective coding did not provide enough detail for the DFDs. The axial coding did however appear to have the level of detail required. The following is an example of how axial and selective coding can be incorporated into SSADM format. Samples of the systems analysis can be found in Appendix H.

The first step of the analysis was to develop a context diagram. A context diagram represents the whole system as a process with all flows into and out of the system shown around the edge of the system (Ashworth and Goodland, 1990). The core category, scheduling, is used as the process and
passenger is the outside entity to which data flows. Although a context diagram can be easily understood and ensures boundaries are shown, there is obviously not enough detail to give to a developer.

The next type of diagram that was generated in the systems analysis was a top level DFD. A top level DFD shows the complete system in very little detail. The detail in a top level DFD is limited generally to the major functions in the system and the major interface between the functions (Yourdon, 1989). Figure 8.2 shows the top level DFD generated for this application. The axial coding was used to find the detail that was needed for this diagram. In this diagram the external entities came from the causal conditions in the axial coding. The two causes which are shown in the diagram are passengers making booking requests and providing the required details and the drivers informing the despatchers of possible delays on the roads. The data flows came on the whole from the properties and specific dimensions of a phenomenon. In the case of the phenomenon Normal Booking the properties and dimensions provide information on trip type and booking time. These can be seen clearly in the top level DFD as trip purpose and time of trip. The DFD processes were developed using the axial coding context and action/interactional strategies, for example the data process Change Trip Time. This process has been taken from the action/interactional strategies of Normal Booking and corresponds to the strategy of offering the closest time available to the passenger.

Despite the lack of detail in a top level DFD, the diagram can easily become complex and confusing to look at. The diagram can be simplified by organising the top level DFD into a series of levels so that each level provides successively more detail about a section of the level above it (Yourdon, 1989). Figure 8.3 shows an example of levelling from this research. The DFD in Figure 8.2 is a levelled DFD of the process Get Booking Details. The lower level shows precisely the data required for booking details and where the data flows to when it has been received.
Figure 8.2 Top Level DFD

Figure 8.3 Levelled Diagram
The final type of diagram used in this system analysis was the logical data structure (LDS) or entity relationship diagram. The LDS is a method for describing what information should be held by the system (Ashworth and Goodland, 1990). A diagram is produced which shows the entities and their relationships. Inputs into the system can be identified by analysing LDM entities, attributes and relationships to identify what events are needed in a system (Betts, 1995). Figure 8.4 is the LDS developed for this research. There are six entities in this analysis: shift; vehicle; shift-trip; driver; booking and passenger. The attributes for each entity are listed and the relationships between the entities are shown by the arrows and lines which run between the entities. The relationships in the case of this analysis are many to one and one to many. The attributes for each entity did not come purely from the axial coding. A data dictionary of the current system used by Central London Dial-A-Ride was used to ensure all the required data was included. This is because some of the items in Scheduling decisions are used to produce administrative reports and not by the despatchers in their knowledge elicitation exercise. Therefore not all the items in the data dictionary would have come through in the data dictionary. However, the data needed to be as accurate as possible in order to provide the full background required for decision making and evaluation.
Figure 8.4 Logical Data Structure
8.2.2 Problems with the Systems Analysis

The main problem with using the axial coding for the DFDs was that although many of the concepts used in making scheduling decisions were present in detail, there was little indication of the order in which these tasks were being made. There was a number of processes but few data flows linking them. A return to the open coding and the knowledge elicitation transcripts provided a step by step order for the procedural knowledge in the grounded theory.

It was decided to return to the lowest level of data collected, the transcripts, to find out if the order of decision making was more apparent. By listing all the processes found in the transcripts the order in which decisions were being made became much clearer. However, the DFDs produced from the transcripts did not include the concept details that had been provided in the DFDs built from the axial coding.

The grounded theory analysis had demonstrated that there were only three basic outcomes in the scheduling process:

- Accept a booking with no changes to the requested times.
- Accept a booking with modifications to the requested times.
- Refuse a booking.

However, there are a number of factors that need to be considered in the decision making process before one of these outcomes can be reached, for example, which shifts are available or how modifiable are the trip times. This meant that there was a large amount of repetition in the DFDs due to the dispatcher having to consider most of these factors for each booking. Such repetition is not easily modelled using DFDs and is deemed more suitable for flow charts. However, flow charts could not show the concepts used in the decision making process to a level required for systems design. It was decided that modelling the repetition in DFDs would be more appropriate than using flow charts because the concepts used in the decision making process were of more importance in the research. Following the systems analysis which analyses the data that is used and how it used in the system the knowledge must be represented in a form that the developer can use.
8.3 Frames

The next stage in the development of the prototype was to represent the knowledge. Knowledge representation is a way of representing knowledge for the computer. It is not the intention of this thesis to review all the knowledge representation types available, because the research is not investigating knowledge representation. Knowledge representation is simply part of building the prototype and not a separate issue for discussion. The type of knowledge representation that was chosen to use in this research is frames. A frame is a data structure for representing stereotypical knowledge of some concept or object. It is basically a network of nodes and relations. The name of an object is represented by the frame, which in turn has slots that are attributes that describe the object represented. The top levels of a frame are fixed and represent things that are always true about an object. The slots are filled by specific instances of data (Apatgiri et al, 1995). Constructing knowledge bases is a major intellectual research problem (Minsky, 1985). Frames can be used because they often reflect the natural structure of knowledge (Ringland, 1988). Durkin (1994) lists the five main features of frames:

- There are different types of frame, such as class frames or instance frames.
- Frames use inheritance.
- Instance frames allow values unique to that instance which overcomes the problems associated with exceptions.
- Frames can be structured into a hierarchy allowing for complexity.
- Frame based systems provide additional control over values through the use of demons. There are two basic types of demons, if-NEEDED and if-CHANGED which execute if a value is required or if a value changes.

Frame-based systems, through their use of rules, can capture the type of decisions made by human experts (Davis et al, 1993).

There are two reasons why frames were chosen as the knowledge representation type for this research based on the fact the grounded theory coding was forming the basis for the prototype:

- Frames are a description of what an object is and can therefore contain declarative and procedural knowledge (Shadbolt, 1988). Grounded theory elicits both declarative and procedural
knowledge, therefore in order to show both types of knowledge the knowledge representation must support the both.

- The nature of grounded theory coding suggests the use of frames because the nature of the data uses demons. The factors that are considered in the decision making process by the despatcher are triggered by aspects of the data about the booking as the information becomes available. The grounded theory coding shows how causal conditions cause a phenomenon and how action/interactional strategies acting on the phenomenon bring about consequences.

The next section describes in detail how the frames were developed for the prototype.

8.4 System Design

One of the aims of this research has been to produce a prototype decision support system which could be used to evaluate the appropriateness of grounded theory analysis in producing knowledge rich enough for a knowledge base. It was not the intention of this research to produce a full software package. Prototypes are used to model aspects of the required system in advance of full development to help with communication between knowledge engineers and experts and to allow experts to experience aspects of the system before it is implemented (Ashworth and Slater, 1993). There are two ways in which a prototype can be developed:

- Horizontally - the top level of all functions work. This type of prototyping is used mainly to test the users' reaction to the interface. There is very little functionality available with this type of prototype.
- Vertically - one path through the system from the interface to code functions fully. This type of prototyping is better for testing systems where the functionality of the system is more important than the interface.

It was decided that this research would use the vertical approach and prototype the scheduling concept of routeing. This would allow the expert to use a number of concepts when making a scheduling decision because the phenomenon of routing in the grounded theory coding was linked to several other phenomena. The vertical approach to prototyping also mirrored the grounded theory idea of being able to trace a path all the way through from coding to data.
Prototyping is normally an iterative process involving feedback from the expert as requirements may need to be refined a number of times (Ashworth and Slater, 1993). However, the nature of this research meant that the expert was not involved with the prototype until the final evaluation stage. This is because the prototype is being used as a tool to assess the extent to which grounded theory coding can be represented in computer form. If an expert was to influence the development of the prototype then it would no longer be representing the grounded theory and the evaluation would be unsound.

The entities were used as the names of the frames and the entity attributes as the slots in the frames. Each slot was given a structure, a demon and a rule. Each slot was also listed together with any other slots required to fire a rule for that slot. A list of rules was produced using the DFDs in the first instance and then the axial coding for more specific detail. Figure 8.5 shows the frame Trip Booking. This can be linked to the selective coding specific dimension of Route and the action/interactional strategy of the Routing example in Chapter 6. This in turn can be linked back to the axial coding examples in Chapters 3 and 6 and the open coding example in Chapter 3. A rule for this frame is shown in Figure 8.6. Taking the slot Popular Destination with a value of True contained in the frame Trip Booking it is possible to see how rule 13 affects the slot if it is fired.
Frame: Trip Booking

Slots.

Trip Purpose Code [1, 1G, 2, 2G, 3, 3G, 4, 4G, 5, 5G, 6, 6G, 7, 7G, 8, 8G, 9, 9G, 10, 11, 12, 13, 99]
Demon on-CHANGED
Rule 1, Rule 12

Special Occasion [True, False]
Demon on-CHANGED
Rule 2, Rule 3

Priority [True, False]
Demon on-CHANGED Display on screen - Priority Booking

Use Alternative [True, False]
Default [False]
Demon Display on screen - Use Alternative Service

Adults [0..15]
Demon on-CHANGED
Rule 5

Children [0..15]
Demon on-CHANGED
Rule 5

Infants [0..15]
Demon on-CHANGED
Rule 5

No. of Passengers [0..45]
Demon on-CHANGED
Rule 4

Flexible [True, False]
Default [False]
Demon on-CHANGED
Rule 13

Popular Destination [True, False]
Default [False]
Demon if-NEEDED Prompt User or Set by User Action

Popular Pickup [True, False]
Default [False]
Demon if-NEEDED Prompt User or Set by User Action

Event Time [Time]
Demon if-NEEDED Check Event Zone

Event Address/Zone
Demon if-NEEDED Calculate Alternative Route

Figure 8.5 Frame Trip Booking
The design for the prototype was handed over to a developer to programme in KnowledgePro for Windows 2.15 (KPWin) as part of the EPSRC project, a high level language which integrates expert systems, multimedia and object-oriented programming technology. Due to time constraints and the learning curve required in order to master KPWin to a satisfactory standard it was judged more appropriate for the knowledge engineer to concentrate on building test cases and developing evaluation criteria. A professional developer could then programme the design. The knowledge engineer was on hand throughout the development stage to ensure the design was being followed closely and to answer any queries the developer may have had. The knowledge engineer was also
alert to problems that may have arisen with the programme design. The aim of the prototype was to show how well grounded theory could be developed into a computer system form. It was not the aim of the prototype to improve or change the current scheduling methods but to show those methods in action in a computerised form. The knowledge engineer was responsible for ensuring the programmer understood that this was the aim of the prototype and did not suggest improvements or changes to the scheduling system.

8.5 The Prototype Windows

Although the grounded theory produced concepts that were used in the decision making process, the data collected also provided information that informed the interface design. In order to understand the comments made during the evaluation it was considered appropriate to examine some screen shots of the prototype to explain how the system operates. The prototype was developed using KnowledgePro for Windows (KPWin) and TransCAD. KPWin provides the data entry screen and textual display of the vehicle shifts and embodies all the frames and most of the explicit rules of the system. TransCAD is used for functions such as checking street names, retrieving post codes and map references and displaying possible routes. Some rules are coded implicitly into TransCAD.

The despatcher operates the prototype from a window called Booking Control (see Figure 8.7). This allows access to the different display windows, for example the Take Booking window (see Figure 8.8). This window allows the despatcher to enter booking details, view the shifts and actually take and store a bookings.

![Figure 8.7 Booking Control Window](image-url)
The despatcher enters a passenger number which displays several details about a passenger, for example the passenger name and the mobility aid used by that passenger. The despatcher then enters data for a trip request. Some of the data entered, for example the trip type, will default to save the despatcher typing in unnecessary details. When the despatcher enters the requested trip time, the pickup and destination addresses the prototype will display using the shift code traffic light possible shifts that could be used for the trip. A red light means the shift cannot not be used for that trip, a green light means the trip can be scheduled onto the shift and an orange light means the trip can go on the shift if another trip is moved or a driver break is moved. By selecting a shift code the despatcher can the view the current shift in the shift window (see Figure 8.9). The despatcher can see where a booking fits in and if it is necessary move another booking or a driver break. In the case of this example four bookings have been taken, two of which overlap which indicates multiple occupation of the bus. The dispatcher now knows if a third booking, for example, can be taken at that time or if another shift needs to be displayed.
The knowledge elicitation exercise captured many of the concepts used in the scheduling process. One of the concepts was the importance of post codes and maps references when building a schedule. This element was developed in the prototype through the Get Post Code feature (see Figure 8.10). The despatcher selects an option that allows them to enter a post code for a booking. The system carries out a search. The prototype displays a map which shows the despatcher the area covered by the requested post code. This allows the despatcher to see if a booking fits in with any other bookings.

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**Figure 8.9 Example Shift Window**

The knowledge elicitation exercise captured many of the concepts used in the scheduling process. One of the concepts was the importance of post codes and maps references when building a schedule. This element was developed in the prototype through the Get Post Code feature (see Figure 8.10). The despatcher selects an option that allows them to enter a post code for a booking. The system carries out a search. The prototype displays a map which shows the despatcher the area covered by the requested post code. This allows the despatcher to see if a booking fits in with any other bookings.
The prototype also offers the despatcher the opportunity to select alternative times for a trip if the passenger is going to a popular destination. One of the main concepts developed in the grounded theory was that of pressure to meet targets. This feature allows the despatcher to get multiple passengers on one shift and therefore make better use of the resources available. A popular destination can also be displayed on a map (see Figure 8.11). In this example the popular destination is a supermarket. The despatcher can see if other bookings are going to this address and try to fit the booking they are taking to go at the same time as the other bookings. The use of this map allows the despatcher to see immediately where the destination is in relation to the pick up address which again can provide a better user of resources.

Another characteristic available to the despatcher are statistics which tell the despatcher the estimated distance of the trip, the duration of the trip and the suggested pick up time for trip. This can also allow the despatcher to make a decision that can make better use of resources.

Figure 8.10 Get Post Code
The Prototype

A.C. Chismall

1998

Figure 8.11 Display Popular Address Window

The prototype also provides the despatcher with a scheduling assistant where a new trip can be displayed showing existing shifts into which it may be possible to enter a new trip. This allows the despatcher to try inserting a trip into a shift and see the effect on screen (see Figure 8.12). A new line is displayed to show how the bus will detour to fit in the new shift. This gives the despatcher the opportunity to test different trip allocation and see the effects on screen which can again lead to improved use of resources.

This section has described some of the features provided by the prototype. The evaluation was based on a demonstration that covered all the elements discussed in this section. The next section of this chapter discusses the development of the evaluation and the problems faced throughout this process. The results of the evaluation are also examined.
8.6 Discussion

Chapter 8 has described the processes involved in representing the grounded theory in a form suitable for a computer system. It has described how the data was taken from a grounded theory monograph, translated into SSADM, illustrated by a knowledge representation technique and used to design a prototype DSS.

The grounded theory coding, in particular the axial coding, was used to develop systems analysis based on SSADM. This was carried out in order to make the grounded theory results suitable for building the prototype decision support system. The problems associated with the systems analysis are based mainly on the issue of repetitiveness and representing this in a DFD. This repetitiveness makes the DFDs very complicated and difficult to read and follow. However due to the time constraints it was decided that the DFDs would remain somewhat complicated. Although the DFDs could be improved visually they are accurate in themselves.

It also became necessary at times for the knowledge engineer to return to the original knowledge elicitation transcripts for data. The aim of the research was to investigate the decisions being made by the expert in dial-a-ride scheduling. Although the grounded theory analysis had produced procedural knowledge, the chronological order in which each decision was made had not been
recorded in the grounded theory coding because this detail of order had not been required for the monograph. However, in order to make the grounded theory suitable for computer form this detailed order is needed and was found by returning back through all grounded theory coding to the transcripts. This return path through the data shows in itself that the coding was grounded properly in the data, a very important objective of grounded theory analysis.

The final design for the prototype was completed using the DFDs and the axial coding in order to achieve the amount of detail required for a programme design. A method of using frames and rules provided the most suitable way of representing the data for the developer because frames allowed the knowledge engineer to represent both the procedural and declarative knowledge of the grounded theory coding. The use of demons in the frames also complemented the nature of this grounded theory data. A future area of research could be investigating how suitable different knowledge representations are for grounded theory data.

A prototype was developed from the systems design exercise which suggests that the grounded theory coding had been represented in a form sufficient for a developer to code. Evaluation of the prototype is discussed in Chapter 9.
9. EVALUATION OF THE PROTOTYPE

9.1 Introduction

This chapter discusses the evaluation of the prototype knowledge based system as mentioned in Chapter 7. The aim of this research is to evaluate the richness, correctness and completeness of knowledge captured from experts in the field of dial-a-ride scheduling using grounded theory analysis. This chapter describes the evaluation carried out to appraise the end product to show the extent to which grounded theory ideas can be usefully computerised. It is also part of this research to investigate some possible ways in which the concepts illustrated in the grounded theory can be reflected in a prototype knowledge-based system. This chapter discusses the evaluation strategies employed to assess the extent to which the prototype reflects the concepts that were used in the computer system.

The development of the prototype was discussed in Chapter 8. This chapter will consider the prototype in relation to the extent to which it represents the concepts used by dial-a-ride schedulers. Evaluations of the prototype were carried out with all the collaborators, including the site used as the external pilot site. In the case of this research the purpose of this evaluation was to see if grounded theory ideas are reflected in the prototype. Therefore an independent evaluation was not suitable as the evaluation needed to include people who had been involved in the development of the grounded theory. The prototype was evaluated as a finished computer system for use at other sites. The results of the evaluations are discussed and analysed. The question in this research is whether the grounded theory is amenable to implementation in software. The evaluation strategy is summarised in Figure 9.1.

![Figure 9.1 Summary of Evaluation Strategy](image-url)
Section 9.2 discusses the evaluation requirements in order to assess the extent to which the prototype decision support system reflects the concepts captured through the grounded theory analysis. Section 9.3 describes the methods used to evaluate the prototype. The results from the evaluations of the prototype are examined in section 9.4. Section 9.5 discusses the overall issues arising from the evaluation of the prototype knowledge-based system. Appendix I shows the evaluation transcripts for the prototype.

9.2 Evaluation Requirements

The formal evaluation of a system is essential if it is to be accepted by the intended users. User interface issues cover a wide range of topics that provide research questions in their own right. It is not the intention of this research to investigate the extent to which the prototype conforms to current user interface issues. This research is concerned with the extent to which the concepts developed in a grounded theory can be usefully computerised. There are two aspects to a formal evaluation, verification and validation (Geissman and Schultz, 1988). Verification means ensuring a knowledge-based system has been developed accurately and does not contain technical faults. Validation means confirming the knowledge-based system satisfies the user’s needs. The system developed in this research is intended only to be a prototype that reflects the concepts evolved in the grounded theory and therefore validation is considered to be of more relevance to the research. However some form of verification will be necessary in order to resolve basic errors that occur when developing software and therefore it was decided that evaluation phase would proceed as follows:

- Discussion of the time and equipment requirements for the evaluation.
- Development of a test plan.
- Development of test data.
- Performing the evaluation.
- Analysing the results of the evaluation.

There are a number of problems commonly associated with evaluating knowledge based systems (Geissman and Schultz, 1988). However this research is concerned with the significance of the prototype to show the concepts developed in the grounded theory and as fully developed knowledge-based system. Therefore issues that would need consideration when developing a full software evaluation are not of importance here.
It is a contention of this research that certain social science methodologies, such as grounded theory, may be appropriate for use in areas like dial-a-ride scheduling where human involvement is high, because the methods are thought to be more appropriate for reflecting actions. The evaluation of the prototype must therefore investigate the extent to which concepts taken from the grounded theory produced in this research are represented in the software. The following criteria were therefore considered in the evaluation questionnaire:

- The extent to which the prototype met the specification of concepts in the grounded theory.
- The degree to which the scheduler can solve despatching problems.
- How the prototype compares to the current method of scheduling.
- The user views of the prototype layout and the functions offered.

The following section describes how a possible evaluation could be carried out to assess the extent to which the prototype meets the criteria formed.

### 9.3 Evaluation Methods

A key aim of this research is to investigate the ability of grounded theory to produce a conceptually rich model of the knowledge used in the domain under study. The prototype decision support system built from the grounded theory developed from this research is described in Chapter 8. In this section resources required for the evaluation and the preparation for the evaluation procedure are considered. The possible methods to perform the evaluation are discussed and the way the evaluation actually took place is recounted.

#### 9.3.1 Resource Requirements.

As discussed in Chapter 8 the prototype was designed using a top down approach. That is, it took one aspect of the grounded theory and followed it through from top level to bottom level rather than looking at a number of issues from one level. The prototype was based on data acquired from Central London Dial-a-Ride and it was therefore decided that the evaluation would take place with this group. The prototype would be developed and tested before taking it to Central London Dial-a-Ride which was the chosen test site. At the test site the despatcher would build a schedule using the prototype and details from previous bookings. The despatcher would schedule shifts for two areas where the areas cross over to assess the extent the prototype aids this type of problem. The time that
the testing was expected to take was six hours which is just less than one working day. The hardware chosen to run the prototype was a 486 compatible using the Windows '95 operating system. A more powerful system would not have been appropriate because it was unlikely the dial-a-ride group would have access to anything better than a 486 compatible. The use of a less powerful system was also deemed to be acceptable because it was not the intention of the evaluation to investigate the speed at which the prototype could run. The equipment and software would be transported from Leicester and set up in London. This was to ensure any problems that arose would not be due to faulty equipment. The extent to which the aims of the evaluation were met would then be assessed using questionnaires and interviews with the dispatcher.

9.3.2 Evaluation Preparation

The first step in the evaluation process was to develop a test plan that could be executed towards the end of the development cycle to ensure the prototype was as bug free as possible for evaluation in London. The prototype is designed to show the concepts and coding developed in the grounded theory. The test plan was devised to list all the functions that needed testing but not to evaluate the extent to which the prototype shows the grounded theory, this was to be assessed separately.

The test plan involved five sections: the interface design; the internal rules that are fired; the frames; the algorithms used; and the GIS functions. Each section was to be tested for accurate I/O structure and to ensure that the correct functions were performed when an option was selected. The prototype was also to be tested to check the correct windows or dialogue boxes were opened when selected. It was the intention of the test plan to ensure the system could cope not only with normal data entry but also with extremes. In a Windows application it is normal procedure to test the keystrokes corresponding to mouse selection. However in the case of this prototype keystrokes were not a priority and therefore were not listed to be tested.

The first section of the test plan concerned the user interface in the sense that options that were implemented were functioning correctly. This was to ensure the user could use the system to see where grounded theory concepts had been included in the system. This research has no further interest in user interface issues.

The second section of the test plan was concerned with testing the internal rules in the prototype. As the rules in the prototype had been derived from the grounded theory, the knowledge engineer knew which rules should be fired and when. Testing the internal rules was concerned mainly with ensuring
certain data was set or reset to reflect the effect of the rule. It was also necessary to check that the prototype did not fire rules incorrectly. For example, the prototype should be able to fire a rule to show whether a booking should have priority status if a certain piece of data is entered. The accuracy of the results of firing a rule was of interest in this section of the test plan.

The third section of the test plan dealt with the frames that hold data associated with objects in the system. The objective was to confirm that each of these objects had the correct data associated with them. Associated data is information such as dates, times and names. There are five frame classes in the prototype: event; shift list; shift; trip booking; and passenger. The test plan covered each frame and allowed all the data associated with each frame to be tested for accuracy.

The fourth section of the test plan involved testing two algorithms in the prototype that calculated distances and travel times for new trips and the effect of delays and events on trips. This testing sought to check that the algorithms produced accurate calculations for the data entered. These two algorithms were of interest because they were developed directly from the grounded theory.

The final section of the test plan intended to investigate the GIS part of the prototype. The main function of interest was the accuracy of the routeing capacity of the prototype.

9.3.3 The Evaluation Questionnaire

A questionnaire was designed for the prototype evaluation. The questionnaire for the prototype evaluation was divided into two sections, one for the booking process and one for the GIS. The aim of the questionnaire was to discover if the windows and options represented the methods used by despatchers to build a schedule. The questionnaire used a scaling technique where the evaluator chooses a point on a scale that bests represents his or her view. The questions were intended to check that all the options required by the despatcher were available and to identify any gaps that might be missing. This should show the extent to which the decision making processes of the despatcher are reflected in the prototype. By asking for the despatcher’s views on the prototype layout the knowledge engineer would also be able to assess the appropriateness of the prototype design.

The answers provided by the despatcher would then form the basis for a discussion of how the prototype compared with the despatcher’s current method of scheduling.
9.3.4 The Evaluation

It was decided that the evaluation of the prototype would take place at Central London Dial-A-Ride over a period of six hours using previous bookings to build a shift with the help of the prototype. The knowledge engineer would then interview the despatcher for their views and ask them to fill in the questionnaire. The evaluation aimed to show the extent to which the prototype met the criteria listed in section 9.2. The interview and questionnaire would be designed to investigate the extent to which the prototype reflected the despatcher’s thought processes in solving scheduling problems. The questionnaire also allowed the scheduler to express their views of the layout of the prototype. If the despatcher considered the prototype did allow problems to be solved in a way that reflected their thought processes and compared favourably with the current scheduling practices, then using grounded theory could be regarded as being successful in this context for eliciting rich knowledge that is suitable for use in a decision support system.

At the time of the evaluation a number of changes had occurred at the test site. The manager and the despatcher at Central London Dial-A-Ride who had taken part in the knowledge elicitation exercise left the dial-a-ride for other jobs. It was decided that the evaluation would still take place at Central London Dial-A-Ride but that the prototype and questionnaire would also be presented to the other groups. This change in method would allow for the original test data to be used but still get opinions on how well the prototype reflected concepts in the grounded theory from people who had been involved in the research process from the start. However Central London Dial-A-Ride were unable to commit the time necessary to complete a full scheduling exercise. The only option available was to demonstrate the prototype to Central London and then conduct an interview based on the questionnaire that should gather enough opinions to assess the extent the prototype met the evaluation criteria.

The first evaluation took place in London. The audience for the demonstration of the software was composed of four people: a representative from London Transport Unit for Disabled Passengers; the general manager from Central London dial-a-ride; the deputy manager from Central London; and the general manager from North London dial-a-ride. The software was demonstrated in two parts. The first session illustrated how a booking could be taken and scheduled onto a shift. A questionnaire had been designed which it was hoped would be filled in by the audience for the demonstration and then followed up with a recorded discussion of the questionnaire answers. However, the audience did not wish to complete the questionnaire so the knowledge engineer carried out a recorded interview with the group based on the items covered in the questionnaire. The same procedure was followed after
the second part of the demonstration that presented the GIS part of the prototype. The comparison of the prototype with the current scheduling method was not possible.

In order to ensure the evaluation procedure was consistent, the same style of an interview based on the original questionnaire was employed throughout. The second evaluation was carried out with an audience comprised of the general managers from Nottingham, Sheffield and Barnsley dial-a-rides. The results of these evaluations are discussed in section 9.4.

9.4 Prototype Evaluation Results

In this section the results from both the prototype evaluations are discussed. The first area considered in the evaluation was the options offered in the booking windows and passenger windows. This was intended to gain views that reflected the extent to which the prototype reflected processes used in scheduling. If the scheduler recognised the concepts used in the scheduling process in the options offered by the prototype then the prototype had succeeded in representing some of the ways in which a schedule was built. The Central London group considered the map function potentially useful for recognising when people from two areas are going to the same place. This was a concept taken from the grounded theory. The function that the group most disliked was the traffic light representation of available shifts. The group considered this feature of no use because it was too time consuming to use and caused the screen to look 'cluttered up'. Knowing the status of a shift was a concept taken from the grounded theory. In the case of Central London therefore, the fact they found the screen 'cluttered' meant the prototype did not reflect this concept adequately. The group agreed that layout of the screens and the order in which data was entered was logical and reflected the way a dispatcher would currently enter data. This suggests that the thought processes used by the scheduler had been reflected in the prototype constructed from concepts contained in the grounded theory.

The second area of discussion was the layout of the windows. The aim of this discussion was to gather user views of the prototype layout and the functions offered. The Central London group found that use of a map in locating postcodes and addresses was very useful but could be improved by making the addresses more accurate. It was agreed that the general overview of the map view was better than showing just small areas on the screen. However the group regarded the time taken by the prototype to display details on the screen to be too long. The main problem with the layout of the data was that the size of screen would not allow for more than one schedule to be viewed easily. The
group also commented that it would be useful to see outward and return trips on the screen simultaneously.

The knowledge engineer finished the first part of the first evaluation by asking for general comments on the booking process offered by the prototype. The aim was to assess the degree to which a despatcher could solve scheduling problems. The main worry voiced by the group concerned unfixed shifts. Unfixed shifts are designed not to have a pre-set start or finish time. This allows the despatcher to schedule bookings that will not fit in easily with other shifts. In order that this flexibility was not lost the group did not feel it appropriate for the prototype to be scheduling this type of shift and considered it essential that only the despatcher should be attending to unfixed shifts. The main feature that would need to be added to the prototype was the ability for despatchers to schedule one booking for multiple passengers. The group concluded that the key question that should be asked to evaluate the system was to ask how many extra trips the prototype would allow the despatcher to schedule and that they doubted the cost benefit would be worth the time taken for the processes to complete. The consensus was that the despatchers would schedule more speedily real time and that the prototype would really only be useful for re-scheduling bookings once the booking time was over and all the bookings could be viewed.

The second part of the first evaluation examined the GIS element of the prototype. The group again decided that the GIS would be useful for re-scheduling purposes. The group particularly liked the capacity of the GIS to display a map on the screen and how a change in the shift can happen. The ability of the prototype to find addresses was also well received. This suggests the prototype had successfully reflected the concepts of shift changes and the importance of addresses in scheduling.

The ability to see the effect on other bookings of adding a further trip was a feature that the group felt was missing. A further function that was absent, in the view of the group, was the capacity to see how driving times could be improved and the length of time a passenger would spend on the bus. The concept of speed was considered to be very important. The chief issue with the GIS map facility was that the maps were too small and the zoom in and out feature was not fast enough. The problem of slowness of the system was a recurring topic of conversation in the interview. The group commented that it took too long to get into the system and that the lack of short-cut keys meant the system was too slow to move around if just using a mouse. The problems with speed can be attributed to the standard of equipment used. However, the purpose of the prototype was to reflect the concepts described in the grounded theory. Issues of speed and human computer interaction were not
considered to be features of the knowledge that was being evaluated for the purposes of this research. A discussion of these issues is provided in Chapter 10.

While the prototype was designed and implemented within certain constraints, an attempt was made to isolate the features that were to be evaluated from other aspects of the system. This kind of response from the users reflects the fact that it is not easy to decouple features of a system in this way and the assessed effectiveness will depend on the apparent effectiveness of the system as a whole.

The second evaluation was carried out with the remaining project collaborators from Nottingham, Sheffield and Barnsley. The knowledge engineer started by asking the group for their views on the layout of the windows. The group agreed that the screen layout was very clear and seemed 'foolproof' and easy to use. The order in which the data was displayed and entered was found to be clear and user friendly. The layout of the prototype was also considered to reflect the concepts used by the despatchers in scheduling. The visual representation of the traffic lights was a particularly favourite feature with the second evaluation group. The group thought this would prove to be an especially useful element in the scheduling process. This suggests the prototype had provided a method to assist the solving of problems by the scheduler. The use of maps was of distinct interest to the second evaluation group because it took the ‘onus off’ the despatcher requiring knowledge of an area and made road information available in a ‘handy’ way. The second group found no problem with the time taken by the prototype because the system allowed more information to be on hand to the despatcher while the passenger was on the phone which would actually speed up the booking process. This is another area in which the prototype had succeeded in identifying the problems encountered by the despatcher. There were features that the second group felt should be added to the prototype: the capacity to know when a bus was full would be useful and the ability to produce fare calculations. The group did accept however that these items were not planned as part of the prototype that concentrated on routing issues.

Following a demonstration of the GIS element of the prototype the knowledge engineer moved onto the second informal interview. The second evaluation group found the visual representation of the maps excellent because it allowed the despatcher the possibility of making connections between bookings that might not otherwise have been made. The linking of bookings is a concept taken from the grounded theory. The ability to overlay shift details on a map was thought to be especially useful in this context. The maps also offered a better utilisation of resources because the despatcher would no longer have to ‘waste time’ looking at an A-Z atlas. The use of maps is a concept contained in the
grounded theory. The prototype had therefore successfully reflected a concept and provided a way for despatchers to solve scheduling problems.

There were a number of features that the group felt could be added to the GIS element of the prototype that would improve it. The group considered the labelling of a booking on the map to be too complicated and that only the time and address needed to be displayed rather than the booking number as well. Also the ability to display booking details in a separate window which could be viewed next to the map would be an advantage.

9.5 Discussion

The most important comment from the point of view of this evaluation is that the second group could see clearly where the information had been taken from the despatcher and used in the system. This is much more the result that was expected because of the amount of detail taken from the grounded theory during the design of the prototype.

There are a number of possible explanations for the differences in opinion between the two groups. The first could be a difference in expectation. Although both groups had been told the knowledge based system produced for this research was merely a prototype it is possible that the Central London group had not fully understood what this meant possibly because of the change of personnel mentioned below. The reason this is possible is drawn from the criticism of the speed with which the data was displayed. It had been explained to the groups that the aim of the prototype was to show the grounded theory concepts and that the speed of the prototype was not a major consideration. The second group appeared to expect the prototype not to perform as quickly as a fully developed product.

A further reason for the difference in expectations could be due to the fact the Central London group had not been involved with the knowledge elicitation stage of the research. Additionally, the group had not participated in the grounded theory evaluation. Again this could have lead to the group not fully understanding the purpose of the prototype. It is possible they expected a more fully developed system and a system that would actually change scheduling methods rather reflect the current way of despatching.
Chapter 9 has described the evaluation process used to assess the extent the prototype meets the following evaluation criteria:

- The degree to which the prototype reflects the concepts contained in the grounded theory.
- The extent to which despatching problems are solved.
- To assess how the prototype compares with the current scheduling method.
- The opinions of the user regarding the prototype layout and functions.

Preparation for the evaluation included ensuring that the necessary resources were available. Initially there were no problems in this area but difficulties did arise with gaining access to a scheduler and the time needed to perform evaluations. These issues were overcome by involving all the dial-a-ride groups, rather than just one, in the evaluation process. Given the importance of using groups, who had been involved in the development of the grounded theory, the inclusion of Central London was more a matter of completeness. The comments made by Barnsley, Nottingham and Sheffield carry more weight in this evaluation. The questionnaire was not followed as originally intended but was used as the basis for interviews to assess how the prototype had performed.

The prototype reflected the concepts contained in the grounded theory through the use of maps by allowing the despatcher to see where addresses were in relation to each other and thereby see how a booking might fit onto a shift. The screen layouts also represented the ways in which a despatcher would enter data to build a schedule. There was some difference of opinion over the ‘traffic light’ feature. The purpose of the ‘traffic lights’ was to show the status of different shifts and allow the despatcher so see at a glance where a booking could be scheduled. The issue of which would the most appropriate shift for a booking is a concept taken from the grounded theory. One group felt that the ‘traffic light’ feature achieved this whereas the other group disagreed. Therefore further investigation of this feature could be an issue for further research.

The prototype can therefore be seen to have reflected a number of concepts from the grounded theory. These concepts are based on the issue of routing and popular destinations that are used throughout the examples in this thesis. The evaluation of the prototype in the context of the all the research will be discussed in Chapter 10.
10. DISCUSSION

10.1 Introduction

This chapter discusses the overall conclusions of the research. Section 10.2 restates the research issues. The research processes used to implement and evaluate the grounded theory and prototype knowledge based system are re-described in section 10.3. The achievements reached by the research are examined in section 10.4. The implications of the research are discussed in section 10.5. Section 10.6 explains some of the limitations faced during this research. A number of future research issues arising from this research are discussed in section 10.7. Final comments are presented in section 10.8.

10.2 The Research Issues

The following research issues have been examined in this research.

- Which knowledge elicitation techniques are suitable for use with grounded theory?
- Can grounded theory be used as the basis of a knowledge acquisition method to produce a conceptually rich model of the knowledge used in the domain under the study?
- Can the model produced be used as the basis of a computerised knowledge-based system?

This research has used a domain where the experts are non-technical: the expert has not taken years of specialist training; the knowledge that is used is not documented in textbooks; local knowledge is important; and temporal and spatial reasoning are involved. Such knowledge is largely derived from experience and intuition rather than formal learning. Therefore a technique that reflects a sociological method could be considered more appropriate for this type of knowledge acquisition than more traditional knowledge engineering techniques. Knowledge acquisition shares some commonalities with qualitative sociology in that both are concerned with investigating how human beings understand, process and make use of symbolic information (Forsythe and Buchanan, 1989). Each discipline also relies on similar data-gathering methods such as interviewing and observation. Grounded theory is recognised as a sociological research method that allows for the systematic generation of conceptual models from qualitative data.
It is a contention of this research that social sciences methodologies, such as grounded theory, may be appropriate for use in areas like dial-a-ride scheduling where human involvement is high because they are designed to deal with human processes. Using dial-a-ride organisations for the case study in this research has allowed the knowledge engineer to determine the processes used in scheduling with the aim of identifying the tasks that can be usefully computerised.

10.3 The Research Achievements

The research issues were described in Chapter 1 and in section 10.2 of this chapter. In this section the results of the research with respect to these issues are discussed.

10.3.1 Which knowledge elicitation techniques are suitable for use with grounded theory?

The research has identified the following knowledge elicitation techniques as suitable for use with grounded theory in this domain:

- Interviewing
- Observation
- Walkthroughs

This conclusion was reached using several processes. Several techniques were reviewed and their attributes compared, as shown in Chapter 2. The characteristics of the techniques were identified and a shortlist of four techniques was drawn up to include interviewing, observation, verbal protocol analysis and walkthroughs. These processes are discussed in Chapter 4. Two pilot studies were performed to test the suitability of these techniques for this domain and to see if open coding could be carried out successfully.

The first pilot study identified that the researcher could carry out the interview technique. The second pilot study investigated the suitability of the interview, observation, verbal protocol analysis and walkthrough techniques. Verbal protocol analysis was found not to be suitable for the domain. The techniques of interviewing, observation and walkthroughs allowed the knowledge engineer to talk to and observe the experts during their decision making processes. This data was then used to develop
walkthroughs that allowed the knowledge engineer to build scenarios and raise any queries that arose during the walkthrough sessions. The three techniques allowed the knowledge engineer to develop open coding from the elicitation transcripts.

The next part of the elicitation exercise took part at three sites. The three techniques allowed the knowledge engineer to develop open, axial and selective coding and a grounded theory monograph. The three techniques when used together built up a clear and detailed depiction of the decision making processes when scheduling dial-a-ride. The fact that the three coding processes used in this method could be completed to allow the development of a grounded theory monologue demonstrates that the elicitation techniques chosen are appropriate for use with grounded theory in this domain. The research methods are discussed fully in Chapter 5 of this thesis.

The problem of knowledge acquisition being time consuming has not been solved by using knowledge elicitation techniques in conjunction with grounded theory. This issue is discussed in more detail in section 10.6.

10.3.2 Can grounded theory be used as the basis of a knowledge acquisition method to produce a conceptually rich model of the knowledge used in the domain under study?

Two evaluations were carried out on the grounded theory using the four groups involved in the knowledge elicitation exercise. The evaluations were based on criteria suggested in the Straussian method of grounded theory analysis:

- Are concepts generated?

  Concepts were produced through the open coding process. The open coding produced 79 concept cards and saturation had been reached. That is, following the completion of the knowledge elicitation no new concepts were being produced. A discussion of the open coding can be found in section 6.2.1.

- Are the concepts linked and grounded in the data?

  The concepts cards were used to develop axial coding. Axial coding shows how concepts are linked. This demonstrates how the concepts in this research are linked. It is possible to trace an occurrence in the axial coding to the open coding concept card and then to the concept
occurrence in the knowledge elicitation transcripts. The examples used in Chapter 6 show how a concept can be traced through the different coding processes.

- Are there many conceptual linkages and are the categories well developed?

  The axial coding was developed using the paradigm model. All the features of the paradigm model were filled using concepts from the open coding. Saturation was reached during the open coding which suggests the categories are well developed.

- Is the theory varied in its phenomena and conditions?

  26 phenomena have been developed in the axial coding. The axial coding can be found in Appendix C and it can be seen that different phenomena appear under different conditions.

- Are the broader conditions that affect the phenomena built into their explanation?

  The axial coding shows the intervening conditions that affect the phenomena. An example of an intervening condition is shown in Figure 6.1 where the phenomena is affected by the need to meet trip targets.

- Has process been taken into account?

  The action/interactional strategies demonstrate the changes that occur to the phenomena in the grounded theory developed in this research.

- Do the findings seem significant?

  The grounded theory represented the domain well as shown by the evaluations in Chapter 7. The organisations involved in the evaluations regarded the grounded theory monograph as an accurate representation of their operations.

The grounded theory was found to be accurate and complete in describing the decision making processes used in scheduling dial-a-ride. This is shown in Chapter 7.

A diagrammatic representation of the grounded theory was developed. The diagram shows the concepts involved in scheduling dial-a-ride and how they are linked. Grounded theory does not usually involve the development of a diagram that represents the concepts discovered in the analysis. This research has demonstrated that a high level overview of the grounded theory can be represented in a diagrammatic form. The grounded theory diagram can be found in Chapter 7.
10.3.3 Can the grounded theory be used to develop a computer system?

One of the chief findings of this research is that the grounded theory has produced a conceptually rich model of the knowledge used to schedule dial-a-ride. The evaluation of the grounded theory found that concepts used in the scheduling process were present. The secondary research issue was to investigate if the grounded theory could be mapped into a computer system.

This research did not intend to develop a full knowledge-based system that could schedule dial-a-ride. The research aimed to map the knowledge in the grounded theory to a prototype knowledge-based system. The grounded theory monograph alone did not provide enough temporal detail to use in a computer system. However, by returning to the axial and open coding sufficient temporal data could be gathered. The axial coding provided the overall requirements for the system and the open coding provided the detail to fill these requirements. At times it was necessary to use the knowledge elicitation transcripts to get further detail. It was hoped that it would not be necessary to return to the transcripts and this would be an issue that would need further investigation if a full computer system were being developed. However, for a prototype the knowledge was satisfactory. Systems analysis, based on SSADM, was carried out; the results of which are discussed in Chapter 8. The systems analysis was used to develop a prototype knowledge-based system that reflected the concepts used by dial-a-ride schedulers. The prototype was evaluated to ascertain the extent to which these concepts were reflected in the computer system.

The grounded theory provided sufficient knowledge for the development of a prototype knowledge-based system and also reflected many of the thought processes used by despatchers. Therefore the grounded theory can be seen to provide a conceptually rich model of the knowledge used in the domain of dial-a-ride scheduling that can be mapped to computer system. It is possible to see in the screen shots of the prototype where the concepts have been taken from the axial and open coding. Figure 8.11 shows how a popular destination can be displayed in a prototype window. The concepts of popular destination can be traced to the example rule shown in Figure 8.6 and example frame in Figure 8.5. The axial coding example in Figure 6.1 shows how the phenomenon route is affected by the intervening condition popular destination and Figure 3.3 shows where the concept of popular destination first appears in the open coding. The open coding shows the paragraph where the concept is taken from in the transcripts. The
example of *popular destination* shows how a grounded theory concept has been translated into a feature of the prototype knowledge based system.

Evaluations of both the grounded theory and the prototype have shown them to be accurate and complete and to reflect many of the concepts used in dial-a-ride scheduling. Therefore the grounded theory analysis would appear to have overcome the problem of gathering complete and accurate knowledge from human expertise. However, the process has proved to be very time consuming and in this respect the grounded theory approach has failed to overcome the problems associated with knowledge elicitation taking too long.

10.4 Implications of the Research

This research provides a comprehensive and ‘up to date’ overview of a number of key knowledge elicitation techniques and the various advantages and disadvantages associated with each technique. The techniques chosen for this research have been used to develop a full grounded theory analysis using the Straussian method. This research represents the first attempt to use the full range of grounded theory techniques to analyse and structure requirements for a knowledge-based system, to evaluate the resulting model and to test it potential as the basis for implementation of a knowledge-based system. As a side effect, the knowledge and grounded theory model developed in this research provides the opportunity for the dial-a-ride sector to examine their working practices and evaluate their efficiency and areas they may wish to modify.

The domain is not typical of the domains where existing expert systems have been built. The research is concerned with a domain where the experts are non-technical: the expert has not taken years of specialist training; and temporal and spatial reasoning are involved. Such knowledge is largely derived from experience and intuition rather than formal learning. This research could be applied to similar domains where the decision making is very dynamic and based on very specific situations. Other scheduling domains could benefit from this research method to investigate the decision making processes.

This research method can be generalised to only cover other scheduling domains, for example taxi or courier firms. It could also be used in domains where human involvement is high. Finally, it could be
generalised for use in areas where the expertise is learnt through experience and colleagues and not through books or training.

This research has raised a number of points about how to apply a grounded theory:

- In retrospect, the knowledge engineer should use the same knowledge elicitation techniques that have been identified in Chapter 4 as being appropriate for use with grounded theory.
- The rules developed for the prototype come from the action/interational strategies in the axial coding. Developing rules earlier in the grounded theory process would not be appropriate because this would place too much structure on the development of concepts. This would go against the grounded theory principle of allowing concepts to develop freely from the data.
- The selective coding is satisfactory as the basis of the monograph and the diagram. Grounded theory research may also benefit from the use of a diagram that shows how concepts are linked.
- The axial coding in this research provided the overall requirements for the prototype knowledge based system. However, the axial coding could be simplified by breaking it down to deal with different cases. This could be achieved by breaking the axial coding sheets down into subsets.
- The knowledge engineer should, in future, try to find a way of automating the indexing of concept cards. If more detail was required from the open coding in a larger case, the issue of writing concepts cards would become a problem.
- It would be good to avoid using the transcripts for systems analysis. In the case of this research where a prototype was being developed, using the transcripts has not been a problem. However, for a larger system more detail would be required in the open coding. This could be achieved by identifying more concepts at the open coding stage and by recording more instances on the concept cards. The current concept cards could be broken down into more than one concept.

10.5 Limitations

Methodological limitations surrounding this research include:

- The first evaluation of the grounded theory was not structured enough due to the lack of data on evaluation criteria. However, a second evaluation gathered sufficient evidence that the grounded theory was accurate and complete.
• Given more time it would have been possible to return to the grounded theory analysis stage and fill in the 'gaps' in the knowledge for the development of the prototype.

• The loss of experts at Central London Dial-A-Ride meant the evaluation of the prototype could not proceed as first planned. It is possible that more accurate conclusions could have been reached and the objective of comparing the prototype with current scheduling practice could have been achieved.

• Grounded theory does not overcome the problem of knowledge acquisition being time consuming. However, the level of detail collected using grounded theory suggests that spending time developing the open and axial coding is time well spent.

• The lack of instruction on how to develop a grounded theory caused delays in developing the axial coding. However, this research has developed an approach that gives a clearer indication to researchers about how to apply grounded theory in knowledge acquisition.

• It was difficult to draw up the criteria for evaluating a grounded theory. A satisfactory evaluation was carried out, however, by allowing people to score what they thought of the grounded theory. That is by asking them to base their answers on a rating scale between one and five.

10.6 Future Research Issues

A number of issues have arisen from this research that could warrant further investigation.

• The recommendations and changes to the grounded theory process outlined in section 10.5 could be applied to another domain.

• The issue of generalisability for other domains, other types of problems and other types of experts could be investigated further.

• A diagrammatic representation of the grounded theory could facilitate future developments of a knowledge-based system if it could show not only how concepts are linked but also the process involved between the concepts. This would make the grounded theory method more accessible to other disciplines.

• The suitability of grounded theory for an object orientated approach could be examined to investigate how well concepts map to objects.
10.7 Summary

This research has shown how it is possible to derive a model of decision making processes from data elicited using a range of techniques, and that grounded theory provides an effective means for analysing the data and structuring the model. This research has identified knowledge elicitation techniques that can be used with grounded theory. The grounded theory has modelled the domain under study. It has been demonstrated that grounded theory is a suitable method for the basis of analysis and design for the development of a knowledge based system. In conclusion, grounded theory contributes to improving the knowledge acquisition process in the following ways:

- Producing a good high level summary of the domain.
- Eliciting concepts.
- Allowing concepts to be tracked up and down levels.
- Showing how the strategies in the domain work.

In this research grounded theory has not contributed to solving the problem of knowledge acquisition being time consuming. There is very little instruction on how to carry out grounded theory analysis, and time was therefore spent investigating and trying ideas out. The amount of structure and detail produced in this research however suggests that the end justifies the means and that the time taken is time well spent.
REFERENCES


APPENDIX A

Sample Knowledge Elicitation Transcripts
A: Do people ask to be put on other services?

M: Yes. If people, for some sort of reason, they're a bit wary that they might not get on the DAR they might ask to go on the social car scheme. We always put that in their notes anyway.

A: Can you explain what vehicle allocation is?

M: The vehicle allocation is done in a different way. We have a vehicle transport coordinator. We work our schedules up to certain size vehicles such as to carry 2 wheelchairs and 8 seated passengers or 4 wheelchairs and 9 seated passengers. He actually allocates the vehicle to the needs of the schedule. We have varying styles of vehicles.

A: When people phone up do they actually ask for morning or afternoon trips or do they give you times?

M: If it's something that's not important to them they give morning, afternoon or evening. If it's something that's a little bit important to them they give you times. But most people ask if they want to go shopping, I go either in the morning or the afternoon. If they've got a home help they specify. We ask them what times they want anyway.

A: If you get a cancellation made on the day of trip, how would you fill it?

M: Obviously we have a fictitious shift anyway that got cancellations on it. If we can offer somebody a journey that fits in with a shift then we will do but it's not always possible to do that.

A: Presumably you have to inform the drivers?

M: Oh yes. We'd alter the schedule and move people up or down or whatever.

A: So what do you do, you just fit them in where the cancellation is and phone the drivers to say?

M: This is what has happened to change the sheet, or if they cancel early enough we can alter the sheet before they go.

A: You said at one point the more people who travel the easier it is to despatch.

M: If you look at the board you can see it's really sparse so theoretically 4 or 5 drivers, 3 evening drivers so it doesn't really make sense to use to use 5 so we've gone down to 4 we might even go down to 2. Sometimes we double the drivers up.

A: What exactly are trip details?

M: To verify the pickup, the destination address and the times, also the amount of people that are going to travel and whether they're in a wheelchair and where they need assistance.
A: What other do details to you store about the passengers on the computer?

M: On the computer its got you know, whether they need assistance in or out of the house, whether they need the door locking, just general information regarding each passenger and their mobility problems. We keep emergency contact information in case, who to contact.

A: The computer keeps more than the details you store for the trip?

M: Yes. There's always stuff in the personal notes about what they need.

A: What would you put on the schedule first, first thing in the morning?

M: Contract services are the first thing that go.

A: How many of those are there?

M: Normally 2 or 3 a day. We try to work the routes around these.

A: You said that you put the spaces in rather than put the spaces to the people?

M: If you look at it in very easy terms, people have trends and there's passenger trends, all we're doing is, we know we can give them what they want so sometimes all we're doing is filling the gaps. Having said that though if there was something a little bit different and out of the ordinary that this person needed to get to a certain place then we would alter that around. Nothing very hard or rigid, everything is flexible.

We try to suit the passenger but we also look at the route. We have to be cost effective more and more.

A: So where as now you've got your route and you have to try and fit people in around that?

M: You have to think can you afford to divert the route from one place to pick up one person, that might not be cost effective. Its something we've never had to consider before.

A: Do you think this has a big impact on the way you schedule?

M: Yes. In some ways CTs have gone away from the fact of giving a specialised service to a more parallel service.

A: How do you deal with holidays, driver holidays and despatcher holidays?

M: Well now there's only 2 of us thats something we've got to talk about. The drivers they're all pre-booked to we'd try to work the schedule and the others do overtime so we can maintain our services.

A: Do you run DAR on bank holidays?

M: No
A: When you're doing the whiteboard I notice that you've got your pretend schedules set up and you're looking at those sheets and at the whiteboard constantly. What are you looking for?

M: Obviously you put your contract services in first, you now really where you've to start and where you've to finish. We've got to try and group as many people together on the route in between so that's why we keep looking. Obviously we might do one shift onto another shift because it might be a better sort of pattern from our point of view. With 2 people working together normally we look at things in different ways.

A: What types of things trigger off the comments you make to change the whiteboard? Would it be say a change of route?

M: A change of route, the type of vehicle we're trying to use. We look at the board when the contracts are on and then we try to put the major groups.

A: Do have in mind the vehicle allocations when you're doing the schedules?

M: Subconsciously yes.

A: So your schedules are built around vehicle allocations as much as?

M: Yes, we don't really do a large amount of group hire so we only have one vehicle. We also do contract hire where we hire out the vehicle and the driver and they're the larger vehicles so have to keep thinking we've only got x amount of large vehicles. One's always out doing the DAB so you've got to be really conscious about what you're doing and why you're doing it. Sometimes you need to say why you've done something in a different sort of way.

A: I notice that after you've put the majority of the bookings on the whiteboard you start to read out the odd passenger.

M: Obviously you're consciously thinking all the time, oh we're going here and we're going to do that but also while we're doing that we can do someone else as well. So what we try to do is like a sweep in system and a sweep out system so we might take, if you work on the borough we could have 4 vehicles in 4 corners working to a centralised part or working out so that's what we try to do.

A: So the people you call out you've realised you can fit them on?

A: Do you have selective data that you enter? How do you work out who does what?

M: What we try to do is split it 50/50. I try to take the bulk of the amendments because Keith does social car and I do group hire.

A: It doesn't go on things like areas?

M: No.
A: When you're entering the amendments into the computer, is that to say yes you've accepted the booking or no you haven't?

M: Yes. When you amend it you put it in as a sort of structure that it's going to be with the sort of times. If it's not going to be accepted we put it onto the cancellation shift, that's the amendment.

A: When you're putting the amendments into the computer do you actually see changes that can be made?

M: Yes. We'll alter it there and then.

A: Does the same thing happen when you're calling people back in the afternoons? Do you sometimes see changes?

M: When we call people back it's the final so there probably wouldn't be changes then.

A: So when you've handed this schedule over to the fleet manager and he comes up with changes that's before you phone people back?

M: Yes.

A: Do you think you're more aware of the bookings you've taken yourself?

M: Yes. Because you're a bit more involved as well.

A: Do you think that taking the calls affects the way you think? If you're taking the calls while you're doing the despatching do you think it distracts you?

M: If you're taking bookings and scheduling at the same time obviously you'll lose your thread. If you do it in a different way where you take the bookings and then schedule... You need to find a compromise. You've always got to take bookings and schedule anyway.

A: Usually you put the bookings straight onto the computer, you don't write them down?

M: Not very often. If there was only one of us so that people weren't held up on the telephone, we'd write them down on a booking form and then put them in when there's time. But we try whenever possible....

A: What type of information are people giving you? When they make the calls?

M: Their registration number, the day, the destination, the times, wheelchairs. The call should not take more than 30 seconds.

A: In the last call you didn't ask them about their wheelchairs and all that?

M: With some people the more often they travel you know what's what?
A: If you know the passenger really well you just ask them for their number so you can bring that information up on the screen?

M: Yes. With some people we know even the number before, we just reiterate the number that's all.

A: So in this case what they this passenger tell you, just the times?

M: Yes, just the times. He didn't give the day or where he was going. He makes a trip once a week to the British Legion.

A: How many of the passengers would say are like that?

M: The majority. They've only got to give us the registration number and the dates. Some of them don't even give us times, some of them say 'number' and I'm travelling Thursday. We don't make many mistakes where we get the wrong information down. You always know if someones missing.

A: Presumably with people you don't know so well you'd ask them?

M: I'm not too hot with numbers over 6,000. Its like as you go along you know certain things, you know the streets where they are, or at least where the area is.

A: I notice that when you're crossing off on the schedule sheet, the details are crossed straight through and sometimes they're crossed with a squiggly line, does that show anything different?

M: What we do is we take the drop off destination and the information where they're being picked up from. All we need to know is who they are, where they are, then we look to where they're going to go anyway. All you have to do is look for the return time. When we put them on the board I just put a line through, I wipe them off. Its just my way of organising them.

The A3 paper is just a continuation of the whiteboard. Sometimes we have more than 4 vehicles and that's all you can fit on the whiteboard so we use other sheets as well. This one is just the accessible car.

A: When you actually looking at the whiteboard what do you see? Because you've written them out you're obviously aware....

M: Because me and Keith have done the scheduling and we know the days and we know the people who go, we know who's going to be there anyway, theoretically Keith could just block them off. Its just the 'oddballs' we need to check on. We just try to put the names down now we don't even put the areas down now because we know where they're going.

A: What are the numbers by the side of the names?

M: Its just the times, although the passenger is aware that it could actually be 1/4 hr either side.
A: Some of the boxes that you've got blocked off...

M: They're breaks and swap over of shifts.

A: What's the Z figure?

M: It's where you're knocking a block out, its traveling time from one point to another point and you can't pick up in between that. You might have to allow twenty mins to 1/2 hr to certain places.

A: When do you put the driver breaks in? Is it something that goes in first or when you've started scheduling?

M: Once we've started scheduling, the morning breaks have to be between 11.30 and 1.00 and they get 1/2 hr so we try and fit it in with that. In the evening it's between 5.30 and 7.00.

A: So the breaks get put in once the schedule's started.

M: Yes. We don't put the breaks in straight in. As long as they have a break every 4 hrs by law, that's why the last break if they start at 8.30 is 12.30.
Observation 1 - Sheffield 14.06.95

* Pull out bookings from file and enter into computer - for Fri (observation is on a Thurs)

NOTE: Bookings have already been taken from phone at 8.30am before I got here.

* Enter details into computer and then enter some details from the computer onto the form

* Looking up something/more details in Sheffield A-Z, presumably map references?

* ASK ABOUT RUNNING DETAILS - TIMES ETC.

* A carer phones up to check bookings details - despatcher takes the call

* Looking up/checking something from a notebook next to her - WHAT IS THIS?

* Collect money from drivers in the evening - the following morning, the totals are checked so they tally with amount collected and the %s of miles are calculated

* Enter some details into computer -> write down booking num on form -> enter price onto form (into 2 separate boxes)

* Skip a lot of details on multi-trip screen because do not need to use them.

* GET A COPY OF THE BOOKING FORM

* Listen out to calls as passenger makes booking onto answer machine - comment on fact one of them forgets to leave the time

10.15

Fill in driver schedule sheet -

<table>
<thead>
<tr>
<th>time</th>
<th>address</th>
<th>destination</th>
<th>W/C</th>
<th>escort (num of passengers)</th>
<th>start mileage/finish mileage</th>
</tr>
</thead>
</table>

* GET A COPY OF THE DRIVER SCHEDULE SHEET

* Makes a mistake because not concentrating BUT notices almost immediately and corrects error on driver schedule sheet using tipex - writes back in corrected details

NOTE: THE MOST IMPORTANT THING TO CHECK APPARENTLY IS THAT PASSENGERS HAVE A RETURN TRIP BECAUSE TRIPS GET CHANGED ON WB BUT NOT ON THE BOOKING FORM. - this is why the despatcher is constantly looking at the WB and booking forms to check the correct details are going on the schedule sheet.
* checking details with other despatcher because has a passenger down for somewhere and they're going somewhere else
* pick up the phone to talk to a passenger who's calling to say they've forgotten where they're going

**NOTE: EVERYTHING SEEMS OT BE RUN ON A PAPER BASIS - THE COMPUTER IS ONLY USED TO PRODUCE A BOOKING NUM AND THE FARE AMOUNTS**

10.45

* Call back passengers to confirm bookings
day+times of pu and rtn+num of passengers+pu point
day+times of pu and rtn
day+times of pu and rtn - passenger is not sure if they want the trip because 15 mins different and will call back, so the bookings form is put to one side
day+times+another day+times
phone back with a refusal

* add a booking to the wb - then write details onto a booking form to ensure they will be put onto the drivers schedule sheet

* 5 CR buses - registration nums are written on top of driver schedule sheet
drivers stick to own vehicles as much as possible - makes things simpler

* booking forms once scheduled on wb go into a folder marked "To Be Contacted" - the forms remain in the folder until passenger has been contacted

* phone up passenger to make a cancellation to a booking - IS THIS A REGULAR OCCUPATION

* updating/modifying wb

* booking forms are filed

* folders for each day for unfulfilled bookings which are analysed at the end of the month

* of a passenger cancels - take booking off driver schedule sheet and take booking form from file and write cancelled across it and then put it into another folder - ALL THESE ARE KEPT FOR STATISTICAL ANALYSIS

* taking bookings off answer machine - write passenger details and travel details straight from answer machine onto booking form

* writing some details onto an A4 pad whilst taking bookings off machine- WHAT ARE THESE DETAILS AND WHY DO THIS - these are DAB details

* HOW OFTEN DO YOU TAKE BOOKINGS OFF THE MACHINE?
* WHEN EXACTLY DOES THE SCHEDULE GET DONE?
  * cross off bottom section of booking form if it's only a single trip
  * fit in a passenger easily onto schedule because very flexible with their travel times - call back immediately to tell passengers the times they've been given - add passengers to the wb

12.00

* move onto DAB bookings - only run on certain days and at certain times - just write down passengers and travel times in any old order to be faxed through to bus company who run DAB service - SCT just take the bookings for DAB

* Limited to 2 trips a week on the DAR (CR)

* if they get (L) groups wanting to travel together then they're advised to book with group hire

* I THINK THIS IS STILL KIND OF FCFS BASIS BECAUSE PASSENGER CAN PHONE UP TO 7 DAYS IN ADVANCE AND SCHEDULE IS BUILT AS EARLY AS POSSIBLE THEREFORE THOSE WHO BOOK LATER HAVE LESS CHANCE OF GETTING ON?

12.30

* taking more bookings off answer machine

* know the passengers and their needs - TO WHAT EXTENT?

* Booking forms when filled in, are filed under the day of the week until they're schedule onto the WB

* clean the wb for the day to be scheduled - cross off certain times straight away - WHY? - add some kind of advanced booking - WHAT IS THIS?

* try to phone passengers back to confirm

* trying to trace a passenger who's made a booking without returning their registration form and they're not sure of the name and phone num - phone directory enquiries - look in the teol. directory - write her a letter to confirm details

* take a call from a passenger who hasn't been picked-up BUT this is because they haven't made a booking and they're a well known passenger
A: There are a number of bookings here that I've marked which are going from two nursing homes to one place at times which follow on from one another, so they look like two separate multi-trips?

B: Yes, one group looks like they're out at 1.00 and back at 2.30. The other's are out at 2.00 and back at 3.30. It seems like two multi-groups. How many on each, shall we assume there's two groups of five people and just put them straight onto the sheets?

A: Yes.

B: They've probably been arranged in that time scale to allow time to drop that lot off and come back again so they'd obviously all go on the same shift so, well they can't go on this shift because that's got to finish before 12.00 so we're left with a choice, I'll put them on this shift because the booking is at 1.00 and that's quite near the beginning of the shift. Vicarage Gate, you're talking 20 mins to get down there so you're not wasting a whole lot of time so I'll put those on here.

A: For 6 people, it doesn't matter which bus you use?

B: No, all our buses are 6 seater, some are 12. The other booking, what time was that? 2.00, so down there, drop them off and then back for 2.00, and that's back at 3.30.

A: What code are you looking for?

B: The map references, they do help with the booking. If you know where everywhere is then you're doing it by using a picture of what's going on, it does help to have the reference when you're not entirely sure of an address.

A: Do you know already where those addresses are?

B: Well I've got a rough idea, yes. I've got a fair idea its not the area I'm most familiar with I'm fairly comfortable with it, I know the main roads. It just often gives you a clue, you may have a fair idea where it is but if you can see a zone code you can see immediately its an adjoining square it does draw it into focus a bit more sometimes. Like for example, Ladbrock Rd, I know Ladbrock Grove and I know its around there somewhere, I didn't realise quite how far south it was, so it makes it clear. It makes a difference in that comparing the codes for the trips, you do 46 to 47 DB, 6 people from one address, there is room on the schedule for someone else if its a fairly local booking, it would have to be a very local trip, because you have bear in mind that 6 people take a long time to get on and off the bus, so there isn't a whole lot of space.

A: I've got another one here that looks like an advanced booking?

B: Yes, 11.30, return 12.15. Again we've got a choice here.
A: When they make an advance booking, do you enter it into the computer as a normal booking, its just the date that you set?

B: Yes, the only thing we don't enter is the shift code because we don't know it until the day before the shifts are booked.

A: There was another booking that looked like an appointment. Is that the only shift you have that runs late?

B: No we have a choice, I'm putting this booking here because its pretty much within the area we're in already and there's big gap. There's always the scope to move them later anyway, it really doesn't make a whole lot of difference which one it goes on at this stage. Its really flip a coin at this stage. It keeps the bus pretty much in a manageable area.

A: So that's how you'd put in the advanced bookings?

B: Yes. It gets done the night before you book the shift.

A: What would they do give you a user number?

B: Yes, that's what we need, they don't always give you that but you try to get that first.

A: OK, lets start with 1008, going to State Bingo. Would she give you an exact time or would she say 'round about 6.00'?

B: It normally is around 6.00 she want's to go, she'd probably say, I'll have the usual dear, so we'd try and coax a little bit more out of her. So you'd like to go at about 6.00, that's ok. And what time do you wan to come back?

A: 9.30

B: 9.30, yes that would be ok. Now I'd put in the other details, map refs, num of passengers, wheelchair details. Depending on how well you know the user, how well you know the trip, at this stage early on I might just be putting the name on for the moment, if I can at a glance remember what's going on.

A: Do you find you do get to know what people mean when they say 'the usual'?

B: In some cases you do, but you still try and confirm it with them for no other reason than they're not always going to get me on the phone, some people know the usual for some people that I don't so it helps other people who are having to do that area on a given day. You might say, the usual that'll be 12.00 and 1.15 to go into town, to confirm it in that way. In this case I'd ask is Mrs. Bloomfield going with her, they normally go together.

A: Do they go from the same address?

B: The same street and they always go together. OK, next one.
A: 1016.

B: That's Mr. Tully from Portabello Rd.

A: He wants to go at 4.15 to Argos.

B: He could go on either of these two, at this stage when there's so much space I can give people pretty much the times they want exactly unless it's something like you're expecting a call for a certain time and you'd try and get them to fit in with that, you might try and adjust it but generally speaking at this stage if they want 12.15 it's fine. It's taking the bus away a little bit from the north area, I could possibly ask him to follow on from this trip because the pick up is not a million miles away from the drop off but that would be an option for later on. What time would the return be?

A: 3.45. Does the number of wheelchairs you have in the bus affect anything?

B: The maximum is three on any of the buses regardless of size, so even in 12 seaters we still only take 3 chairs. Some passengers have extremely large chairs so that cuts the number down to one other chair but that's listed with the passenger details. I should really have been checking if they're taking escorts.

A: 175

B: Bright. What time would you like?

A: 9.00

B: OK, at 9.00 we've got two options and what about the return?

A: 10.30

B: This shift, once you start putting things on you lose the flexibility on it so I tend to keep that blank for as long as possible. Obviously if somebody asked for 7.00 that's the only place I could put it, but at the moment I'm going to try and leave it blank.

A: 226

B: 5.00 trip. **** Lane?

A: Yes. If you went to a funeral would that be a two day booking?

B: It would probably be an advanced one actually. Although this was only booked two days in advance. 5.00 out, what about the return?

A: 8.15.

B: It seems quite an odd time to be in a cemetery so it may be a rendezvous spot for someone else to pick her up and take her on. That one, I'd tend to keep it free at this early stage because
otherwise the bus would have to go all the way there and then all the way back, at that time of night it would virtually stitch that section up. What I think I would and try and do with that would be to try and ask her to go that bit earlier rather than 5.00. Its quite a trek to get back into the area, I'd try and make it about 4.45 to give enough time to get back for the next trip, and the trip is what time?

A: 8.15

B: 8.15 we're going to have a problem with, we've got nothing. If I say 8.15, by the time we've taken her all the way back home and then back again to the bingo we're going to have trouble what I'd rather do is pick her up later, pick her up and then get these on the way, so it would be a pick up later for her at probably 9ish, if she'd go for it. I'd go via *** and then drop these two off and then drop her off to W14 afterwards, so that's what I'd be trying to talk the user into in that case.

A: Well she actually travelled at 4.45 so that's ok but is 8.15 completely out of the question?

B: There is only one space for 8.15 which is there, it would probably just go but it would make an awful lot more sense in terms of operations if we could persuade her to go that bit later. Bear in mind that all these trips, the users are from a certain area, it may be that the trips could be spread across other areas. Sometimes people go for it, sometimes they don't, sometimes it doesn't fit in with their arrangements.

A: Do you tell people if they're travelling with other people?

B: We tend to as far as you can. For example, in that case I'd say how about 9.00 because we can pick someone else up on the way. Its not crucial for these two because the only affect on them is there's someone else on the bus, we'd pick April up first then pick these two and up and then drop them home and then drop April off after that. If it was going to make a difference then I'd probably ring them up, if its just a few yards out of the way then I wouldn't bother but if its a major reshuffle and its going to delay people by more than 5/10 mins then I think you should try and tell them. Generally speaking its a case of who gets in first gets what they want and the others fit in around them. But then again you've got to look at where they trip is, these two are off to their bingo which starts at about 6.30 if you go here there and everywhere picking people up then they loose their time and you have to be aware of that.

A: 1038

B: That's Mrs. Walker, Treverton Street, what time would that be?

A: 8.30

B: And how long do you need?

A: About 1.5 hrs

B: So a 10.00 return. I think we can do that if we put that one here and move Bright over to this one. This is a nice little local trip, it fits in with keeping the bus up that way. Its a bit
much to ask a driver to go all the way down there and then up again. It's doable but I would put this trip on here and gamble that we'd get other bookings around that area locally. I'd move this one out, this is the one that's messing it up, I'd move that across, tell Mrs. Walker that's fine and get her off the phone and then start scribbling.

A: 1057

B: Mr. Watkins to Victoria. That takes us right out of the area. Move that over there and put it on there because it means taking it out of the area. It would just about go on there. I think what I'd do is I'd ask him what time his coach is and how much time he's allowing and...

A: Well his coach is at 10.00 and he wants picking up at 9.00, is that enough time?

B: That's plenty of time, provided he's got his ticket. Assuming the coach goes at 10.00 then 9.00 is ample, more than its going to take. He'll probably get in there by 9.25/9.30, having said that I wouldn't risk putting him on there for a 9.30 pickup which I'd like to be able to do because its just round the corner from this one but that wouldn't work, it's asking for trouble really. So what I'd do is put it there for now, I'd do the 8.30 and then pick him up. I might have tried to persuade him to go slightly earlier to allow us to get back or I might even put it on another area, it verges on the cc area, a lot of the cc work is around that area and it could be that they had a trip that it would tie in with. That would be something that, it depends on what time of day the trip comes in, if it came in now say this afternoon then I would immediately go across there because by then its quietened down and you're not going to be so precious about space, other than that I might try and get him a little bit sooner so it follows on. He might not want to do that, he might not want to hang around Victoria so that's what I'd for now and then I'd think about having a bit of a shuffle round, but we'll leave it for now and see how it goes.

A: 1207

B: Carlos ***, he's definitely a 'usual', 12.00 and 9.00 or there abouts. 11.45, will that be alright? He's the type where once you've got his number you'd say how about 12.00, or 12.15 or 11.45, he's very flexible. Now again we're in trouble with his return. At 9.00 there isn't enough time to get up to W6 so that's ditched, I'd offer him 9.45.

A: Which is quite a lot later, would you not offer him an earlier one?

B: I'd offer him 9.45 in that its the nearest to what he wants and I could give him as it stands without looking on other areas. Other than that to get all the way up there, 8.15 might even be pushing it to allow time to get there, bearing in mind that its already doubled up so you don't want to be running late on it. You'd probably be looking at 8.00, so I'd go for the 9.45, its quite close to the return, adjoining square to this drop, its a short journey and its sort of on the way. That's what I'd be trying to do.

A: What would be the chances that if you were shuffling this around later that you'd get him on later nearer his time?

B: It would depend on what day of the week it was and it really would depend on the other areas. We'd look at everything and see what we could fit in. I'd say that's probably his best
offer and knowing him he'd probably take it, although a lot of others wouldn't and then it would be 'well I'm sorry but there's nothing I can do'. In this case I would say the best I can do is 8.00 or you can go later, how about 9.45 and give them that choice. So we'll go for that, yes.

The other thing I would be doing at this stage once I've started to double things up is to make that information clear to the driver, it's obvious to me that you couldn't possibly do these all singly, but you just need to make sure it's clear.

A: Where would you be putting those comments, on the computer as opposed to the sheets?
B: Yes, it's clear to me on that sheet what I'm doing, I bracket them or something like that to make it clear to myself but that doesn't help the driver on the printout of each job.

A: 1301
B: Mrs. Hughes?
A: Yes, 10.30.
B: Where would you like to go?
A: Post Office, Portabello Rd.
B: And how long do you need to spend there?
A: An hour
B: OK. Can you go a little earlier at about 10.20?
A: No
B: It's just I'm going to have difficulty going at that time, I've got a trip following on close afterwards, so it will have to be that few minutes earlier. I would dig my heels in on this one, I think for the sake of minutes or else I'd say we can do 10.30 but we'd have to bring you back a little bit earlier. The outward is fine, it's the return. To do 11.30 and then go to Stanley Gardens is just a little bit much.
A: Well ok let's say that she'll have less than an hour then.
B: Well if she wants less than an hour she can certainly have 10.30 and say 11.20? Do you see what I mean though, for the sake of moving it just a few minutes its fair to be quite hard about it even if there is an alternative. I would insist that someone moves their time by two hours or has no trip if there's other space available but I think for 10 minutes its fair to do that. I always think that if I'm going out to catch a bus to go and do my shopping I'm not going to know within 10 or 15 mins what time its going to come. We are public transport and not a chauffeur service.
A: I've got two travelling together here, 1375 and 1376.

B: That's to Shepherds Bush, what time will they be leaving at roughly?

A: 9.00am.

B: 9.00am, it does have to be in the morning does it?

A: Yes.

B: Obviously what I'd try to do is tie it up with that because they're very close by and they're going to exactly the same destination but fair enough there's a big difference between morning and afternoon. How long do you need at Argos?

A: Roughly 2 hours.

B: I'm afraid I don't have 9.00 available for that, I can take you a little earlier, about 8.40, something like that?

A: Yes, ok. That's what it was originally.

B: It might well have been to fit in with this one, drop them off and nip round the corner to pick him up. Ok. Do you want a couple of hours actually at the store or between trips? You have to be clear, sometimes people say two hours and you say 8.00 and 10.00 and they say no that's no good I need two hours there or if you say allow 20 min to get there they say it's far too long so it's two later. How about 10.45 for the return? That will be fine. That's two Lawfords from the same address? That ties in quite well.
APPENDIX B

Sample Open Coding Concept Cards
para 3. Prioritise advance bookings on the basis that they are not flexible with time.

para 39. Prioritise certain categories of trip in that we allow advanced bookings for certain things.

if booking 2 days ahead, not concerned with purpose of journey

Card 24 (4) DISPATCHER VISUALISATION

para 254. Look at routes, bus location of drop-offs & next pick-up.

para 259. See it as if out on the street thinking I can go there - nip round the corner there.

With areas that are well-known the dispatcher imagines that they're driving there.

para 263. As time goes on, with queues you don't know, you start to

para 345. Zone codes show how many queues away an address is.

Comparing codes shows if there's room for other bookings.

para 502. Look at adjoining queues as a means of visualising route.
Card 11(h) cont.

para 145 offer a loose time to give schedule a bit of lee way

para 198 know in advance the driver rosters & what resources will be available

para 200 try to avoid changing passengers onto other shift, but would close to get the brig on.

para 201 discuss cues which are close together, how much space there is & what’s already booked.

para 255 try to re-evaluate schedule when things quieten down.

para 259 imagine its being driven if cue is known

other cues that is not so familiar with, rely much more on what seems to have worked in the past.

para 269 driver breaks must be in between 3rd & 5th hour.

para 339 when taking brig just dealing with what's coming in - try to fit them in as best you can.

para 358 will actually schedule right up until shift goes but this is unusual.

para 385 need to get user numbers first.

para 384 ask for PU time & then return time

(Note: Asking for user num, PU time & RTN time) - reg for each call.
para 20 Take brigades build schedule initially in isolation but then look at all the cases together a can see trips crossing over move trips onto other shifts if that's an improvement schedule be changed at any time until the shift is complete

para 57 considering destinations time of travel

para 58 considering the day number passengers considering times of travel

para 62 suggest out & return bus to the passenger

para 64 looking for places where the bus can carry multiple passengers

para 102 modify schedule sheet

para 106 discuss shift detail with another dispatcher

para 110 discuss possible improvements to the schedule sheet with other dispatchers

para 111 compare schedule sheets transfer bookings to improve schedules
Para 460: put a big on unfixed shift rather than expect passenger to make a major time shift.

Try to put a trip onto end of shift to bring a bus back to base.

Para 464: try persuade passenger to go earlier: there's a space on schedule which would keep bus in same area.

Para 502 make a passenger trip slightly later to fit in with another trip & also to allow for driver break.

Very early trips would have to go on unfixed shift.

Para 508: reluctant to bring the bus out of an area just for a short trip.

Look at the squares that have to be crossed on A-4.
Para 313: decisions based on experience and know how long people take.

Para 369: Decide to put advance bike's on a shift based 1stly on on time scale & time shift finishes.

Put on bike 1stly at start of shift & doesn't waste much time.

Para 371: Look at time of another bike, its route & how it follows on fits in p.369 bike.

Might try to adjust time slightly if you're expecting certain time so both bikes fit in.

Para 403: Look at num of options available.

Para 405: Try to keep un-fixed shift empty where poss & otherwise flexibility on it is lost.

Para 411: Try to give enough time for follow on trips if a bike takes a bus quite

Para 423: Move a passenger over to another shift to put another trip on a keep bus in 1 area.

Take a gamble that they'd get other bike's around that area.

Para 424: Look at other areas which work in a nearby area a might be better for a trip.

Para 431: Look at trip, if its an adjoining
para 18 - dispatchers know some cues better than others.
- know almost immediately if a trip will go or not if known area
- unknown areas, have to look at the map.
other people will look at the schedule anyway
consult other dispatchers all the time so dispatcher isn't totally responsible for a whole area.

para 43 - rescheduling is about trying to route things in most efficient way so as many people get out as possible.

para 54-58 - consider destination, times of travel, day, num of passengers.

para 60 - asks the user how long they need.

para 214 - try to decide which passengers can be hung back with changes.

para 249 - at end of day, look at whole days shifts & all areas - try to fit in refusals & move other trips to try to fit in refusals.

para 251 - look at cues which a join to try & get bookings on.

para 256 - scheduling decisions based on how well the area is known.
para 324. A passenger who's nursing home complained about her being refused.

para 328. Feels obliged to passenger who makes special effort to book.

Card 32(b) PRIORITY CRITERIA.

para 323. Wheelchairs are a priority.

para 341. Passengers classified as priority & non-priority.

para 420. Contracts always come first.
Card 16(8) PRIORITIES.

para 92 (b) groups : = more f.

para 94 1st time users

para 96 wheelchair users : cannot use any other form of transport. People who seem more cleansing.

para 99 (b) groups go straight on. Multi-occupancy is a priority.

para 129 type of passenger & type of trip.

para 126 education trips - concerned "think" re these trips are imp't.

para 145 wheelchairs

grps of 3 fury in one area wanting to go into another area / same district.

medical, doctor, hospital appts.

para 304 aiming for a good head count

para 305 good head count priority

para 306 put a passenger on : gets upset if refused

para 314 be transferred from another day put on first

para 313 put on a passenger who's caused so much grief about being turned down they can't stand the "ear-ache" anymore.
APPENDIX C

Axial Coding
Causal Conditions

Building a schedule

Route

Properties of building a schedule

Destinations (pp. 54, 55, 45, 313, 315, 51, 56, 104)

Time of travel (pp. 54, 56, 384, 149, 313, 315, 458, 51, 104)

Day of travel (pp. 58, 59, 54)

Number of passengers (pp. 58, 59, 54)

Resources available (pp. 149, 313, 315)

Address (pp. 384, 313, 315)

Traffic conditions (pp. 313)

Specific dimensions of route

Map (pp. 58)

Position of buses (pp. 143)

Local knowledge (pp. 313, 315, 18)

254, 1490, 336

Context

Possible multiple buses (pp. 149, 313, 315, 164, 168, 169)

Make schedule flexible (pp. 143)

Use what's worked in past (pp. 254, 149, 336)

Try to keep passengers on same shift (pp. 168, 414, 46)

Intervening Conditions

Targets (pp. 334)

Popular destinations (pp. 498, 43, 423)

Number of passenger targets (pp. 32, 83, 164-169, 145, 274, 280, 304, 305, 336)
Action/Intercational Strategies

- Look at all areas for trips crossing over.
- Move trips to improve schedule.
- Suggest times to passengers.
- Look at map.
- Discuss improvements.
- Aim to get trips to follow on.
- Move passengers to make space.
- Use other shifts.
- Imagine driving the area.
- Put in other breaks.
- Make best use of buses.
- Fit breaks in around others.
- Be aware of other commitments.

Consequences

- Create most efficient route.
- Some areas can be dealt with more confidently than others.
- Schedule built as best as possible.
- Use other services.
CARDS: 3B.

Causal Conditions

Building a schedule.

Properties of building a schedule

Poking (B, B, p. 45, 43, 331, 366, 344-5)

Plus (B, B, p. 45, 43, 366)

time 11 trips (B, B, p. 315, 364, 33, 320).

Contracts (B, p. 192)

Time of trip (B, B, p. 320, 366, 344-5)

Specific dimensions of route & distance (B, B, p. 320)

Context

(1) grips more guaranteed (B, p. 45, 194, 279, 355)

Work route in with contracts (B, p. 149, 194)

Intervening Conditions

* must be cost effective (B, B, p. 182)

* popular destinations (B, B, p. 43)
Action/Interational Strategies

* Evaluate schedule (p. 24, 139, 153, 354-360)
* Discuss improvements with other dispatchers (p. 24, 153)
* Link chestining & plus (p. 45, 849, 314, 143) (route efficiently)
* Look cut route (p. 189, 200, 249, 323, 48, 38, 320, 366, 345-5)
* Driver breaks (p. 331, 616, 244, 331, 366).
* Consider length of time passenger is on bus (p. 345)
* Move passengers to make room (p. 85)
* Group together on route (p. 192)

Consequences
Action/Intercational Strategies

* allow time (p. 112, 345, pp. 222-223, 338, p. 314)
* use passenger flexibility (p. 429, 9, pp. 219, 490, 338, p. 294, 301)
* schedule trips for flexible passengers (p., 80)
* account for special needs (p. 226-227, 243, 244, 246, 289, 300, 304; 331, pp. 259, 311, 66, 64, 159, 85-86, 264, 366)
* schedule on "awkward" passengers (pp. 295, 323, 324)
* request passenger put on at certain time (p. 45, 13)

Consequences

* get to know how long people take.

Causal Conditions

→ Phenomenon

Availability of resources

Properties of resource availability

- Num of veh (FB p.4)
- Veh type (FB p.64)
- Driver holiday (FB p.188)
- Driver sickness (FB p.63)

Specific dimensions of resource alloc'n

- Time known (FB p.289, 463)

Context

2 drivers allowed holiday at same time (FB p.205)
Resources will vary day to day (FB p.29)

Intervening Conditions

Policy allows for no cover during driver holiday (FB p.201)
Policy allows for cover shift (FB p.199)
Action/Intercational Strategies

- cancel trips (p.199, p.247)
- in case of sickness - try to replace driver (p.63, p.247)
- re-schedule (p.63, p.247)
- offer alternative trips (p.247)
- moreover
- schedule based on knowing resources (p.184, p.200)

Consequences

Trips can be scheduled (p.199, p.247)
Causal Conditions  ->  Phenomenon

Environmental factors

Properties of environmental factors

-gal requirements (p.269, p.8, 440, 508)
-traffic conditions (p.41, 313, p.68, 42, 364)
-ocal works (p.68, 42)
-otball matches (p.68, 42)

Specific dimensions of resource allocation

resources vary day to day (p.29)
bus size/capacity (p.229, 159)

Context

- know resources available (p.198, p.5-6)

Intervening Conditions
Action/Intercational Strategies

- avoid having 2 buses in 1 area (p. 163, 143)
- keep bus in same area (p. 168, 143)
- use list of vehicle types (p. 184, 200)
- request certain bus used (p. 48, 160)
- make max. use of resources (p. 354)

Consequences
Action/Intercational Strategies

* consider trip purpose (pp. 514)
* categorise b2g (pp. 43)
* allow 1-1½ hrs for shopping trip (pp. 364)

Consequences
CARDS:  

Causal Conditions  >  Phenomenon  

different trip needs  

trip type  

Properties of trip needs: 

- Expected arrival on time (p.417, 424, 614)  

Context  

Specific dimensions of trip type: 

- Social (p.417)  
- Transport (p.424)  
- Multiple PU (p.431)  
- Distance (p.382, 383)  
- Shopping (p.384)  
- Appointment (p.387, 382, 384)  

Intervening Conditions
**Causal Conditions**

Methods by which dispatcher visualises route

Properties of route vis'n
- route (p. 254)
- bus loc'n (p. 254)
- BIOS & DOS (p. 254)
- streets (p. 254)

**Phenomenon**

Dispatcher visualisation

Specific dimensions of dispatcher vis'n
- amount of knowledge of cues (p. 259)
- 3+3, 3+5

**Context**

**Intervening Conditions**
Action/Intercational Strategies

* Look at routes, bus loc'n, C03 & Pubs (p.254-168, 169, 170)
* See route as if out on street (p.259, 260)
* See trips that have worked before (p.263)
* Use map refs to assess route (p.373, 374, 375, p.502, 503)
* Use main refs (p.375)

Consequences

* Schedule quality may differ from day to day.
### Causal Conditions (full) → Phenomenon (Automatic Knowledge)

**Properties of knowing full details**
- Dispatcher recognises passenger voice (BRP.225)
- Knows streets crews use (BRP.381, 49, p.114, 219, 481, p.196, 941)
- Knows classes on which people travel (BRP.236, 49, p.3, 481, p.58, 5)
- Knows passenger details (BRP.263, 49, p.86, 143, 943, 462, 184)
- Knows time on bus (BRP.394)
- Knows num of seats available in veh. (BRP.398)
- Normal travel times (BRP.127, 49, p.202)
- When passengers book (49, p.91, 481, 202, 470, 517-520)

### Context

### Intervening Conditions
Action/Intercational Strategies

* Despatchers only need to check "Oddball" detail (p. 236)
* Passengers give basic time details (p. 224, 229, 229)

* Dispatcher switches on computer (p. 331)
* Knows if the bus will be full then (p. 289)
* Schedules based on dispatcher knowledge of passenger type (p. 301, 313, 410)
* Allows for individual passenger needs (p. 83, 119)
* Speeds up booking process (p. 19, 414)

Consequences

* Can give immediate answer to booking (p. 313, 434)
* Schedule stays similar (p. 17)
Causal Conditions

Lack of knowledge
by dispatchers to schedule
Properties of lack of knowledge
unusual of trip details
unusual of crew
passengers not acting reg. (I53 p.25,26)

Phenomenon

Checking details

Specific dimensions of checking details
nothing sticks out of place (I04 p.35)

Context

Intervening Conditions
Action/Intercational Strategies

- Check details if different to norm (p.171, p.172, p.173, p.174, p.175, p.176, p.177, p.178)
- Phone passengers to confirm (p.179, p.180, p.181, p.182, p.183, p.184, p.185, p.186)
- Discuss with other dispatchers (p.187, p.188, p.189, p.190, p.191, p.192, p.193, p.194)
- Phone courier to confirm (p.211, p.212, p.213, p.214, p.215, p.216, p.217, p.218)

Consequences

An error is found and rectified (p.302)
Causal Conditions

Funding policies force certain targets to be met.

Properties of target meeting:
- Num of heads on bus (p.64)
- Num of trips completed (p.334)
- Cost effectiveness (p.184)

Phenomenon

Target pressure

Specific dimensions of target pressure:
- Extent of pressure

Context

Pressure to meet targets (p.32)
Policy to give passengers min num of trips (p.454)

Intervening Conditions
Action/Intercational Strategies

- Monitor num of trips each passenger has (p. 24, 38p)
- Monitor num of refusals (38p. 24)
- Looking for places where multi-occupancy is possible (p. 339, 13p. 43, 33p. 39, 43, 64, 115, 334, 334, 58p. 4, 43)
- Suggest alternative times to double-up (p. 64)
- Play on passenger flexibility (p. 69)
- Make best use of space available (p. 163, 255, 315)
- Get as many heads on bus (p. 43, 334, 58p. 32)
- Try to give people trips on leg basis otherwise stop making bookings (58p. 334)
- Look at num of miles rather than ease of route (58p. 89)
- Use min resources (58p. 425)
- Modify schedule to be cost effective (58p. 143)

Consequences

- Most efficient schedule is created (58p. 176)
- Best use of resources reached (58p. 168)
- Trip targets cue met (58p. 334)
Causal Conditions

- Bk'g is refused.

Phenomenon

- Refusal

Properties of refused bk'g

- distance (SS. p. 104)

Specific dimensions of refusal

- Less refusal at weekends (SS. p. 345)
- Resources available \( \frac{1}{4} \) refusal

Context

- Monitor refusal rate (SS. p. 252)
- Strict first come, first served policy (SS. p. 37)
- Refuse bk'g if passenger already has a trip (SS. p. 268)
- Refuse bk'g if passenger can use alternate service (SS. p. 290)
- Refuse bk'g if knows passenger will travel another day (SS. p. 2)

Intervening Conditions

- Policy to monitor refusal rate (SS. p. 252)
-presence policy limits use of service (SS. p. 286, 332)
- Policy of giving trip when last refused, doesn't always work (SS. p. 176-177)
Action/Intercational Strategies

* keep a protocol to record refusal (HLB p.247-259, 260)
* store refusal on comp (HLB p.200)
* look at schedule for gaps (HLB p.6, 20, 229, 251)
* move other bookings if necessary (HLB p.232)
* refuse booking initially, 'unsure, but expect to schedule later (HLB p.480)
* improve booking passenger

Consequences

A booking cannot be clone at all (HLB p.261) HLB p.130, 261, 265, 33
Offer alternative time (HLB p.645, 261, 290)
Refusal can be revoked & scheduled (HLB p.181)
Causal Conditions

Passenger A-D-A-R have expectations of each other

Properties of expectations:

- Passenger needs: p.3, 56, 181, 182, 454, 632, 143, 148, 21
- Oper'n methods: p.238, 221, 348, 19
- Passenger flexibility: p.11, 24, 52, 293, 320, 28, 13, 95, 87, 118, 429, 80, 109, 180-185, 321

Specific dimensions of service aims

- Lock/g door p.445
- Extra assistance p.445

Context

- Service aims for multi-occupancy: p.43, 154, 64, 115
- Consider cost effectiveness: p.182, 184, 391, 425, 443, 78
- Click-a-tile policy: p.221, 238, 348, 51
- Pressure to meet targets: p.32, 339
- Where passengers too rigid, trip not desperate passenger can't always travel (p.293)
- Being flexible may give another passenger a trip (p.232)

Intervening Conditions

- Length of passengers: p.223
Action/Intercational Strategies

* looking for shortcuts (55 p. 56)
* look at passenger needs but try to be cost effective (55 p. 182, 391, 425, 443, 98 p. 28)
* try to give passenger requested time (55 p. 320, 55 p. 314)
* look at length of miles and not ease of route (55 p. 391 34 p. 83)
* use min num buses (55 p. 425)
* modify schedule to be cost effective (55 p. 443, 55 p. 333)
* aim not to refuse people (55 p. 32)
* try to keep people using service (55 p. 337)
* make better use of resources (55 p. 39, 163, 146, 255, 315, 135 p. 65, 64)
* offer alternative times (55 p. 33, 64)
* try to suit D-A-R (55 p. 48, 204, 315)

Consequences

* passengers stop making bookings (55 p. 337)
* passenger refuse booking (55 p. 74)
* insist passenger takes what's on offer (55 p. 448)
CARDS: B1A, B1B, B1C

Causal Conditions

Passenger contacts to make cancellation.

Properties of passenger cancels:
- separate phone line (B1F, p.13)
- gets a better offer (B1F, p.133)
- cancels part of trip (B1F, p.135)

Phenomenon

Cancellation

Specific dimensions of Cancellations
- Number of (B1F, p.36-39)
- Time of (B1F, p.152)

Context

Keep fictitious shift with cancelling (B1F, p.163)
Nature of service means cancelling common (B1F, p.15 175, p.255)

Intervening Conditions

Try to fill cancellations (B1F, p.15)
**Action/Intercational Strategies**

* try to fit another block into space ([113] p.15,16,17, [115] p.319,331)
* contact drivers ([113], p.19, p.167)
* relay cancell’n details to dispatcher ([113] p.100)
* cancell’n not yet scheduled - crossed off shift record ([113] p.152)
* alter schedule/move people in response to cancell’n ([113] p.318)
* take cancell’n of trip off comp ([113] p.318)
* store cancell’n in cancell’n folder ([113] p.74)

**Consequences**

* another block is fitted in ([113], p.15,16,17)
* passenger accepts trip but...
Causal Conditions

Passenger contacts to make booking with details

Properties of passenger contacts to make booking

Trip required

Method of making booking (233, p.515, p.520)

Specific dimensions of Normal Booking

Time of booking

Booking confirmation min 2 days in advance (216, p.5)

Frequency of taking booking (215, p.85), p.354

Context

Classify trips as imp’t a/unimp’t (213, p.161)

Intervening Conditions
Action/International Strategies

- take messages off answer machine (pg. 2), p.129
- write booking details onto bkg form (pg. 2), p.129
- phone passengers back with confirm'n (pg. 2), p.129
- passengers call in for confirm'n (pg. 3), p.13 (p. 66)
- enter details from bkg form onto comp (pg. 3), p.14, p.79
- put bkg forms which have been scheduled in a folder labelled "To Be Contacted" (pg. 3, p.79)
  - form remains in folder until passenger contacted.
- enter record passenger x-trip details on bkg form (pg. 3)
- differentiate between single trip & 2 way trip (pg. 79)
- file completed bkg form until scheduled (pg. 3 , p.87)
- give open * bkg clerks take bkg forms (pg. 3, p.2)
- store data into fictitious shifts (pg. 3, p.9)
- bkg forms taken in advance & confirmed with passenger,
- take passenger x-trip details (pg. 3, p.34, p.9, p.7, p.115, p.19, p.79)
- enter details directly into comp (pg. 3, p.7, p.18, p.18, p.179, p.19, p.7)
- amend details on comp (pg. 3, p.87)
- store data into fictitious shifts (pg. 3, p.9)
- try to give immediate y/n answer (pg. 5)
- suggest times of travel to passenger (pg. 3, p.85)
- offer closest times available (pg. 3, p.43)
- will give passenger choice if possible (pg. 3, p.43)

Consequences
CARDs: 26, 101, 143.

Causal Conditions
Passenger contacts to make booking with details

Properties of passenger contacts to make booking
fit people into last minute spaces.

Phenomenon
Last minute bookings
to earn money.

Specific dimensions of last minute bookings
- time booking taken (213 p. 125)
- destination of booking (213 p. 528)
- same day booking (191)

Context
Looking at entire schedule (1913 p. 118, 281)
Dispatchers under more pressure: more info (1915 p. 281)

Intervening Conditions
Policy of taking bookings at certain times (213 p. 125, 126)
Action/Intercational Strategies

* take big after official big time finished (p.125)
* accept late big popular destin (p.628)
* enter late big straight into Comp and not on WB (p.536)
* dispatcher searches entire schedule (p.118, p.123, p.281)
* call a passenger back for details (p.123, p.128)
* contact driver while they're on the road (p.123)
* trip opportunity reduced (p.128, p.149)
* take trip details same as advance normal (p.143)
* offer nearest available time (p.431)
* will give passenger choice if poss (p.433)

Consequences

* easier to miss the obvious * so much info to look at
CARDS: Causal Conditions -> Phenomenon

Need to monitor trends

Properties of monitoring trends:
- Num of refusals (p.250)
- Peak big times (p.475)
- Peak travel times (p.480)
- Num of passengers (p.19)

Specific dimensions of trends:
- Daily basis (p.4)

Context:
- Always some "oddball" who doesn't fit (p.453)

Intervening Conditions
Action/Intercational Strategies

* use cancell'n shift to monitor usage (p. 250)

Consequences
CARDS: \( \text{Axial Coding} \)

\begin{align*}
\text{Causal Conditions} & \quad \Rightarrow \quad \text{Phenomenon} \\
\text{Need to transfer trip details} & \quad \text{Driver Sheet} \\
\text{a form suitable for driver} & \\
\text{Properties of} & \\
\text{Specific dimensions of} & \\
\text{Context} & \\
\text{Intervening Conditions} &
\end{align*}
Action/Intercational Strategies

* copy details from wI3 to driver sheet (113 p. 13)
* alter driver sheet due to cancellation (113 p. 16, p. 30-30)

Consequences
CARDS:

Causal Conditions

Passenger needs to use service on temp. basis

Properties of temp. basis

- Membership for people temp. disabled [47, p. 516]
- People who use other DARS due on holiday [47, p. 516]

Phenomenon

Temporary membership

Specific dimensions of

Context

Intervening Conditions
Action/Intercational Strategies

Consequences
Causal Conditions
CT Service make Cancell'n.

Properties of CT cancell'n.
Driver sickness (81p.25, 82p.199, 83p.199, 87p.247)
over plant (88p.25).

Specific dimensions of

Context

Intervening Conditions
Action/Intercational Strategies

phone passenger to make cancell’n 

Try to move bookings to other buses?
CARDS: 111B

Causal Conditions

Passenger forgets

Properties of

Phenomenon

Cancellation

Specific dimensions of Cancellations

Numer of 111B p. 36-39

Context

Keep general fictitious shift with cancellations (111B p. 163)

Intervening Conditions
Action/Intercational Strategies

* Pass driver calls office if booking forgotten (113, p. 36-39)
* Cleapatcher calls passenger to see if still want to go (113, p. 36-39)
* Delay canc. details to cleapatcher (113, p. 100)

Consequences
Causal Conditions -> Phenomenon

**User criteria**

*Properties of Service Requirements*
- Seasonal disabilities (p.36)
- Need for escorts (p.41)
- Cannot do not take for hospital admittance (p.31)

*Specific dimensions of user criteria*
- Physical disability (p.36)
- Environment disability (p.36)
- Cannot use public transport (p.32)

*Intervening Conditions*
- Policy limits use of service (p.82)
Action/Intercational Strategies

- Ask passengers to describe disability (p. 36)
- Do not accept discharges from hospital (p. 31)

Consequences

- System is abused (p. 36)
CARDS: M, E 2n W

Causal Conditions → Phenomenon

- Problems caused by scheduling process

Properties of problems caused
- Passengers don't understand service (p. 124, 137, 138, 384)
- Passenger trip doesn't fit in easily (p. 141)
- Bus crashes / breaks down (p. 21, 155)
- Driver is sick (p. 199)

Specific dimensions of

Context

Intervening Conditions
Action/Intercational Strategies

- Explain correct use of service (p.146, 184, 362-355)
- Non-passenger phone passengers if service running late (p.23)

Consequences

- More resources may have to be used (p.147, p.21)
- Bookings cue transferred (p.155)
- Bookings refused/cancelled (p.157, 199-201)
CARDS:

Causal Conditions

Clash with existing advance booking (201 p. 299)

Phenomenon

Refused booking

Properties of

Properties of

Specific dimensions of flexibility

Context
Intervening Conditions

Action/Interactional Strategies

* told to normal bIz'g conditions (?).
* refuse bIz'g : "time 1.1 trips too short unless we're known (20:32 6a 5:28)"

Consequences
Causal Conditions

Time to move brigs from advanced to normal.

Properties of

Properties of

Specific dimensions of:
Time (201 p. 383) of transfer.

Context
Intervening Conditions

Action/Interactional Strategies

* Transfer books before normal books process (20L p. 383)
* Consider matching criteria - where books fits in on shift schedule (20L p. 347)

Consequences
Causal Conditions

Passenger contacts to make booking with details

Properties of passenger contacts to make booking

- Special occasion
- Group booking (20L p.148) + (p.293, p.361)
- Funeral (20L p.408-409)
- Medical appointments (20L p.3)
- Properties of catching other forms of transport (2L, p.3)
- Ticket shows (2L, p.3)

Context

- Taken up to 1 month in advance (2L, p.3)
- Not guaranteed but jumps queue (2L, p.3)
- Use same phone line as same day booking (44 p.3)
Intervening Conditions
Policy of limiting num advanc br'gs p.293, 414, p. 5)
Use other services for special occassion br'gs (18, p.29)

Action/Interactional Strategies
Return call from answer machine (20L, p.12)
Write br'g cleartsl onto home schedule sheets (20L, p.13)
Write br'g cleartsl onto advanced schedule sheet enter into comp (20L p.89, 414 p.5, 53)
*ignore normal br'g constraints (20L, p.297)
Check possible to chime from 1 br'g to next (20L, p.299)
Grp br'gs stored as multi-trps (2L, p.332)
br'gs recorded on 1 schedule sheet (411, p.5)

Consequences
CARDS: "O L.1.

Causal Conditions

\[ \text{Passenger contacts} \]

\[ \Rightarrow \]

\[ \text{Advanced Bookings.} \]

---

Properties of

Passenger contacts to make booking:
- Special occasion
- Group booking (20L, p.148, 293)
- Innovate (20L, p. 4083-409)

Properties of

Specific dimensions of flexibility

Context
Intervening Conditions

Action/Interactional Strategies

Tell passenger to ring back with more details.

Consequences
APPENDIX D

Selective Coding
Explicating The Story Line

The main story seems to be about how schedulers in Dial-A-Ride build their schedule. They have a criteria regarding advance and priority bookings and once they've scheduled those they start to put the other bookings on. The schedulers are aware of peak travel times and adverse traffic conditions. The schedulers know in advance resource allocation. All the schedulers rely on passenger flexibility. If passengers will accept alternative trip times, often the schedule can be improved and the main aim of getting as many people out as possible is achieved.
Causal Conditions
Advanced Bookings
Last minute bookings
Normal booking
Passenger calls to make booking. Type of booking is dependent on trip type and when booking is made. Bookings are recorded and the passenger is given an answer using the normal operation method. Limitations exist.

Properties of Bookings
Priorities
Trip type
Different types of trips can affect how booking is taken, e.g. priorities, some trips can afford to run slightly late. Certain trips are prioritised due to their nature, e.g. passenger needs to know if they can make an appointment.

Specific dimensions of Scheduling
Trends
Route
Trends in bookings and trips are monitored, e.g. peak booking times, number of passengers. Routes are built around some of these trends but also take into account resources and areas. The route taken is affected by resource allocation and target pressures. Routes are discussed and modified to create most efficient route.

Context
Driver sheet
Automatic knowledge
Resource allocation
User criteria
Trip type
Passenger type
Scheduling details are recorded in driver form on driver sheet. Despatchers use automatic knowledge to schedule certain bookings. This means they can take bookings and schedule much faster because they don’t need to ask all details from passenger. This also means the schedule may often stay very similar and the despatcher will simply be filling in gaps.
Scheduling is also based on the resources available. The resources available are affected by environmental factors and what the scheduler knows about the resources. Resources available vary form day to day.
User criteria can affect scheduling through the different passenger needs and requirements. The type of trip will affect scheduling as some trips must run on time whereas others can be slightly modified.
Intervening Conditions
Target Pressure
Temporary membership
Problem areas
Temporary membership can affect the way scheduling is done because numbers can go up and down.
Outside pressures to meet targets caused by policies can force the way schedules are built.
There are also a number of problem areas arising with the scheduling process, e.g. passengers don't understand the service and therefore have to be scheduled in.

Action/Intercational Strategies
Transfer Booking
Cancellation
Refusal
Checking details
Despatcher visualisation
Routing
Advanced bookings need to be moved onto normal scheduling sheet.
Cancellations can be made by either passengers or CT service. There are a number of reasons e.g. passenger forgets booking, driver sickness. Do try to fill any spaces. Changes are recorded where necessary.
Bookings can be refused, according to resources available. Operating methods often affect refusals, e.g. passenger has already used up their trip limit. Try to offer passengers alternatives where possible. The extent of refusal is recorded for statistical analysis.
Checking details with other despatchers can show gaps and a booking is accepted. If a despatcher knows an area well they may visualise the route the bus will take and know a booking will fit.
Routing is a primary action. Despatchers account for destinations, PUs, time, day, adverse traffic conditions and resources available. They try to route so multiple occupancy is achieved and target pressures are met. The most efficient route is the aim.

Consequences
Refused Advance Bookings
Service aims
The most basic consequences are a booking is accepted or refused.
Other consequences are the service aims which are basically to get as many people out as possible and meet targets pressures. Both passengers and service need to be flexible for this to work.
Grounded Theory Evaluation Criteria

• Consistency
  ⇒ Is the theory consistent in what it says?
  ⇒ Does it contradict at any point?

• Completeness
  ⇒ Is the theory sufficient in how it represents the domain?
  ⇒ Is the theory too limited?
  ⇒ Does more knowledge need to be added to the theory?

• Comprehensibility
  ⇒ Does the theory explain what is going on?
  ⇒ Does the expert understand what is being described?
  ⇒ Does the theory provide ideas that you recognise?
  ⇒ Can you see links between the data?

• Accuracy
  ⇒ Does the theory provide an accurate description of what is happening?

• Level of Detail
  ⇒ Does the theory show how internal factors affect the ideas?
  ⇒ Does the theory show how external factors affect the ideas?

• User Acceptance
  ⇒ Does the user agree with what has been written?
APPENDIX E

The Grounded Theory Product
1. Introduction

Dial-a-rides are door-to-door transport services for passengers who are mobility handicapped and unable to use conventional public transport because of a disability. The services are typically provided in minibuses adapted to carry wheelchairs and fitted with wheelchair lifts. Bookings are taken in advance and allocated to vehicle shifts with each vehicle shift containing many trips.

Currently available computer systems for scheduling trips are based on mathematical techniques. Schedulers do not recognise the rules used in scheduling software and therefore there is a gap between the human approach and the mathematical solutions that are implemented. There are many problems associated with computer science methods of gathering data. Social science methodologies, such as grounded theory, may be appropriate for use in areas like dial-a-ride scheduling where human involvement is high because they are designed to deal with human processes. In this study the knowledge engineer determines the processes used in scheduling with the aim of identifying the tasks that can be usefully computerised.

The following knowledge elicitation techniques were used to collect data from dial-a-ride despatchers:

- Interviews
- Observation
- Walkthroughs

These techniques were used because they meet grounded theory requirements by supporting an iterative approach and being easily understood. These methods do not prejudice and are capable of eliciting procedural and declarative knowledge.

This grounded theory, Scheduling Dial-A-Ride, is based on data collected from three dial-a-ride groups, all with different operating methods. Therefore, not all the results will apply to each dial-a-ride and not all the information will be relevant. However, despite these differences, it is possible to see how the process of building a schedule is achieved. The grounded theory will be used as the first step in a programming specification. The theory will then form the basis of a diagram to show the procedures used in scheduling, the decision processes being used and the links between them.

2. Causal Conditions

The core category in scheduling dial-a-ride services is the process of scheduling. Passengers contact the service to make a booking. There are different types of booking that can be categorised as advance, normal and last minute.

Advance bookings allow passengers to be guaranteed a place on the bus. There are several attributes associated with advance bookings: special occasions, group bookings, funerals, medical appointments, catching other forms of transport and going to the theatre. Normal booking constraints are ignored, although there are policies that limit the number of advanced bookings. Advance bookings form the basis for the rest of the schedule since the route can become well defined. This can have an impact on which bookings are subsequently accepted. Advance bookings are taken anything up to one month in advance. Advance bookings are
taken either over the phone, using either a special line or the usual line, or by letter. The bookings are then stored on the computer and on advance booking forms.

Normal bookings are the usual method of taking bookings when a passenger requires a trip. The method of taking normal bookings varies from group to group. There are different ranges of confirmation times for the passenger. These extend, in normal booking terms, from an immediate yes or no answer on the day before the trip to calling passengers back seven days in advance. Each group confirmed the majority of bookings two days before the trip. Each despatcher classifies normal bookings further into ‘important’ and ‘less’ important trips. Important trips are those which must arrive on time such as trips to the bingo where the passenger must be there on time at the start of the session. Shopping trips are classed as less important because the trip can run slightly later, without affecting the journey purpose. There are several operational methods for dealing with normal bookings. The booking is taken and the booking details are recorded both on paper and on the computer, although details can be transferred to the computer at a later stage. Depending on how the bookings are confirmed the bookings are stored until the schedule of built either in folders or on the computer (booking details are described at the end of this document). If the requested time is unavailable the despatcher will offer the passenger the closest alternative times possible and a choice if one is available. On occasions the despatcher will suggest alternative times to the passenger if the trip will fit in better on the schedule. Booking s may change in which case the despatcher will modify the booking wherever it is stored.

Last minute bookings are in fact normal bookings but are classified differently because of the time they are taken (the time varies between the day before to the same day of the trip). For the most part, passengers are being fitted into last minute spaces. The destination of the trip will affect whether the booking is accepted as it is more likely there is room for last minute bookings to common destinations and within local areas. Passengers who are flexible with their times are also more likely to get a last minute booking. Last minute bookings are often stored differently. It may not be necessary to store last minute bookings on all the recording mediums because the time for the use of certain mediums may have passed. The usual details are, however, required from the passenger. At times drivers need to be contacted while on the road with additional booking details if the booking occurs during their shift. As with normal bookings, the despatcher will offer the nearest available time and choices if possible. Despatchers find it harder to schedule last minute bookings because they are searching for spaces among the whole schedule rather than just certain areas. It is easier to miss the obvious because there is so much information to consider. Despatchers experience less pressure when taking last minute bookings because passengers in that position generally have fewer expectations.

3. Properties of Bookings

Bookings consist of the attributes of priorities and trip purpose. Sometimes passengers need some type of precedence for their trip. The following is a list of what the dial-a-ride groups consider to be priorities: large groups of passengers; first time users of the service; passengers in a wheelchair; people with more severe disabilities; committee members; education trips; medical appointments; where other forms of transport need to be caught; shows where tickets have to be bought in advance; and weddings. The extent of prioritisation and the methods of dealing with priorities vary in each group. Multiple occupancy is an aim with priority bookings because good head counts are needed. To encourage passengers to use the service, measures are taken in some groups whereby passengers are guaranteed their next trip request if their previous trip was refused. Priorities become much stricter when fewer resources are
available. Large groups represent more money and are usually treated as priorities. Similarly, contract groups provide regular income. In some cases a passenger may be accepted because it is easier to do so than refuse them. The circumstances where this may occur are where a passenger does not understand how the service operates and a dispatcher may be unable to explain this to them. Alternatively, a passenger has made such a nuisance of themselves the dispatcher is unable to say no. Therefore large groups are more likely to get trips.

There are times when the trip purpose is relevant and different need have to be fulfilled. The main reason for this is the importance of the arrival time. There are several trip purposes that the dispatcher must analyse and judge on the importance of their arrival times. The trip purposes are social trips, journeys to catch other forms of transport, multiple pick ups, shopping, an appointment and the distance of the trip. The dispatcher deals with the judgement of the trip by considering the trip purpose and categorising the bookings.

4. Specific Dimensions

There is a requirement to monitor trends in service use. The groups record the following trends: the number of refusals; the day of the week and time they occur; multiple occupancy; peak booking times; peak travel times; the day of travel; the number of passengers; the resources available; and the traffic conditions. Trends are recorded using files, computer records and refusal records.

Certain aspects regarding the route a schedule follows are important. The dispatcher must account for the time of travel, the day of travel, the number of passengers, the resources available and the traffic conditions. Individual passenger needs are also considered. This includes how fast or slow a passenger is and whether they are ready to go when they are collected. Dispatchers rely on memory aids such as maps besides their own local knowledge when routeing.

5. Context

At some point it becomes necessary to transfer trip details to a form that is suitable for a driver. Details are copied from the schedule sheet, booking form, computer screen or whiteboard to the driver sheet. The driver sheet will be altered if there is a cancellation or additional booking.

Scheduling is done partly in the context of the dispatchers' automatic knowledge. This is where the dispatcher knows a passenger's full details when they have only been given the most basic details. Dispatchers can in some cases recognise the passenger and the trip they want purely from recognising the passenger's voice. Other areas that are intuitive to the dispatcher are the days, times, pickups and destinations that certain passenger's book. Some dispatchers can guess who will be on the phone before they have answered the call because passengers are so regular with their booking habits. Dispatchers only need to check passengers who do not use the service regularly. Therefore schedules can be based purely on regular passengers and the dispatcher will just be filling in gaps. However, because the dispatcher knows the passengers well they can allow for individual needs and give immediate answers which speeds up the booking process. Dispatchers also know how much space is available on the buses without checking their schedule.
Allocation of resources is considered when scheduling. Environmental factors can affect resource allocation. Environmental factors are legal requirements, traffic conditions, road works and football matches. Despatchers know in advance the resources available although this may change from day to day. The methods used in controlling resources are to avoid having two buses in one area and to keep buses in the same area. Despatchers use a list of vehicle types and can check if buses are available when a certain type of vehicle is required. These strategies allow the despatchers to make maximum use of the resources available. Resource allocation is also affected by the availability of resources. This can be influenced by the number of vehicles available, the type of vehicles available and the number of drivers available.

Some groups have policies which state that no cover is permissible if a driver is absent, through either sickness or holiday. Other groups, on the other hand, have policies that build in cover shifts as part of their resource allocation. In the case of driver sickness there are several strategies that can be employed: the trips can be cancelled; the driver can be replaced; or the trips can be re-scheduled. Usually a combination of all three is put into use. The type of trip can affect the action taken. A return trip will take priority over an outward trip because the service has responsibility to return all the passengers safely.

User criteria vary from group to group. However, the basic requirement is that the passenger cannot use public transport. Policies limit the use of the service, although groups do account for seasonal disabilities. The sole check on passenger disability is usually only that the passenger is asked to describe their disability and any aids they need.

Scheduling is influenced by different passenger needs. Passenger needs account for the type of disability; whether the passenger is in a wheelchair, the wheelchair type; the mobility of a passenger concerning boarding and alighting, any mobility aids; and whether an escort is required. This can force the despatcher to consider if all the vehicles are suitable for the passenger and how much time to allow for each passenger. Despatchers are reliant on passenger flexibility besides their mobility. It is easier to schedule trips for passengers who are flexible with their times because they can be fitted in where gaps exist. On the other hand, some passengers are unable to be flexible with their times and it may be necessary to put them on because they really cannot travel at other times. To a certain extent, the amount a despatcher ‘likes’ a passenger can have some bearing on how their trip is scheduled. Scheduling is done in the context of the trip purpose. The purpose of the trip dictates the trip flexibility status regarding the time the trip is schedule and whether it can run slightly early or late.

6. Intervening Conditions

There are two categories of intervening conditions, target pressures and general problem areas. Target pressures are caused when funding policies force certain targets to be met. The targets presented to the groups are there must be a certain number of people on the bus, that a minimum of trips are completed, and the schedule is cost effective. The extent of the pressure to meet targets varies from group to group. There are numerous methods for dealing with these target pressures. The despatchers aim at multi-occupancy whenever possible and will suggest alternative times if it means they can increase the number of passengers on the bus. It is at times such as this that the despatcher will take advantage of a passenger who will be flexible with their times. Other tactics to ensure cost efficiencies are looking at the number of miles rather than the ease of the route and using minimum possible resources. Modifying schedules is common to make the best use of space available and get as many heads on the bus as possible. If the despatchers can achieve the best use of resources and develop the most efficient schedule
then trip targets are more likely to be met. The number of trips and refusals are monitored over a determined period to ensure targets are met.

Problems can arise with the schedule that are out of the control of the despatcher but that they will have to deal with. The main problems are usually caused by a bus crashing or breaking down or bad weather. In cases such as these, the despatcher will try to reschedule the trips but may be forced to cancel journeys. Sometimes the despatcher will come across passengers who do not understand how the system works and will therefore waste valuable scheduling time explaining how the system operates. If a passenger phones for a trip that takes the bus out of an area the despatcher may be faced with a trip that does not fit in with the schedule they are building. More resources will have to be used to allow this booking.

7. Action/Interactional Strategies

A time is reached when advance bookings are moved onto the normal booking schedule sheet. The time when this happens is between when advance bookings are no longer taken and when normal bookings start to be taken. Advance bookings also match criteria. The despatcher will look to see if a booking fits on the schedule better in one area than another.

Due to the nature of the service cancellations are common and require actions to manage the situation. There are two sources of cancellations, the passengers and the dial-a-ride group. The dial-a-ride group may be forced to cancel bookings due to driver sickness, overbooking on the bus, bad weather, traffic conditions or bus break down. Passengers are called with cancellations. The main source of cancellations is the passengers. Sometimes passengers cancel because they get another offer of transport for either part or the whole trip. The groups keep records of the number and times of cancellations. The despatchers always try to fill cancellations by fitting another booking into the space. The time of the cancellation affects how it is managed. If the cancellation has not yet been scheduled then the booking is simply stored as a cancellation. However details may need to be removed from schedule sheets, driver sheets and the computer. If the cancellation is very late the despatcher has to contact the driver on the road. Wherever possible the despatcher will try to fill the cancellation with another booking. The schedule will be altered if necessary to fit on more people. Since many of the passengers are elderly, there can be a problem with forgetting bookings or, more commonly, forgetting the time of the booking. It is unlikely the booking could be filled at such a late stage. Cancellations of this type are monitored to catch passengers who do this a lot.

Some bookings are refused. Refusals are caused by lack of resources and will vary with the resources available. Refusals are monitored and it is possible to find patterns where the refusal rate is reduced. The refusal rate is reduced at weekends when fewer passengers want to travel. Where there is a strict first come, first served policy, bookings are refused immediately if there is no obvious room on the bus. Dial-a-rides have reasons for refusals other than lack of room on the bus. Some groups use criteria such as refusing passengers who already have one trip booked or who can use other services. Despatchers will also postpone passenger trips if the passenger will accept the trip on another day. Some groups have policies that try to ensure passengers are not refused all the time. If a passenger’s last trip was refused then they will get a trip next time they book, although this is not always possible. Despatchers will always look at the schedule for any possible gaps and will move other bookings if necessary. They will also offer alternative travel times to the passenger. At times a despatcher may refuse a booking initially because they are unsure of times and distance but do expect to schedule the booking in later. Refusals can always be revoked and scheduled in later.
Lack of knowledge by the despatcher may cause them to check details with colleagues and other sources to schedule a booking. Causes of this are where the despatcher is unsure of trip details, unsure of an area or if the booking details are not consistent with the booking a passenger regularly makes. Sometimes the despatcher will check refusals. Methods of verifying details are looking items up in street guides and directories, discussing the problem with other despatchers, phoning the passengers and checking schedules and shifts against each other. Checking details can lead to error being found and rectified.

Schedules are affected by the methods’ despatcher use to visualise the route they are developing. The attributes considered during this process are the route, the location of the bus, pick-ups and drop-offs. The amount of knowledge a despatcher has of the area affects the amount of visualisation. If a despatcher knows an area well they will visualise the route as if they are out on the street. In areas where the despatcher is inexperienced they will use trip routes that have worked previously or use map references to assess the route. The consequences of this visualisation are that the quality of schedule may vary from day to day.

The process of scheduling is probably most influenced by the action of routeing. The attributes of routeing are destinations, times of travel and traffic conditions. To route the despatchers rely on maps and their own local knowledge. Dynamic scheduling is also reliant on the position of buses on the road. Despatchers base routeing on the need to get multiple pick-ups and to make the schedule flexible. At times they use what has worked in the past and try to keep passengers on the same shift, although this is not a major priority. The main influence on the route developed, however, remains the pressure to meet targets, which are often dictated by conditions such as popular destinations. When developing the schedule, despatchers will route around advanced, contract and priority bookings. They then take a number of actions that build the route. Despatchers examine the schedules for trips that synchronise and where trips follow on. They aim to fit bookings in around others and will move trips to accomplish this. Another common strategy to achieve efficient routeing is to suggest times to passengers that fit in with the developing schedule. Despatchers need to be aware of other commitments at the same time. These commitments are putting in driver breaks and ensuring passengers do not stay on the bus for too long. The aim of such practices is to ensure that the most efficient route is created and the schedule is built in the best way possible. Depending on despatcher local knowledge some areas will be booked more confidently than others.

8. Consequences

The most basic consequences of the actions and interactions are that a booking is either refused or accepted. The more complicated consequences are concerned with whether the aims of the service are met. Both passengers and dial-a-ride groups have expectations of each other. Passenger expectations are where passengers require extra assistance with locking doors when they are picked up from home. Dial-a-rides expect passengers to allow fifteen minute’s leeway either side of the pickup time. The flexibility of both passengers and the service is essential to operation methods. All the despatchers aim to meet target pressures. They consider elements such as how cost effective a trip is and whether multi-occupancy can be reached on the buses. Despatchers realise that passengers cannot always be flexible with their times. Some passengers may have to be in at certain times of the day if a home help comes round. However, on occasions it may be quite easy for a passenger to alter their time slightly and thereby allow someone else a trip. Passengers who are unwilling to be even a little flexible may have their trip refused.
The service tries to satisfy passenger needs while meeting target pressures. Despatchers will try to give passengers the time they have requested but will offer alternative times if this fits in better with the schedule being developed. At times the despatchers will find themselves looking at the number of miles buses travel rather than the ease of the route. By searching for shortcuts and using the minimum number of buses possible, despatchers can make better use of resources.

The service tries not to refuse people because if a passenger feels they are never getting trips they will stop using the service. On the other hand there are times when despatchers must insist a passenger takes what is available, and it is then the passenger who is responsible for accepting or refusing the alternative offer.

Appendix A - Booking Details

Passenger name
Membership name
Telephone number

Day of travel
Pickup time
Pickup address
Destination address

Mobility aid
Comments

Fare
Booking number
Vehicle allocation
APPENDIX F

Grounded Theory Evaluation Stage 1
Scheduling Dial-A-Ride - A Grounded Theory

Instructions

Grounded theory is a social science methodology whereby theory is discovered through structured data collection and analysis. The data is then analysed using grounded theory coding procedures.

- **Open Coding** - The data, for example, an interview transcript, is broken down into concepts and categories. Each category is given a label and then every instance of the category is recorded along with its location in the data.

- **Axial Coding** - During axial coding, connections are made between the categories developed in open coding. This is achieved by using a coding model, known as the paradigm model (see figure 1). This model indicates a central idea, the events that lead to the occurrence of the idea, the circumstances under which the idea happens, the broader background environment, the actions and interactions carried out on the idea and the consequences that result from these actions.

(A) CAUSAL CONDITIONS → (B) PHENOMENON →
(C) CONTEXT → (D) INTERVENING CONDITIONS →
(E) ACTION/INTERACTION STRATEGIES →
(F) CONSEQUENCES

Figure 1 - Paradigm Model

- **Selective Coding** - Selective coding is the process of choosing a central category to which all other categories are related. Using the paradigm model, subsidiary categories are linked to the central category. These links are then validated against the data, which also provides the opportunity for any further development of categories that may be necessary. Figure 2 demonstrates the linking of data to selective coding.

```
SC          SC = Selective Coding
   ↓          AC = Axial Coding
   ↓          OC = Open Coding
   ↓          data = interviews, observations walkthroughs
   ↓
   ↓
   ↓
   ↓
   ↓
   ↓
data   data   data   data
```

Figure 2 - Coding and Data Links

The grounded theory is built on the results of coding the data. The purpose of a grounded theory is to set out the conditions that produce the actions that are applied to an idea and the outcomes that follow. A grounded theory should be evaluated against a number of criteria. The
following questions may help to see if the theory is an accurate analysis of the processes at work in the area under study.

- Does the theory produce ideas that you recognise?
- Can you see links between the ideas?
- Does the theory explain what is occurring?
- Does the theory show how outside factors affect the ideas?
- Is there a sense of process?
- Is the grounded theory significant?
Nottingham CT - 29.02.96 - Grounded Theory Evaluation

A: So really all I want to know are your comments. I realise that its not all exactly what you do.

D: Well you taken the information from the different services that you've booked and accorded the best way of explaining what might occur or how different things are dealt with. Yes, Obviously yourself and Simon explained the system, the grounded theory system, what else can be said?

A: Does it include some things that happen here?

D: Oh yes, the thing is if you look through it and try to pick things out, you've got normal bookings, last minute bookings, priorities, allocation of resources, user criteria, intervening conditions. So basically its all there, the main problems what the despatcher will have to face, where they have to come up with solutions. I suppose regardless of whether its for our dial-a-ride or for several somebody who read it would understand what the problems are right across the board which I assume is main aim, to make it as user friendly as possible. Can you explain to me how far you've got, are we still at the same point where we have the meeting before?

A: Yes, I haven't talked to anybody else since. What I've done is write the grounded theory based on the stacks of cards. What you can do is pick out anything and I can show you an example of where it occurs in the data. I've cards that show instances, in fact I've probably got 2 or 3 cards from each DAR which show instances of various concepts in action.

Where I think its lacking in depth are the actual consequences, the end results. At the end of the day I find that either a booking is accept or its refused and those really are the only 2 results.

D: That's right you've got a booking request that's got three outcomes: its either going to be refused immediately; cancelled at some stage for whatever reason by the user or us: or its going to go ahead so those are the only three consequences of what does on. I mean, all right, there are other consequences, one consequence is the times may have to be changed but in the end they either or they don't but not quite at the time that they want.

This is good explanation of how from the telephone call you put it into the system but then once its in the system what can happen to it after that? Once you've got the booking on paper and you've got it onto the computer, it isn't over until that passenger has been dropped off and taken back home because you can have lots of other things that happen in between. You can have a passenger ring up and change where they want to be picked up from which then creates a scheduling problem where you've got somebody who's gone to one part of town and they've perhaps hired a scooter or something or they've got their own electric wheelchair and they want to be picked up from somewhere else and that's got to be another scheduling problem. Sometimes we get things like a passenger will go into town and you get a phonecall saying my electric wheelchair has just broken down can you pick me up now
otherwise I'm just going to be sitting here in town doing nothing or I don't feel very well and I want to go home. So until you've actually finished and dropped the passenger off; at home there's always an element of surprise but that's something that with this system I would assume you could probably say 'what if the passenger wants to come back from somewhere because they've just been told there's a nice cake shop near the other end of town?'. If its in the local area it doesn't really cause a problem.

A: I suppose that's one of the problems with grounded theory and doing this data collecting and analysis is that if this sort of problem doesn't occur when I'm here then its not picked up.

D: Well there are lots of things that happen, now I'm going back on experience from 1987, so things that I've seen happen might only come up once every 2 years, we've had a couple of instances where a drivers arrived at somebody's and they're dead and obviously you can't schedule that! The drivers got to stay there until the police arrive so you've to do something else with all of the other bookings. It doesn't happen a lot but in a dial-a-ride service where you're dealing elderly and disabled people its going to happen. I know of a dial-a-ride that's had a passenger die on the bus - big problem - but you have to deal with it so that sort of thing happens. You've got problems that can arise like crashes or breakdowns, they're problems that cause you to have to reschedule things. Snow, that's big one. What we have to do there, if we think the service is going to be impaired in any way you have to prioritise your passengers. So you priority would be: A) if there's any passengers that you haven't picked up yet you don't! B) If you've already taken them out and they've got a wheelchair or they've got no access to other services you've got to get them as soon as possible which means you go to them and say if you don't come now I can't take you later on and then you work your way down the list and sometimes you'll be in the situation where you know this particular passenger can use a taxi because they don't have a wheelchair. What you have to do is prioritise by their disability and keep a mental register of it in those situations. for example, if a passenger has epilepsy and needs to get home for medication you must get them there. Its only something like snow that causes that. You wouldn't have to, problems are not the sort of thing you would have to incorporate into this system because you can't anticipate them.

A: That's where the human side of it would come in. That's why you have a human despatcher.

D: That's right, they have to make an instant decision and its got to be on huge amounts of different information.

A: I suppose at the end of the day, even when they reschedule they're still using a lot of the same techniques when they schedule normally, they have to prioritise more.

D: If you read through this it would give the average person an idea of what the despatcher is going through when they receive the call. So from actually receiving the call what action do you take? You can look at this and it gives you an idea of the sort of information because if you look at the system that we're using, this system doesn't provide a facility for telling you whether its a nice person who's flexible or not, so that's the sort of thing the despatcher has to keep a constant update on. I can't see any
different. If you read that it tells you what the despatcher has to do with a phone call but then you say what are the consequences? Once you’ve put this onto the system that’s all right from the despatcher’s point of view.

A: We’re planning on using a GIS to assist the despatcher in the way they already visualise maps and streets. They use that now but don’t expect the driver to take that exact route but if you’re looking at an area the driver might know a short cut that puts them ahead of schedule but you’re still looking at roughly the same kinds of times.

D: From here what do you intend to do? You’ve got all this information and you’ve got all your cards so what is the next step?

A: The next step is represent all of this diagrammatically, starting with this grounded theory, in a way that I can see processes/concepts, outcomes, everything that I need to put into the prototype. The idea to get this feedback now is make sure there’s nothing in there that’s wrong or if you just think it’s a load of rubbish I need to know that! I mean anything you disagree with. Could be taken from somewhere else in which case I can say you’re right it doesn’t apply to you its from **** or anything that you do agree with very strongly.

D: I would say looking at this that it’s fair to say that, dial-a-rides up and down the country all have their different methods and they’re all completely different and sometimes we look at how other dial-a-rides do things and we think we can’t imagine doing that but it works for them. Really what I think is important and what happened with multitrip was that the information was taken from all the different dial-a-rides and put into a pot, everything was in there which just made things so huge and complex and a dinosaur in the end that it couldn’t cope. There was something like 244 different information fields for just a passengers registration, what do you need all that information for? One dial-a-ride might need it and another might not, what you need to do is cut this down to exactly what each dial-a-ride needs to know. To me that’s fine because that’s what we need to know, what this system could help with and then really after once there’s system of doing this then its up to the people who operate dial-a-ride services to say if its working for other people why won’t it work for us and then try and work out how its integrated and then do it yourself. For example last minute bookings, its very often that we take last minute bookings although if someone rings up in the morning and asks to go out that evening and there’s a space we’ll do it.

One of our bit problems is communications, if a passenger says can I go out today, we might have the space to do it but before you can actually say yes you’ve got to call the driver and say there’s another booking and then get in touch with the other drive and that’s causes the big problem with last minute bookings because invariably drivers don’t want to be contacted unless its necessary because they know I’ve got something extra for them to do so they just ignore the radio. But we would like to think if someone rang up and there was a space we’d get them in. We’re looking at new ways of communication now. Its more difficult to ignore a telephone or a pager than a radio. I can’t really see any reason why we wouldn’t say yes this would describe how we operate our dial-a-ride or at least some of the ways and that’s it, no problem.

A: Good, well as long as you think its accurate and acceptable.
Steve Roach at Barnsley Community Transport (BCT) is very busy not only with his own group but in helping the running of another CT group. He had read the grounded theory when he first received it but had not had the time since to evaluate in depth what was written.

Steve agreed with the grounded theory from a first impressions point of view. Nothing immediately caught his eye as being wrong in his opinion. Anything that was not relevant to BCT he assumed was taken from data at other sites. Steve was able to recognise concepts which were used at BCT and agreed with accuracy of these categories. He felt that the methods used had captured much of the BCT system and had extracted a number of concepts that might not have been admitted in formal interviews.

The main areas of interest to BCT were the target pressures and the priorities systems. Steve commented that these were relatively new concepts and concerns and said that had the research been carried out two years ago, these would not be big issues. He agreed that such issues in the theory were appropriate at this time. It was felt that routing and resource allocation were of less relevance although nor entirely unrelated.

Barnsley are currently changing their system and he thought it would be interesting to see how much remained relevant once the change over was complete. As with Nottingham, BCT was interested in what could be learnt from other groups in order to improve their own services.

Steve wants in the near future to debrief his staff on the grounded theory. I have offered to help him with this because feedback of this nature should prove very useful in evaluating the accuracy of the theory.
CLDAR - Grounded Theory Evaluation

1. Introduction

The introduction met all the criteria. The description of grounded theory and the coding processes were accurate and enough detail was provided for the user to understand at a basic level what was being done with their data. There were no comments or criticisms.

2. Methods

The methods were comprehensive and accurate. The users agreed with the definition of a dial-a-ride and the problems faced with computer systems in this area. The users could understand why the techniques were chosen and how they were appropriate for use with grounded theory.

3. Causal Conditions

There were a number of problems with some of the wording used in this section. The users felt that trips should not be described as 'unimportant' but as 'less important'. It was also pointed out that they used the phrase 'same day' booking rather than 'last minute'. The term 'last minute' is used to describe more than same bookings however so the term has been defined more clearly.

The phrase 'minimum of two days in advance' was not generic enough to cover CLDAR. The sentence has been re-written to demonstrate the differences in each group. The users also disagreed with the phrase 'under more pressure with last minute bookings'. The phrase 'harder to schedule' was considered more appropriate.

Due to the lateness of the bookings, trips are less likely with last minute bookings. Besides more common destinations holding more likelihood of a trip being accepted, the users added short local trips and passengers who are flexible with times.

4. Properties of Bookings

The term type of trip has been replaced with trip purpose because CLDAR uses trip type to describe whether the trip is outward or return. This is not an appropriate definition for the phrases use here.

It was also necessary to clarify the term 'different user types'.

5. Specific Dimensions

The word 'need' has been replaced with 'requirement'.

The users added the day of the week and the time of the day to the trends that they record. The phrase 'cancellation shift' has been replaced with 'refusal records' because this is a more accurate description of the function.
The users also added that dispatchers account for individual passenger needs when building a route.

6. Context

The users pointed out that the strategies that can be employed in response to driver sickness can be used in combination as well as separately. The type of trip dictated the response.

The users disagreed completely that the system was abused and this phrase has now been removed. The phrase ‘certain drivers’ has also been removed because this is not common practice in any of the groups. It incorrectly suggests that some drivers are favoured more than others.

The phrase ‘passenger is in a wheelchair’ needed more clarification. This has been done by using the term ‘type of disability’ to show how a wheelchair can affect scheduling.

It was pointed out that by making the best use of resources of and building an efficient schedule does not guarantee that trip targets are met. It simply means it is more likely.

Bad weather is an additional problem that the dispatcher may have to face when scheduling that is out of their control.

7. Action/Interactional Strategies

There are only two sources of cancellations. The users also added bad weather, bad traffic conditions and bus break down as reasons for a dial-a-ride cancelling trips. Passengers forgetting trips altogether is not a common occurrence but does happen. It is much more typical for passengers to forget the times of their trip.

A more generic word is required for ‘A-Zs’. This has now been replaced with ‘street guides’ and ‘directories’ to cover the range of mediums used to check details.

Trips that have worked in the past are not used ‘where possible’. Such trips are used ‘at times’. The phrase ‘trips crossing over’ has now been replaced with ‘trips that follow on’ because this gives a more accurate description of the process.

8. Consequences

The sentences ‘On the whole passengers who are not flexible with times do not urgently need a trip and will be turned down if they refuse to change their times slightly’ has been replaced. The users felt the sentence was too harsh and needed further clarification.

Bookings suggested for other times have been termed ‘alternative offers’.

9. Conclusions

On the whole the grounded theory meets all the evaluation criteria satisfactorily. Any comments made by the users that could not be sufficiently explained has been corrected to reflect the users views.
APPENDIX G

Grounded Theory Evaluation Stage 2
Scheduling Dial-A-Ride - A Grounded Theory Evaluation

Introduction

Grounded theory is a social science method whereby theory is discovered through structured data collection and analysis. The data is analysed using grounded theory coding procedures.

- **Open coding** - The data, for example an interview transcript, is broken down into concepts and categories. Each category is given a label and then every instance of the category is recorded along with its location in the data.

- **Axial coding** - During axial coding, connections are made between the categories developed in open coding. This is achieved by using a coding model, known as the paradigm model (see figure 1). This model indicates a central idea, the events that lead to the occurrence of the idea, the circumstances under which the idea happens, the broader background environment, the actions and interactions carried out on the idea and the consequences that results from these actions.

(A) CAUSAL CONDITIONS  \( \Rightarrow \) (B) PHENOMENON  \( \Rightarrow \)
(C) CONTEXT  \( \Rightarrow \) (D) INTERVENING CONDITIONS  \( \Rightarrow \)
(D) ACTION/INTERACTION STRATEGIES  \( \Rightarrow \)
(F) CONSEQUENCES

Figure 1 - Paradigm Model

- **Selective coding** - Selective coding is the process of choosing a central category to which all other categories are related. Using the paradigm model, subsidiary categories are linked to the central category. These links are then validated against the data, which also provides the opportunity for any further development of categories that may be necessary. Figure 2 demonstrates the linking of data to selective coding.

SC = Selective coding
AC = Axial coding
OC = Open coding
data = interviews, observations, walkthroughs
The grounded theory is built on the results of coding the data. The purpose of a grounded theory is to set out the conditions that produce the actions that are applied to an idea and the outcomes that follow.

Instructions

The attached questionnaire is designed to evaluate the grounded theory developed from the research you have helped with. There are five sections:

- Part A - Organisation Details
- Part B - General Information
- Part C - Detailed Information
- Part D - Personal Information
- Part E - Grounded Theory Evaluation

Some of you will have filled in Parts A-C earlier in the project. We would like to update our records and therefore are asking you to fill in these sections again. There are different ways of recording your answers in the questionnaire but instructions are given each time there is a change of recording method. Once the questionnaire is completed we will arrange to come and see you to talk about your answers. If you do not understand any question or are unsure what to put please record these problems and we will sort them out at the follow up interview.
PART A - ORGANISATION DETAILS

Name of Organisation:

Address:

Telephone number:

Fax number:

Contact name(s):
PART B - GENERAL INFORMATION

1. Which of the following services do you operate? (Please tick all boxes that apply to you)

☐ Dial-a-Ride
☐ Dial-a-Bus
☐ Group Hire
☐ Furniture
☐ Social Car Scheme
☐ Other(s) Please specify:

2. Which of the following services is the most important to your operation? (Please tick one box only)

☐ Dial-A-Ride
☐ Dial-A-Bus
☐ Group Hire
☐ Furniture
☐ Social Car Scheme
☐ Other Please specify:

3. How many vehicles do you operate? (Please enter numbers alongside vehicle type)

Wheelchair accessible minibuses:
Minibuses:
Car:
Other: Please specify:
4. How many staff work at your depot? (Please enter numbers in appropriate boxes)

<table>
<thead>
<tr>
<th></th>
<th>OFFICE</th>
<th>DRIVING</th>
<th>ESCORTING</th>
<th>GARAGE/WORKSHOP</th>
<th>OTHER*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Paid staff</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Volunteer staff</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Please specify:

5. For which of the following do you use computers? (Please tick all boxes that apply to you)

- [ ] Accounts
- [ ] Word-processing
- [ ] Database
- [ ] Mailing
- [ ] Storing bookings
- [ ] Storing schedules
- [ ] Other(s) Please specify:
PART C - DETAILED INFORMATION

6. How many schedulers/despatchers do you use exclusively for your dial-a-ride services?

7. How would you describe your Dial-A-Ride operating area? (Please tick one box only)
   - [ ] Urban
   - [ ] Rural
   - [ ] Both

8. How far in advance do you take bookings for your Dial-A-Ride service? (Please list each type of booking and number of days for each type)

9. How do you take bookings? (Please tick all boxes that apply to you)
   - [ ] Through written requests
   - [ ] Personal phone calls
   - [ ] Answer machines
   - [ ] Via drivers/escorts
   - [ ] Other(s) Please specify:

10. Which of the following do you use the most to take bookings? (Please tick one box only)
    - [ ] Through written requests
    - [ ] Personal phone calls
    - [ ] Answer machines
    - [ ] Via drivers/escorts
    - [ ] Other Please specify:
11. How do you confirm bookings? (Please tick one box only)

☐ Immediate yes/no decision
☐ Ring back and confirm or reject
☐ Other Please specify:
PART D - PERSONAL INFORMATION

12. What is your name?

13. What is your official position/job title?

14. What training and experience have you had in Dial-A-Ride to date?

15. What are your main duties/responsibilities
PART E - GROUNDED THEORY EVALUATION

This part of the questionnaire is divided into five sections. Please answer each question by circling the appropriate number. Please comment on your answers in the space provided.

COMPREHENSIBILITY

16. Do you understand what the grounded theory is saying?

Understand fully 1 2 3 4 5 Do not understand

17. Does the grounded theory explain what is going on in your working environment?

Explains fully 1 2 3 4 5 Does not explain

18. Does the grounded theory talk about ideas that you recognise?

Recognise lots of ideas 1 2 3 4 5 Do not recognise any ideas

19. Can you see links between the ideas in the grounded theory?

Can see plenty of links 1 2 3 4 5 Cannot see any links

Please comment on about the ideas and links you can see in the grounded theory:
**COMPLETENESS**

20. Does the grounded theory show the activities that are going on in the scheduling process?

<table>
<thead>
<tr>
<th>Shows all activities</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Does not show any activities</th>
</tr>
</thead>
</table>

21. Do you think there are any limitations in what the grounded theory shows?

<table>
<thead>
<tr>
<th>No limitations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Lots of limitations</th>
</tr>
</thead>
</table>

22. Do you think more knowledge should be added to the grounded theory?

<table>
<thead>
<tr>
<th>No more knowledge needed</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Much more knowledge needed</th>
</tr>
</thead>
</table>

Please comment on any limitations you can see and what knowledge, if any, you think can be added:
CONSISTENCY

23. Do you think the grounded theory is consistent in what it says?

Very consistent 1 2 3 4 5 Very inconsistent

24. Does the grounded theory contradict itself at any point?

No contradictions 1 2 3 4 5 Contradictions throughout the theory

Please comment on any inconsistencies and/or contradictions you can see:
ACCURACY

25. Do you think the grounded theory provides an accurate description of what is happening?

| Very accurate | 1 | 2 | 3 | 4 | 5 | Very inaccurate |

Please comment on why you think the grounded theory is showing an accurate or inaccurate description:
LEVEL OF DETAIL

26. Does the grounded theory show how internal policies affect the ideas discussed in the theory? (By internal policies we mean your own groups way of doing things. For example, only allowing a passenger a set number of trips a week is an internal policy.)

<table>
<thead>
<tr>
<th>Shows exactly how ideas are affected</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Does not show how any ideas are affected</th>
</tr>
</thead>
</table>

27. Does the grounded theory show how external policies affect the ideas discussed in the theory? (By external policies we mean things you have to do to comply with outside groups. For example, having to get a certain number of trips per week to get funding.)

<table>
<thead>
<tr>
<th>Shows exactly how ideas are affected</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Does not show how any ideas are affected</th>
</tr>
</thead>
</table>

Please comment on how you think internal and external policies affect the ideas in the grounded theory:
Grounded Theory Evaluation - Sheffield - 23.04.97

Ian and Margaret

M: I had a quick read through 3 weeks ago when we first got it, but this morning I haven’t had much time at all.

A: That’s fine. I think the best thing to do is to go through the questionnaires. The idea of this was to re-evaluate the grounded theory having made changes and also to get feedback off the despatchers themselves rather than just the managers.

M: I put 1 for the first question, I can understand what its saying.

I: I put 2. When you say the grounded theory you mean this bit and not the coding stuff that you showed us in Leicester?

A: Yes, this bit.

I: For number 17 I put 2. I think it’s true, it rings a lot of bells.

M: Yes I agree, I suppose everywhere is different thought?

A: Well yes that’s true because it is made up from the three.

I: Yes, I made some comments about that.

M: I put 1 for the next one.

I: I put 2. I don’t think I’ve put a 1 or a 5 anywhere in the questionnaire. I don’t think you can fail to recognise ideas in this. It’s definitely the way we do it. There’s going to be differences, I mean one of the things that I’ve put down is that you feel less pressure when you take a last minute booking.

M: There’s no pressure at all really because there’s so little expectation. When its a last minute they’re really to get anything.

I: But it’s only little things like that that are different.

A: I found that last time Barnsley and Sheffield said that’s not quite how we do it and it would be because that’s how London did it, whereas London would find things that they didn’t like but it would be the way Barnsley and Sheffield did it.

M: I’ve got 2 for number 19.

I: I’ve got 3. I wasn’t really sure what you meant by the links between the ideas.

A: I meant can you see where things carry through, for example can you see where a cause leads on to an effect.

I: Yes I can see stuff like that.

M: I’ve got a 1 for this.

I: I’ve got a 2. There are obviously from what we’ve been saying lots of the activities that we can recognise.
I: I haven’t got an answer for number 21.
M: I haven’t got an answer for 21 or 22.
I: What I put as a comment was that there are different conditions between the despatchers that
its difficult to assess how they rate, which method is going to take precedence. At the end of it
here its just Margaret’s decision at the time and because it changes I didn’t think you could say
if there are limitations.
A: I should imagine if we had more time we could pick up more of these instances that
Margaret’s making at the time.
M: You see once you get to know them properly you get to know what they want.
I: Like what you can get away with, whether its with passengers or policies.
M: Yes, that’s right.
A: The limitations we were looking for would have been fairly basic not the very detailed
knowledge that shows the one off decisions you make.
M: Well I can’t think of anything like that.
I: In terms of the actual knowledge, I wasn’t sure how you could really get the complexity of
the processes like you say in the time scales but the basic decisions that are being made are
there.
I: I put a 2 for 23.
M: I put a 2 as well.
I: On 24 I put a 3 but that’s only because, perhaps that’s not very fair really given the
differences between the groups and also that here we don’t really have the problems of refusing
outright. We’ve got such a large transport available we just put them on something else, we
don’t put large groups on City Ride but I don’t know if that’s relevant.
M: I put a 2 for number 25.
I: I put 3 but that’s only a comment because it applies to a different dial-a-ride so there’s bits
that don’t quite fit but also bits that clearly belong to use.
A: I think if the future if we do this kind of thing again we should mark out more clearly which
bits belong specifically to each group and then the differences are more easily explained.
M: I wondered whether it should be a 2 or a 3 on 26 but I decided on a 2.
I: Yes, I put 2 as well. I think it does point out these certain conditions. It definitely says they
have a bearing on the way things are do. The actual final decision is a mixture of policy and
Margaret because even if a passengers had all their trips for one week, if they want another one
and there’s room then they’ll get their trip. It certainly shows the pressure we’re under so its
quite clear on that.
I: The same goes for number 27 really, I put a 2.
S: I've had a stab at a the questionnaire, how do you want to do this?
A: I just want to go through from section E onwards, your own personal opinions. To just run through your answers.
S: I think it covers what we do. I think it shows quite clearly the scheduling. For Barnsley the highest number of variables is in the decision making in terms of quality and trying to give people what they want. I think the theory shows the inter-linking very well and I'm personally more comfortable with this than the harsh commercial funding behind it. Basically the strength and the weakness behind our operations, we're doing more dial-a-ride services and we have to cost our money. We're not only decision making but we're also considering the rationale behind the funding and this theory show that.

I found 21 difficult because the only limitations in the theory is because of our limitations here. I think you can elaborate but I'm not sure how.

A: Really what I meant with those questions was, was there anything blatantly obvious missing that's very important to you and should be added. You could spend every for years here and still not pick up absolutely everything. If you can confirm that I haven't missed anything really basic rather than something that might happen once in a blue moon
S: Well in that case its fine.
M: I've done ticks for my answers.
A: Its important to get the two views. It just makes it richer and deeper giving a better proof of whether it not works.
M: Question 21, I've put 2 because I don't think there are many limitations in the grounded theory. For 24 I've put 2 as well because at the time this was what we were doing, things have just changed over time.
A: Yes, when I first started doing it you had 4 people.
M: Of course yes. Those are the only differences between my answers and Steves.
A: That's a relief.
APPENDIX H

Sample Systems Analysis and Design
estimate time taken, 10 - EST_TIME.DAT
PROTOTYPE UNKNOWN NAME 20-Nov-96 11:44:55
Page 1 of 1
Allocation

Trip: Shift
Task Allocation Notes

1. Popular Destination and Popular Pickup are set by the user.
   Alternatives: Set by user ✓
   Attribute of address learned by system
   (Need to write reasons later)

2. Suggest alternative time for Popular Pickup or Popular Destination.
   Rules determine whether to ask for alternative time (Rule 13)
   Algorithm to suggest alternative time.
   Dispatcher can accept, suggest another alternative or override based on information from Passenger.
   Support with a map or screen showing positions of Pickups, Dropoffs and Times.
Frames.

Possible route: (GIS usage)
- PU address
- Dest'n address
- Event name
- Event type
- Event-affected area

Road type (GIS/KIS?)

Target pressures:
- Num of pass
- Cost of trip

Priority:
- Trip purpose [shopping | bing | med | appl | ticket show | ongoing travel]

Schedules:
- Schedule date
- Shift type code
- Start time
- Finish time
- Vehicle num
- Vehicle type
- Other attrs:
  - PU address
  - Dest'n address
  - Possible route
  - Num of pass
  - Trip purposes
Frame: Passenger.

Slots:

Last Use Date
[Date]
Default "" Read from passenger
Demon- on changed
Rule 6.

First Time User
[True, False]
Default [False]
Demon- on changed
Rule 7

Mobility Aid Code
[GD1, SH1, SH2, TI, WI, WZ, WE1, WEZ, WL1, WL2, WEL1, WEL2, N1]
Default [N1]
Demon- on changed
Rule 8, Rule 9.

Check Mobility Aid
[True, False]
Default [False]
Demon- on changed
Rule 10.
Wheelchair User:

- [True, False]
- Default [False]
-Q: on: changed

Rule 11
Reject trip (Dislance)

Inputs:
- poss_route
- dest_address
- shifts
- date_of_travel
- pick_up_time
- travel_time

For each shift, test insertion of trip.
Vehicle:

vehicle.no
vehicle.type

Event:

event.date
event.name
event.type
affected.area:

& a to z references

event.start.time
event.finish.time

Time taken:

req.pu.time

by poss

posn

del n. address
pos. delays,
Event

Date

Start Time

Finish Time

Zone List

Name

[List of Zones]
Frame: Trip Booking

Slots....

Trip Purpose Code:
[1, 16, 2, 26, 3, 36, 4, 46, 5, 56, 6, 66, 7, 76, 8, 86, 9, 96, 10, 11, 12, 13, 99]

Demand - on changed
Rule 1, Rule 12

Special Occasion
[True, False]

Demand - on changed
Rule 2
Rule 3

Priority
[True, False]

Demand - on changed
Display on screen - priority booking

Use Alternative
[True, False]

Demand
Display on screen - Use Alternative
Frame Trip Booking

Adults
[0 ... 15]

Demurr on charged
Rule 5

Children
[0 ... 15]

Demurr on charged
Rule 5

Infants
[0 ... 15]

Demurr on charged
Rule 5

No. of Passengers
[0 ... 45]

Demurr on charged
Rule 4

Flexible
[True, False]

Definit [False]

Demurr on charged
Rule 13
Frame: Trip Booking

Popular Destination

- [Time, False]
- Default: [False]
- Demon: if needed
  - Prompt User
  - or Set by user action

Popular Pickup

- [Time, False]
- Default: [False]
- Demon: if needed
  - Prompt User
  - or Set by User action

event.time

- [time]
  - demon: if needed
  - check event.zone

event.occurrences/zone

- [zone]
  - demon: if needed
    - calculate alternative route

- See Frame event

time.effect

- [time]
  - demon: if needed
  - calculate time.effect
Frame: Trip Booking could

ZoneList (list of zones that a trip would pass through – probably derived from GIS.)

demon if changed
Rule 14

Event: Relevant

[True, False]

demon if needed
Rule 14

Relevant: Events (list of Events that could affect a trip.)

demon if needed
Rule 14

demon if changed
Algorithm to be carried out

Start Time
(Time of day)

demon on changed
Rule 16

Finish Time
(Time of day)

demon on changed
Rule 16
Algorithm 1.

Calculate / Estimate Distance from
NewTrip Pickup Address / Zone Code to
Shift Trip Pickup Address / Zone Code (using Brain)

Calculate / Estimate Travel Time for
this Journey (using events)

Calculate / Estimate Distance for New Trip

Calculate / Estimate Travel Time for New Trip
Algorithm 1 cont'd.

\[ \frac{1}{\delta} \left( \text{Time}(T_1 P, T_2 P) + \text{Time}(T_2 P, T_2 D) \right) - \left( \text{Time}(T_1 P, T_1 D) \right) > \text{Extra Pickup Threshold} \]

\[ \text{then } (\text{Pickup } T_2 \text{ first}) \]
\[ T_2 \text{ Pickup Time } = \]
\[ T_1 \text{ Pickup Time } = \]
\[ \text{Time}(T_1 P, T_2 P) \]

\[ \text{else } (\text{Pickup } T_1 \text{ first}) \]
\[ T_2 \text{ Pickup Time } = \]
\[ T_1 \text{ Pickup Time } + \]
\[ \text{Time}(T_1 P, T_2 P) \]
\[ \text{end } T_2 \text{ Dropoff Time } = T_2 \text{ Pickup Time } + \text{Time}(T_1 P, T_2 P) + \text{Time}(T_2 P, T_2 D) \]
\[ \frac{1}{\delta} \left( T_2 \text{ Pickup Time } - T_2 \text{ Stop Time} \right) > \left( \text{Time}(T_2, T_2 P) + 10 \right) \]
\[ \text{then} \]
\[ \text{Can't get from previous stop is } T_2. \]

\[ T_1 \text{ Dropoff Time } = T_2 \text{ Dropoff Time}. \]
\[ \frac{1}{\delta} T_2 \text{ Dropoff Time } + \text{Time}(T_2 D, T_3 S) > T_3 \text{ Stop Time } + 10 \]
\[ \text{then} \]
\[ \text{Can't get to next stop is } T_3. \]
Algorithm 2

(Used to determine what to do when a trip is affected by an event.)

3 options:

1. Calculate delay and offer trip on that basis.
2. Calculate trip time to avoid event and offer.
3. Use GIS to calculate route avoiding affected zones.

Requires clearer definition with GIS.
1. If the purpose code is in 
   \[ \text{Education, } \text{Health, } \text{Transport, } \text{Miscellaneous} \] 
   then Special Occasion is True.

2. If Special Occasion is True 
   and Special Occasion Code is Use All, 
   then Use Alternative is True.

3. If Special Occasion is True 
   and Special Occasion Code is Standard 
   then Priority is True.

4. If No. of passengers > L-Group Threshold 
   then Priority is True.

5. No. of passengers = 
   Adults + 
   Children + 
   Infants

6. If Last Use Date = "" 
   then First Time User is True.

7. If First Time User is True 
   then Priority is True.
If Popular Destination is True then
  For each Shift
    For each Trip
        and Flexible is True
        then
          Prompt to suggest alternative pickup time.
          Algorithm 1 to determine likely alternatives.
          Display map on screen.
          PUU + DOO + Times.
          Accept

Create new frame: Allocate
and fill it with corresponding possible alternatives.
Rule 14
For each Event
   If (Event.Code = Trip.Date) AND
       (Trip.Zone.List \( \cap \) Event.Zone.List \( \neq \) \( \emptyset \)) AND
       (((Trip.Start.Time \geq\) Event.Start.Time) AND
       (Trip.Start.Time \leq\) Event.Finish.Time)) OR
       (Trip.Finish.Time \geq\) Event.Start.Time) AND
       (Trip.Finish.Time \leq\) Event.Finish.Time)
   then
      Event.Relevant is True AND
      add Event to Relevant.Events.
   end if
end for

Rule 15
Refuse is True
For each Shift in Shift list
   If Shift.State = 1 OR Shift.State = 2
      then Refuse is False
end for
Rule 16

For each Shift
If (Trip Start Time < Shift Start Time) or
  (Trip Finish Time > Shift Finish Time)
then Shift List Shift State = 3.

end if

end for

(Note needs another rule to handle whether
the vehicle can reach the first pickup from
bus by the time required.)
Estimated distance is 2.6
Estimated duration is 38
Suggested pickup time is 9:30

Destination Address:
Tesco
Church Street
Camden
London

Destination Comment:

Adults: 1
Children: 0
Under 5’s: 0

Driver Code: DRV
Vehicle Code: VEH

Trip Type: Outward
Trip Date: 26/09/1997
Trip Time: 9:30
Duration: 38

Pickup Address: 137 Iverson Road

Trip Details:

- Standard Fare: 12345678
- Total Fare: 12345678
- Make favourite
- Cancel

Map Layers:
- Sheds
- Stops
- Stops Selection Sets
- FFD
- Current Trip

Schedule Assistant:

- Display
- Sheds
- FFD
- Current Trip

- Trip Details:
  - Standard Fare: 12345678
  - Total Fare: 12345678

- Cancellation Code:

- Distance:

- Make favourite
- Cancel

- Trip Details:
  - Standard Fare: 12345678
  - Total Fare: 12345678

- Cancellation Code:

- Distance:
TESCO, CHURCH STREET is a popular destination. Select a time to drop off there, or press Cancel.

10:00
14:00

CANCEL  View Popular Destinations
Details

Trip Type: Outward
Trip Date: 26/09/1997
Trip Time: 9:30
Duration: 38

Pickup Address: 137 Iverson Road
Zone Code: 37CB
Area Code: CA

Destination Address: 1 Fitzroy Road
Zone Code: 39HB
Area Code:

Trip Purpose: Social - Visiting Friends & Family

Pickup Comment:

Destination Comment:

Adults: 1
Children: 0
Under 5's: 0
Inter Area: Yes

Shift Code: FixF1
Refusal Code:

Driver Code: DRV2
Cancellation Code:

Vehicle Code: VEH2

Standard Fare: 12345678
Total Fare: 12345678

Click on the Map
Recommendations on route.

Estimated distance is 2.6
Estimated duration is 38
Suggested pickup time is 9:30
<table>
<thead>
<tr>
<th>Passenger No.</th>
<th>Surname</th>
<th>Details</th>
<th>New Passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td>8961</td>
<td>Walsh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Trip Details**

- **Trip Type**: Outward
- **Trip Date**: 26/09/1997
- **Trip Time**: 9:30
- **Duration**: 38 minutes
- **Zone Code**: 37CB
- **Area Code**: CA
- **Destination Address**: Tesco Church Street Camden London NW8 8BH
- **Trip Purpose**: Shopping
- **Refusal Code**:
- **Cancellation Code**:
- **Distance**:
- **Standard Fare**: 12345678
- **Total Fare**: 12345678
- **Vehicle Code**: VEH2
- **Driver Code**: DRV2

**Service Details**

- **Wheelchair User**: Yes
- **Wheelchair Always In Use**: Yes
- **Under 5's**: 0
- **Children**: 1
- **Adults**: 1
- **Shift Code**: FixF1

**Other Details**

- **Pickup Address**: 137 Iverson Road NW6 2RA
- **Pickup Comment**:
- **Refund**:
- **Take Booking**:
- **Automatic Saves**:
- **Delete Booking**:
- **Delete Client**:
- **Delete Address**:
- **Load Addresses**:
- **Load Clients**:
- **Save Clients**:
- **Save Addresses**:
- **Show Addresses**:
- **Show Client**:
- **Show Booking**:
- **Show Shift**:

**Notes**

- **Area Code**: CA
- **Destination Comment**:
APPENDIX I

Prototype Evaluation
Prototype Evaluation - CLDAR

Booking System

1. What do you think of the options in the windows?

   The map is good.
   The addresses need to be more accurate.
   Need to see the time taken between addresses.
   The BCOs schedule themselves.
   Could help with re-scheduling.
   Takes up too much time.
   Cannot look at all 5 sheets together.
   Better when the schedule is full.
   General overview of the map is better than (sm) areas shown on the screen.
   Good for seeing when people from 2 areas are going to the same place - can be put onto other area shifts.
   Would allow re-scheduling to start earlier.
   The time taken to take the booking would be too long using the computer.
   Would allow access to more booking times - BCOs could share schemes.
   The main problem would be the size of the screen and showing schedules.

2. Do you like the layout of the windows?

   The layout is in a logical order, similar to how it's done now.
   Would like to see outward and return on the same screen.
   Do not like the traffic light colors because not disability friendly - of no use because takes up too much time to look at them, may as well look at a blank space on the sheet - clutters up the screen because don't want to see unuseable shifts.

3. Do you have any general comments?

   Difficult to deal with unfixed shifts - do not want the system to dictate this.
   How many extra trips would the system provide - that is the key - probably not enough to warrant it.
Not impressed with windows.
Needs to handle multiple members - taking more than one booking.

GIS

Want to see effect on other bookings.
Length of time spent on the vehicle needs to be shown - speed is very important.
2/3 trips together highlights where multi-passenger can be carried.
Need to see easily affects on other trips.
Improve driver times and amount of driving.
Re-scheduling refusals - would be useful for this.
Move trips of driver is sick.
Maps are too small for initial mapping.
Zoom in and out quickly.
Need to be able to pan the map.
Keep the labels.

General

Doesn't suggest optional routes.
Length of time to get information into system before get anything else.
Only one shift at a time.
Taking multiple passengers/group trips to popular destinations.
Short-cut keys required.
Batch multi-trips in advance - ie. group hire
Need to be able to store regular trips.
Like being able to see the map on the screen and how a change in the shift can happen.
Like being able to find addresses.
Prototype Evaluation - CLDAR

Booking System

A: What do you think of the options that the prototype offers?

NL: Well I'm quite impressed with the graphics, not only do you have to spend time working out or guessing where the addresses are, you can also get it wrong and this would help with areas you don't know well.

CL: Well, basically the software is already out there, the London A-Z is on disk and you can add to that. The bit that could be an advantage of that is having the az and being able to see thats south london there, she wants to go there what's the time between them? That's an advantage of the BCO to be able to say that. And to do the scheduling itself. The other thing I found is that the whole concept is looking at rescheduling rather than scheduling.

A: How do you mean?

CL: Well, it could help with a lot of rescheduling, but I'm not sure if, at the moment you could go in there and do scheduling as it was going on as I think it would take up too much time.

A: While someone was on the phone?

CL: Yes. I think what you were saying earlier, where we look at five sheets, and we do just look at five sheets and its that fast. You can't do that that fast on screen. You've got your map in front of you as well. If you was on screen looking at the AZ its Markson road to church street which is five to six minutes, then you've already got that in your head when you're looking at the sheet. Five to six minutes. I'm looking for somewhere for five to six minutes and where I can add that to my sheet.

CL2: I think where it is useful is where its getting to the point when I don't know how im going to fit anything in, you know, where can I fit this in and what effect will it have, lets have a quick look at the map. I think maps are really useful for looking at how far it deviates this bus and lets have a look at this area and see if there's a bus in this area, where its going and whether we can actually put it on.

CL3: An overall general overview of the map is actually more helpful than a small enlarged piece of the map. It only tells you were someone lives, it doesn't really tell you where they are going or what sort of areas we are going to be going through. Unless you've got a large scale map.

CL1: Yes, if you look at the area you're going to be in when you're booking your visit you can add that up on screen. Like you do autoroute, you look at autoroute and say I want to go to bristol via wherever it gives you this flashing line suggesting a route for you on the screen, on
the map. Now if you've got that as an overall saying I want you to go from a to b in this area then the map comes up with that area and its already giving you a suggested route. Going back to the rescheduled thing, later on, you're looking for rescheduling, if the computers already got all this data in then the computers chugging away and could suggest you could pick this one up. (tape goes quiet) .... rather than put it on that sheet. It is then an aid to rescheduling because its then turning round and saying to you Look (missed a word here) .. the BCO but may I suggest this, and the BCO then has a yes or no on it, when they're rescheduling, so its helping to reschedule rather than actually schedule.

CL: An area where its going to help is where you've got people from two travel areas going to the same place as that would actually show up on the map.

CL: Draw them together yes.

CL: So you'll actually be able to say to the person behind you, next to you or whatever oh you're trip xyz Im going to put this one on with that. Because at the moment you actually have to ask them So you could actually start doing that, rescheduling, earlier in the process rather than later. At the moment, your line may be reasonably quiet. Their line, they may actually be talking on the phone.

CL: Also of course, if it was on there then they have actually used the shift over there, you can say right I can combine the shift ... you've got your five sheets in front of you, but that person of threes got another five sheets in front of them, but you cant see them but the computer has got the data in there and its telling you that hey your buddy over there has got someone going that way anyway, you can just turn around and say ok i'll just bung it on there.

CL: The major problem is that if you're a completely manual system, you're going to take a booking on their sheet, and because you're on the phone you're not going to get it through.

CL: You've got to take every booking fully on the computer, from when you start. You can't just put in the name and a couple of postcodes because you know exactly what it is. If nobody else is tapping into what you're doing you'll know what you've already scheduled in.

CL: You're saying no, telling it not to do that but if the computers already worked out, it already does that, its already worked out that you can't put somebody else on there because basically its already doing that. Its already done it this way and so if the other bco is now looking at it and they got blank spaces then they say well I might be able to do that 'bop-bom' and then putting it in and then the computer coming up and saying its now deviated off to somewhere else then they know its already being used by the other person...

CL: Not quite sure about .... (tape goes quiet)

CL: You've got a trip going from a to b and you've got it on your 11:00' clock and there won't be an 11:00' Clock and someone else has got somebody going similiar to or on route and is going
from a to b and and the other person is going with C when it goes to c you will have to cut somewhere else then it tells you, the computer, because its already got the information from the other person anyway, its telling you that its already going somewhere else anyway. It tells you that now that its going somewhere else.It suggests another route to do it, so when it suggests another route, you know why is it suggesting another route ? Because its already got someone else on there, so you know someone else is already allocated another space on that bus.

CL: By the time you’ve pulled one in, it would have been just as quick to ask.

CL: Sometimes you don’t ask because the other person is busy.

CL: Yes

CL: You then put it on one of your vehicles and that would send your vehicles to almost on top of the other persons vehicle and its not till later on in the day when its to late because you then cant move both of those jobs onto another vehicle,

CL: Especially that one being arranged.

CL: Yes, thats right, you’ve got to be able to get their earlier, but it does come back to the amount of time it takes to take/schedule bookings

CL: This is what im saying because the first 15-20 minutes sometimes you dont put any trips in at all.When you’re taking bookings. If you know the area and you know the people you’re dealing with.You’re just pencilling things in, ready to go back into them later.To have this running efficiently, you just note the booking down at the start of the booking period, it depends on how experienced the bco is of course.

NL: I think it goes back to what Peter said that this is going to be more useful for rescheduling than scheduling I think what we have to look at is what we really want and I dont think we should be looking at the case where the computer does all the scheduling.

CL: Oh no.

NL: (not sure about this bit .... Thats not to mean we are willing to a taxi service but not) I think we will definitly have a problem like we were saying, it would be easier to pencil stuff in and then later on put them in. But at the same time, it’ll be also giving you suggestions, so maybe, to make it work effectively, we’ve got to ignore some of those ones,

CL: Oh yes.

NL: Where we’re saying F1 or F3 or cover we’ll take it you know, you have your sheets in front of you so maybe you want to do that, cos you might not want to go into, you know that you dont have any F1 at all. You know you have a few covers and so on for that particular area so you might tend to ignore any suggestion of F1 and use just what you know then later on doing the rescheduling see where it suggests F1. Then to go on to Richards case where you know that would be a problem that its too late to reschedule so (couldnt understand next bit)
C1: Yes, it is.

CL: Very often, once you've got a shift and it's tight although you could say I'll take all these trips apart and out them back together again, you can't because you've already given all these people these times and you can't phone up and say "well actually we're not going out in the morning, we are now going out in the afternoon".

CL: It just doesn't work does it.

CL: That's right, they don't go out, or they won't be in we just haven't got the time to do it, whereas in the morning when we were on the phone we could say, I won't take you out at 11OClock i'll take you out at 1OOClock.Then the person would have been far more flexible about doing that. That's the flexibility about getting it all into the computer system at the time.

What it does give you the opportunity to do is to have shorter, have more booking periods. So more because take bookings from one travel area at one time because you are all sharing, you can all share sheets, which you weren't able to do in the past, and then go onto another booking area...

CL: So the sheets are on screen.

CL: Yes.

CL: So what happens if two people are booking a trip in at exactly the same time on the same shift?

CL: One will get it one won't.

CL: Yes.

CL: So it's first come first served, which is the case at the moment if you're sharing sheets with someone.

CL: If you're sharing sheets...

CL: To a certain degree it is...

CL: But at least you can just look over...

(Bit of speech overlapping here, you work it out mate)

CL: ...Sod off somebody else has just got a trip in there, just as you think you've got the space.

CL: What the newcastle system does is it changes colour. The moment somebody says 11 thirty, there's a preliminary 11 thirty so you can actually see that somebody is offering 11 thirty. What that does do is it means you can spend longer taking the bookings.

CL: You're gonna make both you're bookings at the same place, but the computers still gonna tell you that you can't have the space because somebody else has it.

CL: If you're about to go for the same space then hopefully the computer we actually know.

CL: Well yes
CL: And presumably will schedule both together.
CL: Thats because its taken johns friends back to checking all the details are on screen so that when someone phones in, you’ve got to put their number in and the time in that they want to go to and from. You need them in there to tell you that will be a gap whereas this person is ten seconds behind you and he’s going to put in there 11 o’clock going and he’s now go to compare if they’re compatible and if they’re not compatible turn round and say sorry.
CL: Yes, what its trying to do would be to average out the time of booking so the person who gets through in the first five minutes doesn’t take 30 seconds but maybe a minute and a half. The person who gets through after 1/2 hour wouldn’t take 6 minutes but would still take a minute and a half, but the only way to do that is to have BCOs on the phone at the same time.
CL: And then the biggest ocmplaint we get is the amount of time it takes to get through on the phone but you’re going to spread them out doing that and then it’ll take longer for people to get through on the phone.
CL: The way to stop that is to put more BCOs in for the same period and then it wouldn’t take so long.
CL: It would need to be compared, you’ve got 2 BCOs on the same area and then booking for the 5 shifts but then if each one is taking a minute to take a booking and then the longet it goes on, the longer the booking is resolved, the longer it takes to search through the sheet.
CL: I would disagree witha that.
CL: You’re standing there and you say someone wants to go out at 11 o’clock so you say 1/4 past.
CL: But you’re going to say if you move that one over there and this one down here then I can take them. You’ll always have that, even with someone woh’s taken an hour and a half to get through, you’re still going to get the same problem.
CL: Yes, the later one is far more difficult. If the first one comes through it only takes a minute because all you do is check the number, want to know where they’re coming from and where they’re going to and their times.
CL: But the problem in the first place is how long it takes to get through on the phone.
CL: But what I’m saying is its the first one after the first 1/2 hour, the first one only takes a minute becuase its a blank page.
CL: But it doesn’t matter if they get the trip or not, its the amount of time they’re taking to get through.
CL: But instead of having 2 you had 4, so all the times are going be halved and the time are going to be halved throughout the whole lot. You see instead of booking 2 areas, you’re having 4 booking on one area
CL: So you’re going to cut down the time people can phone through on their area then, so its going to make it worse.

CL: Well it need not necessarily cut down on the amount of time it takes to take bookings for that area, bookings will come through so you could leave the area open.

CL: But even then you’ve got people saying well I can’t phone in the morning or I can’t phone between 9 and 10.30 and I’m out in the afternoon, you’re going to make it even more difficult.

CL: But I don’t mean that you close a booking line down, what you do is try and get more of your bookings through on that line. You still have th booking line open and what you find is that people won’t be moaning because bookings are being taken which is the same case as theirs. If you have your booking line open for 6 hours people phone after 6 hours.

CL: You’ll still get the occasional request that will fit in.

CL: What you’re doing is not answering the phone all the time.

CL: But if people know that the phone is on all day?

CL: There’s no reason why you shouldn’t have four people to start with taking dedicated bookings for area CA and then line be diverted to one person who takes CA and then Cbts taken and then gets transferred to that person because you’re no longer typing in trips within a limited time. And that’s the only way I can see having the schedules on oscreen. I’m not saying its the right answer but that’s the only way I can see it working because of the time factor, getting all the information on the screen.

A: I was wondering what you thought about the order in which you enter data on the screens. Do you think that what we display is accurate? Does it follow the way in which you would enter data manually?

CL: Well its basically what we’ve got at the moment.

CL: Its just a logical order. You’ve got to have a user name to identify the user which ever system you have you need to identify them one way or another, you do that by name or by the number. In this case we use a number and it automatically lifts the data using the number.

CL: The logical thing is wanting to know where to pick them up and drop them off. I guess sometimes the destination is more important than the pickup.

CL: On the system when we looked at it, when Simon did a return trip, what happens if someone took 2 outward trips on the same day but they’ve booked to go somewhere in the morning and then someone is bringing them home in car?

A: If you have just a one trip you can put it down as outward and then you can just leave it that. If you wanted to do the afternoon trip straight away it would bring the morning trip up as the default but you can override them.

CL: It automatically defaults?
A: Yes, with the outward trip it automatically defaults to the home address, and with continuous it uses the last drop off address but you can change them all. It only defaults because they tend to be more common.

CL: Oh, yes.

CL: It would be nice to have the outward and the return on the same screen so you could type in the return time at the same time as the outward time because at the moment what you do is the outward and go through the whole thing and then start another one for the return. Fairly often it's the same shift anyway. There isn't a lot of room taken by the return trip, it's a standard return trip, all you need is another set of those lights and that should be your return trip. Obviously there are going to be times when you need to expand on the return trip because it's not coming back from exactly the same place or whatever.

A: Did you think that the idea of having the traffic lights shifts showing up as being different colours was useful?

CL: Quite honestly no. By the time you look to see which ones are available you'd be just as quick to see the gap on a shift even if was on a screen you'd see a gap far quicker than you would go down and go oh that shifts free, that shifts free and then you've got to find those shifts.

CL: The other thing is you haven't got enough vehicles, presuming that you'd want to put the whole fleet across available to you, six vehicles isn't enough. You've got 30 vehicles here and having 30 lights would be too much.

CL: No, you'd only need the amount you're allocating to each area. You'd show all your resources at the re-schedule stage and not at the booking stage. You've got allocate vehicles to each shift, or rather each area so let's say you've got 32 vehicles and you've four areas, you need eight lights.

CL: Even if you're picking up in the same place and going down the same road?

CL: Yes.

CL: I'm not sure what use it is having late shifts showing for 10 o'clock in the morning, would it not be better just to see the shifts available.

CL: Well in case you were doing a return for the evening.

CL: Well it's cluttering up the screen really.

CL: Yes, you only want to see the shifts that are available not something that's available later because when you put in the timings later for the return you'll see which vehicles are available then.

CL: We're making comments on the system downstairs where the scheduling sheets are on the screen. Because at the beginning of the day you might have 6 shifts and you've probably go in
your minds eye where each of those vehicles is going and you’re going to page each of those vehicles as they go through the day. You’ll have in your minds eye that there’s a Tesco coming in on that one, there’s a luncheon club going in on that one and Mrs. Smith will want to go over and visit her daughter and that will fit nicely on that. You’ve also got to consider the variable times of some shifts, you don’t want the system allocating trips to shifts because you’ll have allocating trips that are 8 hours apart with nothing in between.

CL: You need to be able to see all the shifts together. Its far quicker when you’re re-scheduling, you spread the sheets out and you can see gaps straight away, whereas if you have to scroll through sheet after sheet after sheet you just won’t take it all in.

NL: And as you go on, you have to be doing a lot more of that and the gaps would be fewer

CL: After taking your bookings, you can turn round to the computer at the end of day and ask it to schedule in.

CL: Well it would be a useful tool for that stage but whether its worth what it costs. Everyone in this room would say well its a useful tool and I would use it at some point. You can’t sack any BCOs because you still need them on the phone for your manual system. When you re-schedule you’re only talking about getting a few extra trips in which is important.

CL: That’s where you’ve got to weigh up the cost of the system is on the re-scheduling. You need to say how many trips extra am I getting in on that re-scheduling? Its weighing up that and whether that costs of the system to how many extra bookings you get in. If for instance on the re-scheduling now you manage to get 5 trips in and with the aid of the computer re-scheduling you get 30 trips in then the benefit is 20 trips per schedule and then its worth it.

CL: I’d very surprised if it got 20 more than a BCO could get!

CL: That how you’d have to weigh up the costs though. I don’t see that it would be any faster than what we’re doing now.

CL: I’m not sure that I’m happy about using windows and having to use the mouse all the time.

A: Well on a full system you would have equivalent key strokes.

CL: Well it becomes automatic with the keys when you’re taking a booking. It would never become automatic with a mouse.

CL: The only other problem is the inability to program in multiple people with the same destination or drop off because the moment you’re counting one trip whereas there could be 20 people on the bus. Getting as many members on the bus as possible is the key thing these days.

GIS

A: I’d really like to know your opinions on the options, layout, data entry.
NL: I like the bit where it tells you if two people can travel together. I think that would be really useful.

R: Its got to work fast enough to be of benefit and you need to see the affect of all the other trips because if you keep putting different trips in and changing peoples times by five minutes you'll have someone going out an hour later than they've booked for.

P: I still don't see this as a scheduling tool, more as a re-scheduling tool where everything is on there and you've got your refusals and you sit down and ask the program by putting the times and destinations in and the program then runs through itself of what its done during the day and then lets you know if it will fit on one of the routes. That's what I envisage it doing.

R: Its not going to be any use until you've got some data.

P: Basically what you do is put it in the system and you're doing your manual scheduling and then at the end of the day rather than you sitting there trying to sort it out yourself you then type in your refusals or possibly bring up your refusals on the screen, highlight the refusal, the computer takes that away, searches through itself and then gives you an option where to put it in on the schedule.

R: It would also be useful for when your driver goes sick and then you could re-schedule their bookings.

A: What did you think of the layout of the maps and the dialog boxes?

D: Well its a bit much for me, it seems quite complicated. It seems quite logical but you had to do a lot to get stuff back. It could be simplified.

R: Mind you, you don't know how much Simon was doing because its still in the developers kit. I think the A-Z map is useful but it is hard to see the routes.

D: Yes, its still too small for actual initial scheduling.

P: You can get the geographical A-Z cd and take out the colours, that would also allow you to put in your destination as well. You can actually put that in physically on top of your map. For example, if you wanted to go the post office on Kilburn High Rd, it would show you there on the map and that's already available to us on a £200 cd. Who makes the map in this?

A: Bartholemews.

P: Yes, you see we use the A-Z.

R: I think being able to zoom in and out quickly is important.

P: I don't know if that was the max or min that you could move in and out?

A: I don't know, you'd have to ask Simon.

D: Well, the max zoom in, remember that bit with the actual road on it, was adequate if you're looking for somewhere.

P: If you want to get down to see routes..
D: Yes, if you want to get down to one grid square.

P: Well you’d want to go down more than that, one square is only 1/2 k. If you’re looking on a map for something huge.

R: You might deviate a vehicle 5 miles so you would want to see five miles.

P: So you want to come out and go back so you can actually see.

D: Perhaps you could use the cursor keys so you could move up and across.

A: What do you think of the use of the icons? Do you think people would get to learn them fairly quickly?

D: Well, yes I would think so if you’re going to use the system. Most people tend ot pick up on the icons fairly quickly once they start using them.

R: Possibly you still need the addresses but in a different form, possibly less data on the screen.

D: Like I said earlier there seems to be an awful lot that you have to do to get not a massive amount of information out. Probably because I can sit there doing bookings all the time, I can see it differently to NL and R.

R: I think that one of problems was that because it wasn’t working properly we couldn’t see how things could be done quickly. Simon was perhaps doing 10 steps when only three of them would be needed normally. I think also that one of the things that disappointed me was that it didn’t actually suggest routes, it didn’t way try this route or whatever.

D: Yes, optional route.

NL: I wanted to ask what happens with one way streets?

A: That’s not something that’s down to this system, it depends on the map data you get. For example, A-Z have maps which show one way streets but its very expensive so we didn’t use it for this prototype.

R: So to sum up, the main concern is the amount of time it takes to get the information into the system before you can get anything useful out of it and the inability to deal with groups, multiple people to one destination.

D: And only being able to see one shift at a time. Its just so easy to have them on sheets in front of you to book one area, there’s an overall feel to it.

P: I’m just wondering how much information you actually need. On the left hand side of the screen you’ve got a time scale and then you’ve everything else on the left hand side as well, if you could section that off into five shifts.

R: The problem is while there isn’t much on the scheduling sheets, the information is varied. There’s different amounts of information about each journey which is important because in some cases its a persons name, like Jones or Smith and they know who they are and where they’re going. In another case Jones or Smith isn’t filled in but Sainsbury is as a destination.
and that’s the key for what that journey is. On another occasion it might be a reasonable
distance out and you might just use the zone code.

P: A lot of the things you first look at are basically the minimal information, W1 to W1, then if
I’ve got that basic information I can then look to it further. If I’ve got something there that
wants to go from W1 to W2 then I can say, then I can say to that person, I’ve got a vehicle in
that area at around about that time, they’re not going to look up that and then double click for
the rest of the information because the basics are already there. When your scheduling you’re
looking for something in W1 and I’ve got someone there saying I want to go to W1, I’d look at
W1 and then I’d zoom in afterwards. The actual location in W1, whether the vehicle is big
enough to take another person etc. is all going on very fast. The initial thing on the screen is
your shifts and that this person wants to go from W1 to W2 and basically I’ve got this person
on the phone who now wants to go into W1, can I match those two up? And that all comes in
after you’ve started doing up the shift because in the initial 10 minutes you’ve got plenty of
room to put it in.

R: Although you’re not just filling in gaps. You’ve already got some concept of how you want
that shift to look before you even start taking bookings.

D: Many it hinges on the first booking that comes through and your advance bookings.
Collaborators Evaluation - Notes

Booking System

Screen layout very clear.
Foolproof - looks simple to use.
Good that the computer tells you where to schedule.
Reflects despatcher concept.
Takes onus off despatcher knowing the area.
Needs fare calculation.
More information to hand while the passenger is on the phone - no problem with time taken up.
Like traffic affect - particularly useful.
Needs to tell you when the bus is full - ability to see external shifts + invoice for this external bus.
Clarity/user friendly - follows through.
Visual representation of traffic lights.
Shift blocks of time - know when the passenger is on the bus for whole of that period.
Mapping system particularly useful - handy information.
Visual understanding is very useful.
Suggesting times is useful - helps get more people on the bus.

GIS

Representation is excellent.
Offers possibility of making connections might not otherwise.
Could review routes?
Get rid of booking number display - only need time and address.
Would like to be able to display bookings details.
Short-cut keys required.
Overlay shift details - good.
Stops you having to look at A-Z - can utilise resources better.
Can see where the information has been taken from despatcher and put into the system.
Collaborators Evaluation - Tape Transcript

Booking System

I: I think the representation for a despatcher, it seems to offer the possibility of making decisions that you wouldn't necessarily be able to do. Having a representation like that would mean you could.

D: Would it be clearer if you didn't have the whole booking number there, just have the time and the street because it makes everything too big and too long to look at, all you need to know is the time and the road they're going to be because then its now encroaching on all the other data that's on there. Without having the booking on the screen you could still zoom into the booking couldn't you? If you actually click on the booking number does it show you the booking details?

S: No it doesn't. It possibly could except you wouldn't want to go back to the expert system part, you'd want to do it from in here.

I: Can you have it go to full screen? Not have all this stuff here and just flick back and forth.

D: They'll all go full size won't they?

A: Yes.

D: The only problem is, is that you've got, if you have a full screen and you've still got to have your controls.

I: I was just thinking that if you had a key stroke you could flick back and forth.

D: So in theory, if you were to have several shifts in one day could you overlay one shift over the other? Say if you wanted to pick, if you had four shifts and you wanted to look at the shifts between 11.00 and 1.00 you can overlay the details of those shifts so you could look at them.

I: Could you have it so you could see positions having scheduled the trips, you could see the positions at a particular time.

D: I see what you mean, you know that this journey is going to take 13 minutes so you want to know where the bus will be at 10.30, is that what you mean?

I: Yes, because at the minute you've got a representation of routes, distances and time, it would be nice to tell really by looking at that, it would add another dimension to it.

D: So question box, click on the part of the route that you want to look at and it will tell you the approximate time that that part of the route will be covered. Not that we want to be too complicated about these things!

I: You could have representations of different types throughout the day so you could think of that could go there. You could isolate a certain time.
A: So what do you think of the options available to you?

D: I can only see that being of any use to someone who wanted to book off the telephone. You want to know where your vehicles are now, you want to be able to contact that vehicle and say you've got your passenger on and your going to so and so. To actually know along that route, it doesn't make any difference. Surely you can estimate, like for instance there I would look at those two bookings and if I was going to put these two on the same shift I'd either say to this person right you're going to be picked up at 10.45 and then go there and there and there or be picked up at 10.30 you'd have to go early to get there and back to there because you don't want to get there too early. If you can edit the times like that, then yes, you know once those ideas are put into that system and once he's overcome that I think that would work very quickly as well. It would be very useful.

A: A lot of the buttons he's pressing to get that, is because he hasn't had time to set it up properly. All this stuff at the top of the screen would go.

D: Well its all part of the development program.

A: And an awful lot of the dialog boxes that he clicks are part of development too, it would be much more like you saw this morning.

D: You could get the bookings as you go through each one and then look at that and the computer tells you the journeys that you've already got, the journey that you're looking at, and then you could because that detail comes up straight away you can say to your passenger well I can't pick you up at 11.00 I can do it at 10.45 because you know the vehicle is going to be going past there at that time and they can accept that or refuse, whatever. If not, obviously you've got to look at another shift or just say no. And in a lot of cases we have in the past said to passengers, it they're not going to be flexible by fifteen minutes well I can't fit you in and then the next time they phone up they are flexible because you've got to condition people to realise that although you're there for them you're not just there for them but all your users. So, yes I think that's useful because you know that vehicle is going to pass where that person lives. You can see that without having to have the streets you can see where that vehicles going and you can see that its going to go past the end of that person's road at about 10.45 so you say to the passenger well that's the time I'll offer you and then it fits it into the shift. If they don't want to be there too early where they're going, then you would have assumed that they'd book a bit later or you'd go the other way around and drop off the third passenger first. Its handy just like that, if you have just some basic main road details in the background rather than having, I think the bit map picture of the areas are a bit complicated because there's too much
on there at one time. I mean if you’ve got just got your actual streets as the lines like that, then
that’s exactly what you need. Because you can actually see from there that if they had to to the
driver could drive up there, pick them up, come back and carry on the journey. I mean,
obviously the computer would change that to go down there and down that way or whatever
but you can see that its going to fit in because you can see now there’s a road, however the
computer works it out is not going to be the same as the driver would do it but you can see that
he can do it. And then to be able to go in from there, you’d have your booking details, the
computer shows you a visual representation of where the trips going and the other bookings at
that time on a particular shift or any particular shift and then you edit the times to fit in with
what you’ve got and then your booking’s done.
S: (**says something here but can’t hear it **)
D: Well, you wouldn’t necessarily need to see every street or close. When we select a new
despatcher we show them a picture of the ring road and ask to the point out say Wollerton, we
expect them to visualise that, you might have an A road going across the screen but that’s it.
This would provide useful and relevant information for despatchers. As you say, when the
technology becomes faster to actually transfer across from one to another its going to be so
much easier to have both systems working. I like the idea of both parts of the system, it would
be interesting to see what would happen if they became commercial. For our dial-a-ride it
would certainly be useful. I can see where you’ve taken the information from the despatchers,
you’ve used the information to tell the system how it should do things
Dear Anne,

Thank you for inviting myself and Mr Hatfield to review the results of your work. We both enjoyed the hospitality and were impressed by the visual demonstration.

Having had some involvement at the beginning of this project, as a collaborating organisation, I have to report that the demonstration version of the program performs better than expected.

I can see that from the complexity of the system it has had to involve a great deal of decision making. Obviously the information gathered by yourself has been productive in developing a system that has an impressive image and takes some of the guess work out of the despatching environment. The system was using the decision mechanisms that were previously discussed with the despatching staff and this helped us to visualise how the system dealt with the booking requests. I would expect that if continued to a conclusion the system would be a great help to organisations in the transport sector wishing to economise on vehicle mileage and travel time.

I hope that you would furnish us with a copy of your final analysis of the project, if that is possible, and wish you every success in any future ventures you embark upon.

Yours sincerely

David Tye
Operation Manager
APPENDIX J

Published Material
A DECISION SUPPORT SYSTEM FOR SCHEDULING DEMAND-RESPONSIVE TRANSPORT: TOWARDS A HUMAN CENTRED APPROACH

by

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The dynamic process of scheduling in a 'many-to-many' or 'many-to-few' style of operation, where multi-occupancy of a vehicle is required, in proving ever more difficult to administer manually. It is also clear that attempts to computerise such a system totally are at present neither feasible nor desirable. Discussions with schedulers and their managers suggest that there should be a middle way, which exploits the benefits of computerisation (in handling the administrative functions of database management) and enhances the skills of the schedulers (in freeing them up to give greater attention to making allocative judgments). To do this, it is necessary to gain as complete and objective an assessment of the skills of schedulers operating in a manual environment; and to extract from these those tasks which can be:

(a) usefully routinised by computerisation,
(b) enhanced by a decision support system and
(c) evaluated in terms of their effectiveness.

Figure 1. Diagram representing mathematical solutions to scheduling problems which produce a cognitive dissonance between human heuristics and computer solutions.
A decision support system for scheduling demand-responsive transport

Currently available systems for the scheduling of trips are based on mathematical techniques, such as linear programming. Schedulers do not recognise the heuristics they use in the scheduling software. There is a dissonance between the human approach and the mathematical solutions which are implemented.

This research uses methods drawn from the systems analysis of expert systems and explores the requirements for a more effective approach to dynamic scheduling which appear to rest on four main topics:

(i) Elicitation of the knowledge required and heuristics used by schedulers in making scheduling decisions;
(ii) A visualisation of the scheduling function through identification of the key assumptions which schedulers employ when making scheduling decisions [based on (i)];
(iii) The development and prototyping of a computer-aided decision support system [based on (ii)]; and
(iv) Evaluation of the effectiveness of the decision support system by comparing its performance with that of an unaided scheduling method.

![Diagram representing the approach based on eliciting the knowledge of schedulers.](image)

Four UK dial-a-ride operators are taking part in the research, which has reached the second of the stages listed above.

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REFERENCES


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Knowledge Elicitation Techniques for Grounded Theory

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Abstract

Knowledge acquisition is recognised to be the bottleneck in an expert system's development. Much research has been carried out into techniques to aid in this process and, indeed, computer based tools now exist for knowledge acquisition. Grounded theory is a methodology for deriving theory that is discovered, developed and analysed through systematic data collection. It is an iterative process and stresses the importance of people and experience as continually evolving. It is anticipated that knowledge acquisition using techniques based on grounded theory will provide richer and more complete contextual knowledge and help to overcome the knowledge acquisition bottleneck. This paper describes an approach using knowledge acquisition techniques with grounded theory and presents the results of applying it to case studies for scheduling of community transport.

Introduction

Knowledge acquisition has been described as the bottleneck in the development of expert systems (Feigenbaum and McCorduck 1983), and some authors have quantified this in terms of the hours spent by knowledge engineers and their experts. Medsker and Liebowitz (1994), for example, suggest that an expert talking continuously for a day will produce 300 to 500 pages of transcript. Others suggest that this is only the case where the domain is broad, complex and requires deep knowledge from experts whose availability is limited (Cullen and Bryman, 1988). Davies and Hakiel (1988) suggest that the problem arises from the nature of human expertise and its foundation on increasing levels of automaticity of physical and mental processes. Forsythe and Buchanan (1989) suggest that the problems with knowledge elicitation lie not with the methods used but with the lack of communication skills on the part of the knowledge engineer. These authors are all addressing knowledge acquisition in the context of the development of knowledge based systems, while Cooke (1994), in her review of knowledge elicitation techniques, points out that knowledge is of interest not just to expert system builders, but also to cognitive psychologists, educators and employers of knowledgeable and skilled employees. Techniques for the acquisition of knowledge are therefore of more general importance and applicability. Knowledge based methodologies are available for knowledge acquisition, for example KADS (Knowledge Acquisition and Documentation Structuring). A knowledge based system in KADS is a model of some problem solving expertise (Beynon-Davies, 1993). It is not the intention of this research to investigate previously tried knowledge based methodologies. In the case of this paper, we are addressing the elicitation of knowledge as part of the development cycle of a knowledge based system, and in particular for the scheduling of transport.
The paper is focused on the process of knowledge acquisition in the context of a Grounded Theory framework. It explores the relationship between the acquisition of knowledge and the development of new knowledge. The paper introduces the concept of knowledge creation and discusses its role in the formation of new knowledge. The author emphasizes the importance of understanding the context in which knowledge is acquired and how it influences the process of knowledge creation.

The theoretical framework is grounded in the work of theorists such as Edward de Bono, who developed the concept of lateral thinking. The paper also draws on the work of other theorists, including Howard Gardner, who introduced the concept of multiple intelligences.

The paper argues that knowledge acquisition is a complex process that involves the integration of new information with existing knowledge. It suggests that the process of knowledge creation is influenced by a variety of factors, including cultural context, personal experience, and social interaction.

The paper concludes with a discussion of the implications of the findings for education and research. It suggests that educators and researchers should focus on creating environments that facilitate the acquisition of knowledge and promote the development of new knowledge.

In summary, the paper provides a comprehensive analysis of the process of knowledge acquisition and its role in the development of new knowledge. It highlights the importance of understanding the context in which knowledge is acquired and how it influences the process of knowledge creation.

Grounded Theory

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Grounded theory is based on the method of comparative analysis. The data is broken down into units, or codes (Strauss and Corbin, 1990). The codes are grouped together according to their commonalities or categories (Strauss and Corbin, 1990). The categories are then searched to find similarities between the categories. The similarities among categories are conceptualised by the grounded theorist as higher order categories. This conceptualisation gives rise to a hierarchical structure in which, eventually, a supreme higher order category called a core category is grounded in the categories it subsumes. The categories beneath it are grounded in the categories beneath them and so on until the lowest categories are reached, which are grounded in the codes. The codes are grounded in the data (Rennie, 1994). The theorist records any analyses related to the formulation of theory in memos. Memos contain the products of actual coding, theoretically sensitising and summarising notes and provide directions for sampling (Strauss and Corbin, 1990). The memos form the basis for writing theses on the research.

Problems with Grounded Theory

There are a number of problems associated with grounded theory. Pidgeon et al (1991) discuss the practical problem that grounded theory is highly labour intensive. It is suggested by Pidgeon et al (1991) that the researcher ensures that grounded theory is actually appropriate for the proposed application. Details that should be considered are the suitability and the availability of the data, the features of the problem domain and the final system requirements. By doing these simple checks the researcher will be sure that the area is worth the labour.

Turley (1981) warns that when the area of research is new, a large number of categories will be developed initially. However, as the research continues a set of basic categories or concepts start to express much of what is important to the area and so the need to add to the set lessens.

There is some question whether grounded theory actually produces theory (Bryman, 1988). He points out that much of the approach is focused more on the generation of categories rather than theory. Turley (1981) also quotes doubts whether

"the researcher is genuinely capable of suspending his or her awareness of relevant theories and concepts until a relatively late stage in the process."

as a further possible problem with grounded theory. On the whole, it appears to be the researcher him or herself who is responsible for the success or failure of a grounded theory. A further problem with grounded theory associated with the researcher is that different researchers may develop different categories and accordingly a different theory from the same set of data (Rennie, 1994). Glaser and Strauss (1967) and Glaser (1978) argue this is acceptable as long as each analysis is grounded in the data.

Knowledge elicitition techniques

To enable a knowledge engineer to employ grounded theory when developing a knowledge based system consideration has to be given to the question of which knowledge elicitation techniques might be the most appropriate. Clearly, the domain is being tackled, the types of knowledge being elicited, and the environment in which the expert works are amongst many factors that influence the selection of knowledge elicitation techniques. However we wish here to find the most suitable techniques that will provide knowledge and data in a suitable form for analysis by grounded theory.

Before we can evaluate the appropriateness of different knowledge elicitation techniques to use with grounded theory, it is necessary first to identify some of the requirements of grounded theory.

- The technique should support an iterative approach. Grounded theory requires the knowledge engineer to refine and abstract categories, and therefore to return to the subjects for clarification. Knowledge elicitation techniques which produce a one-off result are therefore inappropriate.
- The technique should produce textual material which is capable of further analysis. This material should be transparent.
- The technique should not prejudice the structure of the knowledge which is being gathered, either by structuring the knowledge elicitation in a way which presupposes particular outcomes or by imposing on it a structure which implies a future knowledge representation.
- The technique should reveal and capture both procedural and declarative knowledge and not be biased towards one or the other.

It is not the purpose of this paper to describe in detail the various knowledge elicitation techniques. Neale (1988) and Cooke (1994) both provide detailed reviews. However, for clarity, we describe briefly some of the more widely used methods and evaluate them against these criteria.

Interviews are considered one of the most common methods for eliciting an expert's knowledge. The method is simple and provides immediate feedback to help clarify issues (Holsapple and Raj, 1994). There are a number of different approaches to interviewing.

In a **Structured Interview** the knowledge engineer uses subject headings to control the order of the interview. The format and line of questioning are planned in advance. **Unstructured interviews** are interviews where the format and line of the questioning are not planned in advance (Holsapple and Raj, 1994). The expert is permitted to introduce concepts, vocabulary and ideas and set the overall direction of the interview. In the case of a **Focused Interview** the knowledge engineer prepares in advance a list of topics for conversation. The focused interview should provide factual knowledge, the type of problems solved by the expert and the functions performed by the expert. Grounded theory is recognised as a qualitative research method, that is, it ensures that produces results not arrived at by quantification methods such as statistical analysis.
A walkthrough is the process of asking the domain expert to walk the knowledge engineer through the task under observation. Walkthroughs are particularly useful in giving first indications of how experts use shortcuts and rules of thumb. They are also useful for eliciting procedural knowledge. This technique differs from protocol analysis in that it is not the thought process that is being considered but the steps which the expert follows to do their job.

Walkthroughs are used to elicit procedural knowledge. Using techniques which are process based with grounded theory provides a means of eliciting both the processes and concepts used by the expert. Walkthroughs are, in addition, case-based which makes knowledge elicited in such a manner close to reality.

There are two forms of teachback:

- The expert describes a procedure to the knowledge engineer, who then explains it back in the expert's terms and to the expert's satisfaction (Neale, 1988).
- The knowledge engineer performs a simulation of the expert task (Greenwell, 1988).

Some elicitation techniques are process based, eliciting procedural rather than declarative knowledge from the expert. Teachback is one such method. However this technique is not based on tasks as they occur and in this respect could be considered less suitable for grounded theory analysis.

Repertory grid is a technique that can be used to elicit the factors that an expert considers in making decisions (Nicholson, 1992). The technique developed out of Kelly's personal construct theory which was a method of eliciting an individual's way of thinking described in terms of the mental constructs he or she uses (Kelly, 1955). The results of this technique are organised and analysed within a frame called a repertory grid. Hart (1986) describes the repertory grid as:

"a representation of the expert's view of a particular problem. A grid is composed of constructs (attributes or features) and elements (objects)... A construct is a bipolar characteristic which each element has to some degree".

Repertory grid does not support an iterative approach to knowledge elicitation. The implication is that the grid produced represents the expert's knowledge of the categories concerned. To go back to the expert and ask them to reconsider the grid would imply that they had got it wrong. Repertory grid appears to be good at capturing declarative knowledge, but poor at capturing procedural knowledge (McGeorge and Rugg, 1992).

Induction is a form of machine learning whereby general rules are generated from a set of examples. Instead of trying to describe their rules, the expert supplies a set of domain examples of different types of decisions, called a training set, with the attributes which describe the examples and values that are assigned to the examples
Rule induction imposes a structure on the data which presupposes a knowledge representation based on production rules. It is a way the antithesis of grounded theory, allocating to a machine the task of extracting theory from data. It focuses on procedural rather than declarative knowledge, and the output is not necessarily transparent.

The ways in which each technique meets grounded theory requirements is summarised in Figure 1.

<table>
<thead>
<tr>
<th>Supports Iteration</th>
<th>Transparency</th>
<th>Does Not Prejudge</th>
<th>Procedural and Declarative</th>
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<tbody>
<tr>
<td>Interview</td>
<td>+</td>
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<tr>
<td>Protocol Analysis</td>
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<td>Observation</td>
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<tr>
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<tr>
<td>Induction</td>
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</table>

(Key: + means that the technique supports the grounded theory requirement.)

Figure 1. Knowledge elicitation techniques evaluated for grounded theory.

The knowledge elicitation stage of building a knowledge based system is a complex and difficult area. While there is a large selection of knowledge elicitation techniques available, there are many disadvantages associated with each one which could, if used in isolation, lead to the production of an inadequate knowledge base.

Grounded theory could provide the solution to the difficulties faced in knowledge elicitation. Using the suggested techniques of interview, observation and protocol analysis to generate data from the expert, it may be possible to analyse it using grounded theory. The iterative nature of grounded theory should compel the knowledge engineer to continue elicitation until theoretical saturation is reached. This should provide a theory which is faithful to the area under study (Strauss and Corbin, 1990), providing full contextual knowledge for a knowledge based system.

The scheduling problem

Grounded theory is being applied as part of an EPSRC funded research project, which is investigating the application of an intelligent decision support system to scheduling dial-a-ride services. Dial-a-ride services provide a door-to-door transport service for people with disabilities in specially adapted minibuses. Many such organisations exist throughout the UK, some funded by local authorities, some funded by Passenger Transport Authorities, and some operating as voluntary organisations with charitable funding. What they all have in common is that they seek to meet the local transport needs of people who, through disability, are unable to use conventional public transport. Practices differ from one operator to another, but typically bookings are taken in advance and scheduled by dispatchers who seek to achieve a number of conflicting objectives: to serve the maximum number of passengers, to minimise mileage and travel times, to stabilise empty vehicle mileage and to carry as many passengers as possible (within the capacity of each vehicle) at the same time. Previous work by one of the authors (Bennett, 1994) has addressed this and other routing and scheduling problems in community transport, but computerised techniques have been applied which do not reflect the approaches adopted by human schedulers, and these have not always been accepted.

The situation is similar in the United States, where software has been developed to schedule bookings using operations research techniques which are typically dependent on taking bookings in advance, scheduling overnight and calling passengers the next day to inform them whether their booking has been accepted. Stone et al. (1992) suggest:

"The scheduling process is difficult in that passenger disabilities and vehicle capability must be matched, special passenger groups must be identified, the origins and destinations of passengers must be sequenced, and the vehicle route optimized. Thus scheduling is a daunting technical and human problem. [Advanced Passenger Transport Systems] technology has only recently had a modest success in automating the process."

The focus of the present research is on the development of a human-centred approach, and an understanding of the knowledge applied by the dispatcher to the task is central to this.

Stage One - The Pilot

The first stage of the project was to pilot a number of knowledge elicitation techniques in the domain to evaluate their suitability for analysis using grounded theory in the following order:

- Unstructured interview
- Observation
- Verbal protocol analysis
- Walkthrough

The aim of the unstructured interview was to provide basic background information on the procedures involved in despatching and scheduling which could be analysed using grounded theory. The interview provided the necessary background for the knowledge engineer to pilot the observation technique. The observation stage allowed
the knowledge engineer to observe the actions of the expert in detail, noting exactly what the expert was doing, providing a clearer picture of the expert at work. More importantly, following the development of some additional categories from the observation data, the knowledge engineer was able to identify gaps in her understanding of the expert's decision making processes.

The knowledge engineer progressed onto piloting verbal protocol analysis. However unforeseen difficulties were experienced with the verbal protocol analysis techniques. The passenger is given an immediate answer to their booking request over the telephone, and the expert in this case was unable to describe her thought processes and decision making at the same time as talking to the passenger. The data produced from the verbal protocol analysis was therefore very poor. No new categories were produced from the transcription of the verbal protocol analysis and none of the gaps in the knowledge engineer's understanding were clarified.

Following the assessment of more elicitation techniques, the knowledge engineer decided the most appropriate alternative to verbal protocol analysis was the walkthrough. The walkthrough provided the expert with the opportunity to think aloud as she built a schedule and also allowed the knowledge engineer to interrupt and clarify any points.

Stage Two Methods

The second stage of the project put the knowledge elicitation techniques into full practice at a second dial-a-ride site. The knowledge elicitation process started with an initial informal interview which outlined the daily processes of the scheduling. The interview was taped and transcribed. A series of observation sessions followed covering all aspects of scheduling. The interview transcript and observation field notes were analysed using the first stage of grounded theory, open coding. Open coding breaks down, examines, compares, conceptualises and categorises the data (Strauss and Corbin, 1990). The first task is to label the phenomena which the knowledge engineer considers important. The knowledge engineer studies the transcripts and notes for categories and concepts that describe the phenomena in the data. Turner (1981) suggests using category cards as a method of recording the developing labels. The labels are noted on index cards, together with references to the data. As the data is analysed more concept cards are generated as different phenomena emerge. The data should also produce further instances of previously discovered phenomena. Figure 2 shows an example category card. Using further interview and observation sessions the knowledge engineer can search for further instances and clarification of these phenomena.

Walkthroughs are the final stage of knowledge elicitation. The knowledge engineer designs the walkthroughs to validate the concepts and categories that have transpired during the grounded theory analysis. The process of validation in grounded theory is known as theoretical sampling and occurs during each stage of grounded theory.

Theoretical sampling is sampling based on concepts that have proved theoretically relevant to the evolving theory (Strauss and Corbin, 1990). The knowledge engineer

<table>
<thead>
<tr>
<th>Card 5 PRORITIES IN SCHEDULING</th>
</tr>
</thead>
<tbody>
<tr>
<td>para. 3 look at passenger needs</td>
</tr>
<tr>
<td>para 4 aiming for multiple pick-ups</td>
</tr>
<tr>
<td>wheelchair users get priority because it is their only form of transport</td>
</tr>
<tr>
<td>para 43 multiple occupancy is a prime target</td>
</tr>
</tbody>
</table>

LINKS WITH: card 3, card 36

cross references note of incident

Figure 2. Example category card

should repeat the process of interview, observation and walkthrough until no new concepts and categories develop from the data, that is theoretical saturation of each category is reached (Glaser and Strauss, 1967). Strauss and Corbin (1990) define theoretical saturation in open coding as when no new or relevant concepts emerge from the data.

Stage Two Results

The initial results from the open coding are promising. Sixty-eight categories were developed from the pilot data and thirty-six categories have emerged from the stage two data, many of which can be broken down into sub-categories. These figures suggest that the knowledge elicitation techniques employed are producing a quality and amount of data suitable for grounded theory analysis.

A grounded theory is produced by integrating all the categories using selective coding. Selective coding is the process of selecting a core category, that is the central phenomenon, systematically relating it to other categories, validating those relationships and filling in the categories that need further refinement and
development (Strauss and Corbin, 1990). Although it is too early in the process to select a core category, it is already possible to see repetition of categories in the pilot study and stage two data. Both groups picture 'imaginary' routes in their heads as they schedule. Both are reliant on the passenger being flexible with their times of travel and have stated this is a key issue when scheduling. Both groups consider the type of disability, the amount of assistance a passenger requires and the type of wheelchair, if any, the passenger uses. Both sites have types of trip that take priority on the schedule and therefore dictate what the schedule is built around. The main difference in scheduling is that the pilot site scheduled dynamically using a first come, first served service, giving passengers immediate yes or no answers. At site two, bookings are taken in advance and the schedule is prepared with all the possible bookings available. At site two the dispatcher places a great deal of importance on the route he is developing. Passengers are also guaranteed a trip if they were refused their previous request. This can make routing much harder and can force an override of some the rules the dispatcher usually follows when scheduling. The pilot site has no such check and the dispatcher simply schedules from the last drop off point to the next pick up point.

Grounded theory is a system of analysis that examines actions and interactions in relation to their conditions and consequences (Strauss and Corbin, 1990). A diagram called the conditional matrix is used to help the analyst to consider the conditions and consequences related to the phenomena. Conditions include factors such as politics, regulations, economies, philosophies, values and history. Again it is too early in the analysis to see the full effect of such conditions. However, the coding from both groups reflects how issues such as cost effectiveness and driving regulations can affect how a schedule is built.

Summary and Conclusions

We have sought to apply grounded theory as a means of conceptualising the knowledge elicited from dispatchers in dial-a-ride as a step towards the development of a knowledge based system for scheduling. The requirements of grounded theory were identified and used to evaluate knowledge elicitation techniques appropriate to use with grounded theory. Interview, observations and verbal protocol analysis were chosen initially. The pilot stage of applying the knowledge elicitation techniques revealed that verbal protocol analysis was inappropriate, and it was replaced with a walkthrough technique. This and the other two techniques were successfully applied at the second site.

Grounded theory has, thus far, provided the researchers with a conceptually rich range of concepts and procedures used in scheduling transport for passengers with disabilities. The number of categories, in grounded theory terms, that has emerged from the knowledge elicitation suggests that it has been successful. In particular, factors concerning the context of the decision making, such as policies on funding and driver regulations, are emerging. Selective coding and the use of the conditional matrix should elucidate these factors.

It is possible that using techniques such as grounded theory may help to overcome some of the problems faced in knowledge acquisition. If this proves successful, future research could consider developing a methodology incorporating grounded theory or examine whether grounded theory could be integrated into an existing methodology.

Acknowledgments

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References


THE SUITABILITY OF GROUNDED THEORY FOR KNOWLEDGE ACQUISITION

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Abstract

Knowledge acquisition is recognised to be the bottleneck in an expert system's development. This paper reports on the use of grounded theory as a means of analysing and structuring knowledge in the domain of dial-a-ride scheduling. Grounded theory is a social science methodology for the systematic generation of conceptual models from qualitative data. Many knowledge elicitation techniques are shared by knowledge engineers and social scientists. It is suggested that analysis of data using grounded theory will overcome some of the problems faced in knowledge acquisition. The subject of this study is dial-a-ride. Dial-a-ride services are provided for people with mobility handicaps who are unable to use conventional public transport. The expertise used in scheduling these services is largely gained experientially and the schedulers are often unable clearly to articulate the rules and heuristics which they apply. The work described in this paper is part of an EPSRC funded project (GR/J71878) to develop a decision support system for scheduling demand responsive transport.

The paper describes the domain in which the techniques of grounded theory have been applied, dial-a-ride scheduling, and identifies relevant characteristics of that domain. The knowledge elicitation techniques employed to provide data for the grounded theory analysis are outlined and the reasoning behind their choice is discussed. The paper reviews the resulting model and presents issues raised by the grounded theory process. Finally the paper provides an evaluation of grounded theory analysis for this kind of problem and suggests areas for future research.
Introduction

Knowledge acquisition has been described as the bottleneck in the development of knowledge based systems (Feigenbaum and McCorduck, 1983). A number of reasons are cited by other authors. Medsker and Liebowitz (1994) blame the large amount of time taken by knowledge engineers and experts. Problems arise from the nature of human expertise and its foundation on increasing levels of automaticity of physical and mental processes (Davies and Hakiel, 1988). Forsythe and Buchanan (1989) allege the lack of communication skills on the part of the knowledge engineer is the problem and not the methods adopted.

These authors are all addressing knowledge acquisition in the context of the development of knowledge based systems, while Cooke (1994), in her review of knowledge elicitation techniques, points out that knowledge is of interest not just to expert system builders, but also to cognitive psychologists, educators and employers of knowledgeable and skilled employees. Techniques for the acquisition of knowledge are therefore of more general importance and applicability.

Some knowledge acquisition techniques lock the knowledge into a form which is determined by its intended use, and by the structure required by software. Our intention has been to capture the knowledge in a form which is independent of implementation, and to produce theory from the data elicited from the expert and his or her working environment. This theory represents the model of the expert's knowledge. The approach which we have taken is to use grounded theory (Glaser and Strauss, 1967), a method for building theory from qualitative data in the social sciences. This approach, which is described in more detail subsequently, ensures that the theory is grounded in data which are captured by the investigator.

The rest of the paper is structured as follows. First the domain and the problems associated with this area are described. Grounded theory is described in more detail and we explain why we believe it provides a good approach to the research question. A number of knowledge elicitation techniques are considered and assessed in terms of their ability to support grounded theory analysis. A discussion of the model produced and an evaluation of grounded theory for this problem is provided. Finally we examine further issues for research.

The Domain of the Research - Dial-a-Ride Scheduling

In the UK dial-a-ride services are provided by a large number of transport operators which range from small voluntary organisations and charities to specialist companies operating across metropolitan areas. Dial-a-rides are door-to-door transport services for passengers who are mobility handicapped and unable to use conventional public transport because of a disability. The services are typically provided in minibuses adapted to carry wheelchairs and fitted with wheelchair lifts. Bookings are taken in advance and allocated to vehicle shifts, and each vehicle shift will contain many trips. The scheduler attempts to schedule a number of pick-ups and drop-offs so that several passengers share the vehicle at any one time.

In the UK most operators create a schedule as they take the bookings, enabling them to give each passenger a clear indication whether or not they will be able to travel at the time requested, while in the USA and Canada bookings are taken and a schedule is created when the total demand is known.

Bodin et al. (1983) classify problems in routeing and scheduling vehicles and their crews. The problem with which we are concerned here is a multi-vehicle static dial-a-ride problem with time windows in those cases where the total demand is known in advance of the scheduling process, and is NP-hard. The typical UK operation falls between this static model and the dynamic or demand-responsive model, in which the scheduler schedules bookings for immediate travel, and can be described as interactive. In general, it is this process of decision making as bookings arrive, in a situation where the demand is only partially known, that is characteristic of UK dial-a-ride operations.

A number of software packages for automated or computer assisted scheduling are available in the USA, and are listed in Schweiger et al. (1994). although the report's authors are circumspect about the success of some of these systems. Stone et al. have stated: "The scheduling process is difficult in that passenger disabilities and vehicle capability must be matched, special passenger groups must be identified, the origins and destinations of passengers must be sequenced, and the vehicle route optimised. Thus scheduling is a daunting technical and human problem." Discussions in the UK with schedulers and their managers suggest that there is need for a computerised approach to scheduling which exploits the
benefits of computerisation (in managing the more laborious functions of database management) and which enhances the skills of schedulers (in freeing them up to give greater attention to allocative judgements). It is this approach which is being taken to develop a decision support system for scheduling and on which this paper is based.

In order to develop a decision support system for dial-a-ride, knowledge acquisition has been used to understand and codify the knowledge which schedulers bring to bear on the scheduling task. It is envisaged that the resulting system will be 'knowledge based', in the sense that it will provide a scheduling tool that reflects the knowledge and heuristics that are used by human schedulers. It will not necessarily be a traditional expert system, but it was felt that an approach based on knowledge acquisition would provide the broadest understanding of the task. For this reason, a technique has been chosen which, it is believed, will produce a model of the concepts and heuristics used by schedulers which does not lock the further development into any particular knowledge representation.

Grounded Theory

The knowledge elicitation stage in the development of knowledge based systems shares features in common with qualitative sociology (Forsythe and Buchanan, 1989), and it is from this discipline that grounded theory is borrowed. Grounded theory is a social science methodology for theory discovery which allows the researcher inductively to develop a theoretical account of a topic which is firmly grounded in empirical observation and data gathering (Glaser and Strauss, 1967). Janesick (1994) outlines some features of qualitative research which are of relevance in the domain of dial-a-ride scheduling: it is holistic and allows for the influence of the environment; the researcher is required to focus on understanding the social setting over time and on being in a position to observe behaviour and interview face-to-face; it demands on-going analysis of the data.

Grounded theory is commonly used in areas which deal with human behaviour. The grounded theorist endorses five strategies: both social and social psychological processes are discovered and analysed; the collection of data and analysis of the research phases proceed simultaneously; discovery and theory development are prompted by analytical processes rather than the verification of pre-existing theories; theoretical sampling is used to refine, elaborate and exhaust conceptual categories; the systematic application of grounded theory analytic methods progressively leads to more abstract analytic levels (Charmaz, 1983).

A grounded theory must meet four main criteria: fit, understanding, generality, and modifiability (Glaser and Strauss, 1967; Glaser, 1978). It should explain what has happened, interpret what is happening and predict what will happen. It should be comprehensible to the people who were the subjects of the study. It should be general enough to be applicable to all contexts of the topic of the study. As the research proceeds in an iterative way, the categories which emerge should be capable of being modified to ensure that they are grounded in the data.

The basis of grounded theory is comparative analysis of data. The data is broken down into units or codes (Strauss and Corbin, 1990). Commonalities in the codes are identified in order to group them into categories, and these are then searched for similarities between them. This process is known as open coding. These similarities are conceptualised by the researcher as higher order categories, known as axial coding. The process is repeated to produce a hierarchical structure, which eventually produces a core category, the process of selective coding. The categories in this hierarchy are grounded in those beneath them (that is, categories which have a lesser explanatory power), until the lowest level categories are grounded in the codes, which are grounded in the data (Rennie, 1994). In a grounded theory study, the term memos is used to apply to documents in which the researcher records analyses relating to the formulation of the theory. Memos contain the products of coding and notes summarising the analysis, and provide the direction for sampling of data. They also form the basis for subsequent writing up of the research (Strauss and Corbin, 1990).

Since dial-a-ride scheduling is very human centred relying on decisions to be based more on experience than technical knowledge, it was anticipated that grounded theory will provide an appropriate mechanism for knowledge acquisition in this domain. Three other factors have a bearing on the choice of grounded theory for this domain. Firstly, dial-a-ride scheduling is not an expert task in the way that, say, medicine is: the scheduler has not undertaken years of specialist training, the knowledge that is used is not documented in text-books, local knowledge is important, and temporal and spatial reasoning are
involved. Moreover, because the scheduler has not learnt the knowledge which he or she applies from textual sources, he or she may have difficulty in verbalising it. It is largely derived from experience and intuition rather than formal learning. Secondly, the scheduler is operating in a broader political context of scarce resources and limited funding. The stated aims of the dial-a-ride operator may conflict with operational decisions which have to be made in order to deal with this situation. Thirdly, as indicated in Stone et al. (1992), the subjects of the scheduling process are humans with complex needs and attributes. In meeting these needs, the scheduler will draw on his or her knowledge of the passenger in question, although he or she may not always realise this. To be able to use grounded theory for knowledge acquisition in this domain, suitable knowledge elicitation techniques had to be chosen. The next section of this paper considers this issue and describes how the methods were chosen.

Knowledge Elicitation

To be able to assess the use of grounded theory as a method for knowledge acquisition it is important that suitable knowledge elicitation techniques are adopted that will allow for the theory to be extracted from the expert. For grounded theory it is important that any technique should satisfy some basic requirements: the technique should be iterative since grounded theory requires refinement of categories; it should also be transparent; the structure of the knowledge should not determine the technique; and the technique should reveal both procedural and declarative knowledge.

As described earlier, the scheduling process and the nature of the expertise held by the schedulers present specific problems that any knowledge elicitation technique will need to be able to cope with. Much of the knowledge is intuitive and based on experience; it is not algorithmic or logical. There are also many external pressures faced by dial-a-ride that impact on the scheduling. In some cases schedulers have knowledge, for example about individuals, that they may not realise they use and, often, do not see as important, that is ‘deep’ knowledge.

The knowledge elicitation techniques considered were the interview, protocol analysis, observation, walkthroughs, teachback, repertory grids and rule induction (for a review of these techniques see Neale (1988) and Cooke (1994)). Our assessment of the ways in which each technique meets grounded theory and dial-a-ride requirements is summarised in Figure 1.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Knowledge Elicitation Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iterative</td>
<td>+</td>
</tr>
<tr>
<td>Transparent</td>
<td>+</td>
</tr>
<tr>
<td>Does not prejudge</td>
<td>+</td>
</tr>
<tr>
<td>Procedural and Declarative</td>
<td>+</td>
</tr>
<tr>
<td>Dial-A-Ride</td>
<td>Intuitive</td>
</tr>
<tr>
<td>External</td>
<td>+</td>
</tr>
<tr>
<td>Deep</td>
<td>+</td>
</tr>
</tbody>
</table>

(Key: - means that the technique supports the grounded theory or dial-a-ride requirement)

Figure 1 - Knowledge Elicitation Techniques Evaluated for Grounded Theory and Dial-A-Ride Scheduling

Discussion of the Model Produced

The model which has been produced by the research is one which is essentially hierarchical. At the top level is the product of the selective coding. This is a textual description of the scheduling process incorporating, in summary, the detail from the lower levels of coding and analysis. It is structured according to the paradigm model put forward by Strauss and Corbin (1990), showing the relationship between concepts in terms of causal conditions, phenomenon, context and the other categories shown in Figure 2. Scheduling itself is the phenomenon in the selective coding. The concepts which have been structured into this top level product are themselves described in a similar way by the paradigm and are...
the products of the axial coding. For example, one of the properties of the concepts which have been identified as the causal conditions of scheduling is entitled priorities. At the axial coding level, priorities is a phenomenon in its own right and is related to other concepts such as connecting transport. Each of these concepts in the axial coding is a product of the process of open coding, and is the title given to a concept card. Each card draws together examples of the concept which it documents, and these examples are drawn from source documents, in this case, transcripts of interviews and walkthroughs and notes of observations. It is thus possible to trace concepts down through this structure to the data in which they are grounded.

Seen as the full range of documentation, the model produced here both provides abstraction, in that the selective coding is essentially a summary of the concepts and their relationships, and provides detail, in that it is possible to trace a concept such as priorities in scheduling through the axial and open coding to the concepts in the interview transcripts and walkthroughs.

The model produced by this research can be contrasted with other attempts to codify the scheduling process of which the authors are aware. These other projects have focused on the production of software and have used conventional systems analysis techniques, including data flow diagrams, data modelling techniques and flow charts. As such, they document procedures and processes, but provide little insight into the decision making processes used by the schedulers. The model produced here is richer in the range of concepts which it contains. By this, we mean that a large number of concepts have been identified in the research which have a bearing on the scheduling process, and that these concepts relate to more issues, including contextual factors such as political and legislative frameworks, than a conventional systems analysis approach would identify. We believe that this reflects the very open approach taken to initial data gathering, the structuring of that data and the iterative analysis of that data which involves identifying gaps in the data and seeking to fill those gaps and to elaborate concepts.

Currently, the model is represented in textual form. The product of the selective coding provides an overview of the scheduling process, and has been validated with the collaborating dial-a-ride operators, and this validation is discussed below. The axial and open coding documents provide more detail and will form the basis of modelling requirements for the pilot decision support system. We are also producing a diagrammatic model of the selective and axial coding products, but it is proving difficult to summarise diagrammatically documents which are rich in content. An alternative approach may be to adopt a hypertext model to represent the products in a way which is easily accessible and which allows the user to examine concepts at each level, with the ability to move down through key concepts to lower levels, and ultimately to paragraphs in the transcripts on which concepts are based. The next section evaluates the grounded theory produced.

Evaluating Grounded Theory

A grounded theory is built on the results of coding the data. The purpose of a grounded theory is to set out the conditions which produce the actions that are applied to an idea and the outcomes that follow. Strauss and Corbin (1990) propose a number of criteria against which a theory can be judged: the theory can be considered an accurate analysis of the processes at work in the area of study if recognisable ideas are produced and there are links between the ideas; the theory must also explain what is going on and show how outside factors affect the ideas; there must be a sense of process.

In addition to meeting general grounded theory requirements, the theory must be evaluated against the specific problems met by the knowledge elicitation techniques in the dial-a-ride domain. Much of the knowledge is automatic and based on personal understanding, the theory must tackle this. The theory also needs to illustrate the many broader background issues faced by the dial-a-ride that impact on the scheduling. The schedulers have 'deep' knowledge where they may not be aware of its use and importance. The theory is required to reflect this knowledge.

Open and axial coding developed the core category as scheduling. Using a coding model known as a paradigm model (see Figure 2) a theory has been developed which identifies the conditions which cause the scheduling process to occur and the properties associated with these conditions. The theory also indicates the circumstances under which the scheduling process develops and the broader background environment. Using data from the observations and walkthroughs the theory illustrates the actions and interactions which are executed on the core category and the consequences that result.
Upon completion of the grounded theory a copy was sent to all the experts for their opinions and comments. Follow-up interviews with the experts have been carried out. The experts believe the theory to be both relevant and accurate and proved particularly effective at demonstrating how outside factors affect scheduling. The iterative character of grounded theory allowed areas where the knowledge was intuitive and 'deep' to be explored until the data reflected these events. Any questions the experts had with the theory were resolved by following a path through the coding processes to the data.

A diagrammatic form of the grounded theory has now been generated and is currently being assessed by the experts. Additional evaluation of the diagrammatic grounded theory will involve using the method to illustrate other examples of grounded theories and to assess the benefits of this technique.

Issues For Research

Grounded theory has, thus far, provided the researchers with a rich range of concepts and procedures used in scheduling transport for passengers with disabilities. The number of categories, in grounded theory terms, that has emerged from the knowledge elicitation suggests that it has been successful. Despite the operational differences at each site, grounded theory analysis shows that similarities in scheduling are emerging. The passenger details required, the resources available, the environment and the passengers themselves all affect decision making. Grounded theory analysis has also shown that other factors, such as the effect of politics on funding and driver regulations, are emerging as influences on the scheduling process.

It is possible that using techniques such as grounded theory may help to overcome some of the problems faced in knowledge acquisition, in particular in areas such as dial-a-ride scheduling, where human factors play such an important part. The theory seemed to be able to cope with experts who are not 'trained' in the formal sense but have acquired their expertise through experience and 'on the job training'. The technique has proven to be very time consuming and a large amount of data has been generated. A possible research area is refining the grounded theory technique and computerisation of the process to help reduce the time taken. Further research efforts will be put into whether the large amount of data generated is suitable for computerisation. Work is currently being done on investigating how grounded theory may be structured in a manner that, for instance, allows the knowledge to be represented graphically.

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